DESCRIPTION

IMAGE PROCESSING DEVICE AND METHOD, AND IMAGE-TAKING DEVICE

Technical Field

The present invention relates to an image processing device and method, and an image-taking device, and particularly relates to an image processing device and method, and an image-taking device, which take into consideration difference between signals detected by sensors and the real world.

Background Art

One type of processing for generating images with higher resolution based on input images, is class classification adaptation processing. An example of class classification adaptation processing is processing wherein coefficients used in processing for generating images with higher resolution are generated beforehand, in the spatial direction, and images are generated with higher resolution in the spatial direction based on the generated coefficients.

Fig. 1 is a block diagram illustrating the configuration of a conventional image processing device for generating coefficients used in class classification adaptation processing for generating HD (High Definition) images from SD (Standard Definition) images.

Frame memory 11 stores input images, which are HD images, in increments of frames. The frame memory 11 supplies the stored HD images to a weighted averaging unit 12 and a corresponding pixel obtaining unit 16.

The weighted averaging unit 12 performs one-quarter weighted averaging on the HD images stored in the frame memory 11, generates SD images, and supplies the generated SD images to the frame memory 13.

The frame memory 13 stores the SD images supplied from the weighted averaging unit 12 in increments of frames, and supplies the stored SD images to a class classification unit 14 and prediction tap obtaining unit 15.

The class classification unit 14 is configured of a class tap obtaining unit 21 and a waveform classification unit 22, and performs class classification of pixels of interest which are the pixel of interest in the SD images stored in the frame memory 13. The class tap obtaining unit 21 obtains a predetermined number of class taps which are pixels of the SD image corresponding to the pixel of interest from the frame memory 13, and supplies the obtained class taps to the waveform classification unit 22.

Fig. 2 is a diagram explaining the class taps obtained by the class tap obtaining unit 21. As shown in Fig. 2, the class tap obtaining unit 21 obtains eleven class taps at predetermined positions.

The waveform classification unit 22 classifies the pixel of interest into one class out of multiple classes, based on the class taps, and supplies a class No. corresponding to the classified class, to the prediction tap obtaining unit 15. The waveform classification unit 22 classifies the pixel of interest into one class out of 2048 classes, based on the eleven class taps.

The prediction tap obtaining unit 15 obtains a predetermined number of prediction taps which are pixels of the SD image, corresponding to the classified class from the frame memory 13, based on the class No., and supplies the obtained prediction taps and class Nos. to a corresponding pixel obtaining unit 16.

Fig. 3 is a diagram explaining prediction taps which the prediction tap obtaining unit 15 obtains. As shown in Fig. 3, the prediction tap obtaining unit 15 obtains nine prediction taps at predetermined locations.

The corresponding pixel obtaining unit 16 obtains, from the frame memory 11, pixels of the HD image corresponding to the pixel values to be predicted, based on the prediction taps and the class Nos., and supplies the prediction taps, class Nos., and the pixels of the HD image corresponding to the obtained pixel values to be predicted, to a normal equation generating unit 17.

The normal equation generating unit 17 generates normal

equations corresponding to relationships between prediction taps and pixel values to be predicted, corresponding to the classes, based on the prediction taps, class Nos., and the obtained pixel values to be predicted, and supplies the generated normal equations corresponding to the classes, to a coefficient calculation unit 18.

The coefficient calculation unit 18 solves the normal equation supplied from the normal equation generating unit 17, calculates coefficient sets corresponding to each class, and supplies the calculated coefficient sets to coefficient set memory 19, along with the class Nos.

The coefficient set memory 19 stores the calculated coefficient sets corresponding to the classes, based on the class Nos.

Fig. 4 is a diagram explaining an overview of class classification adaptation processing. In class classification adaptation processing, a tutor image which is an HD image is used to generate a corresponding SD image, by one-quarter weighted average processing. The generated SD image is called a student image.

Next, a coefficient set for generating an HD image from the SD image is generated, based on the tutor image which is the HD image and the student image which is the corresponding SD image. The coefficient set is configured of coefficients for generating an HD image from an SD image,

by linear prediction and the like.

A quadruple-density image is generated from the coefficients set thus generated and the SD image, by linear prediction and the like. The processing for generating an image or the like with higher density, from a coefficient set and an input image, is also called mapping.

SNR comparison, or visual qualitative evaluation is performed, based on the generated quadruple-density image and a corresponding HD image.

A coefficient set generated from a particular tutor image and corresponding student image is called a self coefficient set of the particular tutor image and corresponding student image. Mapping using the self coefficient set is called self mapping. A coefficient set generated from multiple other tutor images and corresponding student images is called a cross coefficient set.

On the other hand, with images obtained by a video camera taking a foreground subject which moves across a predetermined stationary background, movement blurring occurs in the event that the speed of movement of the object is relatively fast, and mixing of the foreground and background occurs.

With conventional class classification adaptation processing, one set of coefficients is generated for all of the foreground, background, and portions where mixing

between the foreground and background occurs, by learning processing such as described above, and mapping processing is executed based on the coefficient set.

The conventional learning processing for generating coefficients used in the processing for generating HD images from SD images will be described, with reference to the flowchart shown in Fig. 6. In Step S11, an image processing device judges whether or not there are any unprocessed pixels in the student image, and in the event that judgment is made that there are unprocessed pixels in the student image, the flow proceeds to Step S12, and pixels of interest are obtained from the student image, in order of raster scan.

In Step S13, the class tap obtaining unit 21 of the class classification unit 14 obtains a class tap corresponding to the pixel of interest, from the student image stored in the frame memory 13. In Step S14, the waveform classification unit 22 of the class classification unit 14 performs class classification of the pixel of interest, based on the class tap. In Step S15, the prediction tap obtaining unit 15 obtains a prediction tap corresponding to the pixel of interest from the student image stored in the frame memory 13, based on the class into which classification has been made.

In Step S16, the corresponding pixel obtaining unit 16 obtains a pixel corresponding to a pixel value to be

predicted, from tutor data stored in the frame memory 11, based on the class into which classification has been made.

In Step S17, the normal equation generating unit 17 adds a pixel value of a pixel corresponding to the prediction tap and pixel value to be predicted to the matrix for each class, based on the class into which classification has been made, the flow returns to Step S11, and the image processing device repeats judgment regarding whether or not there are any unprocessed pixels. The matrixes for each class to which the pixel value of a pixel corresponding to the prediction tap and pixel value to be predicted are added, correspond to the normal equation for calculating coefficients for each class.

In the event that judgment is made in Step S11 that there are no unprocessed pixels in the student image, the flow proceeds to Step S18, wherein the normal equation generating unit 17 supplies the matrix for each class wherein a pixel value of a pixel corresponding to the prediction tap and pixel value to be predicted has been set, to the coefficient calculation unit 18. The coefficient calculation unit 18 solves the matrix for each class wherein a pixel value of a pixel corresponding to the prediction tap and pixel value to be predicted has been set, and calculates a coefficient set for each class.

In Step S19, the coefficient calculation unit 18

outputs the coefficient for each class that has been calculated, to the coefficient set memory 19. The coefficient set memory 19 stores a coefficient set for each class, and the processing ends.

Fig. 7 is a block diagram illustrating the configuration of a conventional image processing device for generating HD images from SD images, by class classification adaptation processing.

Frame memory 31 stores input images which are SD images, in increments of frames. The frame memory 31 supplies the stored SD images to a mapping unit 32.

The SD images input to the mapping unit 32 are supplied to a class classification unit 41 and a prediction tap obtaining unit 42.

The class classification unit 41 is configured of a class tap obtaining unit 51 and a waveform classification unit 52, and performs class classification of pixels of interest which are the pixel of interest in the SD images stored in the frame memory 31. The class tap obtaining unit 51 obtains from the frame memory 31 a predetermined number of class taps corresponding to the pixel of interest, and supplies the obtained class taps to the waveform classification unit 52.

The waveform classification unit 52 classifies the pixel of interest into one class out of multiple classes,

based on the class taps, and supplies a class No. corresponding to the classified class, to the prediction tap obtaining unit 42.

The prediction tap obtaining unit 42 obtains from the input image stored in the frame memory 31 a predetermined number of prediction taps corresponding to the classified class, based on the class No., and supplies the obtained prediction taps and class Nos. to a prediction computation unit 43.

The prediction computation unit 43 obtains coefficient sets corresponding to classes from the coefficient sets stored in coefficient set memory 33, based on the class No. The prediction computation unit 43 predicts pixel values of predicted images by linear prediction, based on coefficient sets corresponding to classes, and prediction taps. The prediction computation unit 43 supplies the predicted pixel values to frame memory 34.

The frame memory 34 stores predicted pixel values supplied from the prediction computation unit 43, and outputs an HD image wherein the predicted pixel values have been set.

Fig. 8 is a diagram illustrating the pixel values of the input image, and the pixel values of the output image generated by class classification adaptation processing. In Fig. 8, the white squares indicate input signals, and the

solid circles indicate output signals. As shown in Fig. 8, the image generated by the class classification adaptation processing contains waveforms lost in the bandwidth restriction of the SD image. In this sense, it can be said that processing for generating an image with higher resolution by the class classification adaptation processing creates resolution.

The conventional processing for creating images, for generating HD images from SD image with an image processing device which executes class classification adaptation processing, will be described with reference to the flowchart in Fig. 9.

In Step S31, the image processing device judges whether or not there are any unprocessed pixels in the input image, and in the event that judgment is made that there are unprocessed pixels in the input image, the flow proceeds to Step S32, where the mapping unit 32 obtains a coefficient set stored in the coefficient set memory 33. In Step S33, the image processing device obtains pixels of interest from the input image in raster scan order.

In Step S34, the class tap obtaining unit 51 of the class classification unit 41 obtains a class tap corresponding to the pixel of interest, from the input image stored in the frame memory 31. In Step S35, the waveform classification unit 52 of the class classification unit 41

performs class classification of the pixel of interest into one class, based on the class tap.

In Step S36, the prediction tap obtaining unit 42 obtains a prediction tap corresponding to the pixel of interest from the input image stored in the frame memory 31, based on the class into which classification has been made.

In Step S37, the prediction computation unit 43 obtains a pixel value of a predicted image by linear prediction, based on the coefficient set corresponding to the class into which classification has been made, and the prediction tap.

In Step S38, the prediction computation unit 43 outputs the predicted pixel value to the frame memory 34. The frame memory 34 stores the pixel value supplied from the prediction computation unit 43. The procedures return to Step S31, and repeats judgement regarding whether or not there are any unprocessed pixels.

In the event that judgment is made in Step S31 that there are no unprocessed pixels in an input image, the flow proceeds to Step S39, where the frame memory 34 outputs the stored predicted image wherein predicted values are set, and the processing ends.

Also, processing for edge enhancing of images is widely used as processing for raising the sense of resolution of the image.

However, in the event that objects move in front of

still backgrounds, movement blurring occurs not only due to mixture of the moving object images itself, but also due to mixture of the moving object images and the background images. Conventionally, processing images corresponding to the mixing of the background image and the image of the moving object had not been given thought.

Also, applying edge enhancing processing to image containing movement blurring has resulted in unnatural images at times. Setting the degree of edge enhancing lower so that such unnatural images do not occur has resulted in insufficient improvement in sense of resolution of the image

Disclosure of Invention

An example embodiment of the present invention may enable processing of images corresponding to the mixing of background images and images of the moving objects.

Also, the example embodiment may sufficiently raise sense of resolution without making images containing movement blurring into unnatural images.

According to a first aspect of the present invention, there is provided an image processing

device for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said image processing device comprising: region specifying means for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and processing means for processing the input image data for each region specified by the region specifying information.

The processing means may decide a class corresponding to each piece of pixel data of the input image data, corresponding to the region specifying information.

The processing means may enhance the edges of the input image data, corresponding to the region specifying information.

The processing means may process the pixel data of at least one region of the mixed region and the non-mixed region.

The region specifying means may further specify a covered background region and an uncovered background region, and output

region specifying information corresponding to the results of specifying, with the processing means further processing the input image data for each of covered background region and uncovered background region.

The processing means may generate coefficients used in class classification adaptation processing, for each region specified by the region specifying information.

The processing means may generate output image data by class classification adaptation processing, for each region specified by the region specifying information.

The processing means may enhance the edges of the input image data, for each region specified by the region specifying information,

According to a second aspect of the present invention, there is provided an image processing method for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising: a region specifying step for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground

region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a processing step for processing the input image data for each region specified by the region specifying information.

In the processing step, a class corresponding to each piece of pixel data of the input image data may be decided, corresponding to the region specifying information.

In the processing step, the edges of the input image data may be enhanced, corresponding to the region specifying information.

In the processing step, the pixel data of at least one region of the mixed region and the non-mixed region may be processed.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with region specifying information being output corresponding to the results of specifying; and in the processing step, the input image data for each of covered background region and uncovered background region may be further processed.

In the processing step, coefficients used in class classification adaptation processing may be generated for each region specified by the region specifying information. In the

processing step, output image data may be generated by class classification adaptation processing for each region specified by the region specifying information.

In the processing step, the edges of the input image data may be enhanced for each region specified by the region specifying information.

According to a third aspect of the present invention, there is provided a recording medium storing a computer-readable program for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said program comprising: a region specifying step for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a processing step for processing the input image data for each region specified by the region specifying information.

In the processing step, a class corresponding to each piece of pixel data of the input image data may be decided, corresponding to the region specifying information.

In the processing step, the edges of the input image data may be enhanced, corresponding to the region specifying information.

In the processing step, the pixel data of at least one region of the mixed region and the non-mixed region may be processed.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with region specifying information being output corresponding to the results of specifying; and in the processing step, the input image data for each of covered background region and uncovered background region may be further processed.

In the processing step, coefficients used in class classification adaptation processing may be generated for each region specified by the region specifying information.

In the processing step, output image data may be generated by class classification adaptation processing for each region specified by the region specifying information.

In the processing step, the edges of the input image data may be enhanced for each region specified by the region specifying information.

According to a fourth aspect of the present invention, there is provided a program for causing a computer, which processes input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, to execute: a region specifying step for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a processing step for processing the input image data for each region specified by the region specifying information.

In the processing step, a class corresponding to each piece of pixel data of the input image data may be decided, corresponding to the region specifying information.

In the processing step, the edges of the input image data may be enhanced, corresponding to the region specifying information.

In the processing step, the pixel data of at least one region of the mixed region and the non-mixed region may be

processed.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with region specifying information being output corresponding to the results of specifying; and in the processing step, the input image data for each of covered background region and uncovered background region may be further processed.

In the processing step, coefficients used in class classification adaptation processing may be generated for each region specified by the region specifying information.

In the processing step, output image data may be generated by class classification adaptation processing for each region specified by the region specifying information.

In the processing step, the edges of the input image data may be enhanced for each region specified by the region specifying information.

According to a fifth aspect of the present invention, there is provided an image-taking device, comprising: image-taking means for outputting a subject image taken by an image-taking device having a predetermined number of pixels having time-integration effects as image data made up of a predetermined number of pieces of pixel data; region specifying means for specifying, based on the input image data, a mixed region made up of a mixture of a

foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and processing means for processing the image data for each region specified by the region specifying information.

The processing means may decide a class corresponding to each piece of pixel data of the input image data, corresponding to the region specifying information.

The processing means may enhance the edges of the input image data, corresponding to the region specifying information.

The processing means may process the pixel data of at least one region of the mixed region and the non-mixed region.

The region specifying means may further specify a covered background region and an uncovered background region, and output region specifying information corresponding to the results of specifying; and the processing means may further process the input image data for each of covered background region and uncovered background region.

The processing means may generate coefficients used in class classification adaptation processing, for each region specified by the region specifying information.

The processing means may generate output image data by class classification adaptation processing, for each region specified by the region specifying information.

The processing means may enhance the edges of the input image data, for each region specified by the region specifying information.

According to a sixth aspect of the present invention, there is provided an image processing device for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said image processing device comprising: region specifying means for specifying, based on the input image data, a mixed region made up of a mixture of *a* foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and class deciding means for determining classes corresponding to each set of pixel data of the input image data, corresponding to the region specifying information.

The class deciding means may decide a class corresponding

to the pixel data of only regions which are a portion of the mixed region, the foreground region, and the background region.

The image processing device may further comprise generating means for processing the pixel data of the input image data corresponding to the classes that have been decided, and generating coefficients used in class classification adaptation processing.

The image processing device may further comprise converting means for processing the pixel data of the input image data based on a coefficient for each of the classes, corresponding to the classes that have been decided, and converting the input image data into output image data.

The region specifying means may further specify a covered background region and an uncovered background region, and output the region specifying information corresponding to the results of specifying; and the class deciding means may further decide the classes corresponding to the pixel data of the input image data, corresponding to the covered background region or the uncovered background region that have been specified.

According to a seventh aspect of the present invention, there is provided an image processing method for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels

having time-integration effects, said method comprising: a region specifying step for specifying,

based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a class deciding step for determining classes corresponding to each set of pixel data of the input image data, corresponding to the region specifying information.

In the class deciding step, a class corresponding to the pixel data of only regions which are a portion of the mixed region, the foreground region, and the background region, may be decided.

The image processing method may further comprise a generating step for processing the pixel data of the input image data corresponding to the classes that have been decided, and generating coefficients used in class classification adaptation processing.

The image processing method may further comprise a converting step for processing the pixel data of the input image

data based on a coefficient for each of the classes, corresponding to the classes that have been decided, and converting the Input image data into output image data.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying; and in the class deciding step, the classes corresponding to the pixel data of the input image data may be decided corresponding to the covered background region or the uncovered background region that have been specified.

According to an eighth aspect of the present invention, there is provided a recording medium storing a computer-readable program for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said program comprising: a region specifying step for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component

configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a class deciding step for determining classes corresponding to each set of pixel data of the input image data, corresponding to the region specifying information.

In the class deciding step, a class corresponding to the pixel data of only regions which are a portion of the mixed region, the foreground region, and the background region, may be decided.

The program in the recording medium may further comprise a generating step for processing the pixel data of the input image data corresponding to the classes that have been decided, and generating coefficients used in class classification adaptation processing.

The program in the recording medium may further comprise a converting step for processing the pixel data of the input image data based on a coefficient for each of the classes, corresponding to the classes that have been decided, and converting the input image data into output image data.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying; and in the class deciding step, the classes corresponding to the pixel data of the input image data may be decided corresponding to the covered

background region or the uncovered background region that have been specified.

According to a ninth aspect of the present invention, there is provided a program for causing a computer, which processes input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, to execute: a region specifying step for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a class deciding step for determining classes corresponding to each set of pixel data of the input image data, corresponding to the region specifying information.

In the class deciding step, a class corresponding to the pixel data of only regions which are a portion of the mixed region, the foreground region, and the background region, may be decided.

The program may further comprise a generating step for processing the pixel data of the input image data corresponding

to the classes that have been decided, and generating coefficients used in class classification adaptation processing.

The program may further comprise a converting step for processing the pixel data of the input image data based on a coefficient for each of the classes, corresponding to the classes that have been decided, and converting the input image data into output image data.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying; and in the class deciding step, the classes corresponding to the pixel data of the input image data may be decided corresponding to the covered background region or the uncovered background region that have been specified.

According to a tenth aspect of the present invention, there is provided an image-taking device, comprising: image-taking means for outputting a subject image taken by an image-taking device having a predetermined number of pixels having time-integration effects as taken image data made up of a predetermined number of pieces of pixel data; region specifying means for specifying, based on the taken image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a

background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and class deciding means for determining classes corresponding to each set of pixel data of the taken image data, corresponding to the region specifying information.

The class deciding means may decide a class corresponding to the pixel data of only regions which are a portion of 'the mixed region, the foreground region, and the background region.

The image-taking device may further comprise generating means for processing the pixel data of the input image data corresponding to the classes that have been decided, and generating coefficients used in class classification adaptation processing.

The image-taking device may further comprise converting means for processing the pixel data of the input image data based on a coefficient for each of the classes, corresponding to the classes that have been decided, and converting the input image data into output image data.

The region specifying means may further specify a covered background region and an uncovered background region, and output

the region specifying information corresponding to the results of specifying; and the class deciding means may decide the classes corresponding to the pixel data of the input image data, corresponding to the covered background region or the uncovered background region that have been specified.

According to an eleventh aspect of the present invention, there is provided an image processing device for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said image processing device comprising: region specifying means for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and edge enhancing means for enhancing the edges of the input image data, corresponding to the region specifying information.

The region specifying means may further specify a covered background region and an uncovered background region, and output the region specifying information corresponding to the results of specifying; and the edge enhancing means may enhance the edges of the input image data, corresponding to the covered background region or the uncovered background region that have been specified.

According to a twelfth aspect of the present invention, there is provided an image processing method for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising: a region specifying step for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and an edge enhancing step for enhancing the edges of the input image data, corresponding to the region specifying

information.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying; and in the edge enhancing step, the edges of the input image data may be enhanced corresponding to the covered background region or the uncovered background region that have been specified.

According to a thirteenth aspect of the present invention, there is provided a recording medium storing a computer-readable program for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said program comprising: a region specifying step for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and an edge enhancing step for enhancing

the edges of the input image data, corresponding to the region specifying information.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying; and in the edge enhancing step, the edges of the input image data may be enhanced corresponding to the covered background region or the uncovered background region that have been specified.

According to a fourteenth aspect of the present invention, there is provided a program for causing a computer, which processes input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, to execute: a region specifying step for specifying, based on the input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and an edge

enhancing step for enhancing the edges of the input image data, corresponding to the region specifying information.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying; and in the edge enhancing step, the edges of the input image data may be enhanced corresponding to the covered background region or the uncovered background region that have been specified.

According to a fifteenth aspect of the present invention, there is provided an image-taking device, comprising: image-taking means for outputting a subject image taken by an image-taking device having a predetermined number of pixels having time-integration effects as image data made up of a predetermined number of pieces of pixel data; region specifying means for specifying, based on the image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and edge enhancing

means for enhancing the edges of the image data, corresponding to the region specifying information.

The region specifying means may further specify a covered background region and an uncovered background region, and output the region specifying information corresponding to the results of specifying; and the edge enhancing means may enhance the edges of the image data, corresponding to the covered background region or the uncovered background region that have been specified.

According to a sixteenth aspect of the present invention, there is provided an image processing device for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said image processing device comprising: region specifying means for specifying, based on the input image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of

specifying; and processing means for processing the pixel data for the mixed region specified by the region specifying means with a method different from a method for processing the non-mixed region.

The processing means may process one region specified by the region specifying means with a method different from a method for processing the other region.

The region specifying means may further specify the foreground region and the background region, and output the region specifying information corresponding to the results of specifying.

The region specifying means may further specify a covered background region and an uncovered background region, and output region specifying information corresponding to the results of specifying.

The image processing device may further comprise separating means for separating the pixel data of the mixed region into the foreground object component and the background object component, based on the region specifying information, with the processing means processing at least one of the foreground object component and the background object component.

According to a seventeenth aspect of the present invention, there is provided an image

processing method for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising: a region specifying step for specifying, based on the input image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a processing step for processing the pixel data for the mixed region specified by the region specifying means with a method different from a method for processing the non-mixed region.

In the processing step, one region specified by the processing in the region specifying step may be processed with a method different from a method for processing the other region.

In the region specifying step, the foreground region and the background region may be further specified, with the region specifying information being output corresponding to the results

of specifying.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying.

The image processing method may further comprise a separating step for separating the pixel data of the mixed region into the foreground object component and the background object component, based on the region specifying information; and in the processing step, at least one of the foreground object component and the background
object component may be processed.

According to a eighteenth aspect of the present invention, there is provided a recording medium storing a computer-readable program for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising: a region specifying step for specifying, based on the input image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background

object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a processing step for processing the pixel data for the mixed region specified by the region specifying means with a method different from a method for processing the non-mixed region.

In the processing step, one region specified by the processing in the region specifying step may be processed with a method different from a method for processing the other region.

In the region specifying step, the foreground region and the background region may be further specified, with the region specifying information being output corresponding to the results of specifying.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying.

The program in the recording medium may further comprise a separating step for separating the pixel data of the mixed region into the foreground object component and the background object component, based on the region specifying information; and in the processing step, at least one of the foreground object component and the background object component may be

processed.

According to a nineteenth aspect of the present invention, there is provided a program for causing a computer, which processes input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, to execute: a region specifying step for specifying, based on the input image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and a processing step for processing the pixel data for the mixed region specified by the region specifying means with a method different from a method for processing the non-mixed region.

In the processing step, one region specified by the processing in the region specifying step may be processed with a method different from a method for processing the other region.

In the region specifying step, the foreground region and the background region may be further specified, with the region specifying information being output corresponding to the results of specifying.

In the region specifying step, a covered background region and an uncovered background region may be further specified, with the region specifying information being output corresponding to the results of specifying.

The program may further comprise a separating step for separating the pixel data of the mixed region into the foreground object component and the background object component, based on the region specifying information; and in the processing step, at least one of the foreground object component and the background object component may be processed.

According to a twentieth aspect of the present invention, there is provided an image-taking device, comprising: image-taking means for outputting a subject image taken by an image-taking device having a predetermined number of pixels having time-integration effects as image data made up of a predetermined number of pieces of pixel data; region specifying means for specifying, based on the image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring

background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, and outputting region specifying information corresponding to the results of specifying; and processing means for processing the pixel data for the mixed region specified by the region specifying means with a method different from a method for processing the non-mixed region.

The processing means may process one region specified by the region specifying means with a method different from a method for processing the other region.

The region specifying means may further specify the foreground region and the background region, and output the region specifying information corresponding to the results of specifying.

The region specifying means may further specify a covered background region and an uncovered background region, and output the region specifying information corresponding to the results of specifying.

The image-taking device may further comprise separating means for separating the pixel data of the mixed region into the foreground object component and the background object component,

based on the region specifying information; with the processing means processing at least one of the foreground object component and the background object component.

In the example embodiment, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, are specified based on input image data, region specifying information corresponding to the results of specifying is output, and the input image data for each region specified by the region specifying information is processed.

In the example embodiment, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, are specified based on input image data, region specifying information corresponding to the results of specifying is output, and classes corresponding to each set of pixel data of the input image data are determined,

corresponding to the region specifying information.

Thus, images can be processed corresponding to the mixing of background images and moving objects.

In the example embodiment, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, are specified based on input image data, outputting region specifying information corresponding to the results of specifying is output, and the edges of the input image data are enhanced, corresponding to the region specifying information.

Thus, the sense-of-resolution of images containing movement blurring can be sufficiently raised, without forming unnatural images,

In the example embodiment, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of the foreground object component and a background region made up of a background object component configuring the background objects, is specified based

on input image data, region specifying information corresponding to the results of specifying is output, and pixel data is processed for at least one region of the mixed region and the non-mixed region.

Thus, images can be processed corresponding to the mixing of background images and moving objects.

Brief Description of the Drawings

Fig. 1 is a block diagram illustrating the configuration of a conventional image processing device.

Fig. 2 is a diagram explaining class taps.

Fig. 3 is a diagram explaining prediction taps.

Fig. 4 is a diagram describing the overview of class classification adaptation processing.

Fig. 5 is a diagram explaining conventional coefficient sets.

Fig. 6 is a flowchart explaining conventional learning processing.

Fig. 7 is a block diagram illustrating the configuration of a conventional image processing device.

Fig. 8 is a diagram illustrating pixel values of an output image generated by pixel values of an input image, and class classification adaptation processing.

Fig. 9 is a flowchart explaining conventional processing for creating images.

Fig. 10 is a block diagram illustrating the configuration of an embodiment of an image processing device according to the present invention.

Fig. 11 is a block diagram illustrating a configuration of an image processing device.

Fig. 12 is a diagram describing image-taking by a sensor.

Fig. 13 is a diagram describing an arrangement of pixels.

Fig. 14 is a diagram describing operation of a detecting device.

Fig. 15A is a diagram describing an image obtained by taking an image of an object corresponding to a moving foreground, and an object corresponding to a still

background.

Fig. 15B is a diagram describing a model corresponding to an image obtained by taking an image of an object corresponding to a moving foreground, and an object corresponding to a still background.

Fig. 16 is a diagram describing background region, foreground region, mixed region, covered background region, and uncovered background region.

Fig. 17 is a model diagram which develops, over the time direction, the pixel values of pixels adjacently arrayed in one row, in an image wherein an object corresponding to a still foreground and an object corresponding to a still background are subjected to image-taking.

Fig. 18 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 19 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 20 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 21 is a diagram illustrating an example of extracting pixels of the foreground region, background

region, and mixed region.

Fig. 22 is a diagram illustrating how pixels correspond to a model wherein pixel values are developed over the time direction.

Fig. 23 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 24 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 25 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 26 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 27 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 28 is a diagram illustrating the correlation between a divided image, and a model diagram wherein the pixel values of pixels are developed over the time direction.

Fig. 29 is a model diagram illustrating the correlation between a divided image, and a model diagram wherein the pixel values of pixels are developed over the time direction.

Fig. 30 is a diagram illustrating an example of a divided image.

Fig. 31 is a diagram illustrating an example of a divided image.

Fig. 32 is a diagram illustrating the correlation between an image wherein movement blurring has been removed, and a model diagram wherein the pixel values of pixels are developed over the time direction.

Fig. 33 is a diagram describing processing of the image processing device according to the present invention.

Fig. 34 is a flowchart explaining image processing with the image processing device according to the present invention.

Fig. 35 is a block diagram illustrating the configuration of the region specifying unit 103.

Fig. 36 is a diagram describing an image wherein an object corresponding to the foreground is moving.

Fig. 37 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 38 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 39 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding

to shutter time are divided.

Fig. 40 is a diagram describing conditions for region judgment.

Fig. 41A is a diagram illustrating an example of the results of region specification made by the region specifying unit 103.

Fig. 41B is a diagram illustrating an example of the results of region specification made by the region specifying unit 103.

Fig. 41C is a diagram illustrating an example of the results of region specification made by the region specifying unit 103.

Fig. 41D is a diagram illustrating an example of the results of region specification made by the region specifying unit 103.

Fig. 42 is a diagram illustrating an example of the results of region specification made by the region specifying unit 103.

Fig. 43 is a flowchart describing processing for region specifying.

Fig. 44 is a block diagram illustrating another configuration of the region specifying unit 103.

Fig. 45 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 46 is a diagram illustrating an example of a background image.

Fig. 47 is a block diagram illustrating the configuration of a binary object image extracting unit 302.

Fig. 48A is a diagram describing calculating of correlation values.

Fig. 48B is a diagram describing calculating of correlation values.

Fig. 49A is a diagram describing calculating of correlation values.

Fig. 49B is a diagram describing calculating of correlation values.

Fig. 50 is a diagram illustrating an example of a binary object image.

Fig. 51 is a block diagram illustrating the configuration of a time change detecting unit 303.

Fig. 52 is a diagram describing judgment of a region judgment unit 342.

Fig. 53 is a diagram illustrating an example of judgment made by the time change detecting unit 303.

Fig. 54 is a flowchart describing processing for region specification by the region judgment unit 103.

Fig. 55 is a flowchart for describing the processing for region specification in detail.

Fig. 56 is a block diagram illustrating yet another

configuration of the region specifying unit 103.

Fig. 57 is a block diagram describing the configuration of a robustification unit 361.

Fig. 58 is a diagram describing movement compensation of a movement compensation unit 381.

Fig. 59 is a diagram describing movement compensation of a movement compensation unit 381.

Fig. 60 is a flowchart describing the processing for region specification.

Fig. 61 is a flowchart describing details of processing for robustification.

Fig. 62 is a block diagram illustrating an example of the configuration of a mixture ratio calculation unit 104.

Fig. 63 is a diagram illustrating an example of an ideal mixture ratio α.

Fig. 64 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 65 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 66 is a diagram describing approximation using correlation of foreground components.

Fig. 67 is a diagram describing the relation between C, N, and P.

Fig. 68 is a block diagram illustrating the configuration of an estimated mixture ratio processing unit 401.

Fig. 69 is a diagram illustrating an example of an estimated mixture ratio.

Fig. 70 is a block diagram illustrating another configuration of a mixture ratio calculation unit 104.

Fig. 71 is a flowchart describing processing for calculating a mixture ratio.

Fig. 72 is a flowchart describing processing for computing an estimated mixture ratio.

Fig. 73 is a diagram describing a straight line approximating a mixture ratio α.

Fig. 74 is a diagram describing a plane approximating a mixture ratio α.

Fig. 75 is a diagram describing how pixels in multiple frames correspond at the time of calculating the mixture ratio α.

Fig. 76 is a block diagram illustrating another configuration of the mixture ratio estimation processing unit 401.

Fig. 77 is a diagram illustrating an example of an estimated mixture ratio.

Fig. 78 is a flowchart explaining the processing for calculating mixture ratio.

Fig. 79 is a flowchart describing the processing for mixture ratio estimation by way of a model corresponding to a covered background region.

Fig. 80 is a block diagram illustrating an example of the configuration of a foreground/background separation unit 105.

Fig. 81A is a diagram illustrating an input image, foreground component image, and background component image.

Fig. 81B is a model diagram corresponding to an input image, foreground component image, and background component image.

Fig. 82 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 83 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 84 is a model diagram wherein the pixel values are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 85 is a block diagram illustrating an example of the configuration of the separation unit 601.

Fig. 86A is a diagram illustrating an example of a separated foreground component image.

Fig. 86B is a diagram illustrating an example of a

separated background component image.

Fig. 87 is a flowchart describing the processing for separating the foreground and the background.

Fig. 88 is a block diagram illustrating an example of the configuration of a movement blurring removal unit 106.

Fig. 89 is a diagram describing increments of processing.

Fig. 90 is a model diagram wherein the pixel values of a foreground component image are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 91 is a model diagram wherein the pixel values of foreground component image are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 92 is a model diagram wherein the pixel values of foreground component image are developed over the time direction, and periods corresponding to shutter time are divided.

Fig. 93 is a flowchart explaining processing for removing movement blurring contained in the foreground component image by the movement blurring removal unit 106.

Fig. 94 is a diagram illustrating a model of a background component image.

Fig. 95 is a diagram illustrating a model of a

corrected background component image.

Fig. 96 is a block diagram illustrating the configuration of a movement-blurring-removed-image processing unit 108 for generating coefficient sets.

Fig. 97 is a diagram explaining the relation between a tutor image and a student image.

Fig. 98 is a block diagram illustrating the configuration of a learning unit 1006.

Fig. 99A is a diagram explaining class classification processing.

Fig. 99B is a diagram explaining class classification processing.

Fig. 100A is a diagram explaining ADRC processing.

Fig. 100B is a diagram explaining ADRC processing.

Fig. 101 is a diagram explaining coefficient sets which the movement-blurring-removed-image processing unit 108 generates.

Fig. 102 is a flowchart explaining the learning processing for generating coefficient sets by the movement-blurring-removed-image processing unit 108.

Fig. 103 is a flowchart explaining the processing for generating coefficient sets corresponding to the background component image.

Fig. 104 is a block diagram illustrating the configuration of the movement-blurring-removed-image

processing unit 108 which executes class classification adaptation processing and generates a higher resolution image in the spatial direction.

Fig. 105 is a diagram illustrating a model of a foreground component image wherein movement blurring has been removed.

Fig. 106 is a diagram illustrating a model of a foreground component image wherein movement blurring has been added.

Fig. 107 is a block diagram illustrating the configuration of a mapping unit 1103.

Fig. 108 is a flowchart explaining the processing for creating an image with regard to the movement-blurring-removed-image processing unit 108.

Fig. 109 is a flowchart explaining the processing of predicting images corresponding to background component images.

Fig. 110 is a flowchart explaining the processing of images with the image processing device according to the present invention.

Fig. 111 is a block diagram illustrating the configuration of the movement-blurring-removed-image processing unit 108 wherein edge enhancing processing with difference effects is applied for each image.

Fig. 112 is a block diagram illustrating the

configuration of an edge enhancing unit 1203.

Fig. 113A is a diagram describing the processing for edge enhancement.

Fig. 113B is a diagram describing the processing for edge enhancement.

Fig. 113C is a diagram describing the processing for edge enhancement.

Fig. 114 is a diagram illustrating filter coefficients.

Fig. 115 is a diagram explaining operation of a high-pass filter 1221.

Fig. 116 is a diagram illustrating filter coefficients.

Fig. 117 is a diagram explaining operation of a high-pass filter 1221.

Fig. 118 is a block diagram illustrating the configuration of an edge enhancing unit 1203.

Fig. 119 is a diagram illustrating filter coefficients.

Fig. 120 is a diagram explaining operation of a filter 1241.

Fig. 121 is a diagram illustrating filter coefficients.

Fig. 122 is a diagram explaining operation of a filter 1241.

Fig. 123 is a diagram explaining the processing of the movement-blurring-removed-image processing unit 108.

Fig. 124 is a flowchart explaining the processing of edge enhancement processing with the movement-blurring-

removed-image processing unit 108.

Fig. 125 is a block diagram illustrating the configuration of the movement-blurring-removed-image processing unit 108 which generates coefficient sets.

Fig. 126 is a flowchart explaining the learning processing for generating coefficient sets used in class classification adaptation processing for removing noise.

Fig. 127 is a block diagram illustrating the configuration of the movement-blurring-removed-image processing unit 108.

Fig. 128 is a diagram explaining the processing of the movement-blurring-removed-image processing unit 108.

Fig. 129 is a flowchart explaining the processing of the movement-blurring-removed-image processing unit 108 having the configuration shown in Fig. 127.

Fig. 130 is a block diagram illustrating another configuration of the functions of the image processing device.

Fig. 131 is a block diagram illustrating an example of the configuration of a mixture ratio calculation unit 3001.

Fig. 132 is a block diagram illustrating an example of the configuration of a foreground/background separation unit 3002.

Fig. 133 is a block diagram illustrating another configuration of the functions of the image processing

device.

Fig. 134 is a diagram explaining the processing of a separated image processing unit 4002.

Fig. 135 is a block diagram illustrating an example of the configuration of a foreground/background separation unit 4001.

Fig. 136 is a block diagram illustrating an example of the configuration of a separation unit 4101.

Fig. 137 is a block diagram illustrating the configuration of a separated image processing unit 4002 for generating coefficient sets.

Fig. 138 is a block diagram illustrating the configuration of the separated image processing unit 4002 which generates a higher resolution image in the spatial direction.

Fig. 139A is a diagram illustrating an example of an image in the mixed region of a tutor image.

Fig. 139B is a diagram illustrating change in pixel values of an image in the mixed region of a tutor image.

Fig. 140A is a diagram illustrating an example of an image in a mixed region, generated by conventional class classification adaptation processing.

Fig. 140B is a diagram illustrating change in the pixel values of an image in a mixed region, generated by conventional class classification adaptation processing.

Fig. 141A is a diagram illustrating an example of an image in a mixed region, generated by the separated image processing unit 4002.

Fig. 141B is a diagram illustrating change in the pixel values of an image in a mixed region, generated by the separated image processing unit 4002.

Fig. 142A is a diagram illustrating an example of an image in a foreground region of a tutor image.

Fig. 142B is a diagram illustrating change in the pixel values of an image in a foreground region of a tutor image.

Fig. 143A is a diagram illustrating an example of an image in a foreground region, generated by conventional class classification adaptation processing.

Fig. 143B is a diagram illustrating change in the pixel values of an image in a foreground region, generated by conventional class classification adaptation processing.

Fig. 144A is a diagram illustrating an example of an image in a foreground region, generated by the separated image processing unit 4002.

Fig. 144B is a diagram illustrating change in the pixel values of an image in a foreground region, generated by the separated image processing unit 4002.

Fig. 145 is a flowchart explaining the processing of images with the image processing device, the configuration of which is shown in Fig. 133.

Fig. 146 is a flowchart explaining the processing of separating the foreground and background with the foreground/background separation unit 4001.

Fig. 147 is a flowchart explaining learning processing for generating coefficient sets by the separated image processing unit 4002.

Fig. 148 is a flowchart explaining the processing for creating images with the separated image processing unit 4002.

Fig. 149 is a block diagram illustrating the configuration of the separated image processing unit 4002.

Fig. 150 is a diagram explaining the processing by the separated image processing unit 4002.

Fig. 151 is a flowchart explaining the processing of images with the image processing device, the configuration of which is shown in Fig. 133.

Fig. 152 is a flowchart explaining the processing of separated images with the separated image processing unit 4002.

Fig. 153 is a block diagram illustrating yet another configuration of the functions of the image processing device.

Fig. 154 is a block diagram illustrating an example of the configuration of a foreground/background separation unit 4601.

Fig. 155 is a block diagram illustrating another configuration of the functions of the image processing device.

Fig. 156 is a diagram explaining the processing of the region processing unit 5001.

Fig. 157 is a block diagram illustrating the configuration of the region processing unit 5001 which generates coefficient sets.

Fig. 158 is a block diagram illustrating the configuration of the region processing unit 5001 which generates a higher resolution image in the spatial direction.

Fig. 159A is a diagram illustrating an example of an image in the mixed region of a tutor image.

Fig. 159B is a diagram illustrating change in pixel values of an image in the mixed region of a tutor image.

Fig. 160A is a diagram illustrating an example of an image in a mixed region, generated by conventional class classification adaptation processing.

Fig. 160B is a diagram illustrating change in the pixel values of an image in a mixed region, generated by conventional class classification adaptation processing.

Fig. 161A is a diagram illustrating an example of an image in a mixed region, generated by the region processing unit 5001.

Fig. 161B is a diagram illustrating change in the pixel

values of an image in a mixed region, generated by the region processing unit 5001.

Fig. 162A is a diagram illustrating an example of an image in a foreground region of a tutor image.

Fig. 162B is a diagram illustrating change in the pixel values of an image in a foreground region of a tutor image.

Fig. 163A is a diagram illustrating an example of an image in a foreground region, generated by conventional class classification adaptation processing.

Fig. 163B is a diagram illustrating change in the pixel values of an image in a foreground region, generated by conventional class classification adaptation processing.

Fig. 164A is a diagram illustrating an example of an image in a foreground region, generated by the region processing unit 5001.

Fig. 164B is a diagram illustrating change in the pixel values of an image in a foreground region, generated by the region processing unit 5001.

Fig. 165 is a flowchart explaining the processing of images with the image processing device, the configuration of which is shown in Fig. 155.

Fig. 166 is a flowchart explaining the learning processing for generating coefficient sets with the region processing unit 5001.

Fig. 167 is a flowchart explaining the processing for

creating images with the region processing unit 5001.

Fig. 168 is a block diagram illustrating the configuration of the region processing unit 5001.

Fig. 169 is a diagram explaining the processing by the region processing unit 5001.

Fig. 170 is a flowchart explaining the processing of images with the image processing device, the configuration of which is shown in Fig. 155.

Fig. 171 is a flowchart explaining the processing of edge enhancement processing with the region processing unit 5001.

Fig. 172 is a flowchart explaining the processing of images with the image processing device shown in Fig. 155.

Fig. 173 is a block diagram illustrating the configuration of the region processing unit 5001 which generates coefficient sets.

Fig. 174 is a diagram explaining coefficient sets generated by the region processing unit 5001, the configuration of which is shown in Fig. 173.

Fig. 175 is a flowchart explaining the learning processing for generating coefficient sets.

Fig. 176 is a block diagram illustrating the configuration of the region processing unit 5001 which generates images wherein the noise has been removed.

Fig. 177 is a flowchart explaining the processing for

creating images with the region processing unit 5001, the configuration of which is shown in Fig. 176.

Fig. 178 is a block diagram illustrating a configuration of the functions of the image processing device.

Fig. 179 is a flowchart explaining the processing of images with the image processing device according to the present invention.

Fig. 180 is a block diagram illustrating the configuration of a separated image processing unit 7001 which generates coefficient sets.

Fig. 181 is a block diagram illustrating the configuration of a learning unit 7024.

Fig. 182 is a flowchart explaining the learning processing for generating coefficient sets with the separated image processing unit 7001.

Fig. 183 is a flowchart for explaining the processing for generating coefficient sets corresponding to the background component image.

Fig. 184 is a block diagram illustrating the configuration of the separated image processing unit 7001 which generates a higher resolution image in the spatial direction by applying the class classification adaptation processing to the background component image, while also performing linear interpolation of the foreground component

image.

Fig. 185 is a block diagram illustrating the configuration of a mapping unit 7302.

Fig. 186 is a diagram explaining the processing of the separated image processing unit 7001, the configuration of which is shown in Fig. 184.

Fig. 187 is a flowchart explaining the processing of the separated image processing unit 7001 shown in Fig. 184.

Fig. 188 is a flowchart describing processing for predicting images corresponding to the background component image.

Fig. 189 is a block diagram illustrating the configuration of the separated image processing unit 7001 which applies edge enhancement processing to only the background component image.

Fig. 190 is a block diagram illustrating the configuration of an edge enhancing unit 7501.

Fig. 191 is a block diagram illustrating another configuration of the edge enhancing unit 7501.

Fig. 192 is a diagram explaining the processing of the separated image processing unit 7001, the configuration of which is shown in Fig. 189.

Fig. 193 is a flowchart explaining the processing of the separated image processing unit 7001, the configuration of which is shown in Fig. 189.

Fig. 194 is a block diagram illustrating another configuration of the functions of the image processing device.

Best Mode for Carrying Out the Invention

Fig. 10 is a block diagram which illustrates the configuration of an embodiment of the image processing device according to the present invention. A CPU (Central Processing Unit) 71 performs various types of processing following programs stored in ROM (Read Only Memory) 72, or a storage unit 78. RAM (Random Access Memory) 73 suitably stores programs for the CPU 71 to execute, data, and so forth. These CPU 71, ROM 72, and RAM 73 are mutually connected via a bus 74.

The CPU 71 is also connected to an input/output interface 75 via the bus 74. The input/output interface 75 is connected to an input unit 76 such as a keyboard, mouse, microphone, or the like, and is connected to an output unit 77 such as a display, speaker, or the like. The CPU 71 performs various types of processing corresponding to instructions input from the input unit 76. The CPU 71 then outputs images, audio, or the like, which are obtained as a result of processing, to the output unit 77.

The storage unit 78 connected to the input/output interface 75 comprises a hard disk, for example, and stores

programs for the CPU 71 to execute and various types of data. A communication unit 79 communicates with external devices via the Internet or other networks. In this case of the example, the communication unit 79 serves as an obtaining unit which obtains output from a sensor.

Also, an arrangement may be made wherein programs are obtained via the communication unit 79, and are stored in the storage unit 78.

A drive 80 connected to the input/output interface 75 drives a magnetic disk 91, optical disk 92, magneto-optical disk 93, semiconductor memory 94, or the like, in the event that those are mounted thereon, and obtains programs and data stored therein. The obtained programs and data are transmitted to the storage unit 78 and stored therein, as necessary.

Fig. 11 is a block diagram which illustrates the configuration of the functions of the image processing device according to the present invention.

Note that whether each function of the image processing device is realized by hardware or software does not matter. That is to say, each block diagram in the present Specification may be regarded as not only a hardware block diagram but also as a software function block diagram.

Note that movement blurring means distortion which is included in images corresponding to moving objects, which

occurs due to movement of objects which are objects of image-taking in the real world and due to image-taking properties of the sensor.

In the present Specification, images corresponding to objects which are objects of image-taking in the real world are called image objects.

Input images provided to the image processing device are provided to an object extracting unit 101, a region specifying unit 103, a mixture ratio calculation unit 104, and a foreground/background separation unit 105.

The object extracting unit 101 roughly extracts the image objects corresponding to the foreground object contained in the input image, and supplies the extracted image object to the movement detecting unit 102. The object extracting unit 101 roughly extracts the image object corresponding to the foreground object, for example, by detecting the outlines of the image object corresponding to the foreground object included in input image.

The object extracting unit 101 roughly extracts the image object corresponding to the background object contained in the input image, and supplies the extracted image object to the movement detecting unit 102. The object extracting unit 101 roughly extracts the image object corresponding to the background object, by the difference between the input image and the image object corresponding

to the extracted foreground object, for example.

Also, for example, an arrangement may be made wherein the object extracting unit 101 roughly extracts the image objects corresponding to the foreground objects and the image objects corresponding to the background objects based upon the difference between the background images stored in background memory provided therein and the input images.

The movement detecting unit 102 calculates the movement vectors of the image object corresponding to the roughly extracted foreground objects by techniques such as block matching, gradation, phase correlation, and pixel recursion, or the like, and provides the calculated movement vectors and movement vector position information (information for specifying the pixel positions corresponding to the movement vectors) to the region specifying unit 103 and the movement blurring removal unit 106.

The movement vector output from the movement detecting unit 102 includes information corresponding to a movement amount v.

Also, for example, an arrangement may be made wherein the movement detecting unit 102 outputs the movement vector for each image object to the movement blurring removal unit 106 along with the pixel position information for specifying a pixel with regard to the image object.

The movement amount v is a value which represents the

change of position of the image corresponding to the moving object in increments of pixel interval. For example, in the event that the object image corresponding to the foreground moves so as to be displayed at a position four pixels away in the following frame with a given frame as a reference, the movement amount v of the image of the object corresponding to the foreground is 4.

The region specifying unit 103 classifies each of input pixels of an image into one of the foreground region, the background region, or the mixed region, and supplies information which indicates which of the foreground region, the background region, or the mixed region, each pixel belongs to, (which will be referred to as region information hereafter), to the mixture ratio calculation unit 104, the foreground/background separation unit 105, and the movement blurring removal unit 106. Details of the foreground region, the background region, or the mixed region, will be described later.

The mixture ratio calculation unit 104 calculates the mixture ratio corresponding to the pixels contained in the mixed region (which will be referred to as mixture ratio α hereafter) based upon the input image and the region information supplied from the region specifying unit 103, and supplies the calculated mixed ratio to the foreground/background separation unit 105.

The mixture ratio α is a value which represents the ratio of the image component corresponding to the background object (which will also be referred to as background component hereafter) with the pixel value as indicated in Expression (3) described below.

The foreground/background separation unit 105 separates the input images into foreground component images which consist of only the image components corresponding to the foreground object (which will also be referred to as the foreground component hereafter) and background component images which consist of only the background components based upon the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio calculation unit 104, supplies the foreground component images to the movement blurring removal unit 106, and supplies the background component image to a correction unit 107.

The movement blurring removal unit 106 decides the increment of processing, which indicates one or more pixels included in the foreground component images, based upon the movement amount v which is led from the movement vector, and the region information. An increment of processing is the data which designates one group of the pixels which are the object for adjustment processing for the movement blurring amount.

The movement blurring removal unit 106 removes movement blurring contained in the foreground component image based upon the foreground component image supplied from the foreground/background separation unit 105, the movement vector and the position information thereof supplied from the movement detecting unit 102, and the processing increment, and outputs the foreground component image which has been subjected to removal of movement blurring, to a movement-blurring-removed-image processing unit 108.

The correction unit 107 corrects the pixel value of a pixel corresponding to the mixed region in the background component image. The pixel value of a pixel corresponding to the mixed region in the background component image is calculated by subtracting the foreground component from the pixel value of a pixel in the mixed region prior to separation. Accordingly, the pixel value of a pixel corresponding to the mixed region in the background component image decreases corresponding to the mixture ratio α, as compared to the pixel value of a pixel in the adjacent background region.

The correction unit 107 corrects the decrease of the gain corresponding to the mixture ratio α of the pixel value of a pixel corresponding to the mixed region in the background component image, as described above, and supplies the corrected background component image to the movement-

blurring-removed-image processing unit 108.

The movement-blurring-removed-image processing unit 108 individually performs processing for the foreground component image which has been subjected to removal of movement blurring and the corrected background component image by classification adaptation processing.

For example, the movement-blurring-removed-image processing unit 108 generates coefficients which are used in the classifying adaptation processing for generating even higher resolution image, for each foreground component image which has been subjected to removal of movement blurring, and for each corrected background component image.

For example, the movement-blurring-removed-image processing unit 108 creates an even higher resolution image by applying the classifying adaptation processing to each foreground component image which has been subjected to removal of movement blurring, and for each corrected background component image.

The input images supplied to the image processing device will now be described, referring to Fig. 12 through Fig. 27.

Fig. 12 is a diagram which describes image-taking by a sensor. The sensor comprises a CCD video camera or the like, for example, including a CCD (Charge-Coupled Device) area sensor which is a solid-state image-taking device. An

object 111 corresponding to the foreground in the real world moves between an object 112 corresponding to the background in the real world, and the sensor, for example, from the left side to the right side horizontally in the drawing.

The sensor takes images of the object 111 corresponding to the foreground with the object 112 corresponding to the background. The sensor outputs the taken images in increments of one frame. For example, the sensor outputs images of 30 frames per second. In this case, the exposure period of the sensor is 1/30 seconds. The exposure period represents a period from the sensor beginning conversion of input light into electric charges, up to the end of conversion of input light to electric charges. The exposure period will be also referred to as a shutter period hereafter.

Fig. 13 is a diagram which describes an arrangement of pixels. In Fig. 13, A through I denote individual pixels. These pixels are arranged on a plane corresponding to the image. One detecting element corresponding to one pixel is disposed on the sensor. Upon the sensor taking images, one detecting element outputs pixel values corresponding to one pixel which makes up the image. For example, a position in the X direction of the detecting elements corresponds to a position in the horizontal direction on the image, and a position in the Y direction of the detecting elements

corresponds to a position in the vertical direction on the image.

As shown in Fig. 14, for example, the detecting element of the CCD converts the input light into charges for a period corresponding to the shutter period, and accumulates the converted charges. The quantity of charges is approximately proportional to the strength of the input light and the period during which the light is input. The detecting element adds the charges converted from the input light to the accumulated charges in the period corresponding to the shutter period. That is to say, the detecting element integrates the input light during the period corresponding to the shutter period, and accumulates the amount of charges corresponding to the integrated light. It can also be said that the detecting element has integrating effects with regard to time.

The charges accumulated in the detecting element are converted into a voltage value by a circuit not shown in the drawings, which is further converted to pixel values such as digital data or the like, and is output. Accordingly, individual pixel values output from a sensor have values projected in one-dimensional space, which is from a result wherein a given portion having a spatial extension of the object corresponding to the foreground or the background, is integrated for the shutter period.

The image processing device extracts valid information buried in output signals due to such accumulation operations of the sensor, such as the mixture ratio α, for example.

Fig. 15A and Fig. 15B are diagrams which describe the image which is obtained by taking images of the object corresponding to the moving foreground and the object corresponding to the still background. Fig. 15A illustrates the image which is obtained by taking image of the object corresponding to the foreground with movement and the object corresponding to the still background. With the example shown in Fig. 15A, the object corresponding to the foreground moves from the left to the right horizontally in the drawing.

Fig. 15B is a model diagram wherein pixel values corresponding to one line of the image shown in Fig. 15A develop over the time direction. The horizontal direction in Fig. 15B corresponds to the spatial direction X in Fig. 15A.

The pixel values of pixels in the background regions are made up of only the background components, i.e., the image components corresponding to the background objects. The pixel values of pixels in the foreground regions are made up of only the foreground components, i.e., the image components corresponding to the foreground objects.

The pixel values of pixels in mixed regions are made up

of the background components and the foreground components. Since the pixel values in the mixed region consists of the background components and the foreground components, the mixed region can also be said to be a distortion region. The mixed regions are further classified into covered background regions and uncovered background regions.

The covered background region is a mixed region at a position corresponding to a leading portion in the progress direction of the foreground object with regard to the foreground region, and accordingly is a region wherein the background components are covered by the foreground corresponding to elapsing of time.

Conversely, the uncovered background region is a mixed region at a position corresponding to a trailing portion in the progress direction of the foreground object with regard to the foreground region, and accordingly is a region wherein the background components emerge corresponding to elapsing of time.

As described above, images including the foreground region, background region, covered background region, or uncovered background region, are input as input images to the region specifying unit 103, the mixture ratio calculation unit 104, and the foreground/background separation unit 105.

Fig. 16 is a diagram which describes the background

region, foreground region, mixed region, covered background region, and uncovered background region, as described above. In the event of corresponding to the images shown in Fig. 15A, the background region is the still portion, the foreground region is the moving portion, the covered background region of the mixed region is the portion which changes from the background to the foreground, and the uncovered background region of the mixed region is the portion which changes from the foreground to the background.

Fig. 17 is a model diagram wherein pixel values of the pixels arrayed adjacently in one line in the image that has been taken of the objects corresponding to the still foregrounds and the objects corresponding to the still backgrounds, develop over the time direction. For example, pixels arrayed in one line in a screen may be selected, as pixels adjacently arrayed in one line.

The pixel values F01 through F04 shown in Fig. 17 are pixel values of pixels corresponding to the still foreground object. The pixel values B01 through B04 shown in Fig. 17 are pixel values of pixels corresponding to the still background object.

The vertical direction in Fig. 17 represents elapsing of time from the top to the bottom in the drawing. The position of the upper side of the rectangle in Fig. 17 corresponds to the time at which the sensor begins

conversion of the input light into charges, and the position of the lower side of the rectangle in Fig. 17 corresponds to the time at which the sensor ends the conversion of the input light into charges. That is to say, the distance from the upper side to the lower side of the rectangle in Fig. 17 corresponds to the shutter period.

An arrangement wherein the shutter period equals the frame interval will now be described below, by way of an example.

The horizontal direction in Fig. 17 corresponds to the spatial direction X as described in Fig. 15A. More particularly, shown by way of an example in Fig. 17, the distance from the left side of the rectangle denoted by "F01" to the right side of the rectangle denoted by "B04" in Fig. 17, is eight times long as the pixel pitch, that is to say, corresponds to the interval of eight continuous pixels.

In the event that the foreground objects and the background objects keep still, the light input to the sensor is not altered during the period corresponding to the shutter period.

Now, the period corresponding to the shutter period is divided into two or more periods of equal length. For example, in the event that the virtual dividing number is 4, the model diagram shown in Fig. 17 can be represented by the model shown in Fig. 18. The virtual dividing number is set

corresponding to the movement amount v or the like of the object corresponding to the foreground within the shutter period. For example, corresponding to the movement amount v of 4, the virtual dividing number is 4, and the period corresponding to the shutter period is divided into 4 periods.

The uppermost row in the drawing corresponds to the first of the divided periods from the shutter being opened. The second row from the top in the drawing corresponds to the second of the divided periods from the shutter being opened. The third row from the top in the drawing corresponds to the third of the divided periods from the shutter being opened. The fourth row from the top in the drawing corresponds to the fourth of the divided periods from the shutter being opened.

The divided shutter period corresponding to the movement amount v will also be referred to as a shutter period/v hereafter.

In the event that the object corresponding to the foreground keeps still, the foreground component F01/v equals the value in which the pixel value F01 is divided by the virtual dividing number, since the light input to the sensor is not altered. Similarly, in the event that the object corresponding to the foreground keeps still, the foreground component F02/v equals the value of the pixel

value F02 being divided by the virtual dividing number, the foreground component F03/v equals the value of the pixel value F03 being divided by the virtual dividing number, and the foreground component F04/v equals the value of the pixel value F04 being divided by the virtual dividing number.

In the event that the object corresponding to the background keeps still, the background component B01/v equals the value of the pixel value B01 being divided by the virtual dividing number, since the light input to the sensor is not altered. Similarly, in the event that the object corresponding to the background keeps still, the background component B02/v equals the value of the pixel value B02 being divided by the virtual dividing number, B03/v equals the value of the pixel value B03 being divided by the virtual dividing number, and B04/v equals the value of the pixel value B04 being divided by the virtual dividing number.

That is to say, in the event that the object corresponding to the foreground keeps still, the foreground component F01/v corresponding to the first shutter period/v from the shutter opening, the foreground component F01/v corresponding to the second shutter period/v from the shutter opening, the foreground component F01/v corresponding to the third shutter period/v from the shutter opening, and the foreground component F01/v corresponding to the fourth shutter period/v from the shutter opening, are

the same value, since the light corresponding to the foreground object which is input to the sensor is not altered during the period corresponding to the shutter period. F02/v through F04/v have the same relationship as F01/v.

In the event that the object corresponding to the background keeps still, the background component B01/v corresponding to the first shutter period/v from the shutter opening, the background components B01/v corresponding to the second shutter period/v from the shutter opening, the background components B01/v corresponding to the third shutter period/v from the shutter opening, and the background components B01/v corresponding to the fourth shutter period/v from the shutter opening, are the same value, since the light corresponding to the background object which is input to the sensor is not altered during the period corresponding to the shutter period. B02/v through B04/v have the same relationship.

A case will now be described wherein the object corresponding to the foreground moves while the object corresponding to the background keeps still.

Fig. 19 is a model diagram wherein pixel values of the pixels on one line including the covered background region develop over the time direction in the event that the object corresponding to the foreground moves towards the right side

in the drawing. In Fig. 19, the movement amount v of the foreground is 4. Since one frame is a short period, an assumption may be made that the object corresponding to the foreground is a rigid body, and moves at a constant velocity. In Fig. 19, the object image corresponding to the foreground moves so as to be displayed at a position four pixels to the right in the following frame, with a given frame as a reference.

In Fig. 19, the left-most pixel through the fourth pixel from the left, belong to the foreground region. In Fig. 19, the fifth through the seventh pixels from the left belong to the covered background region of the mixed region. In Fig. 19, the right-most pixel belongs to the background region.

Since the object corresponding to the foreground moves so as to hide the object corresponding to the background with elapsing of time, the components contained in the pixel values of the pixels which belong to the covered background region change from the background components to the foreground components at a certain point of the period corresponding to the shutter period.

For example, the pixel value M shown with a heavy frame in Fig. 19, is represented by Expression (1).

$$M = B02/v + B02/v + F07/v + F06/v \quad (1)$$

For example, since the fifth pixel from the left

includes a background component corresponding to one shutter period/v and foreground components corresponding to the three shutter period/vs, the mixture ratio α of the fifth pixel from the left is one-quarter. Since the sixth pixel from the left includes background components corresponding to the two shutter period/vs and two foreground components corresponding to the two shutter period/vs, the mixture ratio α of the sixth pixel from the left is 1/2. Since the seventh pixel from the left includes background components corresponding to the three shutter period/vs and a foreground component corresponding to the one shutter period/v, the mixture ratio α of the seventh pixel from the left is 3/4.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and the foreground image moves at a constant velocity so as to be displayed at a position four pixels to the right in the following frame, the foreground component F07/v of the first shutter period/v from the shutter opening of the fourth pixel from the left in Fig. 19, for example, equals the foreground component corresponding to the second shutter period/v from the shutter opening of the fifth pixel from the left in Fig. 19. Similarly, the foreground component F07/v equals the foreground component corresponding to the third shutter period/v from the shutter opening of the sixth

pixel from the left in Fig. 19, and the foreground component corresponding to the fourth shutter period/v from the shutter opening of the seventh pixel from the left in Fig. 19, respectively.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and that the foreground image moves at a constant velocity so as to be displayed at a point four pixels to the right in the following frame, the foreground component F06/v of the first shutter period/v from the shutter opening of the third pixel from the left in Fig. 19, for example, equals the foreground component corresponding to the second shutter period/v from the shutter opening of the fourth pixel from the left in Fig. 19. Similarly, the foreground component F06/v equals the foreground component corresponding to the third shutter period/v from the shutter opening of the fifth pixel from the left in Fig. 19, and the foreground component corresponding to the fourth shutter period/v from the shutter opening of the sixth pixel from the left in Fig. 19, respectively.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and the foreground image moves at a constant velocity so as to be displayed at a position four pixels to the right in the following frame, the foreground component F05/v of the first

shutter period/v from the shutter opening of the second pixel from the left in Fig. 19, for example, equals the foreground component corresponding to the second shutter period/v from the shutter opening of the third pixel from the left in Fig. 19. Similarly, the foreground component F05/v equals the foreground component corresponding to the third shutter period/v from the shutter opening of the fourth pixel from the left in Fig. 19, and the foreground component corresponding to the fourth shutter period/v from the shutter opening of the fifth pixel from the left in Fig. 19, respectively.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and the foreground image moves at a constant velocity so as to be displayed at a position four pixels to the right in the following frame, the foreground component F04/v of the first shutter period/v from the shutter opening of the left-most pixel in Fig. 19, for example, equals the foreground component corresponding to the second shutter period/v from the shutter opening of the second pixel from the left in Fig. 19. Similarly, the foreground component F04/v equals the foreground component corresponding to the third shutter period/v from the shutter opening of the third pixel from the left in Fig. 19, and the foreground component corresponding to the fourth shutter period/v from the

shutter opening of the fourth pixel from the left in Fig. 19, respectively.

As described above, the foreground region corresponding to the moving object includes movement blurring, so this can be said to be a distorted region.

Fig. 20 is a model diagram wherein the pixel values of the pixels on one line including the uncovered background region develop over the time direction in the event that the foreground moves toward the right side in the drawing. In Fig. 20, the movement amount v of the foreground is 4. Since one frame is a short time, an assumption may be made that the object corresponding to the foreground is a rigid body, and moves at a constant velocity. In Fig. 20, the object image corresponding to the foreground moves to the right side by four pixels in the following frame with a given frame as a reference.

In Fig. 20, the left-most pixel through the fourth pixel from the left, belong to the background region. In Fig. 20, the fifth through the seventh pixels from the left belong to the mixed region of the uncovered background. In Fig. 20, the right-most pixel belongs to the foreground region.

Since the object corresponding to the foreground which has hidden the object corresponding to the background moves so as to be removed from the front of the object

corresponding to the background with elapsing of time, the components included in the pixel values of the pixels which belong to the uncovered background region change from the foreground components to the background components at a certain point in the period corresponding to the shutter period.

For example, the pixel value M' indicated with a heavy frame in Fig. 20, is represented by Expression (2).

$$M' = F02/v + F01/v + B26/v + B26/v \quad (2)$$

For example, since the fifth pixel from the left includes the background components corresponding to the three shutter period/vs, and the foreground component corresponding to the one shutter period/v, the mixture ratio α of the fifth pixel from the left is 3/4. Since the sixth pixel from the left includes the background components corresponding to the two shutter period/vs and the foreground components corresponding to the two shutter period/vs, the mixture ratio α of the sixth pixel from the left is 1/2. Since the seventh pixel from the left includes the background component corresponding to the one shutter period/v and the foreground components corresponding to the three shutter period/vs, the mixture ratio α of the seventh pixel from the left is one-quarter.

Further generalizing Expression (1) and Expression (2), the pixel value M is represented by Expression (3).

$$M = \alpha \cdot B + \sum_i F_i/v \qquad (3)$$

Here, α denotes the mixture ratio. B denotes the pixel value of the background, and Fi/v denotes the foreground component.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and moves at a constant velocity, and the movement amount v is 4, for example, the foreground component F01/v of the first shutter period/v from the shutter opening of the fifth pixel from the left in Fig. 20 equals the foreground component corresponding to the second shutter period/v from the shutter opening of the sixth pixel from the left in Fig. 20. Similarly, F01/v equals the foreground component corresponding to the third shutter period/v from the shutter opening of the seventh pixel from the left in Fig. 20, and the foreground component corresponding to the fourth shutter period/v from the shutter opening of the eighth pixel from the left in Fig. 20, respectively.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and moves at a constant velocity, and the virtual dividing number is 4, the foreground component F02/v of the first shutter period/v from the shutter opening of the sixth pixel from the left in Fig. 20, for example, equals the foreground component corresponding to the second shutter period/v from the

shutter opening of the seventh pixel from the left in Fig. 20. Similarly, the foreground component F02/v equals the foreground component corresponding to the third shutter period/v from the shutter opening of the eighth pixel from the left in Fig. 20.

Since an assumption may be made that the object corresponding to the foreground is an rigid body and moves at a constant velocity, and movement amount v is 4, the foreground component F03/v of the first shutter period/v from the shutter opening of the seventh pixel from the left in Fig. 20, for example, equals the foreground component corresponding to the second shutter period/v from the shutter opening of the eighth pixel from the left in Fig. 20.

While a description has been made in the description of Fig. 18 through Fig. 20 wherein the virtual dividing number is 4, the virtual dividing number corresponds to the movement amount v. The movement amount v generally corresponds to the movement velocity of the object corresponding to the foreground. For example, in the event that the object corresponding to the foreground moves so as to be displayed at a position four pixels to the right in the following frame with a given frame as a reference, the movement amount v is 4. The virtual dividing number is 4 corresponding to the movement amount v. Similarly, for example, in the event that the object corresponding to the

foreground moves so as to be displayed at a position six pixels to the left in the following frame with a given frame as a reference, the movement amount v is 6, and the virtual dividing number is 6.

Fig. 21 and Fig. 22 illustrate the relationship between the foreground region, the background region, and the mixed region which consists of the covered background region or the uncovered background region, and the foreground components and the background components, corresponding to the divided shutter period.

Fig. 21 illustrates an example wherein the pixels of the foreground region, the background region, and the mixed region, are extracted from the image including the foreground corresponding to the object which moves in front of the still background. In an example shown in Fig. 21, the object corresponding to the foreground denoted by reference character A moves horizontally on the screen.

The frame #n + 1 is the frame following the frame #n, and the frame #n + 2 is the frame following the frame #n + 1.

Fig. 22 illustrates a model wherein the pixels of the foreground region, the background region, and the mixed region are extracted from one of frame #n through frame #n + 2, and the pixel values of the extracted pixels are developed over the time direction, with the movement amount v at 4.

Since the object corresponding to the foreground moves, the pixel values of the foreground region consist of four different foreground components corresponding to the period of shutter period/v. For example, the left-most pixel of the pixels of the foreground region shown in Fig. 22 consists of F01/v, F02/v, F03/v, and F04/v. That is to say, the pixels of the foreground region include movement blurring.

Since the object corresponding to the background keeps still, the light corresponding to the background input to the sensor is not altered during the period corresponding to the shutter period. In this case, the pixel values of the background region do not contain movement blurring.

The pixel value of the pixel which belongs to the mixed region made up of the covered background region or the uncovered background region consists of the foreground components and the background components.

Next, a model will be described wherein, in the event that the image corresponding to the object moves, the pixel values of the pixels which are arrayed adjacently in a single line on multiple frames, and at the same position in the frames, develop over the time direction. For example, in the event that the image corresponding to the object moves horizontally on the screen, the pixels arrayed in a single line can be selected as pixels arrayed adjacently in

a single line.

Fig. 23 is a model diagram wherein the pixel values of pixels arrayed adjacently in a single line on three frames of images which are taken of the object corresponding to the still background, and are at the same position in the frames, develop over the time direction. The frame #n is the frame following the frame #n - 1, and the frame #n + 1 is the frame following the frame #n. Other frames are denoted in the same way.

The pixel values of the B01 through B12 shown in Fig. 23 are the pixel values of the pixels corresponding to the object of the still background. Since the object corresponding to the background keeps still, the pixel values of the corresponding pixels do not change in the frame #n - 1 through the frame #n + 1. For example, the pixels in the frame #n and the pixels in the frame #n + 1 at the position corresponding to the pixel having a pixel value B05 in the frame #n - 1, have a pixel value B05, respectively.

Fig. 24 is a model diagram wherein the pixel values of pixels arrayed adjacently in a single line on three frames of images taken of the object corresponding to the foreground which moves to the right side in the drawing with the object corresponding to the still background, and at the same position in the frames, develop over the time direction.

The models shown in Fig. 24 includes the covered background region.

Since an assumption may be made in Fig. 24 that the object corresponding to the foreground is a rigid body and moves at a constant velocity, and the foreground image moves so as to be displayed at a position four pixels to the right side in the following frame, the foreground movement amount v is 4, and the virtual dividing number is 4.

For example, the foreground component of the first shutter period/v from the shutter opening of the left-most pixel of the frame #n - 1 in Fig. 24 is F12/v, the foreground component of the second shutter period/v from the shutter opening of the second pixel from the left in Fig. 24 is also F12/v. The foreground component of the third shutter period/v from the shutter opening of the third pixel from the left in Fig. 24, and the foreground component of the fourth shutter period/v from the shutter opening of the fourth pixel from the left in Fig. 24, are F12/v.

The foreground component of the second shutter period/v from the shutter opening of the left-most pixel in the frame #n - 1 in Fig. 24 is F11/v, and the foreground component of the third shutter period/v from the shutter opening of the second pixel from the left in Fig. 24 is also F11/v. The foreground component of the fourth shutter period/v from the shutter opening of the third pixel from the left in Fig. 24

is F11/v.

The foreground component of the third shutter period/v from the shutter opening of the left-most pixel in the frame #n - 1 in Fig. 24 is F10/v, and the foreground component of the fourth shutter period/v from the shutter opening of the second pixel from the left in Fig. 24 is also F10/v. The foreground component of the fourth shutter period/v from the shutter opening of the left-most pixel in the frame #n - 1 in Fig. 24 is F09/v.

Since the object corresponding to the background keeps still, the background component of the first shutter period/v from the shutter opening of the second pixel from the left in the frame #n - 1 in Fig. 24 is B01/v. The background components of the first and second shutter period/vs from the shutter opening of the third pixel from the left in the frame #n - 1 in Fig. 24 are B02/v. The background components of the first through third shutter period/vs from the shutter opening of the fourth pixel from the left in the frame #n - 1 in Fig. 24 are B03/v.

In the frame #n - 1 in Fig. 24, the left-most pixel belongs to the foreground region, and the second through fourth pixels from the left belong to the mixed region of the covered background region.

The fifth through twelfth pixels from the left in the frame #n - 1 in Fig. 24 belong to the background region, and

the pixel values thereof are B04 through B11, respectively.

The first through fifth pixels from the left in the frame #n in Fig. 24 belong to the foreground region. The foreground component of the shutter period/v in the foreground region in the frame #n, is one of F05/v through F12/v.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and moves at a constant velocity, and the foreground image moves so as to be displayed at a position four pixels to the right side in the following frame, the foreground component of the first shutter period/v from the shutter opening of the fifth pixel from the left in the frame #n in Fig. 24 is F12/v, the foreground component of the second shutter period/v from the shutter opening of the sixth pixel from the left in Fig. 24 is also F12/v. The foreground component of the third shutter period/v from the shutter opening of the seventh pixel from the left in Fig. 24, and the foreground component of the fourth shutter period/v from the shutter opening of the eighth pixel from the left in Fig. 24, are F12/v.

The foreground component of the second shutter period/v from the shutter opening of the fifth pixel from the left in the frame #n in Fig. 24 is F11/v, and the foreground component of the third shutter period/v from the shutter opening of the sixth pixel from the left in Fig. 24 is also

F11/v. The foreground component of the fourth shutter period/v from the shutter opening of the seventh pixel from the left in Fig. 24 is F11/v.

The foreground component of the third shutter period/v from the shutter opening of the fifth pixel from the left in the frame #n in Fig. 24 is F10/v, and the foreground component of the fourth shutter period/v from the shutter opening of the sixth pixel from the left in Fig. 24 is also F10/v. The foreground component of the fourth shutter period/v from the shutter opening of the fifth pixel from the left in the frame #n in Fig. 24 is F09/v.

Since the object corresponding to the background keeps still, the background component of the first shutter period/v from the shutter opening of the sixth pixel from the left in the frame #n in Fig. 24 is B05/v. The background components of the first and second shutter period/vs from the shutter opening of the seventh pixel from the left in the frame #n in Fig. 24 are B06/v. The background components of the first through third shutter period/vs from the shutter opening of the eighth pixel from the left in the frame #n in Fig. 24 are B07/v.

In the frame #n in Fig. 24, the sixth through eighth pixels from the left belong to the mixed region of the covered background region.

The ninth through twelfth pixels from the left in the

frame #n in Fig. 24 belong to the background region, and the pixel values are B08 through B11, respectively.

The first through ninth pixels from the left in the frame #n + 1 in Fig. 24 belong to the foreground region. The foreground component of the shutter period/v in the foreground region in the frame #n + 1 is one of F01/v through F12/v.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and moves at a constant velocity, and the foreground image moves so as to be displayed at a position four pixels to the right side in the following frame, the foreground component of the first shutter period/v from the shutter opening of the ninth pixel from the left in the frame #n + 1 in Fig. 24 is F12/v, and the foreground component of the second shutter period/v from the shutter opening of the tenth pixel from the left in Fig. 24 is also F12/v. The foreground component of the third shutter period/v from the shutter opening of the eleventh pixel from the left in Fig. 24, and the foreground component of the fourth shutter period/v from the shutter opening of the twelfth pixel from the left in Fig. 24, are F12/v.

The foreground component of the second shutter period/v from the shutter opening of the ninth pixel from the left in the frame #n + 1 in Fig. 24 is F11/v, and the foreground component of the third shutter period/v from the shutter

opening of the tenth pixel from the left in Fig. 24 is also F11/v. The foreground component of the fourth shutter period/v from the shutter opening of the eleventh pixel from the left in Fig. 24 is F11/v.

The foreground component of the third shutter period/v from the shutter opening of the ninth pixel from the left in the frame #n + 1 in Fig. 24 is F10/v, and the foreground component of the fourth shutter period/v from the shutter opening of the tenth pixel from the left in Fig. 24 is also F10/v. The foreground component of the fourth shutter period/v from the shutter opening of the ninth pixel from the left in the frame #n + 1 in Fig. 24 is F09/v.

Since the object corresponding to the background keeps still, the background component of the first shutter period/v from the shutter opening of the tenth pixel from the left in the frame #n + 1 in Fig. 24 is B09/v. The background components of the first and second shutter period/vs from the shutter opening of the eleventh pixel from the left in the frame #n + 1 in Fig. 24 are B10/v. The background components of the first through third shutter period/vs from the shutter opening of the twelfth pixel from the left in the frame #n + 1 in Fig. 24 are B11/v.

In the frame #n + 1 in Fig. 24, the tenth through twelfth pixels from the left side correspond to the mixed region which is the covered background region.

Fig. 25 is a model diagram wherein the foreground components are extracted from the pixel values illustrated in Fig. 24.

Fig. 26 is a model diagram wherein the pixel values of the pixels adjacently arrayed in a row in three frames of the images which are taken of the foreground corresponding to the object which moves to the right side in the drawing with the still background, and are at the same position in the frames, develop over the time direction. In Fig. 26, the model diagram includes the uncovered background region.

In Fig. 26, an assumption may be made that the object corresponding to the foreground is a rigid body, and moves at a constant velocity. Since the object corresponding to the foreground moves so as to be displayed at a position four pixels to the right side in the following frame, the movement amount v is 4.

For example, the foreground component of the first shutter period/v from the shutter opening of the left-most pixel in the frame #n - 1 in Fig. 26 is F13/v, and the foreground component of the second shutter period/v from the shutter opening of the second pixel from the left in Fig. 26 is also F13/v. The foreground component of the third shutter period/v from the shutter opening of the third pixel from the left in Fig. 26, and the foreground component of the fourth shutter period/v from the shutter opening of the

fourth pixel from the left in Fig. 26, are F13/v.

The foreground component of the first shutter period/v from the shutter opening of the second pixel from the left in the frame #n - 1 in Fig. 26 is F14/v, and the foreground component of the second shutter period/v from the shutter opening of the third pixel from the left in Fig. 26 is also F14/v. The foreground component of the first shutter period/v from the shutter opening of the third pixel from the left in Fig. 26 is F15/v.

Since the object corresponding to the background keeps still, the background component of the second through fourth shutter period/vs from the shutter opening of the left-most pixel in the frame #n - 1 in Fig. 26 is B25/v. The background components of the third and fourth shutter period/vs from the shutter opening of the second pixel from the left in the frame #n - 1 in Fig. 26 are B26/v. The background component of the fourth shutter period/v from the shutter opening of the third pixel from the left in the frame #n - 1 in Fig. 26 is B27/v.

In the frame #n - 1 in Fig. 26, the left-most pixel through the third pixel belong to a mixed region of the uncovered background region.

The fourth through twelfth pixels from the left in the frame #n - 1 in Fig. 26 belong to the foreground region. The foreground component in the frame is one of F13/v

through F24/v.

The left-most pixel through the fourth pixel from the left in the frame #n in Fig. 26 belong to the background region, and the pixel values are B25 through B28, respectively.

Since an assumption may be made that the object corresponding to the foreground is a rigid body and moves at a constant velocity, and the foreground image moves so as to be displayed at a position four pixels to the right side in the following frame, the foreground component of the first shutter period/v from the shutter opening of the fifth pixel from the left in the frame #n in Fig. 26 is F13/v, and the foreground component of the second shutter period/v from the shutter opening of the sixth pixel from the left in Fig. 26 is also F13/v. The foreground component of the third shutter period/v from the shutter opening of the seventh pixel from the left in Fig. 26, and the foreground component of the fourth shutter period/v from the shutter opening of the eighth pixel from the left in Fig. 26, are F13/v.

The foreground component of the first shutter period/v from the shutter opening of the sixth pixel from the left in the frame #n in Fig. 26 is F14/v, and the foreground component of the second shutter period/v from the shutter opening of the seventh pixel from the left in Fig. 26 is also F14/v. The foreground component of the first shutter

period/v from the shutter opening of the eighth pixel from the left in Fig. 26 is F15/v.

Since the object corresponding to the background keeps still, the background components of the second through fourth shutter period/vs from the shutter opening of the fifth pixel from the left in the frame #n in Fig. 26 are B29/v. The background components of the third and fourth shutter period/vs from the shutter opening of the sixth pixel from the left in the frame #n in Fig. 26 are B30/v. The background component of the fourth shutter period/v from the shutter opening of the seventh pixel from the left in the frame #n in Fig. 26 is B31/v.

In the frame #n in Fig. 26, the fifth through seventh pixels from the left belong to the mixed region of the uncovered background region.

The eighth through twelfth pixels from the left in the frame #n in Fig. 26 belong to the foreground region. The value corresponding to the period of the shutter period/v in the foreground region in the frame #n is one of F13/v through F20/v.

The left-most pixel through the eighth pixel from the left in the frame #n + 1 in Fig. 26, belong to the background region, and the pixel values thereof are B25 through B32, respectively.

Since an assumption may be made that the object

corresponding to the foreground is a rigid body and moves at a constant velocity, and the foreground image moves so as to be displayed at a position four pixels to the right side in the following frame, the foreground component of the first shutter period/v from the shutter opening of the ninth pixel from the left in the frame #n + 1 in Fig. 26 is F13/v, and the foreground component of the second shutter period/v from the shutter opening of the tenth pixel from the left in Fig. 26 is also F13/v. The foreground component of the third shutter period/v from the shutter opening of the eleventh pixel from the left in Fig. 26, and the foreground component of the fourth shutter period/v from the shutter opening of the twelfth pixel from the left in Fig. 26, are F13/v.

The foreground component of the first shutter period/v from the shutter opening of the tenth pixel from the left in the frame #n + 1 in Fig. 26 is F14/v, and the foreground component of the second shutter period/v from the shutter opening of the eleventh pixel from the left in Fig. 26 is also F14/v. The foreground component of the first shutter period/v from the shutter opening of the twelfth pixel from the left in Fig. 26 is F15/v.

Since the object corresponding to the background keeps still, the background components of the second through fourth shutter period/vs from the shutter opening of the ninth pixel from the left in the frame #n + 1 in Fig. 26 are

B33/v. The background components of the third and fourth shutter period/vs from the shutter opening of the tenth pixel from the left in the frame #n + 1 in Fig. 26 are B34/v. The background component of the fourth shutter period/v from the shutter opening of the eleventh pixel from the left in the frame #n + 1 in Fig. 26 is B35/v.

In the frame #n + 1 in Fig. 26, the ninth through eleventh pixels from the left belong to the mixed region of the uncovered background region.

The twelfth pixel from the left in the frame #n + 1 in Fig. 26 belongs to the foreground region. The foreground component of the shutter period/v in the foreground region in the frame #n + 1 is one of F13/v through F16/v.

Fig. 27 is a model diagram of the image wherein the foreground components are extracted from the pixel values shown in Fig. 26.

Fig. 28 is a diagram which illustrates the correspondence of the image divided into pixels each of which belongs to the foreground region, background region, covered background region, or uncovered background region, to a model diagram wherein the pixel values of pixels develop over the time direction.

As shown in Fig. 28, the region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region, of the

input image.

Fig. 29 is a diagram which illustrates the correspondence of the input image divided into the image of the foreground region, the image of the background region, the foreground component image of the covered background region, the background components of the covered background region, the foreground components of the uncovered background region, and the background components of the uncovered background region, to a model diagram wherein the pixel values of pixels develop over the time direction.

As shown in Fig. 29, the input image is classified into the foreground region, background region, covered background region, and uncovered background region, by the region specifying unit 103. The input image is separated into the image of the foreground region, the foreground components of the covered background region, and the foreground component image made up of the foreground components of the uncovered background region, and the image of the background region, the background components of the covered background region, and the background component image made up of the background components of the uncovered background region, based upon the foreground region, background region, covered background region, and uncovered background region, specified by foreground/background separation unit 105, and the mixture ratio α detected by the mixture ratio calculation unit 104.

The separated foreground component image and background component image are processed for each image.

An arrangement may be made wherein the foreground/background separation unit 105 separates the input image into the image of the foreground region, image of the background region, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region, based upon the region information and the mixture ratio α.

Fig. 30 is a diagram which illustrates an example of the image divided into the foreground region, the background region, and the mixed region. The region specifying unit 103 specifies the foreground region, background region, and mixed region, of the input image. The image processing device can divide the input image into the image of the foreground region, image of the background region, and image of the mixed region, based upon the region information indicating the foreground region, background region, and mixed region.

As shown in Fig. 31, the foreground/background separation unit 105 separates the image of the mixed region into the foreground component image of the mixed region and the background component image of the mixed region, based

upon the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio calculation unit 104.

As shown in Fig. 32, the separated background component image is subjected to correction with regard to the pixel values of the mixed region, and the separated foreground component image is subjected to removal of movement blurring.

As shown in Fig. 33, the input image is divided into regions, and separated into the foreground components and the background components. The separated input image is synthesized into the foreground component image and the background component image.

The movement blurring contained in the foreground component image is removed. The background component image is corrected for the pixel values corresponding to the mixed region.

The foreground component image which has been subjected to removal of movement blurring, and the corrected background component image is individually performed processing.

Fig. 34 is a flowchart which describes the processing of the image of the image processing device according to the present invention.

In Step S101, the region specifying unit 103 specifies the foreground region, background region, covered background

region, and uncovered background region of the input image, based upon the movement vector and the position information thereof supplied from the movement detecting unit 102 and the input image. Details of the processing for region specifying will be described later.

In Step S102, the mixture ratio calculation unit 104 calculates the mixture ratio α based upon the region information supplied from the region specifying unit 103 and the input image. Details of the processing of the mixture ratio calculation unit 104 calculating the mixture ratio α will be described later.

In Step S103, the foreground/background separation unit 105 separates the input image into the foreground component image made up of the foreground components and the background component image made up of the background components, based upon the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio calculation unit 104. Details of processing of separation of the image by the foreground/background separation unit 105 will be described later.

In Step S104, the movement blurring removal unit 106 removes movement blurring from the foreground component image supplied from the foreground/background separation unit 105, based upon the movement vector and the position

information thereof supplied from the movement detecting unit 102 and the region information supplied from the region specifying unit 103.

In Step S105, the correction unit 107 corrects the pixel values corresponding to the mixed region of the background component image supplied from the foreground/background separation unit 105.

In Step S106, the movement-blurring-removed image processing unit 108 performs processing of the image for each foreground component image which has been subjected to removal of movement blurring and each background component image which has been corrected, and processing ends. Details of the image processing which the movement-blurring-removed image processing unit 108 performs, will be described later.

As described above, the image processing device according to the present invention separates the input image into the foreground component image and the background component image, removes movement blurring from the foreground component image, and performs processing for each foreground component image which has been subjected to removal of movement blurring, and each background component image.

Description with regard to each configuration of the region specifying unit 103, the mixture ratio calculation

unit 104, the foreground/background separation unit 105, the movement blurring removal unit 106, and the movement-blurring-removed image processing unit 108, will be made below.

Fig. 35 is a block diagram which illustrates an example of the configuration of the region specifying unit 103. The region specifying unit 103, of which the structure is shown in Fig. 35, does not use the movement vectors. Frame memory 201 stores the input images in increments of one frame. In the event that the object of the processing is the frame #n, the frame memory 201 stores the frame #n - 2 which is two frames previous from the frame #n, the frame #n - 1 which is one frame previous from the frame #n, the frame #n, the frame #n + 1 which is one frame following the frame #n, and the frame #n + 2 which is two frames following the frame #n.

A still/motion judgment unit 202-1 reads out the pixel value of the pixel in the frame #n + 2, which is at the same position as the position of the pixel on the image, which is the object of specifying the region in the frame #n, and the pixel value of the pixel in the frame #n + 1, which is at the same position as the position of the pixel on the image, which is the object of specifying the region of the frame #n, from the frame memory 201, and calculates the absolute value of the difference between the read out pixel values. The still/motion judgment unit 202-1 judges whether or not the

absolute value of the difference between the pixel value in the frame #n + 2 and the pixel value in the frame #n + 1 is greater than the predetermined threshold value Th, and in the event that judgment is made that the absolute value of the difference is greater than the threshold value Th, the still/motion judgment unit 202-1 supplies the still/motion judgment, indicating motion, to a region judgment unit 203-1. In the event that judgment is made that the absolute value of the difference between the pixel value of the pixel in the frame #n + 2 and the pixel value of the pixel in the frame #n + 1 is equal to or less than the threshold value Th, the still/motion judgment unit 202-1 supplies the still/motion judgment, indicating "still", to the region judgment unit 203-1.

A still/motion judgment unit 202-2 reads out the pixel value of the pixel in the frame #n + 1, which is at the same position as the position of the pixel on the image, which is the object of specifying the region in the frame #n, and the pixel value of pixel which is the object in the frame #n from the frame memory 201, and calculates the absolute value of the difference between the pixel values. The still/motion judgment unit 202-2 judges whether or not the absolute value of the difference between the pixel value in the frame #n + 1 and the pixel value in the frame #n is greater than the predetermined threshold value Th, and in

the event that judgment is made that the absolute value of the difference between the pixel values is greater than the threshold value Th, the still/motion judgment indicating motion is supplied to the region judgment unit 203-1 and the region judgment unit 203-2. In the event that judgment is made that the absolute value of the difference between the pixel value of the pixel in the frame #n + 1 and the pixel value of the pixel in the frame #n is equal to or smaller than the threshold value Th, the still/motion judgment unit 202-2 supplies the still/motion judgment, indicating "still", to the region judgment unit 203-1 and the region judgment unit 203-2.

The still/motion judgment unit 202-3 reads out the pixel value of the pixel, which is the object of specifying the region in the frame #n, and the pixel value of the pixel in the frame #n - 1, which is at the same position as the position on the image of the pixel, which is the object of specifying the region in the frame #n, from the frame memory 201, and calculates the absolute value of the difference between the pixel values. The still/motion judgment unit 202-3 judges whether or not the absolute value of the difference between the pixel value in the frame #n and the pixel value in the frame #n - 1 is greater than the predetermined value Th, and in the event that judgment is made that the absolute value of the difference between the

pixel values is greater than the threshold value Th, the still/motion judgment indicating motion is supplied to the region judgment unit 203-2 and the region judgment unit 203-3. In the event that judgment is made that the absolute value of the difference between the pixel value of the pixel in the frame #n and the pixel value of the pixel in the frame #n - 1 is equal to or smaller than the threshold value Th, the still/motion judgment unit 202-3 supplies the still/motion judgment indicating "still" to the region judgment unit 203-2 and the region judgment unit 203-3.

The still/motion judgment unit 202-4 reads out the pixel value of the pixel in the frame #n - 1 at the same position as the position of the pixel on the image, which is the object of specifying the region in the frame #n, and the pixel value of the pixel in the frame #n - 2 at the same position as the position of the pixel on the image, which is the object of specifying the region in the frame #n, from the frame memory 201, and calculates the absolute value of the difference between the pixel values. The still/motion judgment unit 202-4 judges whether or not the absolute value of the difference between the pixel value in the frame #n - 1 and the pixel value in the frame #n - 2 is greater than the predetermined threshold value Th, and in the event that judgment is made that the absolute value of the difference between the pixel values is greater than the threshold value

Th, the still/motion judgment indicating motion is supplied to the region judgment unit 203-3. In the event that judgment is made that the absolute value of the difference between the pixel value of the pixel in the frame #n - 1 and the pixel value of the pixel in the frame #n - 2 is equal to or smaller than the threshold value Th, the still/motion judgment unit 202-4 supplies the still/motion judgment indicating "still" to the region judgment unit 203-3.

In the event that the still/motion judgment supplied from the still/motion judgment unit 202-1 indicates "still", and the still/motion judgment supplied from the still/motion judgment unit 202-2 indicates motion, the region judgment unit 203-1 judges that the pixel which is the object of specifying the region in the frame #n belongs to the uncovered background region, and sets the uncovered background region judgment flag corresponding to the judged pixel in the region, to "1", which indicates that the pixel belongs to the uncovered background region.

In the event that the still/motion judgment supplied from the still/motion judgment unit 202-1 indicates motion, or the still/motion judgment supplied from the still/motion judgment unit 202-2 indicates still, the region judgment unit 203-1 judges that the pixel which is the object of specifying the region in the frame #n does not belong to the uncovered background region, and sets the uncovered

background region judgment flag corresponding to the judged pixel in the region to "0", which indicates that the pixel does not belong to the uncovered background region.

The region judgment unit 203-1 supplies the uncovered background region judgment flag which has been set to "1" or "0", as described above, to the judgment flag storing memory 204.

In the event that the still/motion judgment supplied from the still/motion judgment unit 202-2 indicates "still", and the still/motion judgment supplied from the still/motion judgment unit 202-3 indicates "still", the region judgment unit 203-2 judges that the pixel which is the object of specifying the region in the frame #n belongs to the still region, and sets the still region judgment flag corresponding to the pixel judged in the region, to "1", which indicates that the pixel belongs to the still region.

In the event that the still/motion judgment supplied from the still/motion judgment unit 202-2 indicates motion, or the still/motion judgment supplied from the still/motion judgment unit 202-3 indicates motion, the region judgment unit 203-2 judges that the pixel which is the object of specifying the region in the frame #n does not belong to the still region, and sets the still region judgment flag corresponding to the judged pixel in the region, to "0", which indicates that the pixel does not belong to the still

region.

The region judgment unit 203-2 supplies the still region judgment flag which has been set to "1" or "0" as described above, to judgment flag storing frame memory 204.

In the event that the still/motion judgment supplied from the still/motion judgment unit 202-2 indicates motion, and the still/motion judgment supplied from the still/motion judgment unit 202-3 indicates motion, the region judgment unit 203-2 judges the pixel which is the object of specifying the region in the frame #n belongs to the moving region, and sets the moving region judgment flag corresponding to the judged pixel in the region, to "1", which indicates that the pixel belongs to the moving region.

In the event that the still/motion judgment supplied from the still/motion judgment unit 202-2 indicates "still", or the still/motion judgment supplied from the still/motion judgment unit 202-3 indicates "still", the region judgment unit 203-2 judges that the pixel which is the object of specifying the region in the frame #n does not belong to the moving region, and sets the moving region judgment flag corresponding to the judged pixel in the region, to "0", which indicates that the pixel does not belong to the moving region.

The region judgment unit 203-2 supplies the moving region judgment flag which has been set to "1" or "0", to

the judgment flag storing frame memory 204.

In the event that the still/motion judgment supplied from the still/motion judgment unit 202-3 indicates motion, and the still/motion judgment supplied from the still/motion judgment unit 202-4 indicates "still", the region judgment unit 203-3 judges that the pixel which is the object of specifying the region in the frame #n belongs to the covered background region, and sets the covered background region judgment flag corresponding to the judged pixel in the region to "1", which indicates that the pixel belongs to the covered background region.

In the event that the still/motion judgment supplied from the still/motion judgment unit 202-3 indicates "still", or the still/motion judgment supplied from the still/motion judgment unit 202-4 indicates motion, the region judgment unit 203-3 judges that the pixel which is the object of specifying the region in the frame #n does not belong to the covered background region, and sets the covered background region judgment flag corresponding to the judged pixel in the region to "0", which indicates that the pixel does not belong to the covered background region.

The region judgment unit 203-3 supplies the covered background region judgment flag which has been set to "1" or "0" as described above, to the judgment flag storing frame memory 204.

The judgment flag storing frame memory 204 stores the uncovered background region judgment flag supplied from the region judgment unit 203-1, the still region judgment flag supplied from the region judgment unit 203-2, the moving region judgment flag supplied from the region judgment unit 203-2, and the covered background region judgment flag supplied from the region judgment unit 203-3.

The judgment flag storing frame memory 204 supplies the uncovered background region judgment flag, the still region judgment flag, the moving region judgment flag, and the covered background region judgment flag, which are stored therein, to a synthesizing unit 205. The synthesizing unit 205 generates the region information which indicates which of the uncovered background region, the still region, the moving region, or the covered background region, each pixel belongs to, and supplies the information to judgment flag storing frame memory 206, based upon the uncovered background region judgment flag, the still region judgment flag, the moving region judgment flag, and the covered background region judgment flag, which are supplied from the judgment flag storing frame memory 204.

The judgment flag storing frame memory 206 stores the region information supplied from the synthesizing unit 205, and also outputs the stored region information.

An example for processing performed by the region

specifying unit 103 will now be described with reference to Fig. 36 through Fig. 40.

In the event that the object corresponding to the foreground moves, the position of the image corresponding to the object on the screen changes with each frame. As shown in Fig. 36, in the frame #n, the image corresponding to the object which is at the position indicated by Yn(x,y) is at the position Yn + 1(x,y) in the following frame #n + 1.

Fig. 37 is a model diagram wherein the pixel values of pixels of the image corresponding to the foreground object, which are adjacently arrayed in sequence in a image movement direction, develop over the time direction. For example, in the event that the image moving direction corresponding to the foreground object is horizontal to the screen, the model diagram in Fig. 37 indicates the model wherein the pixel values of adjacent pixels in one line develop over the time direction.

In Fig. 37, the line in the frame #n is the same as the line in the frame #n + 1.

The foreground components corresponding to the object, which are included in the second pixel through thirteenth pixel from the left in the frame #n, are included in the sixth through seventeenth pixels from the left in the frame #n + 1.

In the frame #n, the pixels belonging to the covered

background region are the eleventh through thirteenth pixels from the left, and the pixels belonging to the uncovered background region are the second through fourth pixels from the left. In the frame #n + 1, the pixels belonging to the covered background region are the fifteenth through seventeenth pixels from the left, and the pixels belonging to the uncovered background region are sixth through eighth pixels from the left.

With the example shown in Fig. 37, the movement amount v is 4, since the foreground components included in the frame #n move by four pixels in the frame #n + 1. The virtual dividing number is 4, corresponding to the movement value v.

Next, a description will be made regarding the change of the pixel values of the pixels belonging to the mixed region in the frames previous to and following the frame of interest.

In the frame #n wherein the background keeps still and the movement amount v of the foreground is 4, shown in Fig. 38, the pixels belonging to the covered background region are the fifteenth through seventeenth pixels from the left. Since the movement amount v is 4, in the previous frame #n - 1, the fifteenth through seventeenth pixels from the left include only the background components, and belong to the background region. Also, in the frame # n - 2 which is one

further before, the fifteenth through seventeenth pixels from the left contain only the background components, and belong to the background region.

Note that since the object corresponding to the background keeps still, the pixel value of the fifteenth pixel from the left in the frame #n - 1 do not change from the pixel value of the fifteenth pixel from the left in the frame #n - 2. Similarly, the pixel value of the sixteenth pixel from the left in the frame #n - 1 do not change from the pixel value of the sixteenth pixel from the left in the frame #n - 2, and the pixel values of the seventeenth pixel from the left in the frame #n - 1 do not change from the pixel value of the seventeenth pixel from the left in the frame #n - 2.

That is to say, the pixels of the frame #n - 1 and frame #n - 2 corresponding to the pixels belonging to the covered background region in the frame #n consists of only the background components, and the pixel values do not change, and accordingly the absolute value of the difference therebetween is approximately zero. Accordingly, judgment is made that the still/motion judgment for the pixels of the frame #n - 1 and the frame #n - 2 corresponding to the pixels belonging to the mixed region in the frame #n is still by the still/motion judgment unit 202-4.

Since the pixels belonging to the covered background

region in the frame #n contain the foreground components, the pixel values are different from the case wherein the pixel values in the frame #n - 1 consist of only the background components. Accordingly, judgment is made that the still/motion judgment for the pixels belonging to the mixed region in the frame #n and the pixels in the frame #n - 1 corresponding thereto is motion by the still/motion judgment unit 202-3.

As described above, the region judgment unit 203-3 judges that the corresponding pixels belong to the covered background region in the event that the still/motion judgment unit 202-3 supplies the results of the still/motion judgment which indicates motion, and the still/motion judgment unit 202-4 supplies the results of the still/motion judgment which indicates "still".

In the frame #n wherein the background keeps still and the foreground movement amount v is 4 as shown in Fig. 39, the pixels included in the uncovered background region are the second through fourth pixels from the left. Since the movement amount v is 4, in the frame #n + 1 following the frame #n, the second through fourth pixels from the left include only the background components, and belong to the background region. Also, in the frame #n + 2 further one frame following the frame #n + 1, the second through fourth pixels from the left contain only the background components,

and belong to the background region.

Note that since the object corresponding to the background keeps still, the pixel values of the second pixel from the left in the frame #n + 2 does not change from the pixel value of the second pixel from the left in the frame #n + 1. Similarly, the pixel value of the third pixel from the left in the frame #n + 2 does not change from the pixel value of the third pixel from the left in the frame #n + 1, and the pixel value of the fourth pixel from the left in the frame #n + 2 does not change from the pixel value of the fourth pixel from the left in the frame #n + 1.

That is to say, the pixels of the frame #n + 1 and the frame #n + 2, corresponding to the pixels belonging to the uncovered background region in the frame #n, consist of only the background components, so the pixel values thereof do not change, and accordingly the absolute value of the difference thereof is approximately zero. Accordingly, judgment is made that the still/motion judgment for the pixels of the frame #n + 1 and the frame #n + 2 corresponding to the pixels belonging to the mixed region in the frame #n is "still" by the still/motion judgment unit 202-1.

Since the pixels belonging to the uncovered background region in the frame #n contain the foreground components, the pixel values are different from the case wherein the

pixels consists of only the background components in the frame #n + 1. Accordingly, judgment is made that the still/motion judgment for the pixels belonging to the mixed region in the frame #n and the pixels corresponding thereto in the frame #n + 1 is motion by the still/motion judgment unit 202-2.

As described above, the region judgment unit 203-1 judges that the corresponding pixels belong to the uncovered background region in the event that the still/motion judgment unit 202-2 supplies the results of the still/motion judgment which indicates motion, and the still/motion judgment unit 202-1 supplies the still/motion judgment which indicates "still".

Fig. 40 is a diagram which illustrates judgment conditions of the region specifying unit 103 in the frame #n. In the event that judgment is made that the pixel in the frame #n - 2 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, and the pixel in the frame #n - 1 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, are "still", and judgment is made that the pixel in the frame #n - 1 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, and the pixel in the frame #n are motion, the region specifying unit

103 judges that the pixel which is the object of judgment of the frame #n belongs to the covered background region.

In the event that judgment is made that the pixel in the frame #n - 1 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, and the pixel in the frame #n, are judged to be "still", and judgment is made that the pixel in the frame #n and the pixel in the frame #n + 1 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, are judged to be "still", the region specifying unit 103 judges that the pixel which is the object of judgment of the frame #n belongs to the still region.

In the event that judgment is made that the pixel in the frame #n - 1 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, and the pixel in the frame #n, are judged to be motion, and judgment is made that the pixel of the frame #n and the pixel in the frame #n + 1 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, are judged to be motion, the region specifying unit 103 judges that the pixel which is the object of judgment of the frame #n belongs to the movement region.

In the event that judgment is made that the pixel of

the frame #n and the pixel in the frame #n + 1 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, are motion, and judgment is made that the pixel in the frame #n + 1 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, and the pixel in the frame #n + 2 at the same position as the position of the pixel which is the object of judgment on the image in the frame #n, are judged to be "still", the region specifying unit 103 judges that the pixel which is the object of judgment of the frame #n belongs to the uncovered background region.

Fig. 41A through Fig. 41D are diagrams which illustrate examples of results of the region specifying unit 103 specifying the region. In Fig. 41A, the pixels which have been judged to belong to the covered background region are displayed in white. In Fig. 41B, the pixels which have been judged to belong to the uncovered background region are displayed in white.

In Fig. 41C, the pixels which have been judged to belong to the movement region are displayed in white. In Fig. 41D, the pixels which have been judged to belong to the still region are displayed in white.

Fig. 42 is a diagram which illustrates the region information as an image, indicating the mixed region of the

region information which the judgment flag storing frame memory 206 outputs. In Fig. 42, the pixels which have been judged to belong to the covered background region or the uncovered background region, i.e., the pixels judged to belong to the mixed region, are displayed in white. The region information indicating the mixed region, which the judgment flag storing frame memory 206 outputs, indicates the mixed region and the portions which have texture within the foreground region and are surrounded by portions which have no texture.

Next, referring to the flowchart in Fig. 43, the processing for region specifying by the region specifying unit 103 will be described. In Step S201, the frame memory 201 obtains the images of the frame #n - 2 through the frame #n + 2, including the frame #n which is the object of judgment.

In Step S202, the still/motion judgment unit 202-3 judges whether or not the pixel of the frame #n - 1 and the pixel of the frame #n at the same position keep still, and in the event of judgment of "still", the flow proceeds to Step S203, and the still/motion judgment unit 202-2 judges whether or not the pixel of the frame #n and the pixel of the frame #n + 1 at the same position keep still.

In Step S203, in the event that judgment is made that the pixel of the frame #n and the pixel of the frame #n + 1

at the same position are "still", the flow proceeds to Step S204, and the region judgment unit 203-2 sets the still region judgment flag corresponding to the judged pixel in the region to "1" which indicates the pixel belongs to the still region. The region judgment unit 203-2 supplies the still region judgment flag to the judgment flag storing frame memory 204, and the procedure proceeds to Step S205.

In Step S202, in the event that judgment is made that the pixel of the frame #n - 1 and the pixel of the frame #n at the same position are motion, or in Step S203, judgment is made that the pixel of the frame #n and the pixel of the frame #n + 1 at the same position are motion, the pixel of the frame #n does not belong to the still region, and accordingly the processing in Step S204 is skipped, and the procedure proceeds to Step S205.

In Step S205, the still/motion judgment unit 202-3 judges whether or not the pixel of the frame #n - 1 and the pixel of the frame #n at the same position are in motion, and in the event of judgment of motion, the flow proceeds to Step S206, and the still/motion judgment unit 202-2 judges whether or not the pixel of the frame #n and the pixel of the frame #n + 1 at the same position are in motion.

In Step S206, in the event that judgment is made that the pixel of the frame #n and the pixel of the frame #n + 1 at the same position are in motion, the flow proceeds to

Step S207, the region judgment unit 203-2 set the movement region judgment flag corresponding to the judged pixel in the region to "1" which indicates that the pixel belongs to the movement region. The region judgment unit 203-2 supplies the movement region judgment flag to the judgment flag storing frame memory 204, and the procedure proceeds to Step S208.

In Step S205, in the event that judgment is made that the pixel of the frame #n - 1 and the pixel of the frame #n at the same position are "still", or in Step S206, in the event that judgment is made that the pixel of the frame #n and the pixel of the frame #n + 1 at the same position are "still", since the pixel of the frame #n does not belong to the movement region, the processing in Step S207 is skipped, and the procedure proceeds to Step S208.

In Step S208, the still/motion judgment unit 202-4 judges whether or not the pixel of the frame #n - 2 and the pixel of the frame #n - 1 at the same position keeps still, and in the event of judgment of "still", the flow proceeds to Step S209, and the still/motion judgment unit 202-3 judges whether or not the pixel of the frame #n - 1 and the pixel of the frame #n at the same position are in motion.

In Step S209, in the event that judgment is made that the pixel of the frame #n - 1 and the pixel of the frame #n at the same position are in motion, the flow proceeds to

Step S210, and the region judgment unit 203-3 sets the covered background region judgment flag corresponding to the judged pixel in the region to "1" which indicates that the pixel belongs to the covered background region. The region judgment unit 203-3 supplies the covered background region judgment flag to the judgment flag storing frame memory 204, and the procedure proceeds to Step S211.

In Step S208, in the event that judgment is made that the pixel of the frame #n -2 and the pixel of the frame #n - 1 at the same position are in motion, or in Step S209, in the event that judgment is made that the pixel of the frame #n - 1 and the pixel of the frame #n at the same position are "still", the pixel of the frame #n does not belong to the covered background region, so the processing in Step S210 is skipped, and the procedure proceeds to Step S211.

In Step S211, the still/motion judgment unit 202-2 judges whether or not the pixel of the frame #n and the pixel of the frame #n + 1 at the same position are in motion, and in the event of judgment of motion, the flow proceeds to Step S212, and the still/motion judgment unit 202-1 judges whether or not the pixel of the frame #n + 1 and the pixel of the frame #n + 2 at the same position keep still.

In Step S212, in the event that judgment is made that the pixel of the frame #n + 1 and the pixel of the frame #n + 2 at the same position are "still", the flow proceeds to

Step S213, and the region judgment unit 203-1 sets the uncovered background region judgment flag corresponding to the judged pixel in the region to "1" which indicates that the pixel belongs to the uncovered background region. The region judgment unit 203-1 supplies the uncovered background region judgment flag to the judgment flag storing frame memory 204, and the procedure proceeds to Step S214.

In Step S211, in the event that judgment is made that the pixel of the frame #n and the pixel of the frame #n + 1 at the same position are "still", or in Step 212, in the event that judgment is made that the pixel of the frame #n + 1 and the pixel of the frame #n + 2 at the same position are in motion, since the pixel of the frame #n does not belong to the uncovered background region, the processing in Step S213 is skipped, and the procedure proceeds to Step S214.

In Step 214, the region specifying unit 103 judges whether or not all the pixels in the frame #n are region-specified, and in the event that judgment is made that not all pixels are region-specified, the procedure returns to Step S202, and repeats the processing of specifying the region for other pixels.

In Step S214, in the event that judgment is made that all the pixels in the frame #n are region-specified, the flow proceeds to Step S215, and the synthesizing unit 205 generates the region information which indicates the mixed

region based upon the uncovered background region judgment flag and the covered background region judgment flag, which are stored in the judgment flag storing frame memory 204, and furthermore generates the region information which indicates which of the uncovered background region, the still region, the movement region, or the covered background region, each pixel belongs to, sets the generated region information for the judgment flag storing frame memory 206, and the processing ends.

As described above, the region specifying unit 103 can generate region information which indicates which of the movement region, the still region, the uncovered background region, or the covered background region, each pixel contained in the frame belongs to.

Note that an arrangement may be made wherein the region specifying unit 103 generates the region information corresponding to the mixed region and the region information made up of flags which indicates which of the movement region, the still region, or the mixed region, each of pixels contained in the frame belongs to, by applying the logical sum to the region information corresponding to the uncovered background region and the covered background region.

In the event that the object corresponding to the foreground has texture, the region specifying unit 103 can

specify the movement region more accurately.

The region specifying unit 103 can output the region information indicating the movement region as the region information indicating the foreground region, or output the region information indicating the still region as the region information indicating the background region.

While description has been made wherein the object corresponding to the background keeps still, the processing of specifying the region described above can be applied even if the image corresponding to the background region contains motion. For example, in the event that the image corresponding to the background region moves in a constant manner, the region specifying unit 103 shifts the entire image corresponding to the movement, and performs processing in the same manner as with the case wherein the object corresponding to the background keeps still. Also, in the event that the image corresponding to the background region contains a different motion at each local position, the region specifying unit 103 selects the pixel corresponding to the motion, and performs the above-described processing.

Fig. 44 is a block diagram which illustrates another example of the structure of the region specifying unit 103. The region specifying unit 103 shown in Fig. 44 does not use movement vectors. A background image generating unit 301 generates the background image corresponding to the input

image, and supplies the generated background image to a binary object image extracting unit 302. The background image generating unit 301 extracts, for example, the image object corresponding to the background object contained in the input image, and generates the background image.

An example of a model diagram is illustrated in Fig. 45 wherein the pixel values of the pixels arrayed in sequence adjacently in a movement direction of the image corresponding to the foreground object, develop over the time direction. For example, in the event that the movement direction of the image corresponding to the foreground object is horizontal to the screen, the model diagram in Fig. 45 illustrates a model wherein the pixel values of the adjacent pixels in one line develop over the time direction.

In Fig. 45, the line in the frame #n is the same as the line in the frame #n - 1 and the line in the frame #n + 1.

In the frame #n, the foreground components corresponding to the object, which are contained in the sixth pixel through seventeenth pixel from the left, are contained in the second through thirteenth pixels from the left in the frame #n - 1, and are contained in the tenth through twenty-first pixels from the left in the frame #n + 1.

In the frame #n - 1, the pixels belonging to the covered background region are the eleventh through

thirteenth pixels from the left, and the pixels belonging to the uncovered background region are the second through fourth pixels from the left. In the frame #n, the pixels belonging to the covered background region are the fifteenth through the seventeenth pixels from the left, and the pixels belonging to the uncovered background region are the sixth through eighth pixels from the left. In the frame #n + 1, the pixels belonging to the covered background region are the nineteenth through twenty-first pixels from the left, and the pixels belonging to the uncovered background region are the tenth through twelfth pixels from the left.

In the frame #n - 1, the pixels belonging to the background region are the first from the left, and the fourteenth through twenty-first pixels from the left. In the frame #n, the pixels belonging to the background region are the first through fifth pixels from the left, and the eighteenth through twenty-first pixels from the left. In the frame #n + 1, the pixels belonging to the background region are the first through ninth pixels from the left.

An example of the background image corresponding to the example shown in Fig. 45, which is generated by the background image generating unit 301, is illustrated in Fig. 46. The background image is made up of the pixels corresponding to the background object, and does not contain image components corresponding to the foreground object.

The binary object image extracting unit 302 generates a binary object image based upon the correlation between the background image and the input image, and supplies the generated binary object image to a time change detecting unit 303.

Fig. 47 is a block diagram which illustrates the configuration of the binary object image extracting unit 302. A correlation value computing unit 321 computes the correlation between the background image supplied from the background image generating unit 301 and the input image, generates a correlation value, and supplies the generated correlation value to a threshold value processing unit 322.

The correlation value computing unit 321 applies Expression (4) to a block 3 × 3 wherein X_4 is centered in the background image as shown in Fig. 48A, and a block 3 × 3 wherein Y_4 corresponding to the block in the background image is centered in the input image as shown in Fig. 48B, and calculates a correlation value corresponding to the Y_4, for example.

$$\text{Correlation Value} = \frac{\sum_{i=0}^{8}(X_i-\bar{X})\sum_{i=0}^{8}(Y_i-\bar{Y})}{\sqrt{\sum_{i=0}^{8}(X_i-\bar{X})^2 \cdot \sum_{i=0}^{8}(Y_i-\bar{Y})^2}} \qquad (4)$$

$$\bar{X} = \frac{\sum_{i=0}^{8} X_i}{9} \qquad (5)$$

$$\overline{Y} = \frac{\sum_{i=0}^{8} Yi}{9} \qquad (6)$$

The correlation value computing unit 321 supplies the correlation value calculated corresponding to each pixel as described above to the threshold value processing unit 322.

Also, an arrangement may be made wherein the correlation value computing unit 321, for example, applies Expression (7) to the block 3 × 3 in the background image wherein X_4 is centered as shown in Fig. 49A, and the block 3 × 3 in the input image wherein Y_4 is centered corresponding to the block in the background image, and calculates the sum of absolute value of difference corresponding to Y_4.

$$\text{Sum of Absolute Value of Difference} = \sum_{i=0}^{8} |(Xi - Yi)| \qquad (7)$$

The correlation value computing unit 321 supplies the difference absolute value calculated as described above as the correlation value to the threshold value processing unit 322.

The threshold value processing unit 322 compares the pixel value of the correlation image with the threshold value th0, and in the event that the correlation value is equal to or less than the threshold value th0, the threshold value processing unit 322 sets the pixel value of the binary object image to 1, and in the event that the correlation value is greater than the threshold value th0, the threshold

value processing unit 322 sets the pixel value of the binary object image to 0, and outputs the binary object image of which each pixel value has been set to 0 or 1. The threshold value processing unit 322 may store the threshold value th0 beforehand, and may use the threshold value th0 which is input externally.

Fig. 50 is a diagram which illustrates an example of the binary object image corresponding to the model of the input image shown in Fig. 45. In the binary object image, a pixel value of a pixel having a high correlation with the background image is set to 0.

Fig. 51 is a block diagram which illustrates the configuration of the time change detecting unit 303. Frame memory 341 stores the binary object images of the frame #n - 1, frame #n, and frame #n + 1, supplied from the binary object image extracting unit 302 at the point of judgment of the region for the pixel of the frame #n.

A region judgment unit 342 judges the region for each pixel of the frame #n based upon the binary object images of the frame #n -1, frame #n, and frame #n + 1, which are stored in the frame memory 341, generates the region information, and outputs the generated region information.

Fig. 52 is a diagram which describes the judgment made by the region judgment unit 342. In the event that the pixel of interest of the binary object image of the frame #n

is 0, the region judgment unit 342 judges the pixel of interest of the frame #n to belong to the background region.

In the event that the pixel of interest of the binary object image of the frame #n is 1, the corresponding pixel of the binary object image of the frame #n - 1 is 1, and the corresponding pixel of the binary object image of the frame #n + 1 is 1, the region judgment unit 342 judges the pixel of interest of the frame #n to belong to the foreground region.

In the event that the pixel of interest of the binary object image of the frame #n is 1, and the corresponding pixel of the binary object image of the frame #n - 1 is 0, the region judgment unit 342 judges the pixel of interest of the frame #n to belong to the covered background region.

In the event that the pixel of interest of the binary object image of the frame #n is 1, and the corresponding pixel of the binary object image of the frame #n + 1 is 0, the region judgment unit 342 judges the pixel of interest of the frame #n to belong to the uncovered background region.

Fig. 53 is a diagram which illustrates an example wherein the time change detecting unit 303 judges the binary object image corresponding to the model of the input image shown in Fig. 45. The time change detecting unit 303 judges the first through fifth pixels from the left of the frame #n to belong to the background region since the corresponding

pixels of the binary object image of the frame #n are 0.

The time change detecting unit 303 judges the sixth through ninth pixels from the left to belong to the uncovered background region since the pixels of the binary object image of the frame #n are 1, and the corresponding pixels of the frame #n + 1 are 0.

The time change detecting unit 303 judges the tenth through thirteenth pixels from the left to belong to the foreground region since the pixels of the binary object image of the frame #n are 1, the corresponding pixels of the frame #n - 1 are 1, and the corresponding pixels of the frame #n + 1 are 1.

The time change detecting unit 303 judges the fourteenth through seventeenth pixels from the left to belong to the covered background region since the pixels of the binary object image of the frame #n are 1, and the corresponding pixels of the frame #n - 1 are 0.

The time change detecting unit 303 judges the eighteenth through twenty-first pixels from the left to belong to the background region since the corresponding pixels of the binary object image of the frame #n are 0.

The processing of specifying the region by the region judgment unit 103 will be now described, referring to the flowchart shown in Fig. 54. In Step S301, the background image generating unit 301 of the region judgment unit 103,

for example, generates the background image by extracting the image object corresponding to the background object contained in the input image based upon the input image, and supplies the generated background image to the binary object image extracting unit 302.

In Step S302, the binary object image extracting unit 302 computes the correlation value between the input image and the background image supplied from the background image generating unit 301 by the computation described referring to Fig. 48A and Fig. 48B, for example. In Step S303, the binary object image extracting unit 302 computes the binary object image from the correlation value and the threshold value th0 by comparing the correlation value with the threshold value th0, for example.

In Step S304, the time change detecting unit 303 performs processing of region judgment, and the processing ends.

The processing of the region judgment corresponding to Step S304 will be described in detail, referring to the flowchart shown in Fig. 55. In Step S321, the region judgment unit 342 of the time change detecting unit 303 judges whether or not the pixel of interest in the frame #n stored in the frame memory 341 is 0, and in the event that the judgment is made that the pixel of the interest in the frame #n is 0, the flow proceeds to Step S322, makes

settings to the effect that the pixel of interest in the frame #n belongs to the background region, and the processing ends.

In Step S321, in the event that judgment is made that the pixel of interest in the frame #n is 1, the flow proceeds to Step S323, and the region judgment unit 342 of the time change detecting unit 303 judges whether or not the pixel of interest in the frame #n stored in the frame memory 341 is 1, and the corresponding pixel in the frame #n - 1 is 0, and in the event that judgment is made that the pixel of interest in the frame #n is 1, and the corresponding pixel in the frame #n - 1 is 0, the flow proceeds to Step S324, makes settings to the effect that the pixel of interest in the frame #n belongs to the covered background region, and the processing ends.

In Step S323, in the event that judgment is made that the pixel of interest in the frame #n is 0, or the corresponding pixel in the frame #n - 1 is 1, the flow proceeds to Step S325, and the region judgment unit 342 of the time change detecting unit 303 judges whether or not the pixel of interest in the frame #n stored in the frame memory 341 is 1, and the corresponding pixel in the frame #n + 1 is 0, and in the event that judgment is made that the pixel of interest in the frame #n is 1, and the corresponding pixel in the frame #n + 1 is 0, the flow proceeds to Step S326,

makes settings to the effect that the pixel of interest in the frame #n belongs to the uncovered background region, and the processing ends.

In Step 325, in the event that judgment is made that the pixel of interest in the frame #n is 0, or the corresponding pixel in the frame #n + 1 is 1, the flow proceeds to Step S327, and the region judgment unit 342 of the time change detecting unit 303 sets the pixel of interest in the frame #n for the foreground region, and the processing ends.

As described above, the region specifying unit 103 can specify which of the foreground region, the background region, the covered background region, or the uncovered background region, the pixel of the input image belongs to, and can generate region information corresponding to the specified results.

Fig. 56 is a block diagram which illustrates another configuration of the region specifying unit 103. The region specifying unit 103 shown in Fig. 56 uses the movement vector and the position information thereof, which are supplied from the movement detecting unit 102. Portions the same as those shown in Fig. 44 are denoted by the same reference numerals, and description thereof will be omitted.

A robustification unit 361 generates a robustified binary object image based upon N frames of the binary object

image supplied from the binary object image extracting unit 302, and outputs to the time change detecting unit 303.

Fig. 57 is a block diagram which describes the configuration of the robustification unit 361. A movement compensation unit 381 compensates for the movement of the binary object image of N frames based upon the movement vector and the position information thereof supplied from the movement detecting unit 102, and outputs the binary object image which has been subjected to compensation of movement to a switch 382.

The movement compensation of the movement compensation unit 381 will be described with reference to examples shown in Fig. 58 and Fig. 59. For example, in cases wherein the region in the frame #n is judged, in the event that there is input of the binary object images of the frame #n - 1, the frame #n, and the frame #n + 1, shown by way of the example in Fig. 58, the movement compensation unit 381 compensates for movement of the binary object image of the frame #n - 1 and the binary object image of the frame #n + 1, based upon the movement vector supplied from the movement detecting unit 102, and supplies the binary object image which has been subjected to compensation of movement to the switch 382, as indicated in the example shown in Fig. 59.

The switch 382 outputs the binary object image which has been subjected to movement compensation of the first

frame, to the frame memory 383-1, and outputs the binary object image which has been subjected to movement compensation of the second frame to the frame memory 383-2. Similarly, the switch 382 outputs each of the binary object images of which the third through N - 1'th frames have been subjected to compensation for the movement to each of frame memory 383-3 through frame memory 383-(N - 1), respectively, and outputs the binary object image of which the N'th frame has been subjected to movement compensation to frame memory 383- N.

The frame memory 383-1 stores the binary object image of which the first frame has been subjected to movement compensation, and outputs the stored binary object image to a weighting addition unit 384-1. The frame memory 383-2 stores the binary object image of which the second frame has been subjected to movement compensation, and outputs the stored binary object image to a weighting addition unit 384-2.

Similarly, each of the frame memory 383-3 through the frame memory 383-(N - 1) stores each of the binary object images of which one of the third frame through N - 1'th frame has been subjected to compensation for the movement, and outputs the stored binary object image to each of the weighing addition unit 384-3 through the weighing addition unit 384-(N - 1). The frame memory 383-N stores the binary

object image of which N'th frame has been subjected to compensation for the movement, and outputs the stored binary object image to a weighing addition unit 384-N.

The weighing addition unit 384-1 multiplies the pixel value of the binary object image of which the first frame has been subjected to compensation for the movement supplied from the frame memory 383-1 by the predetermined weight w1, and supplies to an accumulation unit 385. The weighing addition unit 384-2 multiplies the pixel value of the binary object image of the second frame which has been subjected to movement compensation supplied from the frame memory 383-2 by the predetermined weight w2, and supplies to an accumulation unit 385.

Similarly, each of the weighting addition unit 384-3 through the weighing addition unit 384-(N - 1) multiplies the pixel value of the binary object image of one of the third through N - 1'th frames, which has been subjected to movement compensation supplied from one of the frame memory 383-3 through the frame memory 383-(N - 1) by one of the predetermined weights w3 through w(N - 1), and supplies to the accumulation unit 385. A weighing addition unit 384-N multiplies the pixel value of the binary object image of the N'th frame supplied from the frame memory 383 - N which has been subjected to movement compensation by the predetermined weight wN, and supplies to the accumulation unit 385.

The accumulation unit 385 accumulates the pixel value corresponding to the binary object image, wherein each of the first through N'th frames which has been subjected to movement compensation is multiplied by one of the predetermined weights w1 through wN, and generates the binary object image by comparing the accumulated pixel value with the predetermined threshold value th0.

As described above, the robustification unit 361 generates the robustified binary object image from the N frames of binary object images, and supplies to the time change detecting unit 303, so the region specifying unit 103 of which the configuration is shown in Fig. 56 can specify the region more accurately as compared with the case shown in Fig. 44, even if the input image contains noise.

The processing for specifying the region of the region specifying unit 103 of which the configuration is shown in Fig. 56 will now be described, referring to the flowchart shown in Fig. 60. The processing in Step S341 through Step S343 is the same as Step S301 through Step S303 described in the flowchart shown in Fig. 54, respectively, and accordingly, description thereof will be omitted.

In Step S344, the robustification unit 361 performs processing for robustification.

In Step S345, the time change detecting unit 303 performs processing for specifying the region, and the

processing ends. Details of the processing in Step S345 are the same as the processing described with reference to the flowchart shown in Fig. 55, so description thereof will be omitted.

Referring to the flowchart shown in Fig. 61, processing of robustification corresponding to the processing in Step S344 shown in Fig. 60 will now be described in detail. In Step S361, the movement compensation unit 381 performs movement compensation processing of the input binary object image based upon the movement vector and the position information thereof supplied from the movement detecting unit 102. In Step S362, one of the frame memory 383-1 through the frame memory 383-N stores the binary object image, which has been subjected to movement compensation, supplied via the switch 382.

In Step S363, the robustification unit 361 judges whether or not N binary object images are stored, and in the event that judgment is made that N binary object images have not been stored, the flow returns to Step S361, and the robustification unit 363 repeats processing of compensation for movement of the binary object image, and processing of storing the binary object image.

In Step S363, in the event that judgment is made that N binary object images stored, the flow proceeds to Step S364, and each of the weighting addition units 384-1 through 384-N

multiplies each of N binary object images, by one of the weights w1 through wN for weighting.

In Step S365, the accumulation unit 385 accumulates the N weighted binary object images.

In Step 366, the accumulation unit 385 generates the binary object image from the accumulated image, by comparing with the predetermined threshold value th1, for example, and the processing ends.

As described above, the region specifying unit 103 of which the configuration is shown in Fig. 56 can generate the region information based upon the robustified binary object image.

As described above, the region specifying unit 103 can generate the region information which indicates which of the movement region, the still region, the uncovered background region, or the covered background region, each of the pixels contained in the frame belongs to.

Fig. 62 is a block diagram which illustrates an example of the configuration of the mixture ratio calculation unit 104. An estimated mixture ratio processing unit 401 calculates estimated mixture ratio for each pixel by computation corresponding to a model of a covered background region based upon the input image, and supplies the calculated estimated mixture ratio to a mixture ratio determination unit 403.

An estimated mixture ratio processing unit 402 calculates estimated mixture ratio for each pixel by computation corresponding to a model of the uncovered background region based upon the input image, and supplies the calculated estimated mixture ratio to the mixture ratio determination unit 403.

Since an assumption may be made that the object corresponding to the foreground moves at a constant velocity within a shutter period, the mixture ratio α of a pixel belonging to the mixed region has a nature such as described below. That is to say, the mixture ratio α changes linearly corresponding to the change of the position of the pixel.

Taking the change of the pixel position to be one-dimensional, the change of the mixture ratio α may be represented by a straight line, and taking the change of the pixel position to be two-dimensional, the change of the mixture ratio α may be represented by a plane.

Note that the period of one frame is short, an assumption may be made that the object corresponding to the foreground is a rigid body, and moves at a constant velocity.

In this case, the inclination of the mixture ratio α is inversely proportionate to the movement amount v of the foreground within the shutter period.

An example of an ideal mixture ratio α is shown in Fig. 63. The inclination l of an ideal mixture ratio α in the

mixed region may be represented by the reciprocal of the movement amount v.

As shown in Fig. 63, an ideal mixture ratio α has a value of 1 in the background region, and has a value of 0 in the foreground region, and has a value which exceeds 0 and is less than 1 in the mixed region.

With the example shown in Fig. 64, the pixel value C06 of the seventh pixel from the left in the frame #n may be represented in Expression (8), using the pixel value P06 of the seventh pixel from the left in the frame #n - 1.

$$\begin{aligned} C06 &= B06/v + B06/v + F01/v + F02/v \\ &= P06/v + P06/v + F01/v + F02/v \\ &= 2/v \cdot P06 + \sum_{i=1}^{2} Fi/v \end{aligned} \qquad (8)$$

In Expression (8), the pixel value C06 is represented as the pixel value M of the pixel in the mixed region, and the pixel value P06 is represented as the pixel value B of the pixel in the background region. That is to say, the pixel value M of the pixel in the mixed region and the pixel value B of the pixel in the background region may be represented as in Expression (9) and Expression (10), respectively.

$$M = C06 \qquad (9)$$

$$B = P06 \qquad (10)$$

In Expression (8), 2/v corresponds to the mixture ratio α. Since the movement amount v is 4, the mixture ratio α of

the seventh pixel from the left in the frame #n is 0.5.

As described above, Expression (3) indicating the mixture ratio α may be rewritten as with Expression (11) by reckoning the pixel value C in the frame #n of interest to be a pixel value in the mixed region, and reckoning the pixel value P in the frame #n - 1 previous to the frame #n to be a pixel value of the background region.

$$C = \alpha \bullet P + f \qquad (11)$$

In Expression (11), f is the sum of the foreground components contained in the pixel of interest, $\sum_i Fi/v$.

The variables included in Expression (11) are two, i.e., the mixture ratio α and the sum of the foreground components f.

In the same way, Fig. 65 illustrates a model wherein the pixel values wherein the movement amount v is 4, and virtual dividing number is 4 in the uncovered background region, develop over the time direction.

Expression (3) indicating the mixture ratio α may be represented as in Expression (12) with the pixel value C in the frame #n of interest as a pixel value in the mixed region, and with the pixel value N in the frame #n + 1 following the frame #n as a pixel value in the background region, in the same manner as the representation in the covered background region described above, in the uncovered background region.

$$C = \alpha \bullet N + f \qquad (12)$$

Note that while description has been made with an assumption that the background object keeps still, Expression (8) through Expression (12) may be applied by using the pixel values of the pixels at the positions corresponding to the background movement amount v, even if the background object moves. For example, in Fig. 64, in the event that the movement amount v of the object corresponding to the background is 2, the virtual dividing number is 2, and the object corresponding to the background moves to the right side in the drawing, the pixel value B of the pixel in the background region in Expression (10) is the pixel value P04.

Expression (11) and Expression (12) include two variables, respectively, and accordingly the mixture ratio α can not be obtained in this state. Here, images generally have great correlation spatially, the adjacent pixels have approximately the same value.

Thus, since the foreground components have great correlation spatially, the mixture ratio is obtained by transforming the expression so as to obtain the sum of the foreground components from the previous or following frame.

The pixel value Mc of the seventh pixel from the left in the frame #n in Fig. 66 may be represented in Expression (13).

$$Mc = \frac{2}{v} \cdot B06 + \sum_{i=11}^{12} Fi/v \qquad (13)$$

The first argument 2/v of the right side in Expression (13) corresponds to the mixture ratio α. The second argument of the right side in Expression (13) is represented as in Expression (14) using the pixel values in the following frame #n + 1.

$$\sum_{i=11}^{12} Fi/v = \beta \cdot \sum_{i=7}^{10} Fi/v \qquad (14)$$

Here, an assumption may be made that Expression (15) holds, using the spatial correlation of the foreground components.

F = F05 = F06 = F07 = F08 = F09 = F10 = F11 = F12 (15)

Expression (14) may be rewritten as Expression (16) using Expression (15)

$$\sum_{i=11}^{12} Fi/v = \frac{2}{v} \cdot F = \beta \cdot \frac{4}{v} \cdot F \qquad (16)$$

As a result, β may be represented in Expression (17).

β = 2/4 (17)

In general, in the event that an assumption is made wherein the foreground components correlated to the mixed region are the same as shown in Expression (15), Expression (18) is formed by the relationship of the internal dividing ratio for all the pixel in the mixed region.

$$\beta = 1 - \alpha \qquad (18)$$

In the event that Expression (18) holds, Expression (11) may develop as indicated in Expression (19).

$$\begin{aligned} C &= \alpha \cdot P + f \\ &= \alpha \cdot P + (1-\alpha) \cdot \sum_{i=\gamma}^{\gamma+V-1} Fi/v \\ &= \alpha \cdot P + (1-\alpha) \cdot N \end{aligned} \qquad (19)$$

Similarly, in the event that Expression (18) holds, Expression (12) may develop as indicated in Expression (20).

$$\begin{aligned} C &= \alpha \cdot N + f \\ &= \alpha \cdot N + (1-\alpha) \cdot \sum_{i=\gamma}^{\gamma+V-1} Fi/v \\ &= \alpha \cdot N + (1-\alpha) \cdot P \end{aligned} \qquad (20)$$

In Expression (19) and Expression (20), since C, N, and P are known pixel values, the variable included in Expression (19) and Expression (20) is only the mixture ratio α. The relationship between C, N, and P in Expression (19) and Expression (20) is illustrated in Fig. 67. C is the pixel value of the pixel of interest in the frame #n for calculating the mixture ratio α. N is the pixel value of the pixel in the frame #n + 1, of which the position in the spatial direction corresponds to that of the pixel of interest. P is the pixel value of the pixel in the frame #n - 1, of which the position in the spatial direction corresponds to that of the pixel of interest.

Accordingly, since Expression (19) and Expression (20) include one variable each, the mixture ratio α can be calculated using the pixel values in three frames. The conditions for calculating an accurate mixture ratio α by solving Expression (19) and Expression (20) are that; the foreground components with regard to the mixed region are the same, that is to say, in the foreground image object which has been taken in the state of the foreground object being still, the pixel values of pixels of a number twice the movement amount v, which are arrayed sequentially at the boundary of the image object, corresponding to the movement direction of the foreground object, are constant.

As described above, the mixture ratio α of the pixel belonging to the covered background region is calculated by Expression (21), and the mixture ratio α belonging to the uncovered background region is calculated by Expression (22).

$$\alpha = (C - N)/(P - N) \quad (21)$$

$$\alpha = (C - P)/(N - P) \quad (22)$$

Fig. 68 is a block diagram which illustrates the configuration of the estimated mixture ratio processing unit 401. Frame memory 421 stores the input image in increments of frames, and supplies the frame following the frame which is input as an input image, to frame memory 422 and a mixture ratio computation unit 423.

The frame memory 422 stores the input image in

increments of frames, and supplies the frame following the frame supplied from the frame memory 421, to the mixture ratio computation unit 423.

Accordingly, in the event that the frame #n + 1 is input as an input image to the mixture ratio computation unit 423, the frame memory 421 supplies the frame #n to the mixture ratio computation unit 423, and the frame memory 422 supplies the frame #n − 1 to the mixture ratio computation unit 423.

The mixture ratio computation unit 423 calculates the estimated mixture ratio of the pixel of interest by the computation represented in Expression (21) based upon the pixel value C of the pixel of interest in the frame #n, the pixel value N of the pixel in the frame #n + 1 wherein the spatial position thereof corresponds to that of the pixel of interest, and the pixel value P of the pixel in the frame #n - 1 wherein the spatial position thereof corresponds to that of the pixel of interest, and outputs the calculated estimated mixture ratio. For example, in the event that the background keeps still, the mixture ratio computation unit 423 calculates the estimated mixture ratio of the pixel of interest based upon the pixel value C of the pixel of interest in the frame #n, the pixel value N of the pixel in the frame #n + 1 at the same position in the frame as the pixel of interest, and the pixel value P of the pixel in the

frame #n - 1 at the same position in the frame as the pixel of interest, and outputs the calculated estimated mixture ratio.

As described above, the estimated mixture ratio processing unit 401 can calculate the estimated mixture ratio based upon the input image, and supply to the mixture ratio decision unit 403.

Note that the processing of the estimated mixture ratio processing unit 402 is the same as that of the estimated mixture ratio processing unit 401 except for the processing wherein, while the estimated mixture ratio processing unit 401 calculates the estimated mixture ratio of the pixel of interest by the computation represented in Expression (21), the estimated mixture ratio processing unit 402 calculates the estimated mixture ratio of the pixel of interest by the computation represented in Expression (22), and accordingly, description thereof will be omitted.

Fig. 69 is a diagram which illustrates an example of the estimated mixture ratio calculated by the estimated mixture ratio processing unit 401. The estimated mixture ratio shown in Fig. 69 indicates the results in a case wherein the foreground movement amount v corresponding to the object which moves at a constant velocity is 11, for one line.

It can be understood that the estimated mixture ratio

changes approximately linearly in the mixed region, as shown in Fig. 63.

Returning to Fig. 62, the mixture ratio decision unit 403 sets the mixture ratio α based upon the region information indicating which of the foreground region, the background region, the covered background region, or the uncovered background region, the pixel which is the object of calculation of the mixture ratio α belongs to, supplied from the region specifying unit 103. In the event that the pixel which is the object belongs to the foreground region, the mixture ratio decision unit 403 sets the mixture ratio α to 0, in the event that the pixel which is the object belongs to the background region, sets the mixture ratio α to 1, in the event that the pixel which is the object belongs to the covered background region, sets the mixture ratio α to the estimated mixture ratio supplied from the estimated mixture ratio processing unit 401, and in the event that the pixel which is the object belongs to the uncovered background region, sets the mixture ratio α to the estimated mixture ratio supplied from the estimated mixture ratio processing unit 402. The mixture ratio decision unit 403 outputs the mixture ratio α which has been set based upon the region information.

Fig. 70 is a block diagram which illustrates another configuration of the mixture ratio calculation unit 104. A

selection unit 441 supplies the pixels belonging to the covered background region and the corresponding pixels in the following and previous frames, to an estimated mixture ratio processing unit 442, based upon the region information supplied from the region specifying unit 103. The selection unit 441 supplies the pixels belonging to the uncovered background region and the corresponding pixels in the previous and following frames, to an estimated mixture ratio processing unit 443, based upon the region information supplied from the region specifying unit 103.

The estimated mixture ratio processing unit 442 calculates the estimated mixture ratio of the pixel of interest belonging to the covered background region by the computation represented in Expression (21) based upon the pixel values input from the selection unit 441, and supplies the calculated estimated mixture ratio to a selection unit 444.

The estimated mixture ratio processing unit 443 calculates the estimated mixture ratio of the pixel of interest belonging to the uncovered background region by the computation represented in Expression (22) based upon the pixel values input from the selection unit 441, and supplies the calculated estimated mixture ratio to the selection unit 444.

In the event that the pixel which is the object belongs

to the foreground region, the selection unit 444 selects the estimated mixture ratio of 0, and sets for the mixture ratio α, and in the event that the pixel which is the object belongs to the background region, the selection unit 444 selects the estimated mixture ratio of 1, and sets for the mixture ratio α, based upon the region information supplied from the region specifying unit 103. In the event that the pixel which is the object belongs to the covered background region, the selection unit 444 selects the estimated mixture ratio supplied from the estimated mixture ratio processing unit 442, and sets for the mixture ratio α, and in the event that the pixel which is the object belongs to the uncovered background region, the selection unit 444 selects the estimated mixture ratio supplied from the estimated mixture ratio processing unit 443, and sets this for the mixture ratio α. The selection unit 444 outputs the mixture ratio α which has been selected and set based upon the region information.

As described above, the mixture ratio calculation unit 104 having another configuration shown in Fig. 70 can calculate the mixture ratio α for each pixel included in the image, and output the calculated mixture ratio α.

Referring to the flowchart shown in Fig. 71, the processing for calculation of the mixture ratio α by the mixture ratio calculation unit 104 of which configuration is

shown in Fig. 62 will be described. In Step S401, the mixture ratio calculation unit 104 obtains the region information supplied from the region specifying unit 103. In Step S402, the estimated mixture ratio processing unit 401 performs processing of computation of the estimated mixture ratio by a model corresponding to the covered background region, and supplies the calculated estimated mixture ratio to the mixture ratio decision unit 403. Details of the processing for computation of the estimated mixture ratio will be described later with reference to the flowchart shown in Fig. 72.

In Step S403, the estimated mixture ratio processing unit 402 performs the processing of the computation of the estimated mixture ratio by a model corresponding to the uncovered background region, and supplies the calculated mixture ratio to the mixture ratio decision unit 403.

In Step S404, the mixture ratio calculation unit 104 judges whether or not the mixture ratio α has been estimated for the entire frame, and in the event that judgment is made that the mixture ratio α has not been estimated for the entire frame, the flow returns to Step S402, and performs the processing of estimation of the mixture ratio α for the following pixel.

In the event that judgment is made in Step S404 that the mixture ratio α has been estimated for the entire frame,

the flow proceeds to Step S405, and the mixture ratio decision unit 403 sets the mixture ratio α based upon the region information which indicates which of the foreground region, the background region, the covered background region, or the uncovered background region, the pixel belongs to, supplied from the region specifying unit 103. In the event that the pixel which is the object belongs to the foreground region, the mixture ratio decision unit 403 sets the mixture ratio α to 0, in the event that the pixel which is the object belongs to the background region, sets the mixture ratio α to 1, in the event that the pixel which is the object belongs to the covered background region, sets the mixture ratio α to the estimated mixture ratio supplied from the estimated mixture ratio processing unit 401, and in the event that the pixel which is the object belongs to the uncovered background region, sets the mixture ratio α to the estimated mixture ratio supplied from the estimated mixture ratio processing unit 402, and the processing ends.

As described above, the mixture ratio calculation unit 104 can calculate the mixture ratio α which is the amount of features corresponding to each pixel based upon the region information supplied from the region specifying unit 103 and the input image.

The processing of calculation of the mixture ratio α by the mixture ratio calculation unit 104 of which

configuration is shown in Fig. 70 is the same as the processing described in the flowchart shown in Fig. 71, so description thereof will be omitted.

The processing for mixture ratio estimation by a model corresponding to the covered background region, which corresponds to Step S402 in Fig. 71, will now be described with reference to the flowchart shown in Fig. 72.

In Step S421, the mixture ratio computation unit 423 obtains the pixel value C of the pixel of interest in the frame #n from the frame memory 421.

In Step S422, the mixture ratio computation unit 423 obtains the pixel value P of the pixel in the frame #n - 1, which corresponds to the pixel of interest, from the frame memory 422.

In Step S423, the mixture ratio computation unit 423 obtains the pixel value N of the pixel in the frame #n + 1, which corresponds to the pixel of interest contained in the input image.

In Step S424, the mixture ratio computation unit 423 computes the estimated mixture ratio based upon the pixel value C of the pixel of interest in the frame #n, the pixel value P of the pixel in the frame #n - 1, and the pixel value N of the pixel in the frame #n + 1.

In Step S425, the mixture ratio computation unit 423 judges whether or not the processing for computation of the

estimated mixture ratio has been ended for the entire frame, and in the event that judgment is made that the processing for computation of the estimated mixture ratio has not been ended for the entire frame, the flow returns to Step S421, and the processing for calculating of the estimated mixture ratio is repeated for the following pixel.

In Step S425, in the event that judgment is made that the processing for computation of the estimated mixture ratio has been ended for the entire frame, the processing ends.

As described above, the estimated mixture ratio processing unit 401 can compute the estimated mixture ratio based upon the input image.

The processing of mixture ratio estimation by a model corresponding to the uncovered background region shown in Step S403 in Fig. 71 is the same as the processing indicated in the flowchart shown in Fig. 72, wherein expressions corresponding to a model of the uncovered background region are used, and accordingly description thereof will be omitted.

Note that the estimated mixture ratio processing unit 442 and the estimated mixture ratio processing unit 443 shown in Fig. 70 compute the estimated mixture ratio by performing the processing the same as the processing indicated in the flowchart shown in Fig. 72, and accordingly

description thereof will be omitted.

Also, while description has been made with an assumption that the object corresponding to the background keeps still, the processing for obtaining the mixture ratio α described above may be applied even if the image corresponding to the background region contains movement. For example, in the event that the image corresponding to the background moves uniformly, the estimated mixture ratio processing unit 401 shifts the entire image corresponding to the background movement, and performs processing in the same manner as in the case wherein the object corresponding to the background keeps still. Also, in the event that the image corresponding to the background region contains the background movement which is different at each local position, the estimated mixture ratio processing unit 401 selects the pixels corresponding to the background movement as the pixels corresponding to the pixels belonging to the mixed region, and performs the processing described above.

Also, an arrangement may be made wherein the mixture ratio calculation unit 104 performs only the processing of the mixture ratio estimation by a model corresponding to the covered background region for all pixels, and outputs the calculated estimated mixture ratio as the mixture ratio α. In this case, the mixture ratio α indicates the ratio of the background components with regard to the pixels belonging to

the covered background region, and indicates the ratio of the foreground components with regard to the pixels belonging to the uncovered background region. The signal processing device can obtain the mixture ratio α indicating the ratio of the background components with regard to the pixels belonging to the uncovered background region, by calculating the absolute value of the difference between the mixture ratio α calculated as described above and 1, and setting the calculated absolute value for the mixture ratio α, with regard to the pixels belonging to the uncovered background region.

Note that similarly, an arrangement may be made wherein the mixture ratio calculation unit 104 performs only the processing for the mixture ratio estimation by a model corresponding to the uncovered background region for all pixels, and outputs the calculated estimated mixture ratio as the mixture ratio α.

Another processing of the mixture ratio calculation unit 104 will now be described.

An expression wherein the mixture ratio α and the sum of the foreground components f are approximated spatially can be formed, using the nature wherein the mixture ratio α changes linearly corresponding to the change of the pixel position due to the object corresponding to the foreground moving at a constant velocity within a shutter period. The

mixture ratio α is calculated by solving the expression wherein the mixture ratio α and the sum of the foreground components f are approximated, using multiple sets of the pixel value of the pixel belonging to the mixed region and the pixel value of the pixel belonging to the background region.

In the event that the change of the mixture ratio α is generally linear, the mixture ratio α is represented in Expression (23).

$$\alpha = il + p \qquad (23)$$

In Expression (23), i denotes the index in the spatial direction wherein the position of the pixel of interest is 0. l is the inclination of the straight line of the mixture ratio α. p is the intercept of the straight line of the mixture ratio α, as well as the mixture ratio α of the pixel of interest. In Expression (23), while the index i is known, the inclination l and the intercept p are unknown.

The correlation between the index i, the inclination l, and the intercept p is shown in Fig. 73.

In Fig. 73, a white circle indicates the pixel of interest, and solid circles indicate pixels near the pixel of interest.

Multiple different mixture ratio α for a plurality of pixels are represented by two variables by approximating the mixture ratio α as in Expression (23). In the example shown

in Fig. 73, five mixture ratios for five pixels are represented by two variables, i.e., the inclination l and the intercept p.

In the event of approximating the mixture ratio α in a planner manner shown in Fig. 74, taking the movement v corresponding to the two directions of the horizontal direction and the vertical direction of the image into consideration, the mixture ratio α is represented in Expression (24) by expanding Expression (23) onto a plane. In Fig. 74, the white circle indicates the pixel of interest.

$$\alpha = jm + kq + p \qquad (24)$$

In Expression (24), j is the index in the horizontal direction wherein the position of the pixel of interest is 0, and k is the index in the vertical direction. m is the inclination of the mixture ratio α in the horizontal direction, and q is the inclination of the plane of the mixture ratio α in the vertical direction. p is the intercept of the plane of the mixture ratio α.

For example, in the frame #n shown in Fig. 64, Expression (25) through Expression (27) hold with regard to C05 through C07, respectively.

$$C05 = \alpha 05 \bullet B05/v + f05 \qquad (25)$$

$$C06 = \alpha 06 \bullet B06/v + f06 \qquad (26)$$

$$C07 = \alpha 07 \bullet B07/v + f07 \qquad (27)$$

Making an assumption that the foreground components

generally agree, i.e., F01 through F03 are the same, and F01 through F03 are written as Fc, Expression (28) holds.

$$f(x) = (1 - \alpha(x)) \cdot Fc \quad (28)$$

In Expression (28), x denotes the position in the spatial direction.

Rewriting $\alpha(x)$ as Expression (24), Expression (28) may be represented as Expression (29).

$$\begin{aligned} f(x) &= (1 - (jm + kq + p)) \cdot Fc \\ &= j \cdot (-m \cdot Fc) + k \cdot (-q \cdot Fc) + ((1 - p) \cdot Fc) \\ &= js + kt + u \end{aligned} \quad (29)$$

In Expression (29), $(-m \cdot Fc)$, $(-q \cdot Fc)$, and $(1-p) \cdot Fc$ are rewritten as Expression (30) through Expression (32).

$$s = -m \cdot Fc \quad (30)$$

$$t = -q \cdot Fc \quad (31)$$

$$u = (1 - p) \cdot Fc \quad (32)$$

In Expression (29), j is the index in the horizontal direction wherein the position of pixel of interest is 0, and k is the index in the vertical direction.

As described above, since an assumption is made that the object corresponding to the foreground moves at a constant velocity within a shutter period, and the components corresponding to the foreground generally agree, the sum of the foreground components is approximated in Expression (29).

Note that in the event of approximating the mixture

ratio α linearly, the sum of the foreground components may be represented in Expression (33).

$$f(x) = is + u \quad (33)$$

Rewriting the mixture ratio α and the sum of the foreground components in Expression (13) using Expression (24) and Expression (29), the pixel value M is represented in Expression (34).

$$M = (jm + kq + p) \cdot B + js + kt + u$$
$$= jB \cdot m + kB \cdot q + B \cdot p + j \cdot s + k \cdot t + u \quad (34)$$

In Expression (34), the unknown variables are the six values of the inclination of the plane of the mixture ratio α in the horizontal direction, m, the inclination of the plane of the mixture ratio α in the vertical direction, q, the intercepts of the plane of the mixture ratio α, p, s, t, and u.

Setting the pixel value M and pixel value B for the normal equation represented in Expression (34) corresponding to the pixels near the pixel of interest, the mixture ratio α is calculated by solving multiple normal equations wherein the pixel value M and the pixel value B have been set, by the least square method.

For example, with the index j of the pixel of interest in the horizontal direction as 0, with the index k of the pixel of interest in the vertical direction as 0, and setting the pixel value M or the pixel value B for the

normal equation represented in Expression (34) with regard to 3 × 3 pixels near the pixel of interest, Expression (35) through Expression (43) are obtained.

$$M_{-1,-1} = (-1) \bullet B_{-1,-1} \bullet m + (-1) \bullet B_{-1,-1} \bullet q + B_{-1,-1} \bullet p + (-1) \bullet s + (-1) \bullet t + u \quad (35)$$

$$M_{0,-1} = (0) \bullet B_{0,-1} \bullet m + (-1) \bullet B_{0,-1} \bullet q + B_{0,-1} \bullet p + (0) \bullet s + (-1) \bullet t + u \quad (36)$$

$$M_{+1,-1} = (+1) \bullet B_{+1,-1} \bullet m + (-1) \bullet B_{+1,-1} \bullet q + B_{+1,-1} \bullet p + (+1) \bullet s + (-1) \bullet t + u \quad (37)$$

$$M_{-1,0} = (-1) \bullet B_{-1,0} \bullet m + (0) \bullet B_{-1,0} \bullet q + B_{-1,0} \bullet p + (-1) \bullet s + (0) \bullet t + u \quad (38)$$

$$M_{0,0} = (0) \bullet B_{0,0} \bullet m + (0) \bullet B_{0,0} \bullet q + B_{0,0} \bullet p + (0) \bullet s + (0) \bullet t + u \quad (39)$$

$$M_{+1,0} = (+1) \bullet B_{+1,0} \bullet m + (0) \bullet B_{+1,0} \bullet q + B_{+1,0} \bullet p + (+1) \bullet s + (0) \bullet t + u \quad (40)$$

$$M_{-1,+1} = (-1) \bullet B_{-1,+1} \bullet m + (+1) \bullet B_{-1,+1} \bullet q + B_{-1,+1} \bullet p + (-1) \bullet s + (+1) \bullet t + u \quad (41)$$

$$M_{0,+1} = (0) \bullet B_{0,+1} \bullet m + (+1) \bullet B_{0,+1} \bullet q + B_{0,+1} \bullet p + (0) \bullet s + (+1) \bullet t + u \quad (42)$$

$$M_{+1,+1} = (+1) \bullet B_{+1,+1} \bullet m + (+1) \bullet B_{+1,+1} \bullet q + B_{+1,+1} \bullet p + (+1) \bullet s + (+1) \bullet t + u \quad (43)$$

Since the index of the pixel of interest in the horizontal direction, j, is 0, and the index in the vertical direction, k, is 0, the mixture ratio α of the pixel of interest is equal to the value wherein j = 0 and k = 0, from

Expression (24), i.e., the intercept p.

Accordingly, the intercept p can be output as the mixture ratio α by calculating the inclination in the horizontal direction, m, the inclination in the vertical direction, q, the intercept p, s, t, and u, by the least square method, based upon the nine expressions of Expression (35) through Expression (43).

More specific procedures for calculating the mixture ratio α by applying the least square method will now be described.

Representing the index i and the index k with one index x, the relationship between the index i, the index k, and the index x, is represented in Expression (44).

$$x = (j + 1) \bullet 3 + (k + 1) \qquad (44)$$

The inclination in the horizontal direction, m, the inclination in the vertical direction, q, the intercept p, s, t, and u, are represented by variables, w0, w1, w2, w3, w4, and w5, respectively, and jB, kB, B, j, k, and l are represented by a0, a1, a2, a3, a4, and a5, respectively. Taking the margin of error ex into consideration, Expression (35) through Expression (43) are rewritten as Expression (45).

$$Mx = \sum_{y=0}^{5} ay \cdot wy + ex \qquad (45)$$

In Expression (45), x denotes one of the integers

between 0 and 8.

Expression (46) may be derived from Expression (45).

$$ex = Mx - \sum_{y=0}^{5} ay \cdot wy \qquad (46)$$

To apply the least square method, the sum of squares of margin of error E is defined as represented in Expression (47).

$$E = \sum_{x=0}^{8} ex^2 \qquad (47)$$

To minimize the margin of error, the partial derivative of the squared-sum of the margin of error E from the variable Wv should be 0. Here v is one of the integers between 0 through 5. Accordingly, wy is calculated so as to satisfy Expression (48).

$$\frac{\partial E}{\partial wv} = 2 \cdot \sum_{x=0}^{8} ex \cdot \frac{\partial ex}{\partial wv}$$

$$= 2 \cdot \sum_{x=0}^{8} ex \cdot av = 0 \qquad (48)$$

Substituting Expression (46) for Expression (48), Expression (49) is obtained.

$$\sum_{x=0}^{8} (av \cdot \sum_{y=0}^{5} ay \cdot wy) = \sum_{x=0}^{8} av \cdot Mx \qquad (49)$$

Applying, for example, the sweeping method (Gauss-Jordan elimination) and so forth, to the six expressions each of which is obtained by substituting one of the integers between 0 and 5 for v in Expression (49), wy is

calculated. As described above, w0 denotes the inclination in the horizontal direction, m, w1 denotes the inclination in the vertical direction, q, w2 denotes the intercept p, w3 denotes s, w4 denotes t, and w5 denotes u.

As described above, the inclination in the horizontal direction, m, the inclination in the vertical direction, q, the intercept p, s, t, and u may be obtained by applying the least square method to an expression wherein the pixel value M and the pixel value B have been set.

In the description corresponding to Expression (35) through Expression (43), while description has been made with the pixel value of the pixel included in the mixed region as M, and the pixel value of the pixel included in the background region as B, the normal equation needs to be formed for each case of the pixel of interest being included in the covered background region, and being included in the uncovered background region.

For example, in a case of obtaining the mixture ratio α of the pixel included in the covered background region of the frame #n shown in Fig. 64, the pixels of the frame #n, C04 through C08, and the pixel values of the pixels of the frame #n - 1, P04 through P08, are set for the normal equation.

In a case of obtaining the mixture ratio α of the pixel included in the uncovered background region of the frame #n

shown in Fig. 65, the pixels of the frame #n, C28 through C32, and the pixel values of the pixels of the frame #n + 1, N28 through N32, are set for the normal equation.

Also, for example, in the event of calculating the mixture ratio α of the pixel included in the covered background region shown in Fig. 75, Expression (50) through Expression (58) described below may be formed. The pixel value of the pixel for calculation of the mixture ratio α is Mc5. In Fig. 75, white circles indicate the pixels which are regarded as backgrounds, and solid circles indicate the pixels which are regarded as pixels in the mixed region.

$$Mc1 = (-1) \bullet Bc1 \bullet m + (-1) \bullet Bc1 \bullet q + Bc1 \bullet p + (-1) \bullet s + (-1) \bullet t + u \quad (50)$$

$$Mc2 = (0) \bullet Bc2 \bullet m + (-1) \bullet Bc2 \bullet q + Bc2 \bullet p + (0) \bullet s + (-1) \bullet t + u \quad (51)$$

$$Mc3 = (+1) \bullet Bc3 \bullet m + (-1) \bullet Bc3 \bullet q + Bc3 \bullet p + (+1) \bullet s + (-1) \bullet t + u \quad (52)$$

$$Mc4 = (-1) \bullet Bc4 \bullet m + (0) \bullet Bc4 \bullet q + Bc4 \bullet p + (-1) \bullet s + (0) \bullet t + u \quad (53)$$

$$Mc5 = (0) \bullet Bc5 \bullet m + (0) \bullet Bc5 \bullet q + Bc5 \bullet p + (0) \bullet s + (0) \bullet t + u \quad (54)$$

$$Mc6 = (+1) \bullet Bc6 \bullet m + (0) \bullet Bc6 \bullet q + Bc6 \bullet p + (+1) \bullet s + (0) \bullet t + u \quad (55)$$

$$Mc7 = (-1) \bullet Bc7 \bullet m + (+1) \bullet Bc7 \bullet q + Bc7 \bullet p + (-1) \bullet s + (+1) \bullet t + u \quad (56)$$

$$Mc8 = (0) \bullet Bc8 \bullet m + (+1) \bullet Bc8 \bullet q + Bc8 \bullet p + (0) \bullet s + (+1) \bullet t + u \quad (57)$$

$$Mc9 = (+1) \bullet Bc9 \bullet m + (+1) \bullet Bc9 \bullet q + Bc9 \bullet p + (+1) \bullet s + (+1) \bullet t + u \quad (58)$$

In the event of calculating the mixture ratio α of the pixel included in the covered background region in the frame #n, the pixel values Bc1 through Bc9 of the pixels in the background region in the frame #n - 1 corresponding to the pixels in the frame #n, are used in Expression (50) through Expression (58).

In the event of calculating the mixture ratio α of the pixel included in the uncovered background region shown in Fig. 75, Expression (59) through Expression (67) described below may be formed. The pixel value of the pixel for calculation of the mixture ratio α is Mu5.

$$Mu1 = (-1) \bullet Bu1 \bullet m + (-1) \bullet Bu1 \bullet q + Bu1 \bullet p + (-1) \bullet s + (-1) \bullet t + u \quad (59)$$

$$Mu2 = (0) \bullet Bu2 \bullet m + (-1) \bullet Bu2 \bullet q + Bu2 \bullet p + (0) \bullet s + (-1) \bullet t + u \quad (60)$$

$$Mu3 = (+1) \bullet Bu3 \bullet m + (-1) \bullet Bu3 \bullet q + Bu3 \bullet p + (+1) \bullet s + (-1) \bullet t + u \quad (61)$$

$$Mu4 = (-1) \bullet Bu4 \bullet m + (0) \bullet Bu4 \bullet q + Bu4 \bullet p + (-1) \bullet s + (0) \bullet t + u \quad (62)$$

$$Mu5 = (0) \bullet Bu5 \bullet m + (0) \bullet Bu5 \bullet q + Bu5 \bullet p + (0) \bullet s + (0) \bullet t + u \quad (63)$$

$$Mu6 = (+1) \bullet Bu6 \bullet m + (0) \bullet Bu6 \bullet q + Bu6 \bullet p + (+1) \bullet s + (0) \bullet t + u \quad (64)$$

$$Mu7 = (-1) \bullet Bu7 \bullet m + (+1) \bullet Bu7 \bullet q + Bu7 \bullet p + (-1) \bullet s + (+1) \bullet t + u \quad (65)$$

$$Mu8 = (0) \bullet Bu8 \bullet m + (+1) \bullet Bu8 \bullet q + Bu8 \bullet p + (0) \bullet s + (+1) \bullet t + u \quad (66)$$

$$Mu9 = (+1) \bullet Bu9 \bullet m + (+1) \bullet Bu9 \bullet q + Bu9 \bullet p + (+1) \bullet s + (+1) \bullet t + u \quad (67)$$

In the event of calculating the mixture ratio α of the pixel included in the uncovered background region in the frame #n, the pixel values Bu1 through Bu9 of the pixels in the background region in the frame #n + 1 corresponding to the pixels in the frame #n, are used in Expression (59) through Expression (67).

Fig. 76 is a block diagram which illustrates the configuration of the estimated mixture ratio processing unit 401. The image input to the estimated mixture ratio processing unit 401 is supplied to a delay circuit 501 and an addition unit 502.

The delay circuit 501 delays the input image by one frame, and supplies to the addition unit 502. At the point that the frame #n is input to the addition unit 502 as an input image, the delay circuit 501 supplies the frame #n - 1 to the addition unit 502.

The addition unit 502 sets the pixel values of the

pixels near the pixel for calculation of the mixture ratio α, and the pixel values of the frame #n - 1, for the normal equation. For example, the addition unit 502 sets the pixel values Mc1 through Mc9, and the pixel values Bc1 through Bc9 for the normal equation based upon Expression (50) through Expression (58). The addition unit 502 supplies the normal equation for which the pixel values have been set, to a computation unit 503.

The computation unit 503 obtains the estimated mixture ratio by solving the normal equation supplied from the addition unit 502 by the sweeping method or the like, and outputs the obtained estimated mixture ratio.

As described above, the estimated mixture ratio processing unit 401 can calculate the estimated mixture ratio based upon the input image, and supply to the mixture ratio decision unit 403.

Note that the estimated mixture ratio processing unit 402 has the same configuration as the estimated mixture ratio processing unit 401, and accordingly description thereof will be omitted.

Fig. 77 is a diagram which illustrates an example of the estimated mixture ratio calculated by the estimated mixture ratio processing unit 401. Fig. 77 illustrates the estimated mixture ratio with regard to one line, wherein the movement v of the foreground corresponding to the object

which moves at a constant velocity is 11, and the results are calculated by the expression generated in increments of blocks 7 × 7 pixels.

It can be understood that the estimated mixture ratio changes generally linearly in the mixed region as shown in Fig. 63.

The mixture ratio decision unit 403 sets the mixture ratio based upon the region information indicating which of the foreground region, the background region, the covered background region, or the uncovered background region the pixel for calculation of the mixture ratio belongs to, supplied from the region specifying unit 101. In the event that the pixel which is the object belongs to the foreground region, the mixture ratio decision unit 403 sets the mixture ratio to 0, in the event that the pixel which is the object belongs to the background region, sets the mixture ratio to 1, in the event that the pixel which is the object belongs to the covered background region, sets the mixture ratio to the estimated mixture ratio supplied from the estimated mixture ratio processing unit 401, and in the event that the pixel which is the object belongs to the uncovered background region, sets the mixture ratio to the estimated mixture ratio supplied from the estimated mixture ratio processing unit 402. The mixture ratio decision unit 403 outputs the mixture ratio which is set based upon the region

information.

Referring to the flowchart shown in Fig. 78, the processing for calculation of the mixture ratio by the mixture ratio calculation unit 102 in a case that the estimated mixture ratio processing unit 401 has a configuration shown in Fig. 76 will be described. In Step S501, the mixture ratio calculation unit 102 obtains the region information supplied from the region specifying unit 101. In Step S502, the estimated mixture ratio processing unit 401 performs the processing of mixture ratio estimation by a model corresponding to the covered background region, and supplies the estimated mixture ratio to the mixture ratio decision unit 403. Details of the processing of mixture ratio estimation will be described later with reference to the flowchart shown in Fig. 79.

In Step S503, the estimated mixture ratio processing unit 402 performs the processing of mixture ratio estimation by a model corresponding to the uncovered background region, and supplies the estimated mixture ratio to the mixture ratio decision unit 403.

In Step S504, the mixture ratio calculation unit 102 judges whether or not the mixture ratio has been estimated for the entire frame, and in the event that judgment is made that the mixture ratio has not been estimated for the entire frame, the flow returns to Step S502, and the processing of

mixture ratio estimation for the following pixel is performed.

In Step S504, in the event that judgment is made that the mixture ratio has been estimated for the entire frame, the flow proceeds to Step S505, and the mixture ratio decision unit 403 sets the mixture ratio based upon the region information which indicates which of the foreground region, the background region, the covered background region, or the uncovered background region the pixel of calculation of the mixture ratio belongs to, supplied from the region specifying unit 101. In the event that the pixel which is the object belongs to the foreground region, the mixture ratio decision unit 403 sets the mixture ratio to 0, in the event that the pixel which is the object belongs to the background region, sets the mixture ratio to 1, in the event that the pixel which is the object belongs to the covered background region, sets the mixture ratio to the estimated mixture ratio supplied from the estimated mixture ratio processing unit 401, and in the event that the pixel which is the object belongs to the uncovered background region, sets the mixture ratio to the estimated mixture ratio supplied from the estimated mixture ratio processing unit 402, and processing ends.

As described above, the mixture ratio calculation unit 102 can calculate the mixture ratio α which is the amount of

features corresponding to each pixel based upon the region information supplied from the region specifying unit 101 and the input image.

Using the mixture ratio α enables the separation of the foreground components and the background components contained in the pixel value while leaving the information of movement blurring contained in the image corresponding to the moving object.

Also, synthesizing an image based upon the mixture ratio α enables creation of an image containing accurate movement blurring corresponding to the speed of the object which moves as if image taking of the real world had been performed again.

The processing of the mixture ratio estimation by a model corresponding to the covered background region, which corresponds to Step S502 shown in Fig. 78, will now be described with reference to the flowchart shown in Fig. 79.

In Step S521, the addition unit 502 sets the pixel values contained in the input image and the pixels contained the image supplied from the delay circuit 501 for the normal equation corresponding to a model of the covered background region.

In Step S522, the estimated mixture ratio processing unit 401 judges whether or not setting of the pixel which is the object has ended, and in the event that judgment is made

that the setting for the pixel which is the object has not ended, the flow returns to Step S521, and the processing of setting of the pixel value for the normal equation is repeated.

In Step S522, in the event that judgment is made that setting of pixel values with regard to the pixel which is the object has ended, the flow proceeds to Step S523, and the computation unit 503 computes the estimated mixture ratio based upon the normal equation which the pixel values have been set for, and outputs the obtained estimated mixture ratio.

As described above, the estimated mixture ratio processing unit 401 can computes the estimated mixture ratio based upon the input image.

The processing of mixture ratio estimation by a model corresponding to the uncovered background region in Step S153 shown in Fig. 78 is the same as the processing shown in the flowchart in Fig. 79 using the normal equation corresponding to a model of the uncovered background region, and accordingly, description thereof will be omitted.

Note that while description has been made with an assumption that the object corresponding to the background keeps still, the processing of obtaining the mixture ratio described above may be applied even if the image corresponding to the background contains movement. For

example, in the event that the image corresponding to the background region moves uniformly, the estimated mixture ratio processing unit 401 shifts the entire image corresponding to the movement, and performs processing in the same manner as a case wherein the object corresponding to the background keeps still. Also, in the event that the image corresponding to the background contains different movement at each local position, the estimated mixture ratio processing unit 401 selects pixels corresponding to the movement as pixels corresponding to pixels belonging to the mixed region, and performs the above-described processing.

The foreground/background separation unit 105 will now be described. Fig. 80 is a block diagram which illustrates an example of the configuration of the foreground/background separation unit 105. The input image supplied to the foreground/background separation unit 105 is supplied to a separation unit 601, a switch 602, and a switch 604. The region information indicating the covered background region and the uncovered background region, which is supplied from the region specifying unit 103, is supplied to the separation unit 601. The region information indicating the foreground region is supplied to the switch 602. The region information indicating the background region is supplied to the switch 604.

The mixture ratio α supplied from the mixture ratio

calculation unit 104 is supplied to the separation unit 601.

The separation unit 601 separates the foreground components from the input image based upon the region information indicating the covered background region, the region information indicating the uncovered background region, and the mixture ratio α, and supplies the separated foreground components to a synthesizing unit 603, as well as separating the background components from the input image, and supplying the separated background components to the synthesizing unit 605.

In the event that the pixel corresponding to the foreground is input, the switch 602 is closed based upon the region information indicating the foreground region, and supplies only the pixels corresponding to the foreground included in the input image to the synthesizing unit 603.

In the event that the pixel corresponding to the background is input, the switch 604 is closed based upon the region information indicating the background region, and supplies only the pixels corresponding to the background included in the input image to the synthesizing unit 605.

The synthesizing unit 603 synthesizes the foreground component image based upon the components corresponding to the foreground supplied from the separation unit 601, and the pixels corresponding to the foreground supplied from the switch 602, and outputs the synthesized foreground component

image. Since the foreground region and the mixed region are not overlapped, the synthesizing unit 603 synthesizes the foreground component image, for example, by applying the logical sum computation to the components corresponding to the foreground, and the pixels corresponding to the foreground.

In the initialization processing which is performed in the first stage of the foreground component image synthesizing processing, the synthesizing unit 603 stores the image, wherein all the pixel values are 0, in built-in frame memory, and in the foreground component image synthesizing processing, the synthesizing unit 603 stores (or overwrites) the foreground component image. Accordingly, the pixel corresponding to the background region, which is the foreground component image output from the synthesizing unit 603, stores 0 as a pixel value.

The synthesizing unit 605 synthesizes the background component image based upon the components corresponding to the background supplied from the separation unit 601, and the pixels corresponding to the background supplied from the switch 604, and outputs the synthesized background component image. Since the background region and the mixed region are not overlapped, the synthesizing unit 605 synthesizes the background component image, for example, by applying the logical sum computation to the components corresponding to

the background, and the pixels corresponding to the background.

In the initialization processing which is performed in the first stage of the background component image synthesizing processing, the synthesizing unit 605 stores the image, wherein all the pixel values are 0, in built-in frame memory, and in the background component image synthesizing processing, the synthesizing unit 605 stores (or overwrites) the background component image. Accordingly, the pixel corresponding to the foreground region, which is the background component image output from the synthesizing unit 605, stores 0 as a pixel value.

Fig. 81A is a diagram which illustrates the input image input to the foreground/background separation unit 105, and the foreground component image and the background component image output from the foreground/background separation unit 105. Fig. 81B is a diagram which illustrates a model corresponding to the input image input to the foreground/background separation unit 105, and the foreground component image and the background component image output from the foreground/background separation unit 105.

Fig. 81A is a schematic diagram which illustrates the displayed image, and Fig. 81B is a model diagram wherein one line of pixels including pixels belonging to the foreground

region, pixels belonging to the background region, and pixels belonging to the mixed region, corresponding to Fig. 81A, develop over the time direction.

As shown in Fig. 81A and Fig. 81B, the background component image output from the foreground/background separation unit 105 is made up of pixels belonging to the background region and background components containing pixels in the mixed region.

As shown in Fig. 81A and Fig. 81B, the foreground component image output from the foreground/background separation unit 105 is made up of pixels belonging to the foreground region and foreground components contained in pixels in the mixed region.

The pixel value of the pixel in the mixed region is separated into the background components and the foreground components by the foreground/background separation unit 105. The separated background components make up a background component image along with pixels belonging to the background region. The separated foreground components make up a foreground component image along with pixels belonging to the foreground region.

As described above, in the foreground component image, the pixel values of the pixels corresponding to the background region are set to 0, and the pixels corresponding to the foreground region and the pixels corresponding to the

mixed region are set to valid pixel values. Similarly, in the background component image, the pixel values of the pixels corresponding to the foreground region are set to 0, and the pixels corresponding to the background region and the pixels corresponding to the mixed region are set to valid pixel values.

A description will now be made regarding the separation processing of the foreground components and the background components from the pixel belonging to the mixed region performed by the separation unit 601.

Fig. 82 is a model of an image which indicates two frames of the foreground components and the background components, including the foreground corresponding to the object which moves from the left to the right in the drawing. In the model of the image shown in Fig. 82, the movement amount v of the foreground is 4, and the virtual dividing number is 4.

In the frame #n, the left-most pixel and the fourteenth through eighteenth pixels from the left are made up of only the background components, and belong to the background region. In the frame #n, the second through fourth pixels from the left are made up of the background components and the foreground components, and belong to the uncovered background region. In the frame #n, the eleventh through thirteenth pixels from the left are made up of the

background components and the foreground components, and belong to the covered background region. In the frame #n, the fifth through tenth pixels from the left are made up of only the foreground components, and belong to the foreground region.

In the frame #n + 1, the first through fifth pixels from the left and the eighteenth pixel from the left are made up of only the background components, and belong to the background region. In the frame #n + 1, the sixth through eighth pixels from the left contain the background components and the foreground components, and belong to the uncovered background region. In the frame #n + 1, the fifteenth through seventeenth pixels from the left contain the background components and the foreground components, and belong to the covered background region. In the frame #n + 1, the ninth through fourteen pixels from the left are made up of only the foreground components, and belong to the foreground region.

Fig. 83 is a diagram which describes the processing for separation of the foreground components from the pixel belonging to the covered background region. In Fig. 83, $\alpha 1$ through $\alpha 18$ are the mixture ratios corresponding to the pixels in the frame #n, respectively. In Fig. 83, the fifteenth through seventeenth pixels from the left belongs to the covered background region.

The pixel value C15 of the fifteenth pixel from the left in the frame #n is represented in Expression (68).

$$C15 = B15/v + F09/v + F08/v + F07/v$$
$$= \alpha 15 \bullet B15 + F09/v + F08/v + F07/v$$
$$= \alpha 15 \bullet P15 + F09/v + F08/v + F07/v \quad (68)$$

Here, $\alpha 15$ denotes the mixture ratio of the fifteenth pixel from the left in the frame #n. P15 denotes the pixel value of the fifteenth pixel from the left in the frame #n - 1.

The sum f15 of the foreground components of the fifteenth pixel from the left in the frame #n is represented in Expression (69) based upon Expression (68).

$$f15 = F09/v + F08/v + F07/v$$
$$= C15 - \alpha 15 \bullet P15 \quad (69)$$

Similarly, the sum f16 of the foreground components of the sixteenth pixel from the left in the frame #n is represented in Expression (70), and the sum f17 of the foreground components of the seventeenth pixel from the left in the frame #n is represented in Expression (71).

$$f16 = C16 - \alpha 16 \bullet P16 \quad (70)$$

$$f17 = C17 - \alpha 17 \bullet P17 \quad (71)$$

As described above, the foreground component fc contained in the pixel value C of the pixel belonging to the covered background region is calculated by Expression (72).

$$fc = C - \alpha \bullet P \quad (72)$$

P denotes the pixel value of the corresponding pixel in the previous frame.

Fig. 84 is a diagram which describes the processing for separating the foreground components from the pixel belonging to the uncovered background region. In Fig. 84, $\alpha 1$ through $\alpha 18$ denote the mixture ratio corresponding to the pixels in the frame #n, respectively. In Fig. 84, the second through fourth pixels from the left belong to the uncovered background region.

The pixel value C02 of the second pixel from the left in the frame #n is represented in Expression (73).

$$C02 = B02/v + B02/v + B02/v + F01/v$$
$$= \alpha 2 \cdot B02 + F01/v$$
$$= \alpha 2 \cdot N02 + F01/v \quad (73)$$

Here, $\alpha 2$ denotes the mixture ratio of the second pixel from the left in the frame #n. N02 denotes the pixel value of the second pixel from the left in the frame #n + 1.

The foreground component sum of the second pixel from the left in the frame #n, f02, is represented in Expression (74) based upon Expression (73).

$$f02 = F01/v$$
$$= C02 - \alpha 2 \cdot N02 \quad (74)$$

Similarly, the foreground component sum of the third pixel from the left in the frame #n, f03, is represented in Expression (75), and the foreground component sum of the

fourth pixel from the left in the frame #n, f04, is represented in Expression (76).

$$f03 = C03 - \alpha 3 \bullet N03 \quad (75)$$

$$f04 = C04 - \alpha 4 \bullet N04 \quad (76)$$

As described above, the foreground component fu contained in the pixel value C of the pixel belonging to the uncovered background region is calculated by Expression (77).

$$fu = C - \alpha \bullet N \quad (77)$$

N denotes the pixel value of the corresponding pixel in the following frame.

As described above, the separation unit 601 can separate the foreground components and the background components from the pixel belonging to the mixed region based upon the information indicating the covered background region and the information indicating the uncovered background region, which is included in the region information, and the mixture ratio α for each pixel.

Fig. 85 is a block diagram which illustrates an example of the configuration of the separation unit 601 for performing the processing described above. The image input to the separation unit 601 is supplied to frame memory 621, and the region information indicating the covered background region and the uncovered background region supplied from the mixture ratio calculation unit 104, and the mixture ratio α is input to a separation processing block 622.

The frame memory 621 stores the input image in increments of frames. In the event that the object of processing is the frame #n, the frame memory 621 stores the frame #n - 1 which is the frame previous to the frame #n, frame #n, and the frame #n + 1 which is the frame following the frame #n.

The frame memory 621 supplies the corresponding pixels in the frame #n -1, the frame #n, and the frame #n + 1 to the separation processing block 622.

The separation processing block 622 separates the foreground components and the background components from the pixel belonging to the mixed region in the frame #n by applying the computation described with reference to Fig. 83 and Fig. 84 to the pixel values of corresponding pixels in the frame #n - 1, the frame #n, and the frame #n + 1, supplied from the frame memory 621, based upon the region information indicating the covered background region and the uncovered background region, and the mixture ratio α, and supplies to the frame memory 623.

The separation processing block 622 comprises an uncovered region processing unit 631, a covered region processing unit 632, a synthesizing unit 633, and a synthesizing unit 634.

A multiplication device 641 of the uncovered region processing unit 631 multiplies the pixel value of the pixel

of the frame #n + 1 supplied from the frame memory 621 by the mixture ratio α, and outputs to a switch 642. In the event that the pixel in the frame #n supplied from the frame memory 621 (which is corresponding to the pixel of the frame #n + 1) belongs to the uncovered background region, the switch 642 is closed, the pixel value which is multiplied by the mixture ratio α supplied from the multiplication device 641 is supplied to a computing device 643 and the synthesizing unit 634. The value wherein the pixel value of the pixel of the frame #n + 1 output from the switch 642 is multiplied by the mixture ratio α is the same as the background component of the pixel value of the corresponding pixel in the frame #n.

The computing device 643 obtains the foreground components by subtracting the background components supplied from the switch 642 from the pixel value of the pixel of the frame #n supplied from the frame memory 621. The computing device 643 supplies the foreground components of the pixel in the frame #n belonging to the uncovered background region, to the synthesizing unit 633.

A multiplication device 651 of the covered region processing unit 632 multiplies the pixel value of the pixel of the frame #n - 1 supplied from the frame memory 621 by the mixture ratio α, and outputs to a switch 652. In the event that the pixel in the frame #n supplied from the frame

memory 621 (corresponding to the pixel of the frame #n - 1) belongs to the covered background region, the switch 652 is closed, and the pixel value which is multiplied by the mixture ratio α supplied from the multiplication device 651 is supplied to a computing device 653 and the synthesizing unit 634. The value wherein the pixel value of the pixel of the frame #n - 1 output from the switch 652 is multiplied by the mixture ratio α, is the same as the background component of the pixel value of the corresponding pixel in the frame #n.

The computing device 653 obtains the foreground components by subtracting the background components supplied from the switch 652 from the pixel value of the pixel of the frame #n supplied from the frame memory 621. The computing device 653 supplies the foreground components of the pixel in the frame #n belonging to the covered background region, to the synthesizing unit 633.

The synthesizing unit 633 synthesizes the foreground components of the pixel belonging to the uncovered background region in the frame #n supplied from the computing device 643, and the foreground components of the pixel belonging to the covered background region supplied from the computing device 653, and supplies to the frame memory 623.

The synthesizing unit 634 synthesizes the background

components of the pixel belonging to the uncovered background region in the frame #n supplied from the switch 642, and the background components of the pixel belonging to the covered background region supplied from the switch 652, and supplies to the frame memory 623.

The frame memory 623 stores the foreground components and the background components of the pixels in the mixed region in the frame #n, supplied from the separation processing block 622, respectively.

The frame memory 623 outputs the foreground components of the pixels in the mixed region in the frame #n stored therein, and the background components of the pixels in the mixed region in the frame #n stored therein.

Using the mixture ratio α which is the feature amount enables complete separation of the foreground components and the background components, contained in the pixel value.

The synthesizing unit 603 generates the foreground component image by synthesizing the foreground components of the pixel in the mixed region in the frame #n output from the separation unit 601, and the pixels belonging to the foreground region. The synthesizing unit 605 generates the background component image by synthesizing the background components of the pixels in the mixed region in the frame #n output from the separation unit 601, and pixels belonging to the background region.

Fig. 86A is a diagram which illustrates an example of the foreground component image corresponding to the frame #n shown in Fig. 82. Fig. 86B is a diagram which illustrates an example of the background component image corresponding to the frame #n shown in Fig. 82.

Fig. 86A illustrates an example of the foreground component image corresponding to the frame #n shown in Fig. 82. Since the left-most pixel and the fourteenth pixel from the left are made up of only the background components before separation of the foreground and the background, the pixel values are 0.

The second through fourth pixels from the left belong to the uncovered background region prior to the foreground and the background being separated, with the background components being 0, and the foreground components being left as they are. The eleventh through thirteenth pixels belong to the covered background region before separation of the foreground and the background, and the background components are 0, and the foreground components are left as they are. Since the fifth through tenth pixels from the left are made up of only the foreground components, those are left as they are.

Fig. 86B illustrates an example of the background component image corresponding to the frame #n shown in Fig. 82. The left-most pixel and the fourteenth pixel from the

left are made up of only the background components prior to the foreground and the background being separated, and accordingly, those are left as they are.

The second through fourth pixels from the left belong to the uncovered background region prior to the foreground and the background being separated, with the foreground components being 0, and the background components being left as they are. The eleventh through thirteenth pixels belong to the covered background region prior to the foreground and the background being separated, the foreground components being 0, and the background components being left as they are. The fifth through tenth pixels from the left are made up of only the foreground components prior to the foreground and the background being separated, and accordingly the pixel values are 0.

The separation processing for the foreground and the background by the foreground/background separation unit 105 will now be described, with reference to the flowchart shown in Fig. 87. In Step S601, the frame memory 621 of the separation unit 601 obtains the input image, and stores the frame #n which is the object of the separation of the foreground and the background, as well as the previous frame #n - 1 and the following frame #n + 1.

In Step S602, the separation processing block 622 of the separation unit 601 obtains the region information

supplied from the mixture ratio calculation unit 104. In Step S603, the separation processing block 622 of the separation unit 601 obtains the mixture ratio α supplied from the mixture ratio calculation unit 104.

In Step S604, the uncovered region processing unit 631 extracts the background components from the pixel value of the pixel belonging to the uncovered background region supplied from the frame memory 621 based upon the region information and the mixture ratio α.

In Step S605, the uncovered region processing unit 631 extracts the foreground components from the pixel value of the pixel belonging to the uncovered background region supplied from the frame memory 621 based upon the region information and the mixture ratio α.

In Step S606, the covered region processing unit 632 extracts the background components from the pixel value of the pixel belonging to the covered background region supplied from the frame memory 621 based upon the region information and the mixture ratio α.

In Step S607, the covered region processing unit 632 extracts the foreground components from the pixel value of the pixel belonging to the covered background region supplied from the frame memory 621 based upon the region information and the mixture ratio α.

In Step S608, the synthesizing unit 633 synthesizes the

foreground components of the pixel belonging to the uncovered background region extracted in the processing in Step S605, and the foreground components of the pixel belonging to the covered background region extracted in the processing in Step S607. The synthesized foreground components are supplied to the synthesizing unit 603. Moreover, the synthesizing unit 603 synthesizes the pixels belonging to the foreground region supplied via the switch 602, and the foreground components supplied from the separation unit 601, and generates the foreground component image.

In Step S609, the synthesizing unit 634 synthesizes the background components of the pixel belonging to the uncovered background region extracted in the processing in Step S604, and the background components of the pixel belonging to the covered background region extracted in the processing in Step S606. The synthesized background components are supplied to the synthesizing unit 605. Moreover, the synthesizing unit 605 synthesizes the pixels belonging to the background region supplied via the switch 604, and the background components supplied from the separation unit 601, and generates the background component image.

In Step S610, the synthesizing unit 603 outputs the foreground component image. In Step S611, the synthesizing

unit 605 outputs the background component image, and the processing ends.

As described above, the foreground/background separation unit 105 can separate the foreground components and the background components from the input image based upon the region information and the mixture ratio α, and output the foreground component image which is made up of only the foreground components, and the background component image which is made up of only the background components.

The removal of movement blurring from the foreground component image will now be described.

Fig. 88 is a block diagram which illustrates an example of the configuration of the movement blurring removal unit 106. The movement vector and the position information thereof supplied from the movement detecting unit 102, and the region information supplied from the region specifying unit 103 are supplied to a processing increment decision unit 801 and the modeling unit 802. The foreground component image supplied from the foreground/background separation unit 105 is supplied to the addition unit 804.

The processing increment decision unit 801 supplies the processing increment generated based upon the movement vector, the position information thereof, and the region information, as well as the movement vector, to the modeling unit 802. The processing increment decision unit 801

supplies the generated processing increment to the addition unit 804.

The processing increment generated by the processing increment decision unit 801 denoted by A in Fig. 89, as illustrated by an example in Fig. 89, indicates the pixels arrayed sequentially in a movement direction beginning at the pixel corresponding to the covered background region of the foreground component image up to the pixel corresponding to the uncovered background region, or the pixels arrayed sequentially in a movement direction beginning at the pixel corresponding to the uncovered background region up to the pixel corresponding to the covered background region. The processing increment is made up of, for example, two pieces of data of the upper-left point (the left-most or the top-most position of the pixel, which is the pixel designated by the processing increment) and the bottom-right point.

The modeling unit 802 performs modeling based upon the movement vector and the input processing increment. More specifically, for example, an arrangement may be made wherein the modeling unit 802 stores the number of pixels included in the processing increment, the virtual dividing number of the pixel value in the time direction, and multiple models corresponding to the number of the foreground components for each pixel beforehand, and selects a model which designates the correspondence of the pixel

value to the foreground components as shown in Fig. 90, based upon the processing increment and the virtual dividing number of the pixel value in the time direction.

For example, in the event that the number of pixel corresponding to the processing increment is 12, and the movement amount v in the shutter period is 5, the modeling unit 802 sets the virtual dividing number to 5, and selects a model made up of eight foreground components overall, wherein the left-most positioned pixel contains one foreground component, the second pixel from the left contains two foreground components, the third pixel from the left contains three foreground components, the fourth pixel from the left contains four foreground components, the fifth pixel from the left contains five foreground components, the sixth pixel from the left contains five foreground components, the seventh pixel from the left contains five foreground components, the eighth pixel from the left contains five foreground components, the ninth pixel from the left contains four foreground components, the tenth pixel from the left contains three foreground components, the eleventh pixel from the left contains two foreground components, and the twelfth pixel from the left contains one foreground component.

Note that an arrangement may be made wherein the modeling unit 802 does not select a model from the models

stored beforehand, but rather generates a model based upon the movement vector and the processing increment in the event that the movement vector and the processing increment are supplied.

The modeling unit 802 supplies the selected model to an expression generating unit 803.

The expression generating unit 803 generates a expression based upon the model supplied from the modeling unit 802. The expression generated by the expression generating unit 803 will be described in a case wherein the number of the foreground components is 8, the number of pixel corresponding to the processing increment is 12, the movement amount v is 5, and the virtual dividing number is 5, with reference to the model for foreground component image shown in Fig. 90.

In the event that the foreground component corresponding to the shutter period/v contained in the foreground component image are F01/v through F08/v, the relationships between F01/v through F08/v and the pixel values C01 through C12 are represented in Expression (78) through Expression (89).

$$C01 = F01/v \tag{78}$$

$$C02 = F02/v + F01/v \tag{79}$$

$$C03 = F03/v + F02/v + F01/v \tag{80}$$

$$C04 = F04/v + F03/v + F02/v + F01/v \tag{81}$$

$$C05 = F05/v + F04/v + F03/v + F02/v + F01/v \quad (82)$$

$$C06 = F06/v + F05/v + F04/v + F03/v + F02/v \quad (83)$$

$$C07 = F07/v + F06/v + F05/v + F04/v + F03/v \quad (84)$$

$$C08 = F08/v + F07/v + F06/v + F05/v + F04/v \quad (85)$$

$$C09 = F08/v + F07/v + F06/v + F05/v \quad (86)$$

$$C10 = F08/v + F07/v + F06/v \quad (87)$$

$$C11 = F08/v + F07/v \quad (88)$$

$$C12 = F08/v \quad (89)$$

The expression generating unit 803 generates expressions by transforming the generated expressions. The expressions generated by the expression generating unit 803 are represented in Expression (90) through Expression (101).

$$C01 = 1 \bullet F01/v + 0 \bullet F02/v + 0 \bullet F03/v+ 0 \bullet F04/v+ 0 \bullet F05/v+ 0 \bullet F06/v+ 0 \bullet F07/v+ 0 \bullet F08/v \quad (90)$$

$$C02 = 1 \bullet F01/v + 1 \bullet F02/v + 0 \bullet F03/v+ 0 \bullet F04/v+ 0 \bullet F05/v+ 0 \bullet F06/v+ 0 \bullet F07/v+ 0 \bullet F08/v \quad (91)$$

$$C03 = 1 \bullet F01/v + 1 \bullet F02/v + 1 \bullet F03/v+ 0 \bullet F04/v+ 0 \bullet F05/v+ 0 \bullet F06/v+ 0 \bullet F07/v+ 0 \bullet F08/v \quad (92)$$

$$C04 = 1 \bullet F01/v + 1 \bullet F02/v + 1 \bullet F03/v+ 1 \bullet F04/v+ 0 \bullet F05/v+ 0 \bullet F06/v+ 0 \bullet F07/v+ 0 \bullet F08/v \quad (93)$$

$$C05 = 1 \bullet F01/v + 1 \bullet F02/v + 1 \bullet F03/v+ 1 \bullet F04/v+ 1 \bullet F05/v+ 0 \bullet F06/v+ 0 \bullet F07/v+ 0 \bullet F08/v \quad (94)$$

$$C06 = 0 \bullet F01/v + 1 \bullet F02/v + 1 \bullet F03/v+ 1 \bullet F04/v+ 1 \bullet F05/v+ 1 \bullet F06/v+ 0 \bullet F07/v+ 0 \bullet F08/v \quad (95)$$

$$C07 = 0 \bullet F01/v + 0 \bullet F02/v + 1 \bullet F03/v+ 1 \bullet F04/v+ 1 \bullet$$

F05/v+ 1 • F06/v+ 1 • F07/v+ 0 • F08/v (96)

C08 = 0 • F01/v + 0 • F02/v + 0 • F03/v+ 1 • F04/v+ 1 • F05/v+ 1 • F06/v+ 1 • F07/v+ 1 • F08/v (97)

C09 = 0 • F01/v + 0 • F02/v + 0 • F03/v+ 0 • F04/v+ 1 • F05/v+ 1 • F06/v+ 1 • F07/v+ 1 • F08/v (98)

C10 = 0 • F01/v + 0 • F02/v + 0 • F03/v+ 0 • F04/v+ 0 • F05/v+ 1 • F06/v+ 1 • F07/v+ 1 • F08/v (99)

C11 = 0 • F01/v + 0 • F02/v + 0 • F03/v+ 0 • F04/v+ 0 • F05/v+ 0 • F06/v+ 1 • F07/v+ 1 • F08/v (100)

C12 = 0 • F01/v + 0 • F02/v + 0 • F03/v+ 0 • F04/v+ 0 • F05/v+ 0 • F06/v+ 0 • F07/v+ 1 • F08/v (101)

Expression (90) through Expression (101) may be represented as with Expression (102).

$$Cj = \sum_{i=01}^{08} aij \cdot Fi/v \qquad (102)$$

In Expression (102), j denotes the pixel position. In this example, j has one of the values between 1 and 12. Also, i denotes the position of the foreground value. In this example, i has one of the values between 1 and 8. Corresponding to the values of i and j, aij has one of the values of 0 or 1.

Taking margin of error into consideration, Expression (102) may be represented as with Expression (103).

$$Cj = \sum_{i=01}^{08} aij \cdot Fi/v + ej \qquad (103)$$

In Expression (103), ej denotes the margin of error contained in the pixel of interest, Cj.

Expression (103) can be rewritten into Expression (104)

$$ej = Cj - \sum_{i=01}^{08} aij \cdot Fi/v \qquad (104)$$

Note that in order to use the least square method, the squared-sum E of the margin of error is defined as represented in Expression (105).

$$E = \sum_{j=01}^{12} ej^2 \qquad (105)$$

To minimize margin of error, the value of the partial derivative from the variable Fk as to the squared-sum of the margin of error E should become 0. Fk is obtained so as to satisfy Expression (106).

$$\frac{\partial E}{\partial Fk} = 2 \cdot \sum_{j=01}^{12} ej \cdot \frac{\partial ej}{\partial Fk}$$

$$= 2 \cdot \sum_{j=01}^{12} \{(Cj - \sum_{i=01}^{08} aij \cdot Fi/v) \cdot (-akj/v) = 0 \qquad (106)$$

In Expression (106), the movement amount v is a fixed value, so Expression (107) can be derived.

$$\sum_{j=01}^{12} akj \cdot (Cj - \sum_{i=01}^{08} aij \cdot Fi/v) = 0 \qquad (107)$$

Developing Expression (107) and transposing arguments, Expression (108) is obtained.

$$\sum_{j=01}^{12} (akj \cdot \sum_{i=01}^{08} aij \cdot Fi) = v \cdot \sum_{j=01}^{12} akj \cdot Cj \qquad (108)$$

Expression (108) is developed into eight expressions, each of which is obtained by substituting one of the integers between 1 and 8 for k in Expression (108). The obtained eight expressions may be represented in one expression by a matrix. The expression is referred to as a normal equation.

An example of the normal equation generated by the expression generating unit 803 based upon such a least square method is represented in Expression (109).

$$\begin{bmatrix} 5 & 4 & 3 & 2 & 1 & 0 & 0 & 0 \\ 4 & 5 & 4 & 3 & 2 & 1 & 0 & 0 \\ 3 & 4 & 5 & 4 & 3 & 2 & 1 & 0 \\ 2 & 3 & 4 & 5 & 4 & 3 & 2 & 1 \\ 1 & 2 & 3 & 4 & 5 & 4 & 3 & 2 \\ 0 & 1 & 2 & 3 & 4 & 5 & 4 & 3 \\ 0 & 0 & 1 & 2 & 3 & 4 & 5 & 4 \\ 0 & 0 & 0 & 1 & 2 & 3 & 4 & 5 \end{bmatrix} \begin{bmatrix} F01 \\ F02 \\ F03 \\ F04 \\ F05 \\ F06 \\ F07 \\ F08 \end{bmatrix} = v \cdot \begin{bmatrix} \sum_{i=08}^{12} Ci \\ \sum_{i=07}^{11} Ci \\ \sum_{i=06}^{10} Ci \\ \sum_{i=05}^{09} Ci \\ \sum_{i=04}^{08} Ci \\ \sum_{i=03}^{07} Ci \\ \sum_{i=02}^{06} Ci \\ \sum_{i=01}^{05} Ci \end{bmatrix} \qquad (109)$$

In the event that Expression (109) is represented by A • F = v • C, then C, A, and v are known, and F is unknown. Also, while A and v are known at the point of modeling, C becomes known by inputting the pixel value in addition operation.

The margin of error contained in the pixel C is dispersed by calculating the foreground components by the

normal equation based upon the least square method.

The expression generating unit 803 supplies the normal equation generated as described above, to the addition unit 804.

The addition unit 804 sets the pixel value C contained in the foreground component image for the expression of the matrix supplied from the expression generating unit 803 based upon the processing increment supplied from the processing increment decision unit 801. The addition unit 804 supplies the matrix which the pixel value C is set for, to the computing unit 805.

The computing unit 805 calculates the foreground component Fi/v which has been subjected to removal of the movement blurring by the processing based upon the method such as the sweeping method (Gauss-Jordan elimination), calculates Fi corresponding to one of the integers i between 0 and 8, which is the pixel value of the foreground which has been subjected to removal of the movement blurring, and outputs the foreground component image which has been subjected to removal of the movement blurring, which is made up of Fi which is the pixel value which has been subjected to removal of the movement blurring as shown by way of an example, shown in Fig. 91.

Note that in the foreground component image which has been subjected to removal of the movement blurring shown in

Fig. 91, each of C03 through C10 is set to each of F01 through F08 so as not to change the position of the foreground component image with regard to the screen, which can correspond to an arbitrary position.

Also, as shown in Fig. 92, for example, in the event that the number of pixel corresponding to the processing increment is 8 and the movement amount v is 4, the movement blurring removal unit 106 generates a matrix expression represented in Expression (110).

$$\begin{bmatrix} 4 & 3 & 2 & 1 & 0 \\ 3 & 4 & 3 & 2 & 1 \\ 2 & 3 & 4 & 3 & 2 \\ 1 & 2 & 3 & 4 & 3 \\ 0 & 1 & 2 & 3 & 4 \end{bmatrix} \begin{bmatrix} F01 \\ F02 \\ F03 \\ F04 \\ F05 \end{bmatrix} = v \cdot \begin{bmatrix} \sum_{i=05}^{08} Ci \\ \sum_{i=04}^{07} Ci \\ \sum_{i=03}^{06} Ci \\ \sum_{i=02}^{05} Ci \\ \sum_{i=01}^{04} Ci \end{bmatrix} \quad (110)$$

The movement blurring removal unit 106 calculates Fi which is the pixel value which has been subjected to adjustment of movement blurring by forming expressions of which number corresponds to the length of the processing increment. In the same way, in the event that the number of pixel contained in the processing increment is one hundred, Fi is calculated by generating expressions corresponding to the one hundred pixels.

As described above, the movement blurring removal unit 106 generates expressions corresponding to the movement

amount v and the processing increment, sets pixel values of the foreground component image for the generated expressions, and calculates an foreground component image which has been subjected to removal of movement blurring.

The processing for removal of movement blurring contained in the foreground component image by the movement blurring removal unit 106 will now be descried with reference to the flowchart shown in Fig. 93.

In Step S801, the processing increment decision unit 801 of the movement blurring removal unit 106 generates the processing increment based upon the movement vector and the region information, and supplies the generated processing increment to the modeling unit 802.

In Step S802, the modeling unit 802 of the movement blurring removal unit 106 performs selecting or generating of the model corresponding to the movement amount v and the processing increment. In Step S803, the expression generating unit 803 creates the normal equation based upon the selected model.

In Step S804, the addition unit 804 sets the pixel values of the foreground component image for the created normal equation. In Step S805, the addition unit 804 judges whether or not the pixel values of all the pixels corresponding to the processing increment are set, and in the event that judgment is made that not all the pixel

values of the pixels corresponding to the processing increment have been set, the flow returns to Step S804 and repeats the processing of setting the pixel values for the normal equation.

In the event that judgment is made that all the pixel values of the pixels of the processing increment have been set in Step S805, the flow proceeds to Step S806, the computing unit 805 calculates the pixel values of the foreground which has been subjected to removal of movement blurring based upon the normal equation wherein the pixel values supplied from the addition unit 804 are set, and the processing ends.

As described above, the movement blurring removal unit 106 can remove movement blurring from the foreground image containing the movement blurring based upon the movement vector and the region information.

That is to say, movement blurring contained in the pixel values which are the sampled data, can be removed.

The correction of the background component image by the correction unit 107 will now be described.

Fig. 94 is a diagram which illustrates an example of the model of the background component image corresponding to the model of the foreground component image shown by way of an example shown in Fig. 90.

As shown in Fig. 94, pixel values of the pixels of the

background component image corresponding to the mixed region in the original input image have been subjected to removal of the foreground components, and accordingly the pixel values are made up of a small number of background components as compared with the pixels corresponding to the background region in the original input image, corresponding to the mixture ratio α.

For example, in the background component image shown by way of an example shown in Fig. 94, the pixel value C01 is made up of four background components B02/Vs, the pixel value C02 is made up of three background components B03/Vs, the pixel value C03 is made up of two background components B04/Vs, and the pixel value C04 is made up of one background component B05/V.

Also, with the background component image shown by way of an example shown in Fig. 94, the pixel value C09 is made up of one background component B10/V, thee pixel value C10 is made up of two background components B11/Vs, the pixel value C11 is made up of three background components B12/Vs, and the pixel value C12 is made up of four background components B13/Vs.

As described above, the pixel value of a pixel corresponding to the mixed region in the original input image is made up of a small number of background components as compared with the pixel corresponding to the background

region in the original input image, and accordingly the image corresponding to the mixed region in the foreground component image becomes a dark image, for example, as compared with the image of the background region.

The correction unit 107 corrects pixel values of the pixels corresponding to the mixed region in the background component image by multiplying each of pixel values of the pixels corresponding to the mixed region in the background component image by a constant corresponding to the mixture ratio α.

For example, in the event that the background component image shown in Fig. 94 is input, the correction unit 107 multiplies the pixel value C01 by 5/4, multiplies the pixel value C02 by 5/3, multiplies the pixel value C11 by 5/3, and multiplies the pixel value C12 by 5/4. In order to match the pixel position of the foreground component image which has been subjected to removal of movement blurring shown by way of an example shown in Fig. 91, the correction unit 107 sets the pixel value C03 through pixel value C11 to 0.

The correction unit 107 outputs a background component image which has been subjected to correction of the pixel values of pixels corresponding to the mixed region shown by way of an example shown in Fig. 95.

As described above, the correction unit 107 corrects pixel values of the pixels corresponding to the mixed region

in the background component image, and also adjusts the pixel position with regard to the foreground component image which has been subjected to removal of movement blurring.

Fig. 96 is a block diagram which illustrates the configuration of the movement-blurring-removed-image processing unit 108 for generating a coefficient set which is used in class classification adaptation processing for generating an even higher resolution image in the spatial direction. For example, the movement-blurring-removed-image processing unit 108 of which the configuration is shown in Fig. 96 generates a coefficient set which is used in class classification adaptation processing for generating a HD image from a SD image based upon the input HD image.

Background component tutor image frame memory 1001 stores the corrected background component image of the tutor image supplied from the correction unit 107. The background component tutor image frame memory 1001 supplies the stored background component image of the tutor image to a weighted averaging unit 1003-1 and a learning unit 1006-1.

Foreground component tutor image frame memory 1002 stores the foreground component image which has been subjected to removal of movement blurring of the tutor image supplied from the movement blurring removal unit 106. The foreground component tutor image frame memory 1002 supplies the stored foreground component image of the tutor image to

a weighted averaging unit 1003-2 and a learning unit 1006-2.

The weighted averaging unit 1003-1 generates a SD image which is a student image by one-quarter weighted-averaging the background component image of a tutor image which is a HD image, and supplies the generated SD image to background component student image frame memory 1004.

For example, the weighted averaging unit 1003-1 takes four pixels of 2 × 2 (width × height) (which are portions represented by white circles in the drawing) as one increment in the tutor image as shown in Fig. 97, adds pixel values of four pixel of each increment, and the sum is divided by 4. The weighted averaging unit 1003-1 sets the one-quarter weighted averaged results described above for the pixel of the student image positioned at the center of each increment (which are the portions represented by solid circles in the drawing).

The background component student image frame memory 1004 stores the student image corresponding to the background component image of the tutor image supplied from the weighted averaging unit 1003-1. The background component student image frame memory 1004 supplies the student image corresponding to the background component image of the tutor image stored therein to the learning unit 1006-1.

The weighted averaging unit 1003-2 generates a SD image

which is a student image by one-quarter weighted-averaging the foreground component image of a tutor image which is a HD image supplied from the foreground component tutor image frame memory 1002, for example, and supplies the generated SD image to foreground component student image frame memory 1005.

The foreground component student image frame memory 1005 stores the student image which is a SD image, corresponding to the foreground component image of the tutor image supplied from the weighted averaging unit 1003-2. The foreground component student image frame memory 1005 supplies the student image corresponding to the foreground component image of the tutor image stored therein to the learning unit 1006-2.

The learning unit 1006-1 generates coefficient sets corresponding to the background component image based upon the background component image of the tutor image supplied from the background component tutor image frame memory 1001 and the student image corresponding to the background component image of the tutor image supplied from the background component student image frame memory 1004, and supplies the generated coefficient sets to coefficient set memory 1007.

The learning unit 1006-2 generates coefficient sets corresponding to the foreground component image based upon

the foreground component image of the tutor image supplied from the foreground component tutor image frame memory 1002 and the student image corresponding to the foreground component image of the tutor image supplied from the foreground component student image frame memory 1005, and supplies the generated coefficient sets to coefficient set memory 1007.

The coefficient set memory 1007 stores the coefficient sets corresponding to the background component image supplied from the learning unit 1006-1 and the foreground component image supplied from the learning unit 1006-2.

In the event that there is no need to differentiate the learning unit 1006-1 and the learning unit 1006-2, individually, these will be simply referred to as a learning unit 1006 below.

Fig. 98 is a block diagram which illustrates the configuration of the learning unit 1006.

A class classification unit 1031 comprises a class tap obtaining unit 1051 and a waveform classification unit 1052, and classifies the pixel of interest of the input image. The class tap obtaining unit 1051 obtains a predetermined number of class taps which are pixel values of the student image corresponding to the pixel of interest, and supplies the obtained class taps to the waveform classification unit 1052.

For example, in Fig. 97, in the event that the pixel which is the i'th from the top and the j'th from the left in the student image (which is a portion indicated by a solid circle in the drawing) is represented by X_{ij}, the class tap obtaining unit 1051 obtains a class tap which consists of nine pixels in total, i.e., the eight pixels at left-top, right-top, left, right, bottom-left, bottom, and right-bottom, adjacent to the pixel of interest X_{ij}, $X_{(i-1)(j-1)}$, $X_{(i-1)j}$, $X_{(i-1)(j+1)}$, $X_{i(j-1)}$, $X_{i(j+1)}$, $X_{(i-1)(j-1)}$, $X_{(i-1)j}$, $X_{(i+1)(j+1)}$, and also the pixel of interest. The class tap is supplied to the waveform classification unit 1052.

Note that in this case, while the class tap consists of a square-shaped block made up of 3 × 3 pixels, this needs not be a square; rather other arbitrary shapes may be used, for example, a rectangle-shape, a cross-shape, or the like. Also, the number of pixels making up the class tap is not restricted to nine pixels of 3 × 3 pixels.

The waveform classification unit 1052 performs class classification processing wherein the input signals are classified into several classes based upon the features thereof, and classifies the pixel of interest into one class based upon the class taps. For example, the waveform classification unit 1052 classifies the pixel of interest into one of 512 classes, and supplies the class No. corresponding to the classified class to a prediction tap

obtaining unit 1032.

Here, the class classification processing will now be described briefly.

Now, let us say that a given pixel of interest and three adjacent pixels make up a class tap which consists of 2 × 2 pixels as shown in Fig. 99A, and each pixel is represented by 1 bit (has a level of either 0 or 1). The solid circle shown in Fig. 99A denotes the pixel of interest. In this case, four pixel block of 2 × 2 pixels containing the pixel of interest can be classified into 16 $(=(2^1)^4)$ patterns by the level distribution for each pixel as shown in Fig. 99B. In Fig. 99B, white circles denote 0, and solid circles denote 1. Accordingly, in this case, the pixel of interest can be classified into sixteen patterns, wherein pattern-classification is the class-classification processing, and the processing is performed by the class classification unit 1031.

Note that an arrangement may be made wherein the class classification processing is performed by taking the activity (complexity of the image)(intensity of change) of the image (class tap) into consideration.

Here, each pixel is generally appropriated around 8 bits. Also, with the present embodiment, the class tap consists of nine pixels of 3 × 3 pixels as described above. Accordingly, performing class classification processing for

such a class tap as an object, the class tap would result the class tap being classified into a great number of classes of which number is $(2^8)^9$.

Accordingly, with the present embodiment, the ADCR processing is performed for the class tap by the waveform classification unit 1052, and this reduces the number of classes by reducing the number of bits of the pixels making up the class tap.

In order to simplify description, with a class tap which consists of four pixels arrayed in a line as shown in Fig. 110A, the maximum value of the pixel value MAX and the minimum value of the pixel value MIN are detected in the ADRC processing. DR = MAX - MIN is then taken as the local dynamic range in the block which consists of a class tap, and the pixel values of the pixels making up the block of the class tap is re-quantized into K bits based upon the dynamic range DR.

That is to say, the minimum value MIN is subtracted from each pixel value within the block, and the subtraction value is divided by $DR/2^k$. The division value obtained as a result is converted into the code (ADRC code) corresponding thereto. Specifically, for example, in the event of taking K as 2, judgment is made which of ranges obtained by dividing the dynamic range DR into four ($=2^2$) equal parts the division value belongs to, as shown in Fig. 100B, and

upon the division value belonging to the range of the bottom-most level, the range of the second level from the bottom, the range of the third level from the bottom, or the range of upper-most level, the division value is encoded into 2-bit code such as 00B, 01B, 10B, or 11B (B indicates a binary number), respectively, for example. Decoding is then performed on the decoding side by the ADRC code 00B, 01B, 10B, or 11B being converted into the median in the range of the most-bottom level L_{00}, the median in the range of the second level from the bottom L_{01}, the median in the range of the third level from the bottom L_{10}, or the median in the range of the most-upper level L_{11}, wherein the ranges are obtained by dividing the dynamic range DR into four equal parts, and the minimum value MIN being added to the converted value.

Here, the ADRC processing described above is referred to as non-edge-matching.

Note that details with regard to the ADRC processing are disclosed in Japanese Unexamined Patent Application Publication No. 3-53778, which has been applied by the present applicant, and so forth, for example.

The number of classes can be reduced by performing the ADRC processing which performs re-quantizing with the number of bits less than the number of bits appropriated to pixels making up the class tap as described above, and the ADRC

processing described above is performed by the waveform classifying unit 1052.

While the class classification processing is performed based upon the ADRC code by the waveform classification unit 1052 in the present embodiment, an arrangement may be made wherein the class classification processing is performed with regard to the data which has been subjected to DPCM (Predictive Coding), BTC (Block Truncation Coding), VQ (Vector Quantizing), DCT (Disperse Cosine Transformation), Hadamard transformation, or the like.

The prediction tap obtaining unit 1032 obtains the prediction tap which is the increment for calculation of the predicted value of the original image (tutor image) corresponding to the class based upon the class No. from pixels of the student image, and supplies the obtained prediction tap and the class No. to a corresponding pixel obtaining unit 1033.

For example, in Fig. 97, let us say that pixel values of nine pixels of 2 × 2 centered on the pixel X_{ij} in the student image (which is denoted by a solid circle in the drawing) in the original image (tutor image) are represented as $Y_{ij}(1)$, $Y_{ij}(2)$, $Y_{ij}(3)$, $Y_{ij}(4)$, respectively, in the direction from the far left to the right, and in the direction from the top to the bottom, the prediction tap obtaining unit 1032 obtains a square-shaped prediction tap

which consists of nine pixels of 3 × 3, $X_{(i-1)(j-1)}$, $X_{(i-1)j}$, $X_{(i-1)(j+1)}$ $X_{i(j-1)}$, X_{ij}, $X_{i(j+1)}$, $X_{(i+1)(j-1)}$, $X_{(i+1)j}$, $X_{(i+1)(j+1)}$, centered on the pixel X_{ij} in the student image, for example, for calculating the coefficients which are necessary for calculation of the predicted values of the pixels $Y_{ij}(1)$ through $Y_{ij}(4)$.

Specifically, for example, the pixel X_{22}, X_{23}, X_{24}, X_{32}, X_{33}, X_{34}, X_{42}, X_{43}, X_{44} make up the prediction tap for calculating the coefficients which are necessary for calculation of the predicted values of four pixels of $Y_{33}(1)$ through $Y_{33}(4)$ in the tutor image, which are enclosed by a quadrangle in Fig. 97, (in this case, the pixel of interest is X_{33}).

The corresponding pixel obtaining unit 1033 obtains pixel values of the pixels in the tutor image corresponding to the pixel values which are to be predicted based upon the prediction tap and the class No., and supplies the prediction tap, the class No., and the obtained pixel values of the pixels in the tutor image corresponding to the pixel values which are to be predicted to a normal equation generating unit 1034.

For example, in the event that the coefficients necessary for calculation of the predicted values of four pixels of $Y_{33}(1)$ through $Y_{33}(4)$ in the tutor image, the corresponding pixel obtaining unit 1033 obtains the pixel values of the pixels, $Y_{33}(1)$ through $Y_{33}(4)$ as the pixels in the tutor image corresponding to the pixel values which are

to be predicted.

The normal equation generating unit 1034 generates normal equations for calculating a coefficient set which is used in the adaptation processing, corresponding to the correlation between the prediction tap and the pixels which are to be predicted, based upon the prediction tap, the class No., and the obtained pixel values which are to be predicted, and supplies the generated normal equations to a coefficient calculation unit 1035 along with the class No.

The coefficient calculation unit 1035 calculates a coefficient set which is used in the adaptation processing, corresponding to the classified class, by solving the normal equations supplied from the normal equation generating unit 1034. The coefficient calculation unit 1035 supplies the calculated coefficient set to the coefficient set memory 1007 along with the class No.

An arrangement may be made wherein the normal equation generating unit 1034 generates a matrix corresponding to such normal equations, and the coefficient calculation unit 1035 calculates a coefficient set based upon the generated matrix.

Here, the adaptation processing will be described.

For example, let us now consider obtaining a predicted value E[y] of the pixel value y in the tutor image from a linear one-dimensional combination model defined by linear

combination of pixel values of several nearby pixels x_1, x_2, ... (which will be referred to as student data as appropriate) and predetermined prediction coefficients w_1, w_2, ... In this case, the predicted value E[y] may be represented in the following Expression.

$$E[y] = w_1 x_1 + w_2 x_2 + \ldots \quad (111)$$

Accordingly, upon defining the matrix W which consists of a set of the prediction coefficients, the matrix X which consists of a set of the student data, and the matrix Y' which consists of a set of the predicted values E[y] as

$$X = \begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{pmatrix}$$

$$W = \begin{pmatrix} w_1 \\ w_2 \\ \cdots \\ w_n \end{pmatrix}, Y' = \begin{pmatrix} E[y_1] \\ E[y_2] \\ \cdots \\ E[y_m] \end{pmatrix},$$ the following observation expression holds.

$$XW = Y' \quad (112)$$

Let us now consider obtaining the predicted value E[y] near the pixel value y of the original image by applying the least square method to the observation expression. In this case upon defining the matrix Y which consists of a set of pixel values y in the original image (which will be referred

to as tutor data as appropriate) and the matrix E which consists of a set of the residuals e of the predicted values E[y] with regard to the pixel values y in the original image as

$$E = \begin{bmatrix} e_1 \\ e_2 \\ \cdots \\ e_m \end{bmatrix}, Y = \begin{bmatrix} y_1 \\ y_2 \\ \cdots \\ y_m \end{bmatrix},$$ the following residual expression holds from Expression (112).

$$XW = Y + E \qquad (113)$$

In this case, the prediction coefficients w_i for obtaining the predicted value E[y] near the pixel value y in the original image can be obtained by minimizing the squared margin of error $\sum_{i=1}^{m} e_i^2$.

Accordingly, in a case that the derivative of the above-described squared margin of error from the prediction coefficient w_i is 0, that is to say, in a case that the prediction coefficient w_i satisfies the following expression, the prediction coefficient w_i is the optimal value for obtaining the predicted values E[y] near the pixel value y in the original image.

$$e_1 \frac{\partial e_1}{\partial w_i} + e_2 \frac{\partial e_2}{\partial w_i} + \cdots + e_m \frac{\partial e_m}{\partial w_i} = 0 \quad (i = 1, 2, \cdots, n) \qquad (114)$$

Here, the following expression holds by differentiating

Expression (113) by the prediction coefficient w_i.

$$\frac{\partial e_i}{\partial w_1}=x_{i1}, \frac{\partial e_i}{\partial w_2}=x_{i2},\cdots \frac{\partial e_i}{\partial w_n}=x_{in}, (i=1,2,\cdots,m) \qquad (115)$$

Expression (116) is obtained from Expression (114) and Expression (115).

$$\sum_{i=1}^{m} e_i x_{i1}=0, \sum_{i=1}^{m} e_i x_{i2}=0,\cdots \sum_{i=1}^{m} e_i x_{in}=0 \qquad (116)$$

Moreover, taking the relationship between the student data x, the prediction coefficient w, the tutor data y, and the residuals e in the residual expression (113), into consideration, the following normal equations can be obtained from Expression (116).

$$\begin{cases} (\sum_{i=1}^{m} x_{i1}x_{i1})w_1+(\sum_{i=1}^{m} x_{i1}x_{i2})w_2+\cdots+(\sum_{i=1}^{m} x_{i1}x_{in})w_n=(\sum_{i=1}^{m} x_{i1}y_i) \\ (\sum_{i=1}^{m} x_{i2}x_{i1})w_1+(\sum_{i=1}^{m} x_{i2}x_{i2})w_2+\cdots+(\sum_{i=1}^{m} x_{i2}x_{in})w_n=(\sum_{i=1}^{m} x_{i2}y_i) \\ \cdots \\ (\sum_{i=1}^{m} x_{in}x_{i1})w_1+(\sum_{i=1}^{m} x_{in}x_{i2})w_2+\cdots+(\sum_{i=1}^{m} x_{in}x_{in})w_n=(\sum_{i=1}^{m} x_{in}y_i) \end{cases}$$

$$\cdots\cdots (117)$$

As many normal equations represented in Expression (117) can be formed as the number of the prediction coefficients w which are to be obtained, and accordingly the optimal prediction coefficients w can be obtained by solving Expression (117). Note that Expressions (117) can be solved

by applying the sweeping method (Gauss-Jordan elimination), for example.

The adaptation processing consists of the optimal prediction coefficients w being obtained for each class, and the predicted values E[y] near the pixel values y in the tutor image being obtained by Expression (111) using the prediction coefficients w.

The normal equation generating unit 1034 generates the normal equations for calculating the most suitable prediction coefficients w for each class, and the coefficient calculation unit 1035 calculates the prediction coefficients w based upon the generated normal equations.

Note that the adaptation processing is different from the interpolation processing with regard to the components which are not contained in the thinned out image and are contained in the original image being reproduced. That is to say, while in the event of taking only Expression (111) into consideration, the adaptation processing is the same as the interpolation processing using the interpolation filter, the prediction coefficients w corresponding to the tap coefficients of the interpolation filter is obtained by learning as if it were, using the tutor data y, and accordingly the adaptation processing can reproduce the components contained in the original image. Accordingly, it can be said that the adaptation processing acts to create an

image, as if it were.

Fig. 101 is a diagram which describes a coefficient set generated by the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 96. The region specifying unit 103 specifies the foreground region, the background region, the covered background region, and the uncovered background region in the input image.

The input image wherein the regions have been specified and the mixture ratio α has been detected by the mixture ratio calculation unit 104, is separated into the foreground component image and the background component image by the foreground/background separation unit 105.

The movement blurring is removed from the separated foreground component image by the movement blurring removal unit 106. The pixel values corresponding to the mixed region in the separated background component image are corrected by the correction unit 107 corresponding to the removal of the movement blurring of the foreground component image.

The movement-blurring-removed-image processing unit 108 calculates a coefficient set corresponding to the foreground component image and a coefficient set corresponding to the background component image, respectively, based upon the foreground component image which has been subjected to removal of movement blurring and the background component

image which has been subjected to correction.

That is to say, the learning unit 1006-1 calculates a coefficient set corresponding to the background component image based upon the separated and corrected background component image, and the learning unit 1006-2 calculates a coefficient set corresponding to the foreground component image based upon the foreground component image which has been subjected to separation and removal of movement blurring.

The coefficient set corresponding to the background component image is used for predicting the pixel values of the image corresponding to the background component image in the class classification adaptation processing for predicting the pixel values, which is to be applied to the separated and corrected background component image.

The coefficient set corresponding to the foreground component image is used for predicting the pixel values of the image corresponding to the foreground component image in the class classification adaptation processing for predicting the pixel values, which is to be applied to the foreground component image which has been subjected to separation from the input image and removal of movement blurring.

The movement blurring is added to the predicted image corresponding to the foreground component image. The

predicted image corresponding to the background component image is corrected corresponding to addition of the movement blurring to the foreground component image.

The predicted image corresponding to the corrected background component image and the predicted image corresponding to the foreground component image which has been subjected to addition of the movement blurring, are synthesized into a single predicted image.

Referring to the flowchart shown in Fig. 102, description will be made with regard to the processing of learning for generating a coefficient set which is used in prediction of the pixel values by the class classification adaptation processing in the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 96.

In Step S1001, the weighted averaging unit 1003-1 and the weighted averaging unit 1003-2 generate a student image corresponding to the background component image and a student image corresponding to the foreground component image. That is to say, the weighted averaging unit 1003-1 generates a student image corresponding to the background component image of the tutor image by one-quarter weighted-averaging of the background component image of the tutor image stored in the background component tutor image frame memory 1001, for example.

The weighted averaging unit 1003-2 generates a student image corresponding to the foreground component image of the tutor image by one-quarter weighted-averaging of the foreground component image of the tutor image stored in the foreground component tutor image frame memory 1002, for example.

In Step S1002, the learning unit 1006-1 generates a coefficient set corresponding to the background component image based upon the background component image of the tutor image stored in the background component tutor image frame memory 1001 and the student image corresponding to the background component image of the tutor image stored in the background component student image frame memory 1004. Details of the processing for generating of a coefficient set in Step S1002 will be described later with reference to the flowchart shown in Fig. 103.

In Step S1003, the learning unit 1006-2 generates a coefficient set corresponding to the foreground component image based upon the foreground component image of the tutor image stored in the foreground component tutor image frame memory 1002 and the student image corresponding to the foreground component image of the tutor image stored in the foreground component student image frame memory 1005.

In Step S1004, the learning unit 1006-1 and the learning unit 1006-2 output a coefficient set corresponding

to the background component image and a coefficient set corresponding to the foreground component image to the coefficient set memory 1007, respectively. The coefficient set memory 1007 stores the coefficient set corresponding to the background component image, or the coefficient set corresponding to the foreground component image, and then the processing ends.

As described above, the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 96 can generate a coefficient set corresponding to the background component image and a coefficient set corresponding to the foreground component image.

Note that it is needless to say that the processing in Step S1002 and Step S1003 may be performed serially or in parallel.

Referring to Fig. 103, the processing for generating of a coefficient set corresponding to the background component image performed by the learning unit 1006-1, corresponding to Step S1002, will now be described.

In Step S1021, the learning unit 1006-1 judges whether or not there are any unprocessed pixels in the student image corresponding to the background component image, and in the event that judgment is made that there are unprocessed pixels in the student image corresponding to the background component image, the flow proceeds to Step S1022, and the

pixel of interest is obtained from the student image corresponding to the background component image in raster scan sequence.

In Step S1023, the class tap obtaining unit 1051 of the class tap classification unit 1031 obtains a class tap corresponding to the pixel of interest from the student image stored in the background component student image frame memory 1004. In Step S1024, the waveform classification unit 1052 of the class classification unit 1031 applies the ADRC processing to the class tap, this reduces the number of bits of pixels making up the class tap, and the pixel of interest is classified. In Step S1025, the prediction tap obtaining unit 1032 obtains a prediction tap corresponding to the pixel of interest from the student image stored in the background component student image frame memory 1004 based upon the classified class.

In Step S1026, the corresponding pixel obtaining unit 1033 obtains pixels corresponding to the pixel value which is to be predicted from the background component image of the tutor image stored in the background component tutor image frame memory 1001 based upon the classified class.

In Step S1027, the normal equation generating unit 1034 adds the pixel values of pixels corresponding to the prediction tap and the pixel value which is to be predicted to the matrix for each class based upon the classified class,

the flow returns to Step S1021, and the learning unit 1006-1 repeats judgment whether or not unprocessed pixels exist. The prediction tap and the matrix for each class to which the pixel values of pixels corresponding to the prediction tap and the pixel value which is to be predicted is added, corresponds to the normal equations for calculating a coefficient set for each class.

In Step S1021, in the event that judgment is made that there are no unprocessed pixels in the student image, the flow proceeds to Step S1028, and the normal equation generating unit 1034 supplies the matrix for each class for which the pixel values of the pixel corresponding to the prediction tap and the pixel value which is to be predicted is set, to the coefficient calculation unit 1035. The coefficient calculation unit 1035 calculates a coefficient set for each class corresponding to the background component image by solving the matrix for each class, for the pixel values of pixels corresponding to the prediction tap and the pixel value which is to be predicted are set.

Note that the coefficient set is not restricted to predicting the pixel values by linear prediction, rather, an arrangement may be made wherein the coefficient calculation unit 1035 calculates a coefficient set for predicting the pixel values by non-linear prediction.

In Step S1029, the coefficient calculation unit 1035

outputs the coefficient set for each class, corresponding to the background component image to the coefficient set memory 1007, and the processing ends.

As described above, the learning unit 1006-1 can generate the coefficient set corresponding to the background component image.

The processing for generating of the coefficient set corresponding to the foreground component image by the learning unit 1006-2 corresponding to Step S1003 is the same as the processing described with reference to the flowchart shown in Fig. 103 except for using the foreground component image stored in the foreground component tutor image frame memory 1002 and the student image corresponding to the foreground component image stored in the foreground component student image frame memory 105, and accordingly, description thereof will be omitted.

As described above, the movement-blurring-removed-image processing unit 108 of which the configuration is shown in Fig. 96 can generate a coefficient set corresponding to the background component image which has been subjected to correction and a coefficient set corresponding to the foreground component image which has been removal of movement blurring individually.

Fig. 104 is a block diagram which illustrates the configuration of the movement-blurring-removed-image

processing unit 108 for generating an even higher resolution image in the spatial direction by performing the class classification adaptation processing. For example, the movement blurring removal processing unit 108 of which the configuration is shown in Fig. 104 generates an HD image by performing the class classification adaptation processing based upon the input image which is a SD image.

Background component image frame memory 1101 stores the background component image which has been subjected to correction supplied from the correction unit 107. The background component image frame memory 1101 supplies the stored background component image to a mapping unit 1103-1.

Foreground component image frame memory 1102 stores the foreground component image which has been subjected to removal of movement blurring supplied from the movement blurring removal unit 106. The foreground component image frame memory 1102 supplies the stored foreground component image to a mapping unit 1103-2.

The mapping unit 1103-1 generates a predicted image corresponding to the background component image stored in the background component image frame memory 1101 by the class classification adaptation processing based upon the coefficient set corresponding to the background component image stored in the coefficient set memory 1104. The mapping unit 1103-1 supplies the generated predicted image

to a correction unit 1105.

The correction unit 1105 sets the pixel value of the predetermined pixel in the predicted image corresponding to the mixed region in the background component image corresponding to the movement blurring, which the movement blurring addition unit 1106 adds, to 0; or divides the pixel value of the predetermined pixel in the predicted image by the predetermined value corresponding to the movement blurring which is added. The correction unit 1005 supplies the predicted image which has been subjected to correction described above to a synthesizing unit 1107.

The mapping unit 1103-2 generates a predicted image corresponding to the foreground component image stored in the foreground component image frame memory 1102 by the class classification adaptation processing based upon the coefficient set corresponding to the foreground component image stored in the coefficient set memory 1104. The mapping unit 1103-2 supplies the generated predicted image to the movement blurring addition unit 1106.

The movement blurring addition unit 1106 adds movement blurring to the predicted image by providing the desired movement blurring adjustment amount v', e.g., the movement blurring adjustment amount v' of which value is the half value of the movement amount v of the input image or the movement blurring adjustment amount v' having no

relationship with the movement amount v. The movement blurring addition unit 1106 calculates the foreground component Fi/v' by dividing the pixel value Fi in the predicted image in the foreground component image which has subjected to removal of movement blurring by the movement blurring adjustment amount v', calculates the sum of the foreground components Fi/v's, and generates the pixel value which movement blurring is added to.

For example, in the event that the predicted image shown in Fig. 105 is input, and the movement blurring adjustment amount v' is 3, the pixel value C02 is (F01)/v', the pixel value C03 is (F01 + F02)/v', the pixel value C04 is (F01 + F02 + F03)/v', and the pixel value C05 is (F02 + F03 + F04)/v' as shown in Fig. 106.

The movement blurring addition unit 1106 supplies the predicted image of the foreground component image which has been subjected to addition of movement blurring described above, to the synthesizing unit 1107.

The synthesizing unit 1107 synthesizes the predicted image corresponding to the background component image which has been subjected to correction supplied from the correction unit 1105, and the predicted image corresponding to the foreground component image which has been subjected to addition of movement blurring supplied from the movement blurring addition unit 1106, and supplies synthesized

predicted image to the frame memory 1108.

The frame memory 1108 stores the predicted image supplied from the synthesizing unit 1107, and also outputs the stored image as an output image.

In the event that there is no need to differentiate the mapping unit 1103-1 and the mapping unit 1103-2 individually, these will be simply referred to as the mapping unit 1103 below.

Fig. 107 is a block diagram which illustrates the configuration of the mapping unit 1103.

The mapping unit 1131 comprises a class classification unit 1141 for performing class classification processing, and a prediction tap obtaining unit 1142 and a prediction computation unit 1143 for performing the adaptation processing.

The class classification unit 1141 comprises a class tap obtaining unit 1151 and a waveform classification unit 1152, and performs class classification for pixel of interest in the input image of either background component image or foreground component image.

The class tap obtaining unit 1151 obtains a predetermined number of class taps corresponding to pixel of interest in the input image, and supplies the obtained class taps to the waveform classification unit 1152. For example, the class tap obtaining unit 1151 obtains nine class taps,

and supplies the obtained class taps to the waveform classification unit 1152.

The waveform classification unit 1152 reduces the number of bits of the pixels making up the class taps by applying the ADRC processing to the class taps, classifies the pixel of interest into one of the predetermined number of classes, and supplies the class No. corresponding to the classified class to the prediction tap obtaining unit 1142. For example, the waveform classification unit 1152 classifies the pixel of interest to one of 512 classes, and supplies the class No. corresponding to the classified class to the prediction tap obtaining unit 1142.

The prediction tap obtaining unit 1142 obtains the predetermined number of prediction taps corresponding to the class from the input image based upon the class No., and supplies the obtained prediction taps and class No. to the prediction computation unit 1143.

The prediction computation unit 1143 obtains the coefficient set corresponding to the class, and corresponding to the input image, from the coefficient set corresponding to the background component image and coefficient set corresponding to the foreground component image, stored in the coefficient set memory 1104 based upon the class No. The prediction computation unit 1143 predicts a pixel value in the predicted image by linear prediction

based upon the coefficient set and the prediction taps corresponding to the class, and corresponding to the input image. The prediction computation unit 1143 supplies the predicted pixel value to the frame memory 1132.

Note that an arrangement may be made wherein the prediction computation unit 1143 predicts the pixel value in the predicted image by non-linear prediction.

The frame memory 1132 stores the predicted pixel values supplied from the mapping processing unit 1131, and outputs the image made up of the predicted pixel values.

Referring to the flowchart shown in Fig. 108, the processing for creation of the image by the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 104 will be now described.

In Step S1101, the mapping unit 1103-1 predicts the image corresponding to the background component image stored in the background component image frame memory 1101 by the class classification adaptation processing based upon the coefficient set corresponding to the background component image stored in the coefficient set memory 1104. Details of the processing for prediction of the image corresponding to the background component image will be described later with reference to the flowchart shown in Fig. 109.

In Step S1102, the mapping unit 1103-2 predicts the image corresponding to the foreground component image stored

in the foreground component image frame memory 1102 by the class classification adaptation processing based upon the coefficient set corresponding to the foreground component image stored in the coefficient set memory 1104.

In Step S1103, the correction unit 1105 corrects the predicted image corresponding to the background component image.

In Step S1104, the movement blurring addition unit 1106 adds movement blurring to the predicted image corresponding to the foreground component image.

In Step S1105, the synthesizing unit 1107 synthesizes the predicted image corresponding to the background component image with the predicted image corresponding to the foreground region. The synthesizing unit 1107 supplies the synthesized image to the frame memory 1108. The frame memory 1108 stores the image supplied from the synthesizing unit 1107.

In Step S1106, the frame memory 1108 outputs the stored and synthesized image, and the processing ends.

As described above, the image processing device having the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 104 generates a predicted image corresponding to the background component image and a predicted image corresponding to the foreground component image which has been subjected to removal of

movement blurring individually.

Note that it is needless to say that the processing in Step S1101 and the processing in Step S1102 may be performed in a serial manner, as well as in a parallel manner.

Referring to the flowchart shown in Fig. 109, the processing for prediction of the image corresponding to the background component image by the mapping unit 1103-1 corresponding to Step S1101 will be described.

In Step S1121, the mapping unit 1103-1 judges whether or not there are any unprocessed pixels in the background component image, and in the event that judgment is made that there are unprocessed pixels in the background component image, the flow proceeds to Step S1122, and the mapping processing unit 1131 obtains the coefficient set corresponding to the background component image stored in the coefficient set memory 1104. In Step S1123, the mapping processing unit 1131 obtains a pixel of interest from the background component image stored in the background component image frame memory 1101 in raster scan sequence.

In Step S1124, the class tap obtaining unit 1151 of the class classification unit 1141 obtains the class tap corresponding to the pixel of interest from the background component image stored in the background component image frame memory 1101. In Step S1125, the waveform classification unit 1152 of the class classification unit

1141 reduces the number of bits of pixels making up the class tap by applying the ADRC processing to the class tap, and performs class classification for the pixel of interest. In Step S1126, the predication tap obtaining unit 1142 obtains the prediction tap corresponding to the pixel of interest from the background component image stored in the background component image frame memory 1101 based upon the classified class.

In Step S1127, the prediction computation unit 1143 predicts pixel values of predicted image by linear prediction based upon the coefficient set and the prediction tap, corresponding to the background component image and the classified class.

Note that the prediction computation unit 1143 may predict the pixel values of the predicted image by non-linear prediction, as well as by linear prediction.

In Step S1128, the prediction computation unit 1143 outputs the predicted pixel value to the frame memory 1132. The frame memory 1132 stores the pixel value supplied from the prediction computation unit 1143. The procedure returns to Step S1121, and judgment whether or not any unprocessed pixels exist is repeated.

In Step S1121, in the event that judgment is made that there are no unprocessed pixels in the background component image, the flow proceeds to Step S1129, the frame memory

1132 outputs the stored predicted image corresponding to the background component image, and processing ends.

As described above, the mapping unit 1103-1 can predict the image corresponding to the background component image based upon the corrected background component image.

The processing for generating of the predicted image corresponding to the foreground component image by the mapping unit 1103-2 corresponding to Step S1102 is the same as the processing described with reference to the flowchart shown in Fig. 109 except for using the foreground component image stored in the foreground component image frame memory 1102 and the coefficient set corresponding to the foreground component image, and accordingly, description thereof will be omitted.

As described above, the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 104 can generate a predicted image corresponding to the background component image and a predicted image corresponding to the foreground component image which has been subjected to removal of movement blurring individually.

Fig. 110 is a flowchart which describes another processing for image by the image processing device according to the present invention. In processing described with reference to the flowchart shown in Fig. 110, the processing for edge enhancement is applied to the image

which has been subjected to removal of movement blurring.

In Step S1201, the region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region, based upon the movement vector and the position information supplied from the movement detecting unit 102, and the input image. The processing in Step S1201 is the same as the processing in Step S101, and accordingly detailed description of the processing will be omitted.

In Step S1202, the mixture ratio calculation unit 104 calculates the mixture ratio α based upon the region information supplied from the region specifying unit 103 and the input image. The processing in Step S1202 is the same as the processing in Step S102, so detailed description with regard to the processing will be omitted.

In Step S1203, the foreground/background separation unit 105 separates the input image into the image in the foreground region, the image in the background region, the foreground component image in the covered background region, the background component image in the covered background region, the foreground component image in the uncovered background region, and the background component image in the uncovered background region, based upon the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio

calculation unit 104. The processing in Step S1203 is the same as the processing in Step S103, and accordingly, description thereof will be omitted.

In Step S1204, the movement blurring removal unit 106 removes movement blurring from the foreground component image supplied from the foreground/background separation unit 105 based upon the movement vector and the position information thereof, supplied from the movement detecting unit 102, and the region information supplied from the region specifying unit 103. The processing in Step S1204 is the same as the processing in Step S104, and accordingly detailed description of the processing will be omitted.

In Step S1205, the correction unit 107 corrects pixel values corresponding to the mixed region in the background component image supplied from the foreground/background separation unit 105. The processing in Step S1205 is the same as the processing in Step S105, and accordingly, description thereof will be omitted.

In Step S1206, the movement-blurring-removed-image processing unit 108 performs the processing of edge enhancement for the foreground component image which has been subjected to removal of movement blurring, and the corrected background component image, respectively, and the processing ends. Details of the processing of edge enhancement performed by the movement-blurring-removed-image

processing unit 108 will be described later.

As described above, the image processing device according to the present invention separates the input image into the foreground component image and the background component image, removes movement blurring from the foreground component image, and performs image processing for the foreground component image which has been subjected to removal of movement blurring, and the background component image, respectively.

Fig. 111 is a block diagram which illustrates the configuration of the movement-blurring-removed-image processing unit 108 for applying edge enhancement processing with different effects for each background component image, or each foreground component image.

Background component image frame memory 1201 stores the corrected background component image supplied from the correction unit 107. The background component image frame memory 1201 supplies the stored background component image to an edge enhancing unit 1203-1.

Foreground component image frame memory 1202 stores the foreground component image which has been subjected to removal of movement blurring, supplied from the movement blurring removal unit 106. The foreground component image frame memory 1202 supplies the stored foreground component image to an edge enhancing unit 1203-2.

The edge enhancing unit 1203-1 applies the processing of edge enhancement suitable for the background component image to the background component image stored in the background component image frame memory 1201.

For example, the edge enhancing unit 1203-1 performs the processing of edge enhancement which further enhances the edge for the background component image which is a still image as compared with the foreground component image. Thus the sense-of-resolution of the background component image can be improved without unnatural degradation of the image occurring in the event of applying the processing of edge enhancement to images containing noise.

The edge enhancing unit 1203-1 supplies the background component image which has been subjected to edge enhancement to a correction unit 1204.

The correction unit 1204 sets the pixel value of pixel in the mixed region in the background component image to 0, or divides the pixel value of the pixel in the mixed region by the predetermined value corresponding to the movement blurring which is to be added, corresponding to the movement blurring added by a movement blurring addition unit 1205. The correction unit 1204 supplies the image corrected as described above, to a synthesizing unit 1206.

The edge enhancing unit 1203-2 applies the processing of edge enhancement suitable for the foreground component

image, to the foreground component image stored in the foreground component image frame memory 1202.

For example, the edge enhancing unit 1203-2 compares the foreground component image with the background component image, and performs the processing of edge enhancement of which degree is less than that for the background component image. Thus the unnatural degradation in the image can be reduced as well as improving the sense-of-resolution in the foreground component image even if the foreground component image which has been subjected to removal of movement blurring contains noise.

The edge enhancing unit 1203-2 supplies the foreground component image which has been subjected to edge enhancement to the movement blurring addition unit 1205.

In the event that there is no need to differentiate the edge enhancing unit 1203-1 and the edge enhancing unit 1203-2 individually, these will be referred to as the edge enhancing unit 1203 below.

Fig. 112 is a block diagram which illustrates the configuration of the edge enhancing unit 1203. The input image which is one of the foreground component image and the background component image, is input to a high pass filter 1221 and an addition unit 1223.

The high pass filter 1221 extracts the components wherein the pixel value changes drastically with regard to

pixel position, i.e., the high image frequency components from the input image based upon the input filter coefficients, and removes the components wherein the change of the pixel value is small with regard to the pixel position, i.e., the low image frequency components, and generates an edge image.

For example, in the event of inputting the image shown in Fig. 113A, the high pass filter 1221 generates the edge image shown in Fig. 113B.

In the event that the input filter coefficients change, the high pass filter 1221 changes the image frequencies which are to be extracted, the image frequencies which are to be removed, and the gain for the image which is to be extracted.

Referring to Fig. 114 through Fig. 117, the relationship between the filter coefficients and the edge image will be described.

Fig. 114 is a diagram which illustrates the first example of the filter coefficients. In Fig. 114, E indicates the exponent of 10. For example, E-04 indicates 10^{-4}, and E-02 indicates 10^{-2}.

For example, the high pass filter 1221 multiplies each of pixel values, i.e., the pixel value of the pixel of interest, the pixel values of the pixels distanced from the pixel of interest by 1 pixel to 15 pixels in a predetermined

direction in the spatial direction Y, and the pixel values of pixels distanced from the pixel of interest by 1 pixel to 15 pixels in another direction in the spatial direction Y, by the corresponding coefficient of the filter coefficients shown in Fig. 114. The high pass filter 1221 calculates the sum of the results obtained by multiplying each pixel value of the pixels by the coefficient corresponding thereto, and sets the calculated sum for the pixel value of the pixel of interest.

For example, in the event of using the filter coefficients shown in Fig. 114, the high pass filter 1221 multiplies the pixel value of the pixel of interest by 1.2169396, multiplies the pixel value of the pixel distanced from the pixel of interest by 1 pixel in the upper direction in the screen by -0.52530356, and multiplies the pixel value of the pixel distanced from the pixel of interest by 2 pixels in the upper direction in the screen by -0.22739914.

In the same way, in the event of using the filter coefficients shown in Fig. 114, the high pass filter 1221 multiplies each of pixels distanced from the pixel of interest by 3 pixels to 13 pixels in the upper direction in the screen by the corresponding coefficient, multiplies the pixel value of the pixel distanced from the pixel of interest by 14 pixels in the upper direction in the screen by -0.00022540586, and multiplies the pixel value of the

pixel distanced from the pixel of interest by 15 pixels in the upper direction in the screen by -0.00039273163.

In the event of using the filter coefficients shown in Fig. 114, in the same way, the high pass filter 1221 multiplies each of pixels distanced from the pixel of interest by 1 pixel to 15 pixels in the bottom direction in the screen by the corresponding coefficient.

The high pass filter 1221 calculates the sum of results obtained by multiplying the pixel value of the pixel of interest, each pixel value of pixels distanced from the pixel of interest by 1 pixel to 15 pixels in the top direction in the screen, and each pixel value of pixels distanced from the pixel of interest by 1 pixel to 15 pixels in the bottom direction in the screen, by the corresponding coefficient. The high pass filter 1221 sets the calculated sum to the pixel value of the pixel of interest.

The high pass filter 1221 moves the position of the pixel of interest in sequence in the spatial direction X, repeats the above-described processing, and calculates pixel values for the entire screen.

The high pass filter 1221 then multiplies the pixel value of the interest, each pixel value of pixels distanced from the pixel of interest by 1 pixel to 15 pixels in a predetermined direction in the spatial direction X, and each pixel value of pixels distanced from the pixel of interest

by 1 pixel to 15 pixels in another direction in the spatial direction X, in the image of which pixel values are calculated based upon the coefficients described above, by the corresponding coefficient. The high pass filter 1221 calculates the sum of the results obtained by multiplying each pixel values of pixels by the corresponding coefficient, and sets the calculated sum to the pixel value of the pixel of interest.

The high pass filter 1221 moves the position of the pixel of interest in sequence in the spatial direction Y, repeats the above-described processing, and calculates pixel values of pixels for the entire image.

That is to say, in this case, the high pass filter 1221 is a so-called one-dimensional filter using the coefficients shown in Fig. 114.

Fig. 115 is a diagram which illustrates the operation of the high pass filter 1221 in the event of using the coefficients shown in Fig. 114. As shown in Fig. 115, the maximum gain for the extracted image component at the high pass filter 1221 is 1 in the event of using the coefficients shown in Fig. 114.

Fig. 116 is a diagram which illustrates the second example of the filter coefficients.

Fig. 117 is a diagram which illustrates the operation of the high pass filter 1221 in the event that the same

processing as the processing using the filter coefficients shown in Fig. 114, is performed using the coefficients shown in Fig. 116. As shown in Fig. 117, in the event of using the coefficients shown in Fig. 116, the maximum gain for extracted image component at the high pass filter 1221 is 1.5.

As described above, the high pass filter 1221 changes the gain for the extracted image component by the supplied filter coefficients.

While examples are not shown here, in the event of supplying different filter coefficients, the high pass filter 1221 can change the extracted image frequencies and the removed image frequencies in the same way.

Returning to Fig. 112, the high pass filter 1221 supplies the generated edge image to a gain adjustment unit 1222.

The gain adjustment unit 1222 amplifies or reduces the edge image supplied from the high pass filter 1221 based upon the input gain adjustment coefficients. In the event that the input gain adjustment coefficient is altered, the gain adjustment unit 1222 changes the amplification ratio (or decay ratio) of the edge image. For example, in the event of inputting the gain adjustment coefficients designating an amplification ratio which is equal to or more than 1, the gain adjustment unit 1222 amplifies the edge

image, and in the event of inputting the gain adjustment coefficients designating the amplification ratio which is less than 1, the gain adjustment unit 1222 attenuates the edge image.

The gain adjustment unit 1222 supplies the edge image which has been subjected to gain adjustment to the addition unit 1223.

The addition unit 1223 adds the divided input image and the edge image which has been subjected to gain adjustment supplied from the gain adjustment unit 1222, and outputs the added image.

For example, in the event of inputting the input image shown in Fig. 113A, and supplying the edge image shown in Fig. 113B from the high pass filter 1221, the addition unit 1223 adds the input image shown in Fig. 113A and the edge image shown in Fig. 113B, and outputs the image shown in Fig. 113C.

As described above, the edge enhancing unit 1203 applies the edge enhancement processing for the input image.

For example, the edge enhancing unit 1203-1 of which configuration is shown in Fig. 112 applies the edge enhancement processing, of which degree is even higher, to the background component image using the coefficients shown in Fig. 116. The edge enhancing unit 1203-2 of which configuration is shown in Fig. 112 applies the edge

enhancement processing, of which degree is relatively lower, to the foreground component image using the coefficients shown in Fig. 114.

Fig. 118 is a block diagram which illustrates another configuration of the edge enhancing unit 1203. In the example shown in Fig. 118, edge enhancing unit 1203 comprises a filter 1241.

The filter 1241 generates an edge enhancement image by amplifying the components wherein the pixel value changes drastically with regard to the pixel position, i.e., the high image frequency components in the input image, based upon the input filter coefficients.

For example, in the event of supplying the coefficients shown by way of an example in Fig. 119, the filter 1241 performs the same processing as the processing described with regard to the high pass filter 1221, based upon the coefficients shown by way of an example in Fig. 119.

Fig. 120 is a diagram which illustrates the operation of the filter 1241 in the event of using the coefficients shown in Fig. 119. As shown in Fig. 120, in the event of using the coefficients shown in Fig. 119, the filter 1241 amplifies the high image frequency components to twice, allows the low image frequency components to pass as they are, and generates an edge enhancement image.

In the event of using the coefficients shown in Fig.

119, the filter 1241 outputs the same output image as the output image from the edge enhancing unit 1203 of which configuration is shown in Fig. 112 in the event that the coefficients shown in Fig. 114 are used and the gain of the gain adjustment unit 1222 is 1.

Fig. 121 is a diagram which illustrates the second example of the filter coefficients supplied to the filter 1241.

Fig. 122 is a diagram which illustrates the operation of the filter 1241 in the event of using the coefficients shown in Fig. 121. As shown in Fig. 122, in the event of using the coefficients shown in Fig. 121, the filter 1241 amplifies the high image frequency components to 2.5 times, allows the low image frequency components to pass as they are, and generates an edge enhancement image.

In the event of using the coefficients shown in Fig. 121, the filter 1241 outputs the same output image as the output image from the edge enhancing unit 1203 of which configuration is shown in Fig. 112 in the event that the coefficients shown in Fig. 116 are used and the gain of the gain adjustment unit 1222 is 1.

As described above, the edge enhancing unit 1203 of which configuration is shown in Fig. 118 can change the degree of edge enhancement in the image by altering the gain of the high frequency components in the image, by the input

filter coefficients.

For example, the edge enhancing unit 1203-1 of which configuration is shown in Fig. 118 applies the edge enhancement processing of which degree is even higher, using the coefficients shown in Fig. 121, to the background component image. The edge enhancing unit 1203-1 of which configuration is shown in Fig. 118 applies the edge enhancement processing of which degree is relatively lower, using the coefficients shown in Fig. 119, to the foreground component image.

As described above, the edge enhancing unit 1203-1 and the edge enhancing unit 1203-2 applies the edge enhancement processing corresponding to the nature of the foreground component image or the background component image, to each foreground component image or each background component image, based upon the different filter coefficients or the gain adjustment coefficients, for example.

Returning to Fig. 111, the movement blurring addition unit 1205 adds movement blurring to the image by giving a desired movement blurring adjustment amount v', for example, the movement blurring adjustment amount v' of which value is the half value of the movement amount v of the input image, or the movement blurring adjustment amount v' of which value has no relationship with the movement amount v, by the same processing as the movement blurring addition unit 1106. The

movement blurring addition unit 1205 calculates the foreground component Fi/v' by dividing the pixel value in the foreground component image which has been subjected to removal of movement blurring, Fi, by the movement blurring adjustment amount v', calculates the sum of the foreground components Fi/v's, and generates a pixel value which has been subjected to addition of movement blurring.

The movement blurring addition unit 1205 adds movement blurring to the foreground component image which has been subjected to edge enhancement, and supplies the foreground component image which has been subjected to addition of movement blurring to a synthesizing unit 1206.

The synthesizing unit 1206 synthesizes the background component image which has been subjected to edge enhancement and correction, supplied from the correction unit 1204, with the foreground component image which has been subjected to edge enhancement and addition of movement blurring, supplied from the movement blurring addition unit 1205, and supplies the synthesized image to frame memory 1207.

The frame memory 1207 stores the synthesized image supplied from the synthesizing unit 1206, and also outputs the stored image as an output image.

As described above, the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 111 applies the edge enhancement processing corresponding to

the nature of each image, for each background component image or each foreground component image, and accordingly the sense-of-resolution of the image is improved without degrading the image unnaturally.

Fig. 123 is a diagram which describes the processing in the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 111.

The specifying unit 103 specifies the foreground region, uncovered background region, covered background region, and background region in the input image. The input image of which regions are specified, is separated into the background component image and foreground component image by the foreground/background separation unit 105.

The movement blurring removal unit 106 removes movement blurring from the separated foreground component image. The correction unit 107 corrects pixel values of the pixels corresponding to the mixed region in the separated background component image.

The movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 111 performs edge enhancement for each of the corrected background component image and the foreground component image which has been subjected to removal of movement blurring, corresponding to the nature of each image.

The background component image which has been subjected

to edge enhancement is corrected, corresponding to addition of the movement blurring to the foreground component image. The desired movement blurring is added to the foreground component image which has been subjected to edge enhancement.

The background component image which has been subjected to edge enhancement and correction, and the foreground component image which has been subjected to edge enhancement and addition of movement blurring, are synthesized.

A description will now be made with regard to the edge enhancement processing in the movement-blurring-removed-image processing unit 108 corresponding to Step S1206 shown in Fig. 110, with reference to the flowchart shown in Fig. 124.

In Step S1401, the edge enhancing unit 1203-1 performs edge enhancement for the background component image stored in the background component image frame memory 1201 by edge enhancement processing corresponding to the nature of the background component image.

In Step S1402, the edge enhancing unit 1203-2 performs edge enhancement for the foreground component image stored in the foreground component image frame memory 1202 by the edge enhancement processing corresponding to the nature of the foreground component image.

In Step S1403, the correction unit 1204 corrects pixel values in the background component image corresponding to

addition of the movement blurring to the foreground component image.

In Step S1404, the movement blurring addition unit 1205 adds the desired movement blurring to the foreground component image.

In Step S1405, the synthesizing unit 1206 synthesizes the background component image which has been subjected to edge enhancement and correction, with the foreground component image which has been subjected to edge enhancement and addition of movement blurring. The synthesizing unit 1206 supplies the synthesized image to the frame memory 1207. The frame memory 1207 stores the image supplied from the synthesizing unit 1206.

In Step S1406, the frame memory 1207 outputs the stored and synthesized image, and the processing ends.

As described above, the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 111 can perform the edge enhancement processing for each background component image and each foreground component image corresponding to the nature of each, and accordingly the sense-of-resolution can be improved without unnatural degradation in the image occurring.

Note that it is needless to say that the processing in Step S1401 and Step S1402 may be performed serially or in parallel.

Fig. 125 is a block diagram which indicates the configuration of the movement-blurring-removed-image processing unit 108 for generating a coefficient set which is used for class classification adaptation processing for removing noise corresponding to the foreground component image which has been subjected to removal of movement blurring.

The movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 125 does not use the corrected background component image.

Tutor image frame memory 2201 stores the foreground component image which has been subjected to removal of movement blurring supplied from the movement blurring removal unit 2001. The tutor image frame memory 2201 supplies the foreground component image which has been subjected to removal of movement blurring, which is the stored tutor image, to a noise addition unit 2202 and a learning unit 2204.

The noise addition unit 2202 generates random numbers, and adds noise to the foreground component image by adding the random numbers to each pixel value in the foreground component image supplied from the tutor image frame memory 2201. The noise addition unit 2202 supplies the foreground component image which has been subjected to addition of noise to a student image frame memory 2203.

The student image frame memory 2203 stores the student image which is the foreground component image, which has been subjected to addition of noise, supplied from the noise addition unit 2202. The student image frame memory 2203 supplies the stored student image to the learning unit 2204.

The learning unit 2204 generates an coefficient set corresponding to the foreground component image which has been subjected to addition of noise, based upon the tutor image which is the foreground component image supplied from the tutor image frame memory 2201 and the student image which is the foreground component image which has been subjected to addition of noise supplied from the student image frame memory 2203, and supplies the generated coefficient set to a coefficient set memory 2205.

The coefficient set memory 2205 stores the coefficient set corresponding to the background component image supplied from the learning unit 2204.

Referring to the flowchart shown in Fig. 126, description will now be made with regard to the processing for learning for generating of a coefficient set which is used for the class classification processing for removing noise by the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 125.

In Step S2201, the noise addition unit 2202 generates a student image corresponding to the foreground component

image which is the tutor image by adding random numbers to the pixel values in the foreground component image which is the tutor image stored in the tutor image frame memory 2201.

In Step S2202, the learning unit 2204 generates a coefficient set corresponding to the foreground component image which has been subjected to addition of noise, based upon the tutor image which is the foreground component image stored in the tutor image frame memory 2201 and the student image which is the foreground component image that has been subjected to addition of noise stored in the student image frame memory 2203, and supplies the generated coefficient set to the coefficient set memory 2205. Details of the processing for generating a coefficient set is the same as the processing described with reference to the flowchart in Fig. 103, and accordingly description thereof will be omitted.

The coefficient set memory 2205 stores the coefficient set corresponding to the foreground component image which has been subjected to addition of noise, and the processing ends.

As described above, the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 125 can generate a coefficient set corresponding to the foreground component image which has been subjected to addition of noise.

Fig. 127 is a block diagram which indicates the configuration of the movement-blurring-removed-image processing unit 108 for removing noise and performing edge enhancement for the background component image by performing the class classification adaptation processing for the foreground component image which has been subjected to removal of movement blurring.

Frame memory 2301 stores the foreground component image which has been subjected to removal of movement blurring supplied from the movement blurring removal unit 2001. The frame memory 2301 supplies the stored foreground component image which has been subjected to removal of movement blurring to a mapping unit 2302.

The mapping unit 2302 generates a predicted image which has been subjected to removal of noise corresponding to the foreground component image stored in the frame memory 2301 based upon the coefficient set corresponding to the foreground component image stored in the coefficient set memory 2303, by the class classification processing. The mapping unit 2302 supplies the generated predicted image to frame memory 2304.

The frame memory 2304 stores the predicted image which has been subjected to removal of noise, and supplies the stored predicted image to a synthesizing unit 2308.

The frame memory 2305 stores the background component

image supplied from the correction unit 2002. The frame memory 2305 supplies the stored background component image to an edge enhancing unit 2306.

The edge enhancing unit 2306 enhances the edge in the background component image stored in the frame memory 2305 by processing of edge enhancement, and supplies the background component image which has been subjected to edge enhancement to frame memory 2307.

The frame memory 2307 stores the background component image which has been subjected to edge enhancement, and supplies the stored background component image to the synthesizing unit 2308.

The synthesizing unit 2308 synthesizes the predicted image which has been subjected to removal of noise corresponding to the foreground component image supplied from the frame memory 2304, with the background component image which has been subjected to edge enhancement supplied from the frame memory 2307, and outputs the synthesized image as an output image.

Fig. 128 is a diagram which describes the processing of the movement-blurring-removed-image processing unit 108.

As shown in Fig. 128, the input image is divided into regions, and separated into the foreground component image and the background component image. The separated input image is synthesized into the foreground component image and

the background component image.

Movement blurring contained in the foreground component image is removed. The background component image is corrected with regard to the pixel values corresponding to the mixed region.

The movement-blurring-removed-image processing unit 108 removes noise in the foreground component image which has been subjected to removal of movement blurring by applying the class classification adaptation processing, and performs edge enhancement for the background component image which has been subjected to correction.

Referring to the flowchart shown in Fig. 129, the processing for creation of the image by the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 127, will now be described.

In Step S2301, the mapping unit 2302 predicts the image which has been subjected to removal of noise from the foreground component image stored in the frame memory 7301 by the class classification adaptation processing based upon the coefficient set corresponding to the foreground component image stored in the coefficient set memory 2303. Details of the processing for prediction of the image are the same as the processing described with reference to the flowchart shown in Fig. 109 except for using the foreground component image instead of the background component image,

and accordingly description thereof will be omitted.

The mapping unit 2302 supplies the image wherein the noise has been removed from the foreground component image, to the frame memory 2304. The frame memory 2304 stores the predicted image which has been subjected to removal of noise corresponding to the foreground component image, and supplies the stored predicted image to the synthesizing unit 2308.

In Step S2302, the edge enhancing unit 2306 performs edge enhancement processing for the background component image stored in the frame memory 2305. The edge enhancing unit 2306 supplies the image which has been subjected to edge enhancement to the frame memory 2307. The frame memory 2307 stores the image which has been subjected to edge enhancement, and supplies the stored edge-enhanced image to the synthesizing unit 2308.

In Step S2303, the synthesizing unit 2308 synthesizes the predicted image which has been subjected to removal of noise corresponding to the foreground component image, and the edge-enhanced background component image. The synthesizing unit 2308 outputs the stored synthesized image, and the processing ends.

As described above, the image processing device having the movement-blurring-removed-image processing unit 108 of which configuration is shown in Fig. 127 can generate a

predicted image which has been subjected to removal of noise corresponding to the foreground component image, perform edge enhancement processing for the background component image, and output the image by synthesizing the predicted image which has been subjected to removal of noise and the edge enhanced background component image, and accordingly noise in the foreground component image due to the processing for removal of movement blurring can be reduced, and also the sense-of-resolution with regard to the entire image can be improved.

Note that it is needless to say that the processing in Step S2301 and Step S2302 may be performed in serial, as well as in parallel.

Fig. 130 is a block diagram which illustrates another configuration of the functions of the image processing device. While the image processing device shown in Fig. 11 performs the region specification and the calculation of the mixture ratio α in sequence, the image processing device shown in Fig. 130 performs the region specification and the calculation of mixture ratio α in a parallel manner.

The same portions as the functions shown in the block diagram in Fig. 11 are denoted by the same reference numerals, and description thereof will be omitted.

The input image is supplied to the objected extracting unit 101, the region specifying unit 103, a mixture ratio

calculation unit 3001, and a foreground/background separation unit 3002.

The mixture ratio calculation unit 3001 calculates the estimated mixture ratio wherein an assumption is made that the pixel belongs to the covered background region, and the estimated mixture ratio wherein an assumption is made that the pixel belongs to the uncovered background region, for each of pixels contained in the input image based upon the input image, and supplies the estimated mixture ratio wherein an assumption is made that the calculated pixel belongs to the covered background region, and the estimated mixture ratio wherein an assumption is made that the pixel belongs to the uncovered background region, to the foreground/background separation unit 3002.

Fig. 131 is a block diagram which illustrates one example of the configuration of the mixture ratio calculation unit 3001.

The estimated mixture ratio processing unit 401 shown in Fig. 131 is the same as the estimated mixture ratio processing unit 401 shown in Fig. 62. The estimated mixture ratio processing unit 402 shown in Fig. 131 is the same as the estimated mixture ratio processing unit 402 shown in Fig. 62.

The estimated mixture ratio processing unit 401 calculates the estimated mixture ratio for each pixel by the

computation corresponding to the model of the covered background region based upon the input image, and outputs the calculated estimated mixture ratio.

The estimated mixture ratio processing unit 402 calculates the estimated mixture ratio for each pixel by the computation corresponding to the model of the uncovered background region based upon the input image, and outputs the calculated estimated mixture ratio.

The foreground/background separation unit 3002 separates the input image into the background component image and the foreground component image based upon the estimated mixture ratio wherein an assumption is made that the pixel belongs to the covered background region and the estimated mixture ratio wherein an assumption is made that the pixel belongs to the uncovered background region, supplied from the mixture ratio calculation unit 3001, and the region information supplied from the region specifying unit 103, and supplies the separated images to the movement-blurring-removed-image processing unit 108.

Fig. 132 is a block diagram which illustrates one example of the configuration of the foreground/background separation unit 3002.

The same portions as the movement blurring removal unit 106 shown in Fig. 80 are denoted by the same reference numerals, and description thereof will be omitted.

A selection unit 3021 selects either of the estimated mixture ratio wherein an assumption is made that the pixel belongs to the covered background region, or the estimated mixture ratio wherein an assumption is made that the pixel belongs to the uncovered background region, supplied from the mixture ratio calculation unit 3001 based upon the region information supplied from the region specifying unit 103, and supplies the selected estimated mixture ratio as a mixture ratio α to the separation unit 601.

The separation unit 601 extracts the foreground components and the background components from the pixel values of the pixels belonging to the mixed region based upon the mixture ratio α supplied from the selection unit 3021 and the region information, and separates into the background components in the uncovered background region, the foreground components in the uncovered background region, the background components in the covered background region, and the foreground components in the covered background region.

The configuration of the separation unit 601 may be the same as the configuration shown in Fig. 85.

As described above, the image processing device of which configuration is shown in Fig. 130 can perform processing for each background component image and each foreground component image, corresponding to the nature of

each image.

As described above, in the image processing device according to the present invention, the input image is separated into the background component image and the foreground component image, and the processing suitable for the separated images is performed, and accordingly an even higher resolution image is generated without unnatural images occurring, for example.

Fig. 133 is a block diagram which illustrates another configuration of the functions of the image processing device.

The same portions as those shown in Fig. 11 are denoted by the same reference numerals, and description thereof will be omitted.

The object extracting unit 101 roughly extracts the image objects corresponding to the foreground objects contained in the input image, and supplies the extracted image objects to the movement detecting unit 102.

The movement detecting unit 102 calculates the movement vectors of the image objects corresponding to the roughly extracted foreground objects by techniques such as block matching, gradation, phase correlation, and pixel recursion, or the like, and provides the calculated movement vectors and movement vector position to the region specifying unit 103.

The region specifying unit 103 classifies each of pixels of the input images into one of foreground region, background region, or mixed region which consists of the covered background region and the uncovered background region, and supplies the region information to the mixture ratio calculation unit 104 and a foreground/background separation unit 4001.

The mixture ratio calculation unit 104 calculates the mixture ratio α corresponding to the pixels contained in the mixed region based upon the input image and the region information supplied from the region specifying unit 103, and supplies the calculated mixture ratio to the foreground/background separation unit 4001.

The foreground/background separation unit 4001 separates the input image into the components of the image corresponding to the foreground object and the background component image which consists of only the background components based upon the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio calculation unit 104, and supplies the image in the background region, the image which consists of only the background components in the uncovered background region (which will be referred to as the background component image in the uncovered background region below), the image which consists of only the

foreground components in the uncovered background region (which will be referred to as the foreground component image in the uncovered background region below), the image which consists of only the background components in the covered background region (which will be referred to as the background component image in the covered background region below), the image which consists of only the foreground components in the covered background region (which will be referred to as the foreground component image in the covered background region below), and the image in the foreground region, to a separated image processing unit 4002.

The separated image processing unit 4002 performs processing for the image in the background region, the background component image in the uncovered background region, the foreground component image in the uncovered background region, the background component image in the covered background region, the foreground component image in the covered background region, and the image in the foreground region, supplied from the foreground/background separation unit 4001, respectively.

For example, the separated image processing unit 4002 generates coefficients which are used in the class classification adaptation processing for generating a even higher resolution image for each of the image in the background region, background component image in the

uncovered background region, foreground component image in the uncovered background region, background component image in the covered background region, foreground component image in the covered background region, and image in the foreground region.

For example, the separated image processing unit 4002 creates an even higher resolution image by applying the class classification adaptation processing for each of the image in the background region, background component image in the uncovered background region, foreground component image in the uncovered background region, background component image in the covered background region, foreground component image in the covered background region, and image in the foreground region.

Fig. 134 is a diagram which describes the processing in the separated image processing unit 4002 of which configuration is shown in Fig. 133. The region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region, in the input image.

The input image wherein the regions thereof are specified and the mixture ratio α is detected by the mixture ratio calculation unit 104, is separated into the image in the foreground region, image in the background region, foreground component image in the covered background region,

background component image in the covered background region, foreground component image in the uncovered background region, and background component image in the uncovered background region by the foreground/background separation unit 4001.

The separated image processing unit 4002 calculates a coefficient set corresponding to the image in the foreground region, a coefficient set corresponding to the image in the background region, a coefficient set corresponding to the foreground component image in the covered background region, a coefficient set corresponding to the background component image in the covered background region, a coefficient set corresponding to the foreground component image in the uncovered background region, and a coefficient set corresponding to the background component image in the uncovered background region individually, based upon the separated image in the foreground region, image in the background region, foreground component image in the covered background region, background component image in the covered background region, foreground component image in the uncovered background region, and background component image in the uncovered background region.

The coefficient set corresponding to the background region is used for prediction of the pixel value in the background region in the class classification adaptation

processing for predicting pixel values. The coefficient set corresponding to the background component image in the uncovered background region is used for prediction of the pixel value corresponding to the background component image in the uncovered background region in the class classification adaptation processing for predicting pixel values. The coefficient set corresponding to the foreground component image in the uncovered background region is used for prediction of the pixel value corresponding to the foreground component image in the uncovered background region in the class classification adaptation processing for predicting pixel values.

The coefficient set corresponding to the background component image in the covered background region is used for prediction of the pixel value corresponding to the background component image in the covered background region in the class classification adaptation processing for predicting pixel values. The coefficient set corresponding to the foreground component image in the covered background region is used for prediction of the pixel value corresponding to the foreground component image in the covered background region in the class classification adaptation processing for predicting pixel values.

The coefficient set corresponding to the foreground region is used for prediction of the pixel value in the

foreground region in the class classification adaptation processing for predicting pixel values.

The predicted image corresponding to the image in the background region, the predicted image corresponding to the background component image in the uncovered background region, the predicted image corresponding to the foreground component image in the uncovered background region, the predicted image corresponding to the background component image in the covered background region, the predicted image corresponding to the foreground component image in the covered background region, and the predicted image corresponding to the image in the foreground region, are synthesized into a single predicted image.

Fig. 135 is a block diagram which illustrates one example of the configuration of the foreground/background separation unit 4001. The input image supplied to the foreground/background separation unit 4001 is supplied to a separation unit 4101, a switch 4102, and a switch 4103. The region information which indicates the covered background region and the uncovered background region supplied from the region specifying unit 103 is supplied to the separation unit 4101. The region information which indicates the foreground region is supplied to the switch 4102. The region information which indicates the background region is supplied to the switch 4103.

The mixture ratio α supplied from the mixture ratio calculation unit 104 is supplied to the separation unit 4101.

The separation unit 4101 separates the background components from the covered background region in the input image, as well as foreground components, based upon the region information which indicates the covered background region and the mixture ratio α, and outputs the foreground component image in the covered background region which consists of the separated foreground components, and the background component image in the covered background region which consists of the separated background components.

The separation unit 4101 separates the background components from the uncovered background region in the input image, as well as foreground components, based upon the region information which indicates the uncovered background region and the mixture ratio α, and outputs the foreground component image in the uncovered background region which consists of the separated foreground components, and the background component image in the uncovered background region which consists of the separated background components.

In the event of inputting the pixel corresponding to the foreground region, the switch 4102 is closed based upon the region information which indicates the foreground region, and outputs the image in the foreground region.

In the event of inputting the pixel corresponding to

the background region, the switch 4103 is closed based upon the region information which indicates the background region, and outputs the image in the background region.

Fig. 136 is a block diagram which illustrates one example of the configuration of the separation unit 4101. The image input to the separation unit 4101 is supplied to frame memory 4121, and the region information which indicates the covered background region and the uncovered background region and the mixture ratio α supplied from the mixture ratio calculation unit 104 are input to a separation processing block 4122.

The frame memory 4121 stores input image in increments of frames. In the event that the frame #n is the object of the processing, the frame memory 4121 stores the frame #n - 1 one frame previous to the frame #n, the frame #n, and the frame #n + 1 one frame following the frame #n.

The frame memory 4121 supplies pixels corresponding to the frame #n - 1, the frame #n, and the frame #n + 1 to the separation processing block 4122.

The separation processing block 4122 separates the foreground components and the background components from the pixel belonging to the mixed region in the frame #n by applying the calculation described with reference to Fig. 83 and Fig. 84 to the pixel values of the pixels corresponding to the frame #n - 1, the frame #n, and the frame #n + 1

supplied from the frame memory 4121 based upon the region information which indicates the covered background region and the uncovered background region and the mixture ratio α.

The separation processing block 4122 comprises an uncovered region processing unit 4131 and a covered region processing unit 4132.

A multiplication device 4141 of the uncovered region processing unit 4131 multiplies the pixel value of the pixel in the frame #n + 1 supplied from the frame memory 4121 by the mixture ratio α, and outputs to a switch 4142. In the event that the pixel (corresponding to the pixel in the frame #n + 1) in the frame #n supplied from the frame memory 4121 belongs to the uncovered background region, the switch 4142 is closed, and supplies the pixel value multiplied by the mixture ratio α supplied from the multiplication device 4141 to a computation device 4143. The value wherein the pixel value of the pixel in the frame #n + 1 which is output from the switch 4142 multiplied by the mixture ratio α, is the same as the background component of the pixel value of the pixel corresponding to the frame #n, which is output as a background component image in the uncovered background region.

The computation device 4143 obtains the foreground component by subtracting the background component supplied from the switch 4142 from the pixel value of the pixel in

the frame #n supplied from the frame memory 4121. The computation device 4143 outputs the foreground component image made up of pixels in the frame #n belonging to the uncovered background region.

A multiplication device 4151 of the covered region processing unit 4132 multiplies the pixel value of the pixel in the frame #n - 1 supplied from the frame memory 4121 by the mixture ratio α, and outputs to a switch 4152. In the event that the pixel (corresponding to the pixel in the frame #n - 1) in the frame #n supplied from the frame memory 4121 belongs to the covered background region, the switch 4152 is closed, and supplies the pixel value multiplied by the mixture ratio α supplied from the multiplication device 4151 to a computation device 4153. The value wherein the pixel value of the pixel in the frame #n - 1 which is output from the switch 4152 multiplied by the mixture ratio α, is the same as the background component of the pixel value of the pixel corresponding to the frame #n, which is output as a background component image in the covered background region.

The computation device 4153 obtains the foreground component by subtracting the background component supplied from the switch 4152 from the pixel value of the pixel in the frame #n supplied from the frame memory 4121. The computation device 4153 outputs the foreground component

image made up of pixels in the frame #n belonging to the covered background region.

Using the mixture ratio α which is the amount of features enables entire separation of the foreground component and background component, contained in the pixel value.

Fig. 137 is a block diagram which illustrates the configuration of the separated image processing unit 4002 for generating a coefficient set which is used for the class classification adaptation processing for generating a even higher resolution image in the spatial direction. For example, the separated image processing unit 4002 of which configuration is shown in Fig. 137 generates a coefficient set which is used for the class classification adaptation processing for generating an HD image from an SD image based upon the input HD image.

Background region tutor image frame memory 4201 stores the image in the background region in the tutor image supplied from the foreground/background separation unit 4001. The background region tutor image frame memory 4201 supplies the stored image in the background region in the tutor image to a weighted averaging unit 4207-1 and a learning unit 4214-1.

Uncovered background region background component tutor image frame memory 4202 stores the background component

image in the uncovered background region in the tutor image supplied from the foreground/background separation unit 4001. The uncovered background region background component tutor image frame memory 4202 supplies the stored background component image in the uncovered background region in the tutor image to a weighted averaging unit 4207-2 and a learning unit 4214-2.

Uncovered background region foreground component tutor image frame memory 4203 stores the foreground component image in the uncovered background region in the tutor image supplied from the foreground/background separation unit 4001. The uncovered background region foreground component tutor image frame memory 4203 supplies the stored foreground component image in the uncovered background region in the tutor image to a weighted averaging unit 4207-3 and a learning unit 4214-3.

Covered background region background component tutor image frame memory 4204 stores the background component image in the covered background region in the tutor image supplied from the foreground/background separation unit 4001. The covered background region background component tutor image frame memory 4204 supplies the stored background component image in the covered background region in the tutor image to a weighted averaging unit 4207-4 and a learning unit 4214-4.

Covered background region foreground component tutor image frame memory 4205 stores the foreground component image in the covered background region in the tutor image supplied from the foreground/background separation unit 4001. The covered background region foreground component tutor image frame memory 4205 supplies the stored foreground component image in the covered background region in the tutor image to a weighted averaging unit 4207-5 and a learning unit 4214-5.

Foreground region tutor image frame memory 4206 stores the image in the foreground region in the tutor image supplied from the foreground/background separation unit 4001. The foreground region tutor image frame memory 4206 supplies the stored image in the foreground region in the tutor image to a weighted averaging unit 4207-6 and a learning unit 4214-6.

The weighted averaging unit 4207-1 generates an SD image which is a student image by one-quarter weighted-averaging the image in the background region in the tutor image which is an HD image, for example, supplied from the background region tutor image frame memory 4201, and supplies the generated SD image to background region student image frame memory 4208.

The background region student image frame memory 4208 stores the student image corresponding to the image in the

background region in the tutor image supplied from the weighted averaging unit 4207-1. The background region student image frame memory 4208 supplies the stored student image corresponding to the image in the background region in the tutor image to the learning unit 4214-1.

The weighted averaging unit 4207-2 generates an SD image which is a student image by one-quarter weighted-averaging the background component image in the uncovered background region in the tutor image which is an HD image, for example, supplied from the uncovered background region background component tutor image frame memory 4202, and supplies the generated SD image to uncovered background region background component student image frame memory 4209.

The uncovered background region background component student image frame memory 4209 stores the student image, which is an SD image, corresponding to the background component image in the uncovered background region in the tutor image supplied from the weighted averaging unit 4207-2. The uncovered background region background component student image frame memory 4209 supplies the stored student image corresponding to the background component image in the uncovered background region in the tutor image to the learning unit 4214-2.

The weighted averaging unit 4207-3 generates an SD image which is a student image by one-quarter weighted-

averaging the foreground component image in the uncovered background region in the tutor image which is an HD image, for example, supplied from the uncovered background region foreground component tutor image frame memory 4203, and supplies the generated SD image to uncovered background region foreground component student image frame memory 4210.

The uncovered background region foreground component student image frame memory 4210 stores the student image, which is an SD image, corresponding to the foreground component image in the uncovered background region in the tutor image supplied from the weighted averaging unit 4207-3. The uncovered background region foreground component student image frame memory 4210 supplies the stored student image corresponding to the foreground component image in the uncovered background region in the tutor image to the learning unit 4214-3.

The weighted averaging unit 4207-4 generates an SD image, which is a student image, by one-quarter weighted-averaging the background component image in the covered background region in the tutor image, for example, supplied from the covered background region background component tutor image frame memory 4204, and supplies the generated SD image to covered background region background component student image frame memory 4211.

The covered background region background component

student image frame memory 4211 stores the student image, which is an SD image, corresponding to the background component image in the covered background region in the tutor image supplied from the weighted averaging unit 4207-4. The covered background region background component student image frame memory 4211 supplies the stored student image corresponding to the background component image in the covered background region in the tutor image to the learning unit 4214-4.

The weighted averaging unit 4207-5 generates an SD image, which is a student image, by one-quarter weighted-averaging the foreground component image in the covered background region in the tutor image, for example, supplied from the covered background region foreground component tutor image frame memory 4205, and supplies the generated SD image to covered background region foreground component student image frame memory 4212.

The covered background region foreground component student image frame memory 4212 stores the student image, which is an SD image, corresponding to the foreground component image in the covered background region in the tutor image supplied from the weighted averaging unit 4207-5. The covered background region foreground component student image frame memory 4212 supplies the stored student image corresponding to the foreground component image in the

covered background region in the tutor image to the learning unit 4214-5.

The weighted averaging unit 4207-6 generates an SD image which is a student image by one-quarter weighted-averaging the image in the foreground region in the tutor image which is an HD image, for example, supplied from the foreground region tutor image frame memory 4206, and supplies the generated SD image to foreground region student image frame memory 4213.

The foreground region student image frame memory 4213 stores the student image, which is an SD image, corresponding to the image in the foreground region in the tutor image supplied from the weighted averaging unit 4207-6. The foreground region student image frame memory 4213 supplies the stored student image corresponding to the image in the foreground region in the tutor image to the learning unit 4214-6.

The learning unit 4214-1 generates a coefficient set corresponding to the background region based upon the image in the background region in the tutor image supplied from the background region tutor image frame memory 4201 and the student image corresponding to the image in the background region in the tutor image supplied from the background region student image frame memory 4208, and supplies the generated coefficient set to coefficient set memory 4215.

The learning unit 4214-2 generates a coefficient set corresponding to the background component image in the uncovered background region based upon the background component image in the uncovered background region in the tutor image supplied from the uncovered background region background component tutor image frame memory 4202 and the student image corresponding to the background component image in the uncovered background region in the tutor image supplied from the uncovered background region background component student image frame memory 4209, and supplies the generated coefficient set to the coefficient set memory 4215.

The learning unit 4214-3 generates a coefficient set corresponding to the foreground component image in the uncovered background region based upon the foreground component image in the uncovered background region in the tutor image supplied from the uncovered background region foreground component tutor image frame memory 4203 and the student image corresponding to the foreground component image in the uncovered background region in the tutor image supplied from the uncovered background region foreground component student image frame memory 4210, and supplies the generated coefficient set to the coefficient set memory 4215.

The learning unit 4214-4 generates a coefficient set corresponding to the background component image in the covered background region based upon the background

component image in the covered background region in the tutor image supplied from the covered background region background component tutor image frame memory 4204 and the student image corresponding to the background component image in the covered background region in the tutor image supplied from the covered background region background component student image frame memory 4211, and supplies the generated coefficient set to the coefficient set memory 4215.

The learning unit 4214-5 generates a coefficient set corresponding to the foreground component image in the covered background region based upon the foreground component image in the covered background region in the tutor image supplied from the covered background region foreground component tutor image frame memory 4205 and the student image corresponding to the foreground component image in the covered background region in the tutor image supplied from the covered background region foreground component student image frame memory 4212, and supplies the generated coefficient set to the coefficient set memory 4215.

The learning unit 4214-6 generates a coefficient set corresponding to the foreground region based upon the image in the foreground region in the tutor image supplied from the foreground region tutor image frame memory 4206 and the student image corresponding to the image in the foreground region in the tutor image supplied from the foreground

region student image frame memory 4213, and supplies the generated coefficient set to the coefficient set memory 4215.

The coefficient set memory 4215 stores the coefficient set corresponding to the background region supplied from the learning unit 4214-1, the coefficient set corresponding to the background component image in the uncovered background region supplied from the learning unit 4214-2, the coefficient set corresponding to the foreground component image in the uncovered background region supplied from the learning unit 4214-3, the coefficient set corresponding to the background component image in the covered background region supplied from the learning unit 4214-4, the coefficient set corresponding to the foreground component image in the covered background region supplied from the learning unit 4214-5, and the coefficient set corresponding to the foreground region supplied from the learning unit 4214-6.

Note that the learning units 4214-1 through 4214-6 have the same configuration as the learning unit 1006, so description thereof will be omitted.

Fig. 138 is a block diagram which illustrates the configuration of the separated image processing unit 4002 for generating an even higher resolution image in the spatial direction by performing the class classification adaptation processing. For example, the separated image

processing unit 4002 of which configuration is shown in Fig. 138 generates an HD image by performing the class classification processing based upon the input image which is an SD image.

Background region frame memory 4301 stores the image in the background region made up of pixels belonging to the background region supplied from the foreground/background separation unit 4001. The background region frame memory 4301 supplies the stored image in the background region to a mapping unit 4307-1.

Uncovered background region background component image frame memory 4302 stores the background component image in the uncovered background region supplied from the foreground/background separation unit 4001. The uncovered background region background component image frame memory 4302 supplies the stored background component image in the uncovered background region to a mapping unit 4307-2.

Uncovered background region foreground component image frame memory 4303 stores the foreground component image in the uncovered background region supplied from the foreground/background separation unit 4001. The uncovered background region foreground component image frame memory 4303 supplies the stored foreground component image in the uncovered background region to a mapping unit 4307-3.

Covered background region background component image

frame memory 4304 stores the background component image in the covered background region supplied from the foreground/background separation unit 4001. The covered background region background component image frame memory 4304 supplies the stored background component image in the covered background region to a mapping unit 4307-4.

Covered background region foreground component image frame memory 4305 stores the foreground component image in the covered background region supplied from the foreground/background separation unit 4001. The covered background region foreground component image frame memory 4305 supplies the stored foreground component image in the covered background region to a mapping unit 4307-5.

Foreground region frame memory 4306 stores the image in the foreground region made up of pixels belonging to the foreground region supplied from the foreground/background separation unit 4001. The foreground region image frame memory 2306 supplies the stored image in the foreground region to a mapping unit 4307-6.

The mapping unit 4307-1 generates a predicted image corresponding to the image in the background region stored in the background region frame memory 4301 by the class classification adaptation processing based upon the coefficient set corresponding to the background region stored in coefficient set memory 4308. The mapping unit

4307-1 supplies the generated predicted image to a synthesizing unit 4309.

The mapping unit 4307-2 generates a predicted image corresponding to the background component image in the uncovered background region stored in the uncovered background region background component image frame memory 4302 by the class classification adaptation processing based upon the coefficient set corresponding to the background component image in the uncovered background region stored in the coefficient set memory 4308. The mapping unit 4307-2 supplies the generated predicted image to the synthesizing unit 4309.

The mapping unit 4307-3 generates a predicted image corresponding to the foreground component image in the uncovered background region stored in the uncovered background region foreground component image frame memory 4303 by the class classification adaptation processing based upon the coefficient set corresponding to the foreground component image in the uncovered background region stored in the coefficient set memory 4308. The mapping unit 4307-3 supplies the generated predicted image to the synthesizing unit 4309.

The mapping unit 4307-4 generates a predicted image corresponding to the background component image in the covered background region stored in the covered background

region background component image frame memory 4304 by the class classification adaptation processing based upon the coefficient set corresponding to the background component image in the covered background region stored in the coefficient set memory 4308. The mapping unit 4307-4 supplies the generated predicted image to the synthesizing unit 4309.

The mapping unit 4307-5 generates a predicted image corresponding to the foreground component image in the covered background region stored in the covered background region foreground component image frame memory 4305 by the class classification adaptation processing based upon the coefficient set corresponding to the foreground component image in the covered background region stored in the coefficient set memory 4308. The mapping unit 4307-5 supplies the generated predicted image to the synthesizing unit 4309.

The mapping unit 4307-6 generates a predicted image corresponding to the image in the foreground region stored in the foreground region frame memory 4306 by the class classification adaptation processing based upon the coefficient set corresponding to the foreground region stored in the coefficient set memory 4308. The mapping unit 4307-6 supplies the generated predicted image to the synthesizing unit 4309.

The synthesizing unit 4309 synthesizes the predicted image corresponding to the image in the background region supplied from the mapping unit 4307-1, the predicted image corresponding to the background component image in the uncovered background region supplied from the mapping unit 4307-2, the predicted image corresponding to the foreground component image in the uncovered background region supplied from the mapping unit 4307-3, the predicted image corresponding to the background component image in the covered background region supplied from the mapping unit 4307-4, the predicted image corresponding to the foreground component image in the covered background region supplied from the mapping unit 4307-5, and the predicted image corresponding to the image in the foreground region supplied from the mapping unit 4307-6, and supplies the synthesized predicted image to frame memory 4310.

The frame memory 4310 stores the predicted image supplied from the synthesizing unit 4309, and also outputs the stored image as an output image.

Note that the mapping units 4307-1 through 4307-6 have the same configuration as the mapping unit 1103, so description thereof will be omitted.

Referring to the images shown in Fig. 139A through Fig. 144B, description will be made with regard to the results of the processing of the image processing device according to

the present invention having the separated image processing unit 4002 of which configuration is shown in Fig. 138.

In the processing for generating results shown by way of examples, the sum of the number of classes in the class classification adaptation processing in the image processing device of the present invention is approximately the same as the number of classes in the conventional class classification adaptation processing. That is to say, the number of classes in the conventional class classification adaptation processing is 2048, and the number of the classes in the class classification adaptation processing in the image processing device of the present invention corresponding to the images in each region is arranged to be 512.

Also, the number of the prediction taps in the conventional class classification adaptation processing and the number of the prediction taps in the class classification adaptation processing for each region in the image processing device of the present invention, are 9, i.e., the same.

Referring to Fig. 139A through Fig. 141B, the results of the prediction in the covered background region will be described.

Fig. 139A is a diagram which illustrates an example of the image in the mixed region of the tutor image. Fig. 139B

is a diagram which indicates the change in pixel value corresponding to the position in the spatial direction in the image in the mixed region of the tutor image.

Fig. 140A is a diagram which illustrates an example of the image in the mixed region generated by the conventional class classification adaptation processing corresponding to the tutor image illustrated in Fig. 139A. Fig. 140B is a diagram which indicates the change in the pixel value corresponding to the position in the spatial direction in the image in the mixed region, generated by the conventional class classification adaptation processing, corresponding to the tutor image illustrated in Fig. 139A.

Fig. 141A is a diagram which illustrates an example of the image in the mixed region, generated by the separated image processing unit 4002 of which configuration is shown in Fig. 138, corresponding to the tutor image shown in Fig. 139A. Fig. 141B is a diagram which indicates the change in pixel value corresponding to the position in the spatial direction in the image in the mixed region, generated by the separated image processing unit 4002 of which configuration is shown in Fig. 138, corresponding to the tutor image shown in Fig. 139A.

The pixel values in the image in the mixed region, generated by the conventional class classification adaptation processing, change in a stepped manner, as

compared with the tutor image, and also are visually confirmed to change in a stepped manner in the actual generated image.

Conversely, the pixel values in the image in the mixed region, generated by the separated image processing unit 4002 of which configuration is shown in Fig. 138 change more smoothly as compared with conventional arrangement, and indicates change even closer to the tutor image. Also, in the event of visually confirming the image generated by the separated image processing unit 4002, the image is confirmed to be an even smoother image as compared with conventional arrangement.

The image in the mixed region, generated by the separated image processing unit 4002 of which configuration is shown in Fig. 138, changes more smoothly as compared with the image generated by the input image being divided into the foreground region, mixed region, or background region.

Referring to Fig. 142A through Fig. 144B, description will be made with regard to the results of the prediction in the foreground region wherein the pixel values change generally linearly with regard to the pixel position.

Fig. 142A is a diagram which illustrates an example of the image in the foreground region in the tutor image wherein the pixel values change generally linearly. Fig. 142B is a diagram which indicates change in the pixel value

corresponding to the position in the spatial direction in the image in the foreground region of the tutor image wherein the pixel values change generally linearly.

Fig. 143A is a diagram which illustrates an example of the image in the foreground region, corresponding to the image shown in Fig. 142A, generated by the conventional class classification adaptation processing. Fig. 143B is a diagram which indicates the change of the pixel values corresponding to the position in the spatial direction, in the image in the foreground region, corresponding to the image shown in Fig. 142A, generated by the conventional class classification adaptation processing.

Fig. 144A is a diagram which illustrates an example of the image in the foreground region corresponding to the image shown in Fig. 142A, generated by the separated image processing unit 4002 of which configuration is shown in Fig. 138. Fig. 144B is a diagram which indicates the change of the pixel values, corresponding to the position in the spatial direction, in the image in the foreground region, corresponding to the image shown in Fig. 142A, generated by the separated image processing unit 4002 of which configuration is shown in Fig. 138.

The pixel values in the image in the foreground region generated by the conventional class classification adaptation processing change in a stepped manner as compared

with the tutor image in the same manner as the mixed region, and the change in a stepped manner can be visually recognized in the actual image.

Conversely, the pixel values in the image in the foreground region generated by the separated image processing unit 4002 of which configuration is shown in Fig. 138 change more smoothly as compared with conventional arrangement, and are extremely close to the values in the tutor image. In the visual confirmation of the image generated by the separated image processing unit 4002, the difference between the image and the tutor image could not be observed.

Fig. 145 is a flowchart which describes the processing for the image by the image processing device of which configuration is shown in Fig. 133.

In Step S4001, the region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region, in the input image based upon the movement vector and the position information thereof supplied from the movement detecting unit 102 and the input image. The processing in Step S4001 is the same as the processing in Step S101, so description thereof will be omitted.

In Step S4002, the mixture ratio calculation unit 104 calculates the mixture ratio α based upon the region

information supplied from the region specifying unit 103, and the input image. The processing in Step S4002 is the same as the processing in Step S102, so description thereof will be omitted.

In Step S4003, the foreground/background separation unit 4001 separates the input image into the image in the foreground region, the image in the background region, the foreground component image in the covered background region, the background component image in the covered background region, the foreground component image in the uncovered background region, and the background component image in the uncovered background region, based upon the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio calculation unit 104. Details of the processing for the separation of the image by the foreground/background separation unit 4001 will be described later.

In Step S4004, the separated image processing unit 4002 performs image processing for each of the separated images, i.e., the image in the foreground region, the image in the background region, the foreground component image in the covered background region, the background component image in the covered background region, the foreground component image in the uncovered background region, and the background component image in the uncovered background region, and the

processing ends. Details of the image processing performed by the separated image processing unit 4002 will be described later.

As described above, the image processing device according to the present invention separates the input image into the image in the foreground region, the image in the background region, the foreground component image in the covered background region, the background component image in the covered background region, the foreground component image in the uncovered background region, and the background component image in the uncovered background region, and performs the image processing for each of the separated images, i.e., the image in the foreground region, the image in the background region, the foreground component image in the covered background region, the background component image in the covered background region, the foreground component image in the uncovered background region, and the background component image in the uncovered background region.

The separation processing of the foreground and the background by the foreground/background separation unit 4001 will now be described, with reference to the flowchart shown in Fig. 146. In Step S4101, the frame memory 4121 of the separation unit 4101 obtains the input image, and stores the frame #n which is the object of separation of the foreground

and the background, as well as the previous frame #n - 1 and the following frame #n + 1.

In Step S4102, the separation processing block 4122 of the separation unit 4101 obtains the region information supplied from the region specifying unit 103. In Step S4103, the separation processing block 4122 of the separation unit 4101 obtains the mixture ratio α supplied from the mixture ratio calculation unit 104.

In Step S4104, the uncovered region processing unit 4131 extracts the background components from the pixel value of the pixel belonging to the uncovered background region supplied from the frame memory 4121 based upon the region information and the mixture ratio α and outputs this as a background component image of the uncovered background region.

In Step S4105, the uncovered region processing unit 4131 extracts the foreground components from the pixel value of the pixel belonging to the uncovered background region supplied from the frame memory 4121 based upon the region information and the mixture ratio α and outputs this as a foreground component image of the uncovered background region.

In Step S4106, the covered region processing unit 4132 extracts the background components from the pixel value of the pixel belonging to the covered background region

supplied from the frame memory 4121 based upon the region information and the mixture ratio α and outputs this as a background component image of the covered background region.

In Step S4107, the covered region processing unit 4132 extracts the foreground components from the pixel value of the pixel belonging to the covered background region supplied from the frame memory 4121 based upon the region information and the mixture ratio α and outputs this as a foreground component image of the covered background region, and the processing ends.

In this way, the foreground/background separation unit 4001 can separate the foreground component and the background component from the input image, based upon the region information and the mixture ratio α, and output a foreground component image consisting only of foreground components, and a background component image consisting only of background components.

The learning processing for the separated image processing unit 4002, of which the configuration is shown in Fig. 137, to generate coefficient sets used for predicting pixel values from the class classification adaptation processing, will be described with reference to the flowchart in Fig. 147.

In Step S4201, the weighting averaging units 4207-1 through 4207-6 generate student images of the background

region image, the foreground region image, the background component image of the uncovered background region, the foreground component image of the uncovered background region, the background component image of the covered background region, and the foreground component image of the covered background region. That is to say, the weighting averaging unit 4207-1 performs, for example, one-quarter weighting averaging of a background region image of a tutor image stored in background region tutor image frame memory 4201, and generates a student image corresponding to the background region of the tutor image.

The weighting averaging unit 4207-2 performs, for example, one-quarter weighting averaging of a background component image in an uncovered background region image of a tutor image stored in uncovered background region background component tutor image frame memory 4202, and generates a student image corresponding to the background component image in the uncovered background region of the tutor image.

The weighting averaging unit 4207-3 performs, for example, one-quarter weighting averaging of a foreground component image in an uncovered background region of a tutor image stored in uncovered background region foreground component tutor image frame memory 4203, and generates a student image corresponding to the foreground component image in the uncovered background region of the tutor image.

The weighting averaging unit 4207-4 performs, for example, one-quarter weighting averaging of a background component image in a covered background region of a tutor image stored in covered background region background component tutor image frame memory 4204, and generates a student image corresponding to the background component image in the covered background region of the tutor image.

The weighting averaging unit 4207-5 performs, for example, one-quarter weighting averaging of a foreground component image in a covered background region of a tutor image stored in covered background region foreground component tutor image frame memory 4205, and generates a student image corresponding to the foreground component image in the covered background region of the tutor image.

The weighting averaging unit 4207-6 performs, for example, one-quarter weighting averaging of a foreground region image of a tutor image stored in foreground region tutor image frame memory 4206, and generates a student image corresponding to the foreground region image of the tutor image.

In Step S4202, the learning unit 4214-1 generates a coefficient set corresponding to the background region, based on the background region image of the tutor image stored in the background region tutor image frame memory 4201, and the student image corresponding to the background

region image of the tutor image stored in the background region student image frame memory 4208.

In Step S4203, the learning unit 4214-2 generates a coefficient set corresponding to the background component image of the uncovered background region, based on the background component image of the uncovered background region of the tutor image which is stored in uncovered background region background component tutor image frame memory 4202, and the student image, corresponding to the background component image of the uncovered background region of the tutor image, which is stored in uncovered background region background component student image frame memory 4209.

In Step S4204, the learning unit 4214-3 generates a coefficient set corresponding to the foreground component image of the uncovered background region, based on the foreground component image of the uncovered background region of the tutor image which is stored in uncovered background region foreground component tutor image frame memory 4203, and the student image, corresponding to the foreground component image of the uncovered background region of the tutor image, which is stored in uncovered background region foreground component student image frame memory 4210.

In Step S4205, the learning unit 4214-4 generates a

coefficient set corresponding to the background component image of the covered background region, based on the background component image of the covered background region of the tutor image which is stored in covered background region background component tutor image frame memory 4204, and the student image, corresponding to the background component image of the covered background region of the tutor image, which is stored in covered background region background component student image frame memory 4211.

In Step S4206, the learning unit 4214-5 generates a coefficient set corresponding to the foreground component image of the covered background region, based on the foreground component image of the covered background region of the tutor image which is stored in covered background region foreground component tutor image frame memory 4205, and the student image, corresponding to the foreground component image of the covered background region of the tutor image, which is stored in covered background region foreground component student image frame memory 4212.

In Step S4207, the learning unit 4214-6 generates a coefficient set corresponding to the foreground region, based on the foreground region image of the tutor image stored in the foreground region tutor image frame memory 4206, and the student image corresponding to the foreground region image of the tutor image stored in the foreground

region student image frame memory 4213.

In Step S4208, the learning units 4214-1 through 4214-6 respectively output a coefficient set corresponding to the background region, a coefficient set corresponding to the background component image of the uncovered background region, a coefficient set corresponding to the foreground component image of the uncovered background region, a coefficient set corresponding to the background component image of the covered background region, a coefficient set corresponding to the foreground component image of the covered background region, and a coefficient set corresponding to the foreground region, to coefficient set memory 4215. The coefficient set memory 4215 stores the coefficient sets corresponding to the background region, the foreground region, the background component image of the uncovered background region, the foreground component image of the uncovered background region, the background component image of the covered background region, and the foreground component image of the covered background region, respectively, and the processing ends.

Thus, the separated image processing unit 4002 of which configuration is shown in Fig. 137 can generate a coefficient set corresponding to the background region, a coefficient set corresponding to the background component image of the uncovered background region, a coefficient set

corresponding to the foreground component image of the uncovered background region, a coefficient set corresponding to the background component image of the covered background region, a coefficient set corresponding to the foreground component image of the covered background region, and a coefficient set corresponding to the foreground region image.

The details of the processing in Step S4202 through Step S4207 are the same as the processing described with reference to the flowchart in Fig. 103, so description thereof will be omitted.

Further, it is needless to say that the processing in Step S4202 through Step S4207 can be performed in a serial manner or in a parallel manner.

Next, the processing for the separated image processing unit 4002 of which the configuration is shown in Fig. 138 to create images will be described with reference to the flowchart in Fig. 148.

In Step S4301, the mapping unit 4307-1 predicts an image corresponding to the background region image stored in the background region frame memory 4301 by class classification adaptation processing, based on the coefficient set corresponding to the background region which is stored in the coefficient set memory 4308.

In Step S4302, the mapping unit 4307-2 predicts an image corresponding to the background component image of the

uncovered background region which is stored in uncovered background region background component image frame memory 4302 by class classification adaptation processing, based on the coefficient set corresponding to the background component image of the uncovered background region which is stored in coefficient set memory 4308.

In Step S4303, the mapping unit 4307-3 predicts an image corresponding to the foreground component image of the uncovered background region which is stored in uncovered background region foreground component image frame memory 4303 by class classification adaptation processing, based on the coefficient set corresponding to the foreground component image of the uncovered background region which is stored in coefficient set memory 4308.

In Step S4304, the mapping unit 4307-4 predicts an image corresponding to the background component image of the covered background region which is stored in covered background region background component image frame memory 4304 by class classification adaptation processing, based on the coefficient set corresponding to the background component image of the covered background region which is stored in coefficient set memory 4308.

In Step S4305, the mapping unit 4307-5 predicts an image corresponding to the foreground component image of the covered background region which is stored in covered

background region foreground component image frame memory 4305 by class classification adaptation processing, based on the coefficient set corresponding to the foreground component image of the covered background region which is stored in coefficient set memory 4308.

In Step S4306, the mapping unit 4307-6 predicts an image corresponding to the foreground region image stored in the foreground region frame memory 4306 by class classification adaptation processing, based on the coefficient set corresponding to the foreground region which is stored in the coefficient set memory 4308.

In Step S4307, the synthesizing unit 4309 synthesizes the predicted image corresponding to the background region image, the predicted image corresponding to the background component image of the uncovered background region, the predicted image corresponding to the foreground component image of the uncovered background region, the predicted image corresponding to the background component image of the covered background region, the predicted image corresponding to the foreground component image of the covered background region, and the predicted image corresponding to the foreground region. The synthesizing unit 4309 supplies the synthesized image to the frame memory 4310. The frame memory 4310 stores the synthesized image supplied from the synthesizing unit 4309.

In Step S4308, the frame memory 4310 outputs the synthesized image stored therein, and the processing ends.

Thus, an image processing device having the separated image processing unit 4002 of which configuration is shown in Fig. 138 can generate predicted images for each of the separated background region image, background component image of the uncovered background region, foreground component image of the uncovered background region, background component image of the covered background region, foreground component image of the covered background region, and foreground region image.

The details of the processing in Step S4301 through Step S4306 are the same as the processing described with reference to the flowchart in Fig. 109, so description thereof will be omitted.

Further, it is needless to say that the processing in Step S4301 through Step S4306 can be performed in a serial manner or in a parallel manner.

Fig. 149 is a block diagram illustrating the configuration of a separated image processing unit 4002 which applies edge enhancement processing with different effects to each of background region image, background component image of the uncovered background region, foreground component image of the uncovered background region, background component image of the covered background

region, foreground component image of the covered background region, and foreground region image.

The background region frame memory 4501 stores the background region image made up of pixels belonging to the background region, supplied from the foreground/background separation unit 4001. The background region frame memory 4501 supplies the stored background region image to the edge enhancing unit 4507-1.

The uncovered background region background component image frame memory 4502 stores the background component image of the uncovered background region, supplied from the foreground/background separation unit 4001. The uncovered background region background component image frame memory 4502 supplies the stored background component image of the uncovered background region to the edge enhancing unit 4507-2.

The uncovered background region foreground component image frame memory 4503 stores the foreground component image of the uncovered background region, supplied from the foreground/background separation unit 4001. The uncovered background region foreground component image frame memory 4503 supplies the stored foreground component image of the uncovered background region to the edge enhancing unit 4507-3.

The covered background region background component

image frame memory 4504 stores the background component image of the covered background region, supplied from the foreground/background separation unit 4001. The covered background region background component image frame memory 4504 supplies the stored background component image of the covered background region to the edge enhancing unit 4507-4.

The covered background region foreground component image frame memory 4505 stores the foreground component image of the covered background region, supplied from the foreground/background separation unit 4001. The covered background region foreground component image frame memory 4505 supplies the stored foreground component image of the covered background region to the edge enhancing unit 4507-5.

The foreground region frame memory 4506 stores the foreground region image made up of pixels belonging to the foreground region, supplied from the foreground/background separation unit 4001. The foreground region frame memory 4506 supplies the stored foreground region image to the edge enhancing unit 4507-6.

The edge enhancing unit 4507-1 applies edge enhancement processing suitable to the image of the background region, to the background region image stored in the background region frame memory 4501, and supplies the background region image which has been subjected to edge enhancement to the synthesizing unit 4508.

For example, the edge enhancing unit 4507-1 performs the processing of edge enhancement, which further enhances the edge for the background region image which is a still image, as compared with the foreground region. Thus, the sense-of-resolution of the background region image can be improved without unnatural degradation of the image occurring in the event of applying the processing of edge enhancement to a moving image.

The edge enhancing unit 4507-2 applies edge enhancement processing suitable to the background component image of the uncovered background region, to the image stored in the uncovered background region background component image frame memory 4502, and supplies the image which has been subjected to edge enhancement to the synthesizing unit 4508.

For example, the edge enhancing unit 4507-2 performs the processing of edge enhancement, which further enhances the edge for the background component image of the uncovered background region which is a still image, as compared with the foreground region. Thus, the sense-of-resolution of the background region image can be improved without unnatural degradation of the image occurring in the event of applying the processing of edge enhancement to a moving image.

The edge enhancing unit 4507-3 applies edge enhancement processing suitable to the foreground component image of the uncovered background region, to the image stored in the

uncovered background region foreground component image frame memory 4503, and supplies the image which has been subjected to edge enhancement to the synthesizing unit 4508.

For example, the edge enhancing unit 4507-3 performs the processing of edge enhancement, which enhances the edge for the foreground component image of the covered background region made up of moving foreground components less than as compared with the background region. Thus, the sense-of-resolution of the foreground component image of the covered background region can be improved without unnatural degradation of the image occurring in the event of applying the processing of edge enhancement to a moving image.

The edge enhancing unit 4507-4 applies edge enhancement processing suitable to the background component image of the covered background region, to the image stored in the covered background region background component image frame memory 4504, and supplies the image which has been subjected to edge enhancement to the synthesizing unit 4508.

For example, the edge enhancing unit 4507-4 performs the processing of edge enhancement, which further enhances the edge for the background component image of the covered background region which is a still image, as compared with the foreground region. Thus, the sense-of-resolution of the background region image can be improved without unnatural degradation of the image occurring in the event of applying

the processing of edge enhancement to a moving image.

The edge enhancing unit 4507-5 applies edge enhancement processing suitable to the foreground component image of the covered background region, to the image stored in the covered background region foreground component image frame memory 4505, and supplies the image which has been subjected to edge enhancement to the synthesizing unit 4508.

For example, the edge enhancing unit 4507-5 performs the processing of edge enhancement, which enhances the edge for the foreground component image of the covered background region made up of moving foreground components less than as compared with the background region. Thus, the sense-of-resolution of the foreground region image of the covered background region can be improved without unnatural degradation of the image occurring in the event of applying the processing of edge enhancement to a moving image.

The edge enhancing unit 4507-6 applies edge enhancement processing suitable to the foreground region image, to the foreground region image stored in the foreground region frame memory 4506, and supplies the foreground region image which has been subjected to edge enhancement to the synthesizing unit 4508.

For example, the edge enhancing unit 4507-6 performs the processing of edge enhancement, which enhances the edge of the moving foreground region image less than as compared

with the background region. Thus, the sense-of-resolution of the foreground region image can be improved without unnatural degradation of the image occurring in the event of applying the processing of edge enhancement to a moving image.

The synthesizing unit 4508 synthesizes the background region image subjected to edge enhancing that has been supplied from the edge enhancing unit 4507-1, the background component image of the uncovered background region subjected to edge enhancing that has been supplied from the edge enhancing unit 4507-2, the foreground component image of the uncovered background region subjected to edge enhancing that has been supplied from the edge enhancing unit 4507-3, the background component image of the covered background region subjected to edge enhancing that has been supplied from the edge enhancing unit 4507-4, the foreground component image of the covered background region subjected to edge enhancing that has been supplied from the edge enhancing unit 4507-5, and the foreground region image subjected to edge enhancing that has been supplied from the edge enhancing unit 4507-6, and supplies the synthesized image to the frame memory 4509.

The frame memory 4509 stores the synthesized image supplied from the synthesizing unit 4508, and also outputs the stored image as an output image.

Thus, the separated image processing unit 4002 of which

configuration is shown in Fig. 149 can apply edge enhancement processing corresponding to the image nature of each of the background region image, background component image of the uncovered background region, foreground component image of the uncovered background region, background component image of the covered background region, foreground component image of the covered background region, and foreground region image, so the sense-of-resolution of the foreground region image can be improved without unnatural degradation of the image occurring.

The edge enhancing units 4507-1 through 4507-6 have the same configuration as the edge enhancing unit 1203, so description thereof will be omitted.

Fig. 150 is a diagram explaining the processing of the separated image processing unit 4002 of which the configuration is shown in Fig. 149. The region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region, of the input image.

The input image regarding which the regions have been specified and the mixture ratio α has been detected by the mixture ratio calculation unit 104 is separated into a foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground

component image of the uncovered background region, and background component image of the uncovered background region, by the foreground/background separation unit 4001.

The separated image processing unit 4002 applies edge enhancement processing to each of the separated foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region.

The background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region, which have each been subjected to edge enhancement, are synthesized into one image.

Fig. 151 is a flowchart explaining the processing of images with the image processing device of which the configuration is indicated in Fig. 133.

In Step S4501, the region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region, of the input image, based on the movement vector and the position information thereof supplied from the movement detecting unit 102. The

processing in Step S4501 is the same as the processing in Step S4001, so description thereof will be omitted.

In Step S4502, the mixture ratio calculation unit 104 calculates the mixture ratio α based on the region information supplied from the region specifying unit 103 and the input image. The processing in Step S4502 is the same as the processing in Step S4002, so description thereof will be omitted.

In Step S4503, the foreground/background separation unit 4001 separates the input image into a foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region, based on the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio calculation unit 104. The processing in Step S4503 is the same as the processing in Step S4003, so description thereof will be omitted.

In Step S4504, the separated image processing unit 4002 applies edge enhancement processing to each of the separated foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground

component image of the uncovered background region, and background component image of the uncovered background region, and the processing ends. Details of the image processing which the separated image processing unit 4002 executes will be described later.

Thus, the image processing device according to the present invention separates an input image into a foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region, and executes edge enhancement processing for each separated foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region.

Next, the edge enhancement processing of the separated image processing unit 4002, corresponding to Step S4504, will be described with reference to the flowchart in Fig. 152.

In Step S4521, the edge enhancing unit 4507-1 performs edge enhancement of the background region image stored in

the background region frame memory 4501, by edge enhancement processing corresponding to the nature of the background region image.

In Step S4522, the edge enhancing unit 4507-2 performs edge enhancement of the background component image of the uncovered background region, stored in the uncovered background region background component image frame memory 4502, by edge enhancement processing corresponding to the nature of the background component image of the uncovered background region.

In Step S4523, the edge enhancing unit 4507-3 performs edge enhancement of the foreground component image of the uncovered background region, stored in the uncovered background region foreground component image frame memory 4503, by edge enhancement processing corresponding to the nature of the foreground component image of the uncovered background region.

In Step S4524, the edge enhancing unit 4507-4 performs edge enhancement of the background component image of the covered background region, stored in the covered background region background component image frame memory 4504, by edge enhancement processing corresponding to the nature of the background component image of the covered background region.

In Step S4525, the edge enhancing unit 4507-5 performs edge enhancement of the foreground component image of the

covered background region, stored in the covered background region foreground component image frame memory 4505, by edge enhancement processing corresponding to the nature of the foreground component image of the covered background region.

In Step S4526, the edge enhancing unit 4507-6 performs edge enhancement of the foreground region image stored in the foreground region frame memory 4506, by edge enhancement processing corresponding to the nature of the foreground region image.

In Step S4527, the synthesizing unit 4508 synthesizes the foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region, regarding which each has been subjected to edge enhancement. The synthesizing unit 4508 supplies the synthesized image to the frame memory 4509. The frame memory 4509 stores the image supplied from the synthesizing unit 4508.

In Step S4528, the frame memory 4509 outputs the synthesized image stored therein, and the processing ends.

Thus, the separated image processing unit 4002 of which the configuration shown in Fig. 149 can execute edge enhancement processing corresponding to the nature of each

of the foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region, so the sense-of-resolution can be improved without causing unnatural distortion in moving images.

Note that it is needless to say that the processing in Step S4521 through Step S4526 can be performed in a serial manner or in a parallel manner.

Fig. 153 is a block diagram illustrating another configuration of the functions of the image processing device for separating an input image and processing each separated image. While the image processing device shown in Fig. 133 performs region specification and calculation of the mixture ratio α serially, the image processing device shown in Fig. 153 performs region specification and calculation of the mixture ratio α in parallel.

Portions which are the same as the function in the block diagram shown in Fig. 133 are denoted with the same numerals, and description thereof will be omitted.

The input image is supplied to the object extracting unit 101, region specifying unit 103, mixture ratio calculation unit 3001, and foreground/background separation

unit 4601.

Based on an input image, the mixture ratio calculation unit 3001 calculates an estimated mixture ratio in a case wherein a pixel is assumed to belong to the covered background region, and an estimated mixture ratio in a case wherein the pixel is assumed to belong to the uncovered background region, for each of the pixels contained in the input image, and supplies the estimated mixture ratio in a case wherein the pixel is assumed to belong to the covered background region and the estimated mixture ratio in a case wherein the pixel is assumed to belong to the uncovered background region, thus calculated, to the foreground/background separation unit 4601.

Based on the estimated mixture ratio in a case wherein the pixel is assumed to belong to the covered background region and the estimated mixture ratio in a case wherein the pixel is assumed to belong to the uncovered background region, supplied from the mixture ratio calculation unit 3001, and the region information supplied from the region specifying unit 103, the foreground/background separation unit 4601 separates the input image into a foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component

image of the uncovered background region, and supplies the separated image to the separated image processing unit 4002.

Fig. 154 is a block diagram illustrating an example of the configuration of the foreground/background separation unit 4601.

Portions which are the same as the foreground/background separation unit 4001 shown in Fig. 135 are denoted with the same numeral, and description thereof will be omitted.

A selecting unit 4621 selects one or the other of the estimated mixture ratio in a case wherein the pixel is assumed to belong to the covered background region and the estimated mixture ratio in a case wherein the pixel is assumed to belong to the uncovered background region, supplied from the mixture ratio calculation unit 3001, based on the region information supplied from the region specifying unit 103, and supplies the selected estimated mixture ratio to the separation unit 4101 as mixture ratio α.

The separation unit 4101 extracts the foreground component and background component from the pixel values of the pixels belonging to the mixed region, based on the mixture ratio α supplied from the selecting unit 4621 and the region information, and separates into a background component image of the uncovered background region, a foreground component image of the uncovered background

region, a background component image of the covered background region, and a foreground component image of the covered background region.

The separation unit 4101 may have the same configuration as the configuration shown in Fig. 136.

Thus, the image processing device of which the configuration is shown in Fig. 153 is capable of executing processing for each of the foreground region image, background region image, foreground component image of the covered background region, background component image of the covered background region, foreground component image of the uncovered background region, and background component image of the uncovered background region, corresponding to the respective nature of each.

Fig. 155 is a block diagram illustrating yet another configuration of the functions of the image processing device.

Portions which are the same as those shown in Fig. 11 are denoted with the same numerals, and description thereof will be omitted.

The input image supplied to the image processing device is supplied to the object extracting unit 101, region specifying unit 103, and region processing unit 5001.

The object extracting unit 101 roughly extracts the image object corresponding to the foreground object

contained in the input image, and supplies the extracted image object to the movement detecting unit 102. The object extracting unit 101 roughly extracts the image object corresponding to the background object contained in the input image, and supplies the extracted image object to the movement detecting unit 102.

The movement detecting unit 102 calculates the movement vectors of the image object corresponding to the roughly extracted foreground objects by techniques such as block matching, gradation, phase correlation, and pixel recursion, or the like, and provides the calculated movement vectors and movement vector position information to the region specifying unit 103.

The region specifying unit 103 specifies each of the pixels of the image input, into foreground region, background region, or mixed region, and supplies region information indicating which of the foreground region, background region, or mixed region, that each pixel belongs to, to the region processing unit 5001.

The region processing unit 5001 divides the input image into each of the foreground region, background region, and mixed region, based on the region information supplied from the region specifying unit 103, and executes image processing for each of the divided input images. For example, the region processing unit 5001 divides the input

image into each of the foreground region, background region, and mixed region, and generates coefficients used for class classification adaptation processing for generating images with higher resolution, for each of the divided input images.

For example, the region processing unit 5001 divides the input image into each of the foreground region, background region, and mixed region, and creates images with higher resolution by applying class classification adaptation processing to each of the divided input images.

Fig. 156 is a diagram describing the processing of the region processing unit 5001 of which the configuration is shown in Fig. 155. The region processing unit 5001 individually calculates coefficient sets corresponding to the background region, coefficient sets corresponding to the uncovered background region, coefficient sets corresponding to the foreground region, and coefficient sets corresponding to the covered background region.

The coefficient sets corresponding to the background region are used for predicting pixel values in the background region, in the class classification adaptation processing for predicting pixel values. The coefficient sets corresponding to the uncovered background region are used for predicting pixel values in the uncovered background region, in the class classification adaptation processing for predicting pixel values.

The coefficient sets corresponding to the covered background region are used for predicting pixel values in the covered background region, in the class classification adaptation processing for predicting pixel values. The coefficient sets corresponding to the foreground region are used for predicting pixel values in the foreground region, in the class classification adaptation processing for predicting pixel values.

The predicted image corresponding to the background image, the predicted image corresponding to the uncovered background region, the predicted image corresponding to the covered background region, and the predicted image corresponding to the foreground image, are synthesized into one predicted image.

Fig. 157 is a block diagram illustrating the configuration of the region processing unit 5001 which generates coefficient sets used for class classification adaptation processing for generating images with higher resolution in the spatial direction. Tutor image frame memory 5101 stores input images which are HD images, for example, in increments of frames. The tutor image frame memory 5101 supplies the stored input image to a region dividing unit 5102.

The region dividing unit 5102 divides the tutor image into the background region, foreground region, covered

background region, or uncovered background region, based on the region information supplied from the region specifying unit 103.

The region dividing unit 5102 supplies images made up of pixels belonging to the background region of the tutor image, which is the divided tutor image, to background region tutor image frame memory 5103, supplies images made up of pixels belonging to the uncovered background region of the tutor image to uncovered background region tutor image frame memory 5104, supplies images made up of pixels belonging to the covered background region of the tutor image to covered background region tutor image frame memory 5105, and supplies images made up of pixels belonging to the foreground region of the tutor image to foreground region tutor image frame memory 5106.

The background region tutor image frame memory 5103 stores images made up of pixels belonging to the background region of the tutor image, supplied from the region dividing unit 5102. The background region tutor image frame memory 5103 supplies images made up of pixels belonging to the background region of the tutor image stored therein to a weighted averaging unit 5107-1 and learning unit 5112-1.

The uncovered background region tutor image frame memory 5104 stores images made up of pixels belonging to the uncovered background region of the tutor image, supplied

from the region dividing unit 5102. The uncovered background region tutor image frame memory 5104 supplies images made up of pixels belonging to the uncovered background region of the tutor image stored therein to a weighted averaging unit 5107-2 and learning unit 5112-2.

The covered background region tutor image frame memory 5105 stores images made up of pixels belonging to the covered background region of the tutor image, supplied from the region dividing unit 5102. The covered background region tutor image frame memory 5105 supplies images made up of pixels belonging to the covered background region of the tutor image stored therein to a weighted averaging unit 5107-3 and learning unit 5112-3.

The foreground region tutor image frame memory 5106 stores images made up of pixels belonging to the foreground region of the tutor image, supplied from the region dividing unit 5102. The foreground region tutor image frame memory 5106 supplies images made up of pixels belonging to the foreground region of the tutor image stored therein to a weighted averaging unit 5107-4 and learning unit 5112-4.

The weighted averaging unit 5107-1 performs one-quarter weighted averaging on the image made up of pixels belonging to the background region of the tutor image which is an HD image, for example, supplied from the background region tutor image frame memory 5103, so as to generate an SD image

which is a student image, and supplies the generated SD image to background region student image frame memory 5108.

The background region student image frame memory 5108 stores student images corresponding to the image made up of pixels belonging to the background region of the tutor image supplied from the weighted averaging unit 5107-1. The background region student image frame memory 5108 supplies the student image corresponding to the image made up of pixels belonging to the background region of the tutor image stored therein, to the learning unit 5112-1.

The weighted averaging unit 5107-2 performs one-quarter weighted averaging, for example, on the image made up of pixels belonging to the uncovered background region of the tutor image which is an HD image, supplied from the uncovered background region tutor image frame memory 5104, so as to generate an SD image which is a student image, and supplies the generated SD image to uncovered background region student image frame memory 5109.

The uncovered background region student image frame memory 5109 stores student images which are SD images corresponding to the image made up of pixels belonging to the uncovered background region of the tutor image supplied from the weighted averaging unit 5107-2. The uncovered background region student image frame memory 5109 supplies the student image corresponding to the image made up of

pixels belonging to the uncovered background region of the tutor image stored therein, to the learning unit 5112-2.

The weighted averaging unit 5107-3 performs one-quarter weighted averaging, for example, on the image made up of pixels belonging to the covered background region of the tutor image, supplied from the covered background region tutor image frame memory 5105, so as to generate an SD image which is a student image, and supplies the generated SD image to covered background region student image frame memory 5110.

The covered background region student image frame memory 5110 stores student images which are SD images corresponding to the image made up of pixels belonging to the covered background region of the tutor image supplied from the weighted averaging unit 5107-3. The covered background region student image frame memory 5110 supplies the student image corresponding to the image made up of pixels belonging to the covered background region of the tutor image stored therein, to the learning unit 5112-3.

The weighted averaging unit 5107-4 performs one-quarter weighted averaging on the image made up of pixels belonging to the foreground region of the tutor image which is an HD image, for example, supplied from the foreground region tutor image frame memory 5106, so as to generate an SD image which is a student image, and supplies the generated SD

image to foreground region student image frame memory 5111.

The foreground region student image frame memory 5111 stores student images which are SD images corresponding to the image made up of pixels belonging to the foreground region of the tutor image supplied from the weighted averaging unit 5107-4. The foreground region student image frame memory 5111 supplies the student image corresponding to the image made up of pixels belonging to the foreground region of the tutor image stored therein, to the learning unit 5112-4.

The learning unit 5112-1 generates a coefficient set corresponding to the background region, based on the image made up of pixels belonging to the background region of the tutor image supplied from the background region tutor image frame memory 5103 and the student image corresponding to the image made up of pixels belonging to the background region of the tutor image supplied from the background region student image frame memory 5108, and supplies the generated coefficient set to coefficient set memory 5113.

The learning unit 5112-2 generates a coefficient set corresponding to the uncovered background region, based on the image made up of pixels belonging to the uncovered background region of the tutor image supplied from the uncovered background region tutor image frame memory 5104 and the student image corresponding to the image made up of

pixels belonging to the uncovered background region of the tutor image supplied from the uncovered background region student image frame memory 5109, and supplies the generated coefficient set to coefficient set memory 5113.

The learning unit 5112-3 generates a coefficient set corresponding to the covered background region, based on the image made up of pixels belonging to the covered background region of the tutor image supplied from the covered background region tutor image frame memory 5105 and the student image corresponding to the image made up of pixels belonging to the covered background region of the tutor image supplied from the covered background region student image frame memory 5110, and supplies the generated coefficient set to coefficient set memory 5113.

The learning unit 5112-4 generates a coefficient set corresponding to the foreground region, based on the image made up of pixels belonging to the foreground region of the tutor image supplied from the foreground region tutor image frame memory 5106 and the student image corresponding to the image made up of pixels belonging to the foreground region of the tutor image supplied from the foreground region student image frame memory 5111, and supplies the generated coefficient set to coefficient set memory 5113.

The coefficient set memory 5113 stores the coefficient set corresponding to the background region supplied from the

learning unit 5112-1, the coefficient set corresponding to the uncovered background region supplied from the learning unit 5112-2, the coefficient set corresponding to the covered background region supplied from the learning unit 5112-3, and the coefficient set corresponding to the foreground region supplied from the learning unit 5112-4.

The learning unit 5112-1 through learning unit 5112-4 have the same configuration as the learning unit 1006, so description thereof will be omitted.

Fig. 158 is a block diagram illustrating the configuration of a region processing unit 5001 for executing class classification adaptation processing, and generating images with higher resolution in the spatial direction. The frame memory 5201 stores input images which are SD images, for example, in increments of frames. The frame memory 5201 supplies the stored input images to the region dividing unit 5202.

The region dividing unit 5202 divides the input image into the background region, foreground region, covered background region, or uncovered background region, based on the region information supplied from the region specifying unit 103. That is to say, the region dividing unit 5202 takes the divided input image and supplies an image made up of pixels belonging to the background region to the background region frame memory 5203, supplies an image made

up of pixels belonging to the uncovered background region to the uncovered background region frame memory 5204, supplies an image made up of pixels belonging to the covered background region to the covered background region frame memory 5205, and supplies an image made up of pixels belonging to the foreground region to the foreground region frame memory 5206.

The background region frame memory 5203 stores the image made up of pixels belonging to the background region, supplied from the region dividing unit 5202. The background region frame memory 5203 supplies the image made up of pixels belonging to the background region stored therein, to the mapping unit 5207-1.

The uncovered background region frame memory 5204 stores the image made up of pixels belonging to the uncovered background region, supplied from the region dividing unit 5202. The uncovered background region frame memory 5204 supplies the image made up of pixels belonging to the uncovered background region stored therein, to the mapping unit 5207-2.

The covered background region frame memory 5205 stores the image made up of pixels belonging to the covered background region, supplied from the region dividing unit 5202. The covered background region frame memory 5205 supplies the image made up of pixels belonging to the

covered background region stored therein, to the mapping unit 5207-3.

The foreground region frame memory 5206 stores the image made up of pixels belonging to the foreground region, supplied from the region dividing unit 5202. The foreground region frame memory 5206 supplies the image made up of pixels belonging to the foreground region stored therein, to the mapping unit 5207-4.

The mapping unit 5207-1 generates a predicted image corresponding to the image made up of pixels belonging to the background region stored in the background region frame memory 5203 by class classification adaptation processing, based on the coefficient set corresponding to the background region, stored in the coefficient set memory 5208. The mapping unit 5207-1 supplies the generated predicted image to a synthesizing unit 5209.

The mapping unit 5207-2 generates a predicted image corresponding to the image made up of pixels belonging to the uncovered background region stored in the uncovered background region frame memory 5204 by class classification adaptation processing, based on the coefficient set corresponding to the uncovered background region, stored in the coefficient set memory 5208. The mapping unit 5207-2 supplies the generated predicted image to the synthesizing unit 5209.

The mapping unit 5207-3 generates a predicted image corresponding to the image made up of pixels belonging to the covered background region stored in the covered background region frame memory 5205 by class classification adaptation processing, based on the coefficient set corresponding to the covered background region, stored in the coefficient set memory 5208. The mapping unit 5207-3 supplies the generated predicted image to the synthesizing unit 5209.

The mapping unit 5207-4 generates a predicted image corresponding to the image made up of pixels belonging to the foreground region stored in the foreground region frame memory 5206 by class classification adaptation processing, based on the coefficient set corresponding to the foreground region, stored in the coefficient set memory 5208. The mapping unit 5207-4 supplies the generated predicted image to the synthesizing unit 5209.

The synthesizing unit 5209 synthesizes the predicted image corresponding to the image made up of pixels belonging to the background region that has been supplied from the mapping unit 5207-1, the predicted image corresponding to the image made up of pixels belonging to the uncovered background region that has been supplied from the mapping unit 5207-2, the predicted image corresponding to the image made up of pixels belonging to the covered background region

that has been supplied from the mapping unit 5207-3, and the predicted image corresponding to the image made up of pixels belonging to the foreground region that has been supplied from the mapping unit 5207-4, and supplies the synthesized predicted image to frame memory 5210.

The frame memory 5210 stores the predicted images supplied from the synthesizing unit 5209, and also outputs the stored images as output images.

The mapping unit 5207-1 through mapping unit 5207-4 have the same configuration as the mapping unit 1103, and accordingly description thereof will be omitted.

An example of the results of processing my the image processing device according to the present invention having the region processing unit 5001 of which configuration is shown in Fig. 158 will be described with reference to the images shown in Fig. 159A through Fig. 164B.

In the processing for generating the results shown in the example, the sum of the number of classes in the class classification adaptation processing of the image processing device according to the present invention is the same as the number of classes in conventional class classification adaptation processing. That is, the number of classes in conventional class classification adaptation processing is 2048, and the number of classes in the class classification adaptation processing for each of the regions with the image

processing device according to the present invention is 3112.

Also, the number of prediction taps in the conventional class classification adaptation processing and the number of prediction taps in the class classification adaptation processing for each of the regions with the image processing device according to the present invention is nine, which is the same.

The results of prediction for the covered background region will be described with reference to Fig. 159A through Fig. 161B.

Fig. 159A is a diagram illustrating an example of an image in the mixed region of a tutor image. Fig. 159B is a diagram illustrating the change of pixel values corresponding to the position in the spatial direction of the image in the mixed region of the tutor image.

Fig. 160A is a diagram illustrating an example of an image in the mixed region, generated by conventional class classification adaptation processing, corresponding to the tutor image shown in Fig. 159A. Fig. 160B is a diagram illustrating the change of pixel values corresponding to the position in the spatial direction of the image in the mixed region, generated by conventional class classification adaptation processing, corresponding to the tutor image shown in Fig. 159A.

Fig. 161A is a diagram illustrating an example of an

image in the mixed region, generated by the region processing unit 5001 of which the configuration is shown in Fig. 158, corresponding to the tutor image shown in Fig 159A. Fig. 161B is a diagram illustrating the change of pixel values corresponding to the spatial direction of the image in the mixed region, generated by the region processing unit 5001 of which the configuration is shown in Fig. 158, corresponding to the tutor image shown in Fig 159A.

The pixel values in the image in the mixed region, generated by the conventional class classification adaptation processing, change in a stepped manner, as compared with the tutor image, and also are visually confirmed to change in a stepped manner in the actually-generated image.

Conversely, the pixel values in the image in the mixed region, generated by the region processing unit 5001 of which configuration is shown in Fig. 158, change more smoothly as compared with conventional arrangement, and indicates change even closer to the tutor image. Also, in the event of visually confirming the image generated by the region processing unit 5001, the image is confirmed to be an even smoother image as compared with the conventional arrangement.

Referring to Fig. 162A through Fig. 164B, description will be made with regard to the results of the prediction in

the foreground region wherein the pixel values change generally linearly with regard to the pixel position.

Fig. 162A is a diagram which illustrates an example of the image in the foreground region in the tutor image wherein the pixel values change generally linearly. Fig. 162B is a diagram which indicates change in pixel value corresponding to the position in the spatial direction in the image in the foreground region of the tutor image wherein the pixel values change generally linearly.

Fig. 163A is a diagram which illustrates an example of the image in the foreground region, corresponding to the image shown in Fig. 162A, generated by the conventional class classification adaptation processing. Fig. 163B is a diagram which indicates the change in pixel value corresponding to the position in the spatial direction, in the image in the foreground region, corresponding to the image shown in Fig. 162A, generated by the conventional class classification adaptation processing.

Fig. 164A is a diagram which illustrates an example of the image in the foreground region corresponding to the image shown in Fig. 162A, generated by the region processing unit 5001 of which configuration is shown in Fig. 158. Fig. 164B is a diagram which indicates the change in pixel value, corresponding to the position in the spatial direction, in the image in the foreground region, corresponding to the

image shown in Fig. 162A, generated by the region processing unit 5001 of which configuration is shown in Fig. 158.

The pixel values in the image in the foreground region generated by the conventional class classification adaptation processing change in a stepped manner as compared with the tutor image in the same manner as the mixed region, and the change in a stepped manner can be visually recognized in the actual image.

Conversely, the pixel values in the image in the foreground region generated by the region processing unit 5001 of which configuration is shown in Fig. 158, change more smoothly as compared with conventional arrangement, and are extremely close to the values in the tutor image. In visual confirmation of the image generated by the region processing unit 5001, difference between the image and the tutor image could not be observed.

Also, the SN ratio at each of the regions of the image generated by conventional class classification adaptation processing and the SN ratio at each of the regions of the image generated by class classification adaptation processing with the image processing device according to the present invention are obtained and compared.

The SN ratio in the covered background region of the image generated by conventional class classification adaptation processing was 32.1716 dB, the SN ratio in the

uncovered background region was 31.8744 dB, the SN ratio in the foreground region was 31.8835 dB, and the SN ratio in the background region was 31.9985 dB.

Conversely, the SN ratio in the covered background region of the image generated by the image processing device according to the present invention was 32.1799 dB, the SN ratio in the uncovered background region was 31.8922 dB, the SN ratio in the foreground region was 32.0925 dB, and the SN ratio in the background region was 32.0177 dB.

In this way, the SN ratio in images generated by the image processing device according to the present invention were higher than the SN ratio of images generated by conventional class classification adaptation processing in all of the regions.

Fig. 165 is a flowchart explaining the processing of images with the image processing device of which configuration is shown in Fig. 155.

In Step S5001, the region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region, in the input image, based on the movement vector and the positional information thereof supplied from the movement detecting unit 102. The processing in Step S5001 is the same as the processing in Step S101, so description thereof will be omitted.

In Step S5002, the region processing unit 5001 divides

the input image into the foreground region, background region, covered background region, and uncovered background region, which have been specified, and executes image processing for the foreground region, background region, and covered background region, and uncovered background region, which have been divided, and the processing ends.

In this way, the image processing device according to the present invention divides the input image into the foreground region, background region, covered background region, and uncovered background region, and executes image processing for each of the foreground region, background region, covered background region, and uncovered background region, which have been divided.

The learning processing for generating coefficient sets used for prediction of pixel values in the class classification adaptation processing by the region processing unit 5001, of which configuration is shown in Fig. 157, will be described with reference to the flowchart shown in Fig. 166.

In Step S5101, the region dividing unit 5102 divides the tutor image stored in the tutor image frame memory 5101, based on the region information supplied from the region specifying unit 103. That is, the region dividing unit 5102 supplies images made up of pixels belonging to the background region of the tutor image, which is the divided

tutor image, to background region tutor image frame memory 5103. The region dividing unit 5102 supplies images made up of pixels belonging to the uncovered background region of the tutor image, which is the divided tutor image to uncovered background region tutor image frame memory 5104.

The region dividing unit 5102 supplies images made up of pixels belonging to the covered background region of the tutor which is the divided tutor image to covered background region tutor image frame memory 5105. The region dividing unit 5102 supplies images made up of pixels belonging to the foreground region of the tutor which is the divided tutor image to foreground region tutor image frame memory 5106.

In Step S5102, weighted averaging units 5107-1 through 5107-4 generate student images for the background region, foreground region, uncovered background region, and covered background region. That is to say, the weighted averaging unit 5107-1 performs one-quarter weighted averaging, for example, on the image made up of pixels belonging to the background region of the tutor image, stored in background region tutor image frame memory 5103, so as to generate a student image corresponding to the image made up of pixels belonging to the background region of the tutor image. The weighted averaging unit 5107-2 performs one-quarter weighted averaging, for example, on the image made up of pixels belonging to the uncovered background region of the tutor

image, stored in uncovered background region tutor image frame memory 5104, so as to generate a student image corresponding to the image made up of pixels belonging to the uncovered background region of the tutor image.

The weighted averaging unit 5107-3 performs one-quarter weighted averaging, for example, on the image made up of pixels belonging to the covered background region of the tutor image, stored in covered background region tutor image frame memory 5105, so as to generate an image made up of pixels belonging to the covered background region of the tutor image. The weighted averaging unit 5107-4 performs one-quarter weighted averaging, for example, on the image made up of pixels belonging to the foreground region of the tutor image, stored in foreground region tutor image frame memory 5106, so as to generate a student image corresponding to the image made up of pixels belonging to the foreground region of the tutor image.

In Step S5103, the learning unit 5112-1 generates a coefficient set corresponding to the background region, based on the image made up of pixels belonging to the background region of the tutor image stored in the background region tutor image frame memory 5103 and the student image corresponding to the image made up of pixels belonging to the background region of the tutor image stored in the background region student image frame memory 5108.

In Step S5104, the learning unit 5112-2 generates a coefficient set corresponding to the uncovered background region, based on the image made up of pixels belonging to the uncovered background region of the tutor image stored in the uncovered background region tutor image frame memory 5104 and the student image corresponding to the image made up of pixels belonging to the uncovered background region of the tutor image stored in the uncovered background region student image frame memory 5109.

In Step S5105, the learning unit 5112-3 generates a coefficient set corresponding to the covered background region, based on the image made up of pixels belonging to the covered background region of the tutor image stored in the covered background region tutor image frame memory 5105 and the student image corresponding to the image made up of pixels belonging to the covered background region of the tutor image stored in the covered background region student image frame memory 5110.

In Step S5106, the learning unit 5112-4 generates a coefficient set corresponding to the foreground region, based on the image made up of pixels belonging to the foreground region of the tutor image stored in the foreground region tutor image frame memory 5106 and the student image corresponding to the image made up of pixels belonging to the foreground region of the tutor image stored

in the foreground region student image frame memory 5111.

In Step S5107, the learning units 5112-1 through 5112-4 supply the coefficient set corresponding to the background region, the coefficient set corresponding to the uncovered background region, the coefficient set corresponding to the covered background region, and the coefficient set corresponding to the foreground region, to the coefficient set memory 5113. The coefficient set memory 5113 stores the coefficient sets corresponding to each of the background region, the foreground region, the uncovered background region, and the covered background region, and the processing ends.

In this way, the region processing unit 5001 of which configuration is shown in Fig. 157 can generate coefficient sets corresponding to the background region, coefficient sets corresponding to the uncovered background region, coefficient sets corresponding to the covered background region, and coefficient sets corresponding to the foreground region.

The details of processing in Step S5103 through Step S5106 are the same as the processing described with reference to the flowchart shown in Fig. 103, and accordingly, description thereof will be omitted.

Further, it is needless to say that the processing in Step S5103 through Step S5106 can be performed in a serial

manner or in a parallel manner.

Next, the processing for creating images with the region processing unit 5001 of which configuration is shown in Fig. 158 will be described with reference to the flowchart shown in Fig. 167.

In Step S5201, the region dividing unit 5202 divides the input image into the background region, foreground region, covered background region, or uncovered background region, based on the region information supplied from the region specifying unit 103. That is to say, the region dividing unit 5202 takes the divided input image and supplies an image made up of pixels belonging to the background region to the background region frame memory 5203, supplies an image made up of pixels belonging to the uncovered background region to the uncovered background region frame memory 5204, supplies an image made up of pixels belonging to the covered background region to the covered background region frame memory 5205, and supplies an image made up of pixels belonging to the foreground region to the foreground region frame memory 5206.

In Step S5202, the mapping unit 5207-1 predicts an image corresponding to the image made up of pixels belonging to the background region stored in the background region frame memory 5203 by class classification adaptation processing, based on the coefficient set corresponding to

the background region, stored in the coefficient set memory 5208.

In Step S5203, the mapping unit 5207-2 predicts an image corresponding to the image made up of pixels belonging to the uncovered background region stored in the uncovered background region frame memory 5204 by class classification adaptation processing, based on the coefficient set corresponding to the uncovered background region, stored in the coefficient set memory 5208.

In Step S5204, the mapping unit 5207-3 predicts an image corresponding to the image made up of pixels belonging to the covered background region stored in the covered background region frame memory 5205 by class classification adaptation processing, based on the coefficient set corresponding to the covered background region, stored in the coefficient set memory 5208.

In Step S5205, the mapping unit 5207-4 predicts an image corresponding to the image made up of pixels belonging to the foreground region stored in the foreground region frame memory 5206 by class classification adaptation processing, based on the coefficient set corresponding to the foreground region, stored in the coefficient set memory 5208.

In Step S5206, the synthesizing unit 5209 synthesizes the predicted image corresponding to the image made up of

pixels belonging to the background region, the predicted image corresponding to the image made up of pixels belonging to the uncovered background region, the predicted image corresponding to the image made up of pixels belonging to the covered background region, and the predicted image corresponding to the foreground region. The synthesizing unit 5209 supplies the synthesized image to frame memory 5210. The frame memory 5210 stores the image supplied from the synthesizing unit 5209.

In Step S5207, the frame memory 5210 outputs the stored predicted images output, and the processing ends.

In this way, the image processing device having the region processing unit 5001 of which configuration is shown in Fig. 158 can divide input images for each of the background region, the uncovered background region, the covered background region, and the foreground region, and generate predicted images for each divided image.

The details of processing in Step S5202 through Step S5205 are the same as the processing described with reference to the flowchart shown in Fig. 109, and accordingly, description thereof will be omitted.

Further, it is needless to say that the processing in Step S5202 through Step S5205 can be performed in a serial manner or in a parallel manner.

Also, the processing executed by the movement-blurring-

removed-image processing unit 108, the separated image processing unit 4002, and the region processing unit 5001 is not restricted to the generating of the coefficients corresponding to an SD image and an HD image, or the processing for generating of an HD image from an SD image, and an arrangement may be made wherein an even higher resolution image in the spatial direction is generated by generating the coefficients for generating an even higher resolution image in the spatial direction, for example. Moreover, an arrangement may be made wherein the movement-blurring-removed-image processing unit 108, the separated image processing unit 4002, and the region processing unit 5001 perform processing for generating an even higher resolution image in the time direction.

Note that an arrangement may be made wherein the movement-blurring-removed-image processing unit 108, the separated image processing unit 4002, and the region processing unit 5001, generate coefficients from predetermined information, and execute class classification adaptation processing based on the generated coefficients.

Also, an arrangement may be made wherein the movement-blurring-removed-image processing unit 108, the separated image processing unit 4002, and the region processing unit 5001 perform other processing, e.g., image size conversion into a desired size, extracting of color signals such as RGB,

noise removal, image compressing, encoding, etc., based on class classification processing. For example, the compression ratio can be increased with little deterioration of the image over conventional arrangements, by the movement-blurring-removed-image processing unit 108, the separated image processing unit 4002, and the region processing unit 5001, compressing images of each of the regions with low compression ratio in directions following movement vectors and high compression ratio in directions orthogonal to movement vectors, based on movement vectors corresponding to the classes into which classification has been made and each of the images.

Fig. 168 is a block diagram which illustrates another configuration of the region processing unit 5001 for applying the edge enhancement processing having different effects to each of the background region, the uncovered background region, the covered background region, or the foreground region.

The frame memory 5501 stores the input image in increments of frames. The frame memory 5501 supplies the input image stored therein to the region dividing unit 5502.

The region dividing unit 5502 divides the input image into the background region, foreground region, covered background region, or uncovered background region, based on the region information supplied from the region specifying

unit 103. That is to say, the region dividing unit 5502 takes the divided input image and supplies a background image made up of pixels belonging to the background region to the background region frame memory 5503, supplies an image made up of pixels belonging to the uncovered background region to the uncovered background region frame memory 5504, supplies an image made up of pixels belonging to the covered background region to the covered background region frame memory 5505, and supplies a foreground image made up of pixels belonging to the foreground region to the foreground region frame memory 5506.

The background region frame memory 5503 stores the background image made up of pixels belonging to the background region, supplied from the region dividing unit 5502. The background region frame memory 5503 supplies the background image stored therein, to the edge enhancing unit 5507-1.

The uncovered background region frame memory 5504 stores the image made up of pixels belonging to the uncovered background region, supplied from the region dividing unit 5502. The uncovered background region frame memory 5504 supplies the image made up of pixels belonging to the uncovered background region stored therein, to the edge enhancing unit 5507-2.

The covered background region frame memory 5505 stores

the image made up of pixels belonging to the covered background region, supplied from the region dividing unit 5502. The covered background region frame memory 5505 supplies the image made up of pixels belonging to the covered background region stored therein, to the edge enhancing unit 5507-3.

The foreground region frame memory 5506 stores the foreground image made up of pixels belonging to the foreground region, supplied from the region dividing unit 5502. The foreground region input image frame memory 5506 supplies the foreground image stored therein, to the edge enhancing unit 5507-4.

The edge enhancing unit 5507-1 applies processing for edge enhancement suitable for the background image, to the background image stored in the background region frame memory 5503, and supplies the background image that has been subjected to edge enhancement to the synthesizing unit 5508.

For example, the edge enhancing unit 5507-1 executes edge enhancing processing for enhancing the edges of the background image, which is a still image, more than as compared with the uncovered background region, covered background region, or foreground region. Thus, the sense-of-resolution of the background image can be improved even further, without causing unnatural image deterioration upon application of edge enhancement processing to moving images.

The edge enhancing unit 5507-2 applies edge enhancement processing suitable for the uncovered background image, to the image stored in the uncovered background region frame memory 5504, and supplies the image that has been subjected to edge enhancement to the synthesizing unit 5508.

For example, the edge enhancing unit 5507-2 executes edge enhancing processing for enhancing the edges of the uncovered background image, which is an image containing moving foreground components, to a degree less than as compared with the background region. Thus, unnatural image deterioration upon application of edge enhancement processing to moving images can be reduced, while improving the sense-of-resolution, in uncovered background region images.

The edge enhancing unit 5507-3 applies edge enhancement processing suitable for the covered background region image, to the image stored in the covered background region frame memory 5505, and supplies the image that has been subjected to edge enhancement to the synthesizing unit 5508.

For example, the edge enhancing unit 5507-3 executes edge enhancing processing for enhancing the edges of the covered background image, which is an image containing moving foreground components, to a degree less than as compared with the background region. Thus, unnatural image deterioration upon application of edge enhancement

processing to moving images can be reduced, while improving the sense-of-resolution, in covered background region images.

The edge enhancing unit 5507-4 applies edge enhancement processing suitable for the foreground image, to the foreground image stored in the foreground region frame memory 5506, and supplies the foreground image that has been subjected to edge enhancement to the synthesizing unit 5508.

For example, the edge enhancing unit 5507-4 executes edge enhancing processing for enhancing the edges of the moving foreground image to a degree of edge enhancing less than as compared with the background region. Thus, unnatural image deterioration upon application of edge enhancement processing to moving images can be reduced, while improving the sense-of-resolution, in foreground region images.

The synthesizing unit 5508 synthesizes the background image subjected to edge enhancement that has been supplied from the edge enhancing unit 5507-1, the image made up of pixels belonging to the uncovered background region subjected to edge enhancement that has been supplied from the edge enhancing unit 5507-2, the image made up of pixels belonging to the covered background region subjected to edge enhancement that has been supplied from the edge enhancing unit 5507-3, and the foreground image subjected to edge enhancement that has been supplied from the edge enhancing

unit 5507-4, and supplies the synthesized image to frame memory 5509.

The frame memory 5509 stores the synthesized images supplied from the synthesizing unit 5508, and also outputs the stored images as output images.

In this way, the region processing unit 5001 of which configuration is shown in Fig. 168 applies edge enhancement processing corresponding to the nature of each image, for each of the background region, uncovered background region, covered background region, or foreground region, so the sense-of-resolution of the image can be improved without unnatural deterioration of the image.

The edge enhancing unit 5507-1 through edge enhancing unit 5507-4 have the same configuration as the edge enhancing unit 1203, and accordingly description thereof will be omitted.

Fig. 169 is a diagram describing the processing of the region processing unit 5001 of which configuration is shown in Fig. 168.

The foreground region, uncovered background region, covered background region, and background region of the input image are specified by the region specifying unit 103.

The input image regarding which regions have been specified is divided into the regions by the region dividing unit 5001. The background region image, uncovered

background region image, covered background region image, and foreground region image, which have been divided, are each subjected to edge enhancement, for each image, corresponding to the nature of each image, by the region processing unit 5001 of which configuration is shown in Fig 168.

The background region image, uncovered background region image, covered background region image, and foreground region image, which have each been subjected to edge enhancement, are synthesized.

Fig. 170 is a flowchart describing the processing of images with the image processing device of which configuration is shown in Fig. 115.

In Step S5501, the region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region of the input image, based on the movement vector and the positional information thereof supplied from the movement detecting unit 102. The processing in Step S5501 is the same as the processing in Step S5001, so description thereof will be omitted.

In Step S5502, the region processing unit 5001 divides the input image into the foreground region, background region, covered background region, and uncovered background region, which have been specified, and executes edge enhancement processing of the images for the foreground

region, background region, and covered background region, and uncovered background region, which have been divided, and the processing ends.

In this way, the image processing device according to the present invention divides the input image into the foreground region, background region, covered background region, and uncovered background region, and executes edge enhancement processing for each of the foreground region, background region, covered background region, and uncovered background region, which have been divided.

Next, the processing for edge enhancement by the region processing unit 5001 corresponding to Step S5502 will be described with reference to the flowchart in Fig. 171.

In Step S5521, the region dividing unit 5502 divides the input image into the background region, foreground region, covered background region, or uncovered background region, based on the region information supplied from the region specifying unit 103. That is to say, the region dividing unit 5502 supplies background images made up of pixels belonging to the background region, which is the divided input image, to background region frame memory 5503, supplies images made up of pixels belonging to the uncovered background region to uncovered background region frame memory 5504, supplies images made up of pixels belonging to the covered background region to covered background region

frame memory 5505, and supplies foreground images made up of pixels belonging to the foreground region to foreground region frame memory 5506.

In Step S5522, the edge enhancing unit 5507-1 performs edge enhancement of the background image stored in the background region frame memory 5503, by edge enhancement processing corresponding to the nature of the background image.

In Step S5523, the edge enhancing unit 5507-2 performs edge enhancement of the uncovered background region image, stored in the uncovered background region frame memory 5504, by edge enhancement processing corresponding to the nature of the image of the uncovered background region.

In Step S5524, the edge enhancing unit 5507-3 performs edge enhancement of the covered background region image, stored in the covered background region frame memory 5505, by edge enhancement processing corresponding to the nature of the image of the covered background region.

In Step S5525, the edge enhancing unit 5507-4 performs edge enhancement of the foreground image, stored in the foreground region frame memory 5506, by edge enhancement processing corresponding to the nature of the foreground image.

In Step S5526, the synthesizing unit 5508 synthesizes the background image, the image of the uncovered background

region, the image of the covered background region, and the foreground image, which are each subjected to edge enhancement. The synthesizing unit 5508 supplies the synthesized image to the frame memory 5509. The frame memory 5509 stores the images supplied from the synthesizing unit 5508.

In Step S5527, the frame memory 5509 outputs the synthesized image stored therein, and the processing ends.

In this way, the region processing unit 5001 of which configuration is shown in Fig. 168 applies edge enhancement processing corresponding to the nature or each image, for each of the background image, uncovered background region image, covered background region image, and foreground image, so the sense-of-resolution of the image can be improved without unnatural distortion in moving images.

Note that it is needless to say that the processing in Step S5522 through Step S5525 can be performed in a serial manner or in a parallel manner.

Fig. 172 is a diagram describing yet other processing of the image processing device of which configuration is shown in Fig. 131.

As shown in Fig. 172, the input image has the foreground region, background region, and mixed region thereof specified, and is divided into the specified foreground region, background region, and mixed region.

Processing for generating coefficients, or processing for noise removal, etc., for example, is applied to each of the image of the foreground region and the image of the background region which have been divided.

Fig. 173 is a block diagram illustrating the configuration of a region processing unit 5001 for generating coefficient sets used in class classification adaptation processing for removing noise. Tutor image frame memory 5701 stores input images in increments of frames. The tutor image frame memory 5701 supplies the stored input images to a region dividing unit 5702.

The region dividing unit 5702 divides the tutor image, which is the input image, into the background region or foreground region, based on the region information supplied from the region specifying unit 103.

The region processing unit 5001 shown in Fig. 173 uses neither images of the uncovered background region nor images of the covered background region.

The region dividing unit 5702 supplies the background region image of the tutor image, which is the divided tutor image, to background region tutor image frame memory 5703, and supplies the foreground region image of the tutor image to foreground region tutor image frame memory 5704.

The background region tutor image frame memory 5703 stores the background region image of the tutor image

supplied from the region dividing unit 5702. The background region tutor image frame memory 5703 supplies the background region image of the tutor image stored therein to a noise adding unit 5705-1 and a learning unit 5708-1.

The foreground region tutor image frame memory 5704 stores the foreground region image of the tutor image supplied from the region dividing unit 5702. The foreground region tutor image frame memory 5704 supplies the foreground region image of the tutor image stored therein to a noise adding unit 5705-2 and a learning unit 5708-2.

The noise adding unit 5705-1 generates random numbers, for example, and adds the random numbers to the pixels values of the background region image of the tutor image supplied from the background region tutor image frame memory 5703, thereby adding noise to the image of the background region. The noise adding unit 5705-1 supplies the background region image to which noise has been added, to background region student image frame memory 5706.

The background region student image frame memory 5706 stores the background region image to which noise has been added which has been supplied from the noise adding unit 5705-1, as a student image. The background region student image frame memory 5706 supplies the student image corresponding to the background region image of the tutor image stored therein, to the learning unit 5708-1.

The noise adding unit 5705-2 generates random numbers, for example, and adds the random numbers to the pixels values of the foreground region image of the tutor image supplied from the foreground region tutor image frame memory 5704, thereby adding noise to the image of the foreground region. The noise adding unit 5705-2 supplies the foreground region image to which noise has been added, to foreground region student image frame memory 5707.

The foreground region student image frame memory 5707 stores the foreground region image to which noise has been added which has been supplied from the noise adding unit 5705-2, as a student image. The foreground region student image frame memory 5707 supplies the student image corresponding to the foreground region image of the tutor image stored therein, to the learning unit 5708-2.

The learning unit 5708-1 generates a coefficient set corresponding to the background region, based on the tutor image which is the image of the background region supplied from the background region tutor image frame memory 5703 and the student image to which noise has been added that is supplied from the background region student image frame memory 5706, and supplies the generated coefficient set to the coefficient set memory 5709.

The learning unit 5708-2 generates a coefficient set corresponding to the foreground region, based on the tutor

image which is the image of the foreground region supplied from the foreground region tutor image frame memory 5704 and the student image to which noise has been added that is supplied from the foreground region student image frame memory 5707, and supplies the generated coefficient set to the coefficient set memory 5709.

The coefficient set memory 5709 stores the coefficient set corresponding to the background region supplied from the learning unit 5708-1, and the coefficient set corresponding to the foreground region supplied from the learning unit 5708-2.

Fig. 174 is a diagram describing the coefficient sets which the region processing unit 5001 of which configuration is shown in Fig. 173 generates. The region processing unit 5001 individually calculates coefficient sets corresponding to the background region and coefficient sets corresponding to the foreground region. The region processing unit 5001 does not generate coefficient sets corresponding to the uncovered background region or the covered background region.

That is to say, the region dividing unit 5702 divides the input image into an image of the background region, an image made up of pixels belonging to the uncovered background region, an image made up of pixels belonging to the covered background region, and an image of the foreground region.

The learning unit 5708-1 calculates a coefficient set corresponding to the background region, based on the divided background region image, and the learning unit 5708-2 calculates a coefficient set corresponding to the foreground region, based on the divided foreground region image.

The coefficient set corresponding to the background region is used for prediction of pixel values of the background region in the class classification adaptation processing for predicting pixel values from which noise has been removed. The coefficient set corresponding to the foreground region is used for prediction of pixel values of the foreground region in the class classification adaptation processing for predicting pixel values from which noise has been removed.

The predicted image corresponding to the image of the background region, the image corresponding to the uncovered background region, the image corresponding to the covered background region, and the predicted image corresponding to the image of the foreground region, are synthesized into one image.

The learning processing for generating coefficient sets used for prediction of pixel values in the class classification adaptation processing by the region processing unit 5001 of which configuration is shown in Fig. 173 will be described with reference to the flowchart in Fig.

175.

In Step S5701, the region dividing unit 5702 region divides the tutor image stored in the tutor image frame memory 5701, based on the region information supplied from the region specifying unit 103. That is to say, the region dividing unit 5702 supplies the background region image of the tutor image, which is the region-divided tutor image, to background region tutor image frame memory 5703. The region dividing unit 5702 supplies the foreground region image of the tutor image, which is the region-divided tutor image, to foreground region tutor image frame memory 5704.

In Step S5702, the noise adding units 5705-1 and 5705-2 generate student images for both the background region and the foreground region. That is to say, the noise adding unit 5705-1 generates random numbers, for example, and adds the random numbers to the pixels values of the background region image stored in the background region tutor image frame memory 5703, thereby adding noise to the image of the background region. The noise adding unit 5705-2 generates random numbers, and adds the random numbers to the pixels values of the foreground region image stored in the foreground region tutor image frame memory 5704, thereby adding noise to the image of the foreground region.

In Step S5703, the learning unit 5708-1 generates a coefficient set corresponding to the background region,

based on the tutor image which is the image of the background region stored in the background region tutor image frame memory 5703 and the student image to which noise has been added that is stored in the background region student image frame memory 5706. The details of the processing for generating coefficient sets is the same as the processing that has been described with reference to the flowchart shown in Fig. 103, so description thereof will be omitted.

In Step S5704, the learning unit 5708-2 generates a coefficient set corresponding to the foreground region, based on the tutor image which is the image of the foreground region stored in the foreground region tutor image frame memory 5704 and the student image to which noise has been added that is stored in the foreground region student image frame memory 5707. The details of the processing for generating coefficient sets is the same as the processing that has been described with reference to the flowchart shown in Fig. 103, so description thereof will be omitted.

In Step S5705, the learning units 5708-1 and 5708-2 supply the coefficient set corresponding to the background region and the coefficient set corresponding to the foreground region, respectively, to the coefficient set memory 5709. The coefficient set memory 5709 stores the

coefficient sets corresponding to the background region and the foreground region, respectively, and the processing ends.

In this way, the region processing unit 5001 of which configuration is shown in Fig. 173 can generate coefficient sets corresponding to the background region and coefficient sets corresponding to the foreground region.

Note that it is needless to say that the processing in Step S5703 and Step S5704 can be performed in a serial manner or in a parallel manner.

Fig. 176 is a block diagram illustrating the configuration of the region processing unit 5001 for executing class classification adaptation processing to generate images from which noise has been removed. Frame memory 5901 stores the input image in increments of frames. The frame memory 5901 supplies the input images stored therein to the region dividing unit 5902.

The region dividing unit 5902 divides the input image into the foreground region, and background region, covered background region, or uncovered background region, based on the region information supplied from the region specifying unit 103. That is to say, the region dividing unit 5902 supplies the background region image, which is the divided input image, to background region frame memory 5903, and supplies the foreground region image to foreground region frame memory 5906.

The region dividing unit 5902 supplies the covered background region and the uncovered background region image, which is the divided input image, to the synthesizing unit 5907.

The background region frame memory 5903 records the background region image made up of pixel belonging to the background region supplied from the region dividing unit 5902. The background region frame memory 5903 supplies the stored background region image to the mapping unit 5905-1.

The foreground region frame memory 5904 records the foreground region image made up of pixel belonging to the foreground region supplied from the region dividing unit 5902. The foreground region input image frame memory 506 supplies the stored foreground region image to the mapping unit 5905-2.

The mapping unit 5905-1 generates a predicted image from which noise has been removed, corresponding to the background region image stored in the background region frame memory 5903 by class classification adaptation processing based on the coefficient set corresponding to the background region, stored in the coefficient set memory 5906. The mapping unit 5905-1 supplies the generated predicted image to the synthesizing unit 5907.

The mapping unit 5905-2 generates a predicted image from which noise has been removed, corresponding to the

foreground region image stored in the foreground region frame memory 5904 by class classification adaptation processing based on the coefficient set corresponding to the foreground region, stored in the coefficient set memory 5906. The mapping unit 5905-2 supplies the generated predicted image to the synthesizing unit 5907.

The synthesizing unit 5907 synthesizes the predicted image corresponding to the image of the background region supplied from the mapping unit 5905-1, the predicted image corresponding to the image of the foreground region supplied from the mapping unit 5905-2, and the images of the covered background region and uncovered background region supplied from the region dividing unit 5902, and supplies the synthesized image to the frame memory 5908.

The frame memory 5908 stores the image supplied from the synthesizing unit 5907, and also outputs the image stored therein as an output image.

Next, the processing for creating an image with the region processing unit 5001 of which configuration is shown in Fig. 176, will be described with reference to the flowchart shown in Fig. 177.

In Step S5901, the region dividing unit 5902 divides the input image into the background region, foreground region, covered background region, or uncovered background region, based on the region information supplied from the

region specifying unit 103. That is to say, the region dividing unit 5902 supplies the background region image, which is the divided input image, made up of pixels belonging to the background region, to background region frame memory 5903, and supplies the foreground region image, made up of pixels belonging to the foreground region, to foreground region frame memory 5904.

The region dividing unit 5902 supplies the image made up of pixels belonging to the covered background region and the image made up of pixels belonging to the uncovered background region, to the synthesizing unit 5907.

In Step S5902, the mapping unit 5905-1 predicts an image from which noise has been removed, corresponding to the background region image stored in the background region frame memory 5903 by class classification adaptation processing based on the coefficient set corresponding to the background region, stored in the coefficient set memory 5906. The details of the processing for predicting images from which noise has been removed is the same as the processing that has been described with reference to the flowchart shown in Fig. 109, so description thereof will be omitted.

In Step S5903, the mapping unit 5905-2 predicts an image from which noise has been removed, corresponding to the foreground region image stored in foreground region frame memory 5904 by class classification adaptation

processing based on the coefficient set corresponding to the foreground region, stored in the coefficient set memory 5906. The details of the processing for predicting images from which noise has been removed is the same as the processing that has been described with reference to the flowchart shown in Fig. 109, so description thereof will be omitted.

In Step S5904, the synthesizing unit 5907 synthesizes the predicted image corresponding to the image of the background region, and the predicted image corresponding to the image of the foreground region, and the image of the covered background region and the image of the uncovered background region. The synthesizing unit 5907 supplies the synthesized image to the frame memory 5908. The frame memory 5908 stores the image supplied from the synthesizing unit 5907.

In Step S5905, the frame memory 5908 outputs the stored synthesized image, and the processing ends.

In this way, the image processing device comprising the region processing unit 5001 of which configuration is shown in Fig. 176 can divide an input image into each of the background region, uncovered background region, covered background region, and foreground region, generate predicted images for each of the divided background region image and foreground region image, and synthesize the generated predicted images with the images of the uncovered background

region and covered background region, so noise of the overall image can be reduced without unnatural degradation of images occurring at the mixed region.

Note that it is needless to say that the processing in Step S5902 and Step S5903 can be performed in a serial manner or in a parallel manner.

Also, with the present invention, image processing encompasses processing for allowing images to pass without change.

Fig. 178 is a block diagram illustrating yet another configuration of the functions of the image processing device according to the present invention.

Parts which are the same as the case shown in Fig. 11 are denoted with the same reference numerals, and description thereof will be omitted.

Input images provided to the signal processing device are provided to an object extracting unit 101, a region specifying unit 103, a mixture ratio calculation unit 104, and a foreground/background separation unit 105.

The object extracting unit 101 roughly extracts the image objects corresponding to the foreground object contained in the input image, and supplies the extracted image object to the movement detecting unit 102. The object extracting unit 101 roughly extracts the image object corresponding to the background object contained in the

input image, and supplies the extracted image object to the movement detecting unit 102.

The movement detecting unit 102 calculates the movement vectors of the image object corresponding to the roughly extracted foreground objects by techniques such as block matching, gradation, phase correlation, and pixel recursion, or the like, and provides the calculated movement vectors and movement vector position information (information for specifying the pixel positions corresponding to the movement vectors) to the region specifying unit 103.

The region specifying unit 103 classifies each pixels of an input image into one of the foreground region, the background region, or the mixed region, and supplies region information to the mixture ratio calculation unit 104 and the foreground/background separation unit 105. Details of the foreground region, the background region, or the mixed region, will be described later.

The mixture ratio calculation unit 104 calculates the mixture ratio α corresponding to the pixels contained in the mixed region based upon the input image and the region information supplied from the region specifying unit 103, and supplies the calculated mixture ratio to the foreground/background separation unit 105.

The foreground/background separation unit 105 separates the input images into foreground component images and

background component images based upon the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio calculation unit 104, and supplies foreground component images and background component images to a separated image processing unit 7001.

The separated image processing unit 7001 applies different processing for each of the foreground component image and background component image. For example, the separated image processing unit 7001 generates coefficients used in class classification adaptation processing for generating an even higher resolution image, based on the background component image.

For example, the separated image processing unit 7001 applies class classification adaptation processing to the background component image, so as to create an image with even higher resolution, and also applies linear interpolation processing to the foreground component image, thereby generating an image.

Also, the separated image processing unit 7001 applies edge enhancement processing to only the background component image, and allows the foreground component image to pass as it is.

Fig. 179 is a flowchart describing the processing of images with the image processing device according to the

present invention.

In Step S7001, the region specifying unit 103 specifies the foreground region, background region, covered background region, and uncovered background region, based on the movement vectors and the position information thereof, supplied from the movement detecting unit 102. The processing in Step S7001 is the same as the processing in Step S101, so description thereof will be omitted.

In Step S7002, the mixture ratio calculation unit 104 calculates the mixture ratio α based upon the input image and the region information supplied from the region specifying unit 103. The processing in Step S7002 is the same as the processing in Step S102, and accordingly description thereof will be omitted.

In Step S7003, the foreground/background separation unit 105 separates the input images into foreground component images made up of foreground components and background component images made up of background components based upon the region information supplied from the region specifying unit 103 and the mixture ratio α supplied from the mixture ratio calculation unit 104. The processing in Step S7003 is the same as the processing in Step S103, and accordingly description thereof will be omitted.

In Step S7004, the separated image processing unit 7001 executes processing for each of the foreground component

image and background component image, and the processing ends. Details of the image processing which the separated image processing unit 7001 executes will be described later.

In this way, the image processing device according to the present invention separates the input image into foreground component image and background component image, and executes image processing on the separated foreground component image and background component image.

Fig. 180 is a block diagram illustrating the configuration of the separated image processing unit 7001 for generating a coefficient set which is used in class classification adaptation processing for generating an even higher resolution image in the spatial direction, corresponding to the background component image. For example, the separated image processing unit 7001 of which the configuration is shown in Fig. 180 generates a coefficient set which is used in class classification adaptation processing for generating HD images from SD images based upon input SD images corresponding to the background image.

The separated image processing unit 7001 of which configuration is shown in Fig. 180 does not use foreground component images.

Tutor image frame memory 7021 stores the background component image supplied from the foreground/background

separation unit 105. The tutor image frame memory 7021 supplies the background component image stored therein, i.e., the tutor image, to a weighted averaging unit 7022 and a learning unit 7024.

The weighted averaging unit 7022 generates an SD image which is a student image by one-quarter weighted-averaging of the background component image in the HD image, which is a tutor image, for example, supplied from the tutor image frame memory 7021, and supplies the generated SD image to student image frame memory 7023.

The student image frame memory 7023 stores the student image corresponding to the background component image which is the tutor image supplied from the weighted averaging unit 7022. The student image frame memory 7023 supplies the stored student image to the learning unit 7024.

The learning unit 7024 generates a coefficient set corresponding to the background component image based upon the background component image which is the tutor image supplied from the tutor image frame memory 7021 and the student image corresponding to the background component image supplied from the student image frame memory 7023, and supplies the generated coefficient set to coefficient set memory 7025.

The coefficient set memory 7025 stores the coefficient set corresponding to the background component image supplied

from the learning unit 7024.

Fig. 181 is a block diagram illustrating the configuration of the learning unit 7024.

A class classification unit 7121 comprises a class tap obtaining unit 7131 and a waveform classification unit 7132, and classifies a pixel of interest, which is a pixel at interest, of the input student image. The class tap obtaining unit 7131 obtains a predetermined number of class taps which are pixels of the student image corresponding to the pixel of interest, and supplies the obtained class taps to the waveform classification unit 7132.

The waveform classification unit 7132 performs class classification processing wherein the input signals are classified into several classes based upon the features thereof, and classifies a pixel of interest into one class, based on the class taps. For example, the waveform classification unit 7132 classifies the pixel of interest into one of 512 classes, and supplies the class No. corresponding to the classified class to a prediction tap obtaining unit 7122.

The prediction tap obtaining unit 7122 obtains from the pixel of the student image the prediction tap which is an increment for calculation of the predicted value of the original image (tutor image), corresponding to the class, based upon the class No., and supplies the obtained

prediction tap and the class No. to a corresponding pixel obtaining unit 7123.

The corresponding pixel obtaining unit 7123 obtains pixel values of the pixels in the tutor image corresponding to the pixel values which are to be predicted, based upon the prediction tap and the class No., and supplies the prediction tap, the class No., and the obtained pixel values of the pixels in the tutor image corresponding to the pixel values which are to be predicted, to a normal equation generating unit 7124.

The normal equation generating unit 7124 generates normal equations for calculating a coefficient set which is used in the adaptation processing, corresponding to the relationship between the prediction tap and the pixels which are to be predicted, based upon the prediction tap, the class No., and the obtained pixels which are to be predicted, and supplies the generated normal equations to a coefficient calculation unit 7125 along with the class No.

The coefficient calculation unit 7125 calculates a coefficient set which is used in the adaptation processing, corresponding to the classified class, by solving the normal equations supplied from the normal equation generating unit 7124. The coefficient calculation unit 7125 supplies the calculated coefficient set to the coefficient set memory 7025, along with the class No.

An arrangement may be made wherein the normal equation generating unit 7124 generates a matrix corresponding to such normal equations, and the coefficient calculation unit 7125 calculates a coefficient set based upon the generated matrix.

The normal equation generating unit 7124 generates the normal equations for calculating the optimal prediction coefficients w for each class, and the coefficient calculation unit 7125 calculates the prediction coefficients w based upon the generated normal equations.

Also, the adaptation processing is not restricted to processing for creating images with high resolution in the spatial direction, and may be arranged to create images wherein the image resolution is the same and noise is reduced, for example.

The learning processing for generating coefficient sets used for prediction of pixel values with class classification adaptation processing by the separated image processing unit 7001 of which configuration is shown in Fig. 180 will be described with reference to the flowchart shown in Fig. 182.

In Step S7021, the weighted averaging unit 7022 generates a student image corresponding to the background component image which is the tutor image, by one-quarter weighted-averaging of the background component image which

is a tutor image, fore example, stored in the tutor image frame memory 7021.

In Step S7022, the learning unit 7024 generates a coefficient set corresponding to the background component image based upon the background component image which is the tutor image stored in the tutor image frame memory 7021 and the student image corresponding to the background component image stored in the student image frame memory 7023, and supplies the generated coefficient set to the coefficient set memory 7025. The coefficient set memory 7025 stores the coefficient set corresponding to the background component image, and the processing ends.

In this way, the separated image processing unit 7001 of which configuration is shown in Fig. 180 can generate coefficient sets corresponding to the background component image.

Referring to the flowchart shown in Fig. 183, description will now be made with regard to the processing for generating of a coefficient set corresponding to the background component image, performed by the learning unit 7024, corresponding to the processing in Step S7022.

In Step S7121, the learning unit 7024 judges whether or not there are any unprocessed pixels in the student image corresponding to the background component image, and in the event that judgment is made that there are unprocessed

pixels in the student image corresponding to the background component image, the flow proceeds to Step S7122, and the learning unit 7024 obtains the pixel of interest from the student image corresponding to the background component image in raster scan sequence.

In Step S7123, the class tap obtaining unit 7131 of the class classification unit 7121 obtains the class tap corresponding to the pixel of interest from the student image stored in the student image frame memory 7023. In Step S7124, the waveform classification unit 7132 of the class classification unit 7121 reduces the number of bits of the pixels making up the class tap by applying the ADRC processing to the class tap, and performs class classification for the pixel of interest. In Step S7125, the prediction tap obtaining unit 7122 obtains the prediction tap corresponding to the pixel of interest from the student image stored in the student image frame memory 7023 based upon the classified class.

In Step S7126, the corresponding pixel obtaining unit 7123 obtains pixels corresponding to the pixel value which is to be predicted, from the background component image which is a tutor image stored in the tutor image frame memory 7021, based upon the classified class.

In Step S7127, the normal equation generating unit 7124 adds pixel values of the pixels corresponding to the

prediction tap and the pixel value which is to be predicted, to the matrix for each class, based upon the class into which classification has been made, the flow returns to Step S7121, and the learning unit 7024 repeats judgment whether or not there are any unprocessed pixels. The matrix for each class to which pixel values of the pixels corresponding to the prediction tap and the pixel value which is to be predicted are added, corresponds to the normal equation for calculating of the coefficient set for each class.

In Step S7121, in the event that judgment is made that there are no unprocessed pixels in the student image, the flow proceeds to Step S7128, and the normal equation generating unit 7124 supplies the matrix for each class, wherein pixel values of the pixels corresponding to the prediction tap and the pixel value which is to be predicted have been set, to the coefficient calculation unit 7125. The coefficient calculation unit 7125 calculates the coefficient set for each class corresponding to the background component image by solving the matrix for each class wherein pixel values of the pixels corresponding to the prediction tap and the pixel value which is to be predicted have been set.

Note that an arrangement may be made wherein the coefficient calculation unit 7125 calculates the coefficient set for predicting of the pixel value by non-linear

prediction, as well as by linear prediction.

In Step S7129, the coefficient calculation unit 7125 outputs the coefficient set for each class corresponding to the background component image to the coefficient set memory 7025, and the processing ends.

As described above, the learning unit 7024 can generate a coefficient set corresponding to the background component image.

As described above, the separated image processing unit 7001 of which configuration is shown in Fig. 180 can generate a coefficient set corresponding to the background component image.

Fig. 184 is a block diagram which illustrates the configuration of the separated image processing unit 7001 for generating an even higher resolution image in the spatial direction by performing the class classification adaptation processing for the background component image, and performing interpolation for the foreground component image. For example, the separated image processing unit 7001 of which configuration is shown in Fig. 184 generates an HD image by applying the class classification adaptation processing to the background component image of the input image which is an SD image, and applying interpolation processing to the foreground component image of the input image which is an SD image.

Frame memory 7301 stores the background component image supplied from the separated image processing unit 105. The frame memory 7301 supplies the stored background component image to a mapping unit 7302.

The mapping unit 7302 generates an predicted image corresponding to the background component image stored in the frame memory 7301 by the class classification adaptation processing based upon the coefficient set corresponding to the background component image stored in coefficient set memory 7303. The mapping unit 7302 supplies the generated predicted image to frame memory 7304.

The frame memory 7304 stores the predicted image corresponding to the stored background component image, and supplies the stored predicted image to a synthesizing unit 7308.

Frame memory 7305 stores the foreground component image supplied from the separated image processing unit 105. The frame memory 7305 supplies the stored foreground component image to a linear interpolation processing unit 7306.

The linear interpolation processing unit 7306 generates an image subjected to interpolation corresponding to the foreground component image stored in the frame memory 7305 by linear interpolation processing.

For example, in the event of calculating the pixel value of the pixel $Y_{33}(1)$ in an image which is to be

subjected to interpolation, enclosed by a quadrangle in Fig. 97, the linear interpolation processing unit 7306 multiplies the corresponding predetermined weight to each of pixels, i.e., X_{22}, X_{23}, X_{24}, X_{32}, X_{33}, X_{34}, X_{42}, X_{43}, X_{44}, and sets the sum of the products to the pixel value of the pixel $Y_{33}(1)$. In the same way, in the event of calculating the pixel value of the pixel $Y_{33}(2)$ in an image which is to be interpolated, the linear interpolation processing unit 7306 multiplies the predetermined weight different from the case of calculating the pixel value of the pixel $Y_{33}(1)$ to each of the pixels, i.e., X_{22}, X_{23}, X_{24}, X_{32}, X_{33}, X_{34}, X_{42}, X_{43}, X_{44}, and sets the sum of the products to the pixel value of the pixel $Y_{33}(2)$.

The linear interpolation processing unit 7306 calculates the pixel values of the pixel $Y_{33}(3)$ and the pixel $Y_{33}(4)$ based upon the pixels X_{22}, X_{23}, X_{24}, X_{32}, X_{33}, X_{34}, X_{42}, X_{43}, X_{44}, by the same interpolation processing.

The linear interpolation processing unit 7306 supplies the image subjected to interpolation to frame memory 7307.

The frame memory 7307 stores the image subjected to interpolation based upon the foreground component image, and supplies the stored image to the synthesizing unit 7308.

The synthesizing unit 7308 synthesizes the predicted image corresponding to the background component image supplied from the frame memory 7304 and the image which has been subjected to interpolation based upon the foreground

component image supplied from the frame memory 7307, and outputs the synthesized image as an output image.

Fig. 185 is a block diagram which illustrates the configuration of the mapping unit 7302.

A mapping unit 7321 comprises a class classification unit 7331 for performing the class classification processing, a prediction tap obtaining unit 7332 for performing the adaptation processing, and a prediction calculation unit 7333.

The class classification unit 7331 comprises a class tap obtaining unit 7351 and a waveform classification unit 7352, and performs class classification processing for the pixel of interest in the background component image.

The class tap obtaining unit 7351 obtains the predetermined number of class taps corresponding to the pixel of interest in the input image, and supplies the obtained class taps to the waveform classification unit 7352. For example, the class tap obtaining unit 7351 obtains nine class taps, and supplies the obtained class taps to the waveform classification unit 7352.

The waveform classification unit 7352 reduces the number of bits of pixels making up the class tap by applying the ADRC processing to the class tap, classifies the pixel of interest into one of the predetermined number of classes, and supplies the class No. corresponding to the classified

class to the prediction tap obtaining unit 7332. For example, the waveform classification unit 7352 classifies the pixel of interest into one of 512 classes, and supplies the class No. corresponding to the classified class to the prediction tap obtaining unit 7332.

The prediction tap obtaining unit 7332 obtains the predetermined number of prediction taps corresponding to the class from the input image based upon the class No., and supplies the obtained prediction taps and the class No. to the prediction calculation unit 7333.

The prediction calculation unit 7333 obtains a coefficient set corresponding to the class from the coefficient sets corresponding to the background component image stored in the coefficient set memory 7303 based upon the class No. The prediction calculation unit 7333 predicts pixel values of the predicted image by linear prediction based upon the coefficient set corresponding to the class, and the prediction tap. The prediction calculation unit 7333 supplies the predicted pixel values to the frame memory 7322.

Note that the prediction calculation unit 7333 may predict pixel values of the predicted image by non-linear prediction.

The frame memory 7322 stores the predicted pixel values supplied from the mapping processing unit 7321, and outputs

the image made up of the predicted pixel values.

Fig. 186 is a diagram which describes the processing by the separated image processing unit 7001 of which configuration is shown in Fig. 184.

As shown in Fig. 186, the input image is divided into regions, and separated into the foreground components and the background components. The separated input image is synthesized into foreground component image and the background component image.

The separated image processing unit 7001 applies the class classification adaptation processing to the separated background component image. The separated image processing unit 7001 applies linear interpolation processing to the separated foreground component image.

Referring to the flowchart shown in Fig. 187, description will now be made with regard to the processing for creation of an image by the separated image processing unit 7001 of which configuration is shown in Fig. 184.

In Step S7301, the mapping unit 7302 predicts the image corresponding to the background component image stored in the frame memory 7301 by the class classification adaptation processing based upon the coefficient set corresponding to the background component image stored in the coefficient set memory 7303. Details of the processing for prediction of the image corresponding to the background component image

will be described later with reference to the flowchart shown in Fig. 188.

The mapping unit 7302 supplies the predicted image corresponding to the background component image to the frame memory 7304. The frame memory 7304 stores the predicted image corresponding to the background component image, and supplies the stored predicted image to the synthesizing unit 7308.

In Step S7302, the linear interpolation processing unit 7306 performs linear interpolation for the foreground component image stored in the frame memory 7305. The linear interpolation processing unit 7306 supplies the image subjected to linear interpolation to the frame memory 7307. The frame memory 7307 stores the image subjected to linear interpolation, and supplies the stored image subjected to linear interpolation to the synthesizing unit 7308.

In Step S7303, the synthesizing unit 7308 synthesizes the predicted image corresponding to the background component image and the image wherein the foreground component image has been subjected to linear interpolation. The synthesizing unit 7308 outputs the stored synthesized image, and the processing ends.

As described above, the image processing device having the separated image processing unit 7001 of which configuration is shown in Fig. 184 can generate a predicted

image corresponding to the background component image, individually generate images subjected to linear interpolation corresponding to the foreground component image, synthesize the generated images, and output the synthesized image.

Note that it is needless to say that the processing in Step S7301 and Step S7302 may be performed in parallel, as well as in serial.

Referring to the flowchart shown in Fig. 188, description will be made with regard to the processing for prediction of the image corresponding to the background component image by the mapping unit 7302 corresponding to Step S7301.

In Step S7321, the mapping unit 7302 judges whether or not there are any unprocessed pixels in the background component image, and in the event that judgment is made that there are unprocessed pixels in the background component image, the flow proceeds to Step S7322, and the mapping processing unit 7321 obtains the coefficient set corresponding to the background component image stored in the coefficient set memory 7303. In Step S7323, the mapping processing unit 7321 obtains the pixel of interest from the background component image stored in the frame memory 7301 in raster scan sequence.

In Step S7324, the class tap obtaining unit 7351 of the

class classification unit 7331 obtains the class tap corresponding to the pixel of interest from the background component image stored in the frame memory 7301. In Step S7325, the waveform classification unit 7352 of the class classification unit 7331 reduces the number of bits of pixels making up the class tap by applying the ADRC processing to the class tap, and performs class classification for the pixel of interest. In Step S7326, the prediction tap obtaining unit 7332 obtains the prediction tap corresponding to the pixel of interest from the background component image stored in the frame memory 7301 based upon the classified class.

In Step S7327, the prediction computation unit 7333 predicts pixel values of the predicted image by linear prediction based upon the coefficient set corresponding to the background component image and the classified class, and the prediction tap.

Note that the prediction computation unit 7333 may predict pixel values of the predicted image by non-linear prediction, as well as by linear prediction.

In Step S7328, the prediction computation unit 7333 outputs the predicted pixel value to the frame memory 7322. The frame memory 7322 stores the pixel values supplied from the prediction calculation unit 7333. The flow returns to Step S7321, and repeats judgment whether or not there are

any unprocessed pixels.

In Step S7321, in the event that judgment is made that there are no unprocessed pixels in the background component image, the flow proceeds to Step S7329, the frame memory 7322 outputs the predicted image corresponding to the stored background component image, and the processing ends.

As described above, the mapping unit 7302 can predict the image corresponding to the background component image based upon the background component image.

As described above, the separated image processing unit 7001 of which configuration is shown in Fig. 184 can generate a predicted image corresponding to the background component image, perform linear interpolation for the foreground component image, and accordingly generate an image, wherein the resolution in the spatial direction has been enhanced, without unnatural degradation occurring in the foreground component image containing movement blurring.

Fig. 189 is a block diagram which illustrates another configuration of the separated image processing unit 7001 for applying edge enhancement processing for the background component image. The separated image processing unit 7001 of which configuration is shown in Fig. 189 applies edge enhancement processing to the background component image, and synthesizes the foreground component image as it is and the background component image to which edge enhancement

processing has been applied.

The background component image supplied from the foreground/background separation unit 105 is input to an edge enhancing unit 7501, and the foreground component image supplied from the foreground/background separation unit 105 is input to a synthesizing unit 7502.

The edge enhancing unit 7501 applies edge enhancing processing suitable to the background component image to the background component image supplied from the foreground/background separation unit 105, and supplies the background component image subjected to edge enhancing to the synthesizing unit 7502.

For example, the edge enhancing unit 7501 performs edge enhancing processing, which further enhances edges, for the background component image which is a still image. Thus, the sense-of-resolution of the background component image can be improved without unnatural degradation occurring in the image in the event of applying the edge enhancing processing to the moving image.

Also, for example, in the event that the background moves, the edge enhancing unit 7501 performs edge enhancing processing, of which degree is less than as compared with the case wherein the background keeps still, on the background component image. Thus, the sense-of-resolution of the background component image can be further improved

without unnatural degradation of the image occurring in the event of applying edge enhancing processing to the moving image.

The synthesizing unit 7502 synthesizes the background component image subjected to edge enhancing that has been supplied from the edge enhancing unit 7501 and the foreground component image supplied from the foreground/background separation unit 105, and outputs the synthesized image.

As described above, the separated image processing unit 7001 of which configuration is shown in Fig. 189 synthesizes the foreground component image as it is and the background component image to which the edge enhancing processing corresponding to the nature of the background component image has been applied, and accordingly, the sense-of-resolution of the image can be improved without unnatural degradation of the image occurring.

Fig. 190 is a block diagram which illustrates the configuration of the edge enhancing unit 7501. The background component image is input to a high pass filter 7521 and an addition unit 7523.

The high pass filter 7521 extracts components wherein the pixel value drastically changes with regard to the pixel position, so-called high image frequency components, and removes components wherein the change in pixel value is

small with regard to the pixel position, so-called low image frequency components, from the background component image based upon the input filter coefficients and generates an edge image.

The high pass filter 7521 supplies the generated edge image to a gain adjustment unit 7522.

The gain adjustment unit 7522 amplifies or reduces the edge image supplied from the high pass filter 7521 based upon the input gain adjustment coefficient. In the event that the input gain adjustment coefficient is altered, the gain adjustment unit 7522 changes the amplification ratio (decay ratio) of the edge image. For example, in the event of inputting the gain adjustment coefficient which designates the amplification ratio equal to or more than 1, the gain adjustment unit 7522 amplifies the edge image, and in the event of inputting the gain adjustment coefficient which designates the amplification ratio less than 1, the gain adjustment unit 7522 reduces the edge image.

The gain adjustment unit 7522 supplies the edge image subjected to gain adjustment to the addition unit 7523.

The addition unit 7523 adds the background component image and the edge image subjected to gain adjustment, supplied from the gain adjustment unit 7522, and outputs the image subjected to addition.

As described above, the edge enhancing unit 7501

applies edge enhancing processing to the background component image.

Fig. 191 is a block diagram which illustrates another configuration of the edge enhancing unit 7501. In an example shown in Fig. 191, the edge enhancing unit 7501 comprises a filter 7541.

The filter 7541 generates an edge-enhanced image by amplifying components wherein the pixel value drastically changes with regard to the pixel position in the background component image, so-called high image frequency components, based upon the input filter coefficients.

As described above, the edge enhancing unit 7501 performs edge enhancing processing corresponding to the nature of the background component image based upon different filter coefficients or gain adjustment coefficients, for example.

Fig. 192 is a diagram which describes the processing by the separated image processing unit 7001 of which configuration is shown in Fig. 189.

As shown in Fig. 192, the input image is divided into regions, and separated into the foreground components and the background components. The separated input image is synthesized into the foreground component image and the background component image.

The separated image processing unit 7001 applies edge

enhancing processing to the separated background component image, and outputs the background component image subjected to edge enhancing. The separated foreground component image is output as it is.

Referring to the flowchart shown in Fig. 193, the processing by the separated image processing unit 7001 of which configuration is shown in Fig. 189 will now be described.

In Step S7501, the edge enhancing unit 7501 applies edge enhancing processing to the background component image. The edge enhancing unit 7501 supplies the background component image subjected to edge enhancing to the synthesizing unit 7502.

In Step S7502, the synthesizing unit 7502 synthesizes the background component image subjected to edge enhancing and the foreground component image supplied from the foreground/background separation unit 105, outputs the synthesized image, and the processing ends.

As described above, the image processing device having the separated image processing unit 7001 of which configuration is shown in Fig. 189 can perform edge enhancing for background component image, synthesize the background component image subjected to edge enhancing and the foreground component image as it is, and output the synthesized image, and accordingly, the image processing

device can generate an image wherein the sense-of-resolution is improved without unnatural degradation occurring in the foreground component image containing movement blurring.

Fig. 194 is a block diagram which further illustrates another configuration of the functions of the image processing device. While the image processing device shown in Fig. 178 performs region specification and calculation of the mixture ratio α sequentially, the image processing device shown in Fig. 194 performs region specification and calculation of the mixture ratio α in a parallel manner.

The same portions as the functions shown in the block diagram in Fig. 178 are denoted by the same reference numerals, and description thereof will be omitted.

The input image is supplied to the object extracting unit 101, the region specifying unit 103, the mixture ratio calculation unit 3001, and the foreground/background separation unit 3002.

The mixture ratio calculation unit 3001 calculates the estimated mixture ratio wherein an assumption is made that the pixel belongs to the covered background region, and the estimated mixture ratio wherein an assumption is made that the pixel belongs to the uncovered background region, for each of pixels contained in the input image, based upon the input image, and supplies the estimated mixture ratio wherein an assumption is made that the calculated pixel

belongs to the covered background region and the estimated mixture ratio wherein an assumption is made that the pixel belongs to the uncovered background region, to the foreground/background separation unit 3002.

As described above, the image processing device according to the present invention can perform processing for an image corresponding to the mixture of the background image and the image of the moving object.

Also, the image processing device according to the present invention can sufficiently improve the sense-of-resolution without the image which contains movement blurring becoming unnatural.

Note that while the movement of the object which is the foreground has been described as being from the left to the right, it is needless to say that this is not restricted to that direction.

In the above, an example has been given of a case of projecting images in real space having three-dimensional space and time-axis information onto time-space having two-dimensional space and time-axis information, using a video camera, but the present invention is not restricted to this example, and may be applied to cases of projecting a greater amount of first information of a first dimension onto less second information of a second dimension.

Note that the sensor is not restricted to a CCD, and

may be a sensor which is a solid-state image-taking device, e.g., a CMOS (Complementary Metal Oxide Semiconductor (complementary metal oxide film semiconductor)), BBD (Bucket Brigade Device), CID (Charge Injection Device), or CPD (Charge Priming Device) or the like, and is not restricted to a sensor wherein detecting elements are arrayed in a matrix fashion, but may rather be a sensor wherein the detecting elements are arrayed in a row.

The recording medium storing the program for executing the signal processing of the present invention is not only configured of packaged media such as a magnetic disk 91 (including floppy (Registered Trademark) disks), optical disk 92 (including CD-ROMs (Compact Disc-Read Only Memory), DVDs (Digital Versatile Disc)), magneto-optical disk 93 (including MDs (Mini-Disc) (Registered Trademark)), or semiconductor memory 94 or the like, storing the program, to be distributed separately from the computer as shown in Fig. 10 for providing the program to users, but is configured of ROM 72 or a hard disk included in the storage unit 78 or the like storing the program, provided to the user in the state of being assembled into the computer beforehand.

Also, in the present Specification, the steps describing the program recorded in the recording medium includes processing which is executed in the time-sequence following the described order, of course, and also

processing which is executed in parallel or individually, even if not processed in time-sequence.

Industrial Applicability

According to the first present invention, an image can be processed corresponding to the mixture of the background image and the image of the moving object.

According to the second present invention, an image can be processed corresponding to the mixture of the background image and the image of the moving object.

According to the third present invention, the sense-of-resolution can be sufficiently improved without the image which contains movement blurring becoming unnatural.

According to the fourth present invention, an image can be processed corresponding to the mixture of the background image and the image of the moving object.

CLAIMS

1. An image processing device for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said image processing device comprising:

region specifying means for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

processing means for processing said input image data for each region specified by said region specifying information.

2. An image processing device according to Claim 1, wherein said processing means decide a class corresponding to each piece of pixel data of said input image data, corresponding to said region specifying information.

3. An image processing device according to Claim 1, wherein said processing means enhance the edges of said

input image data, corresponding to said region specifying information.

4. An image processing device according to Claim 1, wherein said processing means process said pixel data of at least one region of said mixed region and said non-mixed region.

5. An image processing device according to Claim 1, wherein said region specifying means further specify a covered background region and an uncovered background region, and output region specifying information corresponding to the results of specifying;

and wherein said processing means further process said input image data for each of covered background region and uncovered background region.

6. An image processing device according to Claim 1, wherein said processing means generate coefficients used in class classification adaptation processing, for each region specified by said region specifying information.

7. An image processing device according to Claim 1, wherein said processing means generate output image data by class classification adaptation processing, for each region specified by said region specifying information.

8. An image processing device according to Claim 1, wherein said processing means enhance the edges of said input image data, for each region specified by said region

specifying information.

9. An image processing method for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a processing step for processing said input image data for each region specified by said region specifying information.

10. An image processing method according to Claim 9, wherein, in said processing step, a class corresponding to each piece of pixel data of said input image data is decided, corresponding to said region specifying information.

11. An image processing method according to Claim 9, wherein, in said processing step, the edges of said input

image data are enhanced, corresponding to said region specifying information.

12. An image processing method according to Claim 9, wherein, in said processing step, said pixel data of at least one region of said mixed region and said non-mixed region is processed.

13. An image processing method according to Claim 9, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and region specifying information is output corresponding to the results of specifying;

and wherein, in said processing step, said input image data for each of covered background region and uncovered background region is further processed.

14. An image processing method according to Claim 9, wherein, in said processing step, coefficients used in class classification adaptation processing are generated for each region specified by said region specifying information.

15. An image processing method according to Claim 9, wherein, in said processing step, output image data is generated by class classification adaptation processing for each region specified by said region specifying information.

16. An image processing method according to Claim 9, wherein, in said processing step, the edges of said input image data are enhanced for each region specified by said

region specifying information.

17. A recording medium storing a computer-readable program for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said program comprising:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a processing step for processing said input image data for each region specified by said region specifying information.

18. A recording medium according to Claim 17, wherein, in said processing step, a class corresponding to each piece of pixel data of said input image data is decided, corresponding to said region specifying information.

19. A recording medium according to Claim 17, wherein, in said processing step, the edges of said input image data are

enhanced, corresponding to said region specifying information.

20. A recording medium according to Claim 17, wherein, in said processing step, said pixel data of at least one region of said mixed region and said non-mixed region is processed.

21. A recording medium according to Claim 17, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and region specifying information is output corresponding to the results of specifying;

and wherein, in said processing step, said input image data for each of covered background region and uncovered background region is further processed.

22. A recording medium according to Claim 17, wherein, in said processing step, coefficients used in class classification adaptation processing are generated for each region specified by said region specifying information.

23. A recording medium according to Claim 17, wherein, in said processing step, output image data is generated by class classification adaptation processing for each region specified by said region specifying information.

24. A recording medium according to Claim 17, wherein, in said processing step, the edges of said input image data are enhanced for each region specified by said region specifying information.

25. A program for causing a computer, which processes input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, to execute:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a processing step for processing said input image data for each region specified by said region specifying information.

26. A program according to Claim 25, wherein, in said processing step, a class corresponding to each piece of pixel data of said input image data is decided, corresponding to said region specifying information.

27. A program according to Claim 25, wherein, in said processing step, the edges of said input image data are enhanced, corresponding to said region specifying

information.

28. A program according to Claim 25, wherein, in said processing step, said pixel data of at least one region of said mixed region and said non-mixed region is processed.

29. A program according to Claim 25, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and region specifying information is output corresponding to the results of specifying;

and wherein, in said processing step, said input image data for each of covered background region and uncovered background region is further processed.

30. A program according to Claim 25, wherein, in said processing step, coefficients used in class classification adaptation processing are generated for each region specified by said region specifying information.

31. A program according to Claim 25, wherein, in said processing step, output image data is generated by class classification adaptation processing for each region specified by said region specifying information.

32. A program according to Claim 25, wherein, in said processing step, the edges of said input image data are enhanced for each region specified by said region specifying information.

33. An image-taking device, comprising:

image-taking means for outputting a subject image taken by an image-taking device having a predetermined number of pixels having time-integration effects as image data made up of a predetermined number of pieces of pixel data;

region specifying means for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

processing means for processing said image data for each region specified by said region specifying information.

34. An image-taking device according to Claim 33, wherein said processing means decide a class corresponding to each piece of pixel data of said image data, corresponding to said region specifying information.

35. An image-taking device according to Claim 33, wherein said processing means enhance the edges of said image data, corresponding to said region specifying information.

36. An image-taking device according to Claim 33, wherein said processing means process said pixel data of at least

one region of said mixed region and said non-mixed region.

37. An image-taking device according to Claim 33, wherein said region specifying means further specify a covered background region and an uncovered background region, and output region specifying information corresponding to the results of specifying;

and wherein said processing means further process said image data for each of covered background region and uncovered background region.

38. An image-taking device according to Claim 33, wherein said processing means generate coefficients used in class classification adaptation processing, for each region specified by said region specifying information.

39. An image-taking device according to Claim 33, wherein said processing means generate output image data by class classification adaptation processing, for each region specified by said region specifying information.

40. An image-taking device according to Claim 33, wherein said processing means enhance the edges of said image data, for each region specified by said region specifying information.

41. An image processing device for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration

effects, said image processing device comprising:

region specifying means for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

class deciding means for determining classes corresponding to each set of pixel data of said input image data, corresponding to said region specifying information.

42. An image processing device according to Claim 41, wherein said class deciding means decide a class corresponding to said pixel data of only regions which are a portion of said mixed region, said foreground region, and said background region.

43. An image processing device according to Claim 41, further comprising generating means for processing said pixel data of said input image data corresponding to said classes that have been decided, and generating coefficients used in class classification adaptation processing.

44. An image processing device according to Claim 41,

further comprising converting means for processing said pixel data of said input image data based on a coefficient for each of said classes, corresponding to said classes that have been decided, and converting said input image data into output image data.

45. An image processing device according to Claim 41, wherein said region specifying means further specify a covered background region and an uncovered background region, and output said region specifying information corresponding to the results of specifying;

and wherein said class deciding means decide said classes corresponding to said pixel data of said input image data, corresponding to said covered background region or said uncovered background region that have been specified.

46. An image processing method for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object

component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a class deciding step for determining classes corresponding to each set of pixel data of said input image data, corresponding to said region specifying information.

47. An image processing method according to Claim 46, wherein, in said class deciding step, a class corresponding to said pixel data of only regions which are a portion of said mixed region, said foreground region, and said background region, is decided.

48. An image processing method according to Claim 46, further comprising a generating step for processing said pixel data of said input image data corresponding to said classes that have been decided, and generating coefficients used in class classification adaptation processing.

49. An image processing method according to Claim 46, further comprising a converting step for processing said pixel data of said input image data based on a coefficient for each of said classes, corresponding to said classes that have been decided, and converting said input image data into output image data.

50. An image processing method according to Claim 46, wherein, in said region specifying step, a covered

background region and an uncovered background region are further specified, and said region specifying information is output corresponding to the results of specifying;

and wherein, in said class deciding step, said classes corresponding to said pixel data of said input image data is decided corresponding to said covered background region or said uncovered background region that have been specified.

51. A recording medium storing a computer-readable program for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said program comprising:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a class deciding step for determining classes corresponding to each set of pixel data of said input image data, corresponding to said region specifying information.

52. A recording medium according to Claim 51, wherein, in said class deciding step, a class corresponding to said pixel data of only regions which are a portion of said mixed region, said foreground region, and said background region, is decided.

53. A recording medium according to Claim 51, said program further comprising a generating step for processing said pixel data of said input image data corresponding to said classes that have been decided, and generating coefficients used in class classification adaptation processing.

54. A recording medium according to Claim 51, said program further comprising a converting step for processing said pixel data of said input image data based on a coefficient for each of said classes, corresponding to said classes that have been decided, and converting said input image data into output image data.

55. A recording medium according to Claim 51, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and said region specifying information is output corresponding to the results of specifying;

and wherein, in said class deciding step, said classes corresponding to said pixel data of said input image data is decided corresponding to said covered background region or

said uncovered background region that have been specified.

56. A program for causing a computer, which processes input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, to execute:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a class deciding step for determining classes corresponding to each set of pixel data of said input image data, corresponding to said region specifying information.

57. A program according to Claim 56, wherein, in said class deciding step, a class corresponding to said pixel data of only regions which are a portion of said mixed region, said foreground region, and said background region, is decided.

58. A program according to Claim 56, further comprising a

generating step for processing said pixel data of said input image data corresponding to said classes that have been decided, and generating coefficients used in class classification adaptation processing.

59. A program according to Claim 56, further comprising a converting step for processing said pixel data of said input image data based on a coefficient for each of said classes, corresponding to said classes that have been decided, and converting said input image data into output image data.

60. A program according to Claim 56, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and said region specifying information is output corresponding to the results of specifying;

and wherein, in said class deciding step, said classes corresponding to said pixel data of said input image data is decided corresponding to said covered background region or said uncovered background region that have been specified.

61. An image-taking device, comprising:

image-taking means for outputting a subject image taken by an image-taking device having a predetermined number of pixels having time-integration effects as taken image data made up of a predetermined number of pieces of pixel data;

region specifying means for specifying, based on said taken image data, a mixed region made up of a mixture of a

foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

class deciding means for determining classes corresponding to each set of pixel data of said taken image data, corresponding to said region specifying information.

62. An image-taking device according to Claim 61, wherein said class deciding means decide a class corresponding to said pixel data of only regions which are a portion of said mixed region, said foreground region, and said background region.

63. An image-taking device according to Claim 61, further comprising generating means for processing said pixel data of said taken image data corresponding to said classes that have been decided, and generating coefficients used in class classification adaptation processing.

64. An image-taking device according to Claim 61, further comprising converting means for processing said pixel data of said taken image data based on a coefficient for each of said classes, corresponding to said classes that have been

decided, and converting said taken image data into output image data.

65. An image-taking device according to Claim 61, wherein said region specifying means further specify a covered background region and an uncovered background region, and output said region specifying information corresponding to the results of specifying;

and wherein said class deciding means decide said classes corresponding to said pixel data of said taken image data, corresponding to said covered background region or said uncovered background region that have been specified.

66. An image processing device for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said image processing device comprising:

region specifying means for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to

the results of specifying; and

edge enhancing means for enhancing the edges of said input image data, corresponding to said region specifying information.

67. An image processing device according to Claim 66, wherein said region specifying means further specify a covered background region and an uncovered background region, and output said region specifying information corresponding to the results of specifying;

and wherein said edge enhancing means enhance the edges of said input image data, corresponding to said covered background region or said uncovered background region that have been specified.

68. An image processing method for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background

object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

an edge enhancing step for enhancing the edges of said input image data, corresponding to said region specifying information.

69. An image processing method according to Claim 68, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and said region specifying information is output corresponding to the results of specifying;

and wherein, in said edge enhancing step, the edges of said input image data are enhanced corresponding to said covered background region or said uncovered background region that have been specified.

70. A recording medium storing a computer-readable program for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said program comprising:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a

foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

an edge enhancing step for enhancing the edges of said input image data, corresponding to said region specifying information.

71. A recording medium according to Claim 70, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and said region specifying information is output corresponding to the results of specifying;

and wherein, in said edge enhancing step, the edges of said input image data are enhanced corresponding to said covered background region or said uncovered background region that have been specified.

72. A program for causing a computer, which processes input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, to execute:

a region specifying step for specifying, based on said input image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects

and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

an edge enhancing step for enhancing the edges of said input image data, corresponding to said region specifying information.

73. A program according to Claim 72, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and said region specifying information is output corresponding to the results of specifying;

and wherein, in said edge enhancing step, the edges of said input image data are enhanced corresponding to said covered background region or said uncovered background region that have been specified.

74. An image-taking device, comprising:

image-taking means for outputting a subject image taken by an image-taking device having a predetermined number of pixels having time-integration effects as image data made up of a predetermined number of pieces of pixel data;

region specifying means for specifying, based on said

image data, a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

edge enhancing means for enhancing the edges of said image data, corresponding to said region specifying information.

75. An image-taking device according to Claim 74, wherein said region specifying means further specify a covered background region and an uncovered background region, and output said region specifying information corresponding to the results of specifying;

and wherein said edge enhancing means enhance the edges of said image data, corresponding to said covered background region or said uncovered background region that have been specified.

76. An image processing device for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration

effects, said image processing device comprising:

region specifying means for specifying, based on said input image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

processing means for processing said pixel data for said mixed region specified by said region specifying means with a method different from a method for processing said non-mixed region.

77. An image processing device according to claim 76, wherein said region specifying means further specify said foreground region and said background region, and output said region specifying information corresponding to the results of specifying.

78. An image processing device according to claim 76, wherein said region specifying means further specify a covered background region and an uncovered background region, and output region specifying information corresponding to the results of specifying.

79. An image processing device according to claim 76, further comprising separating means for separating said pixel data of said mixed region into said foreground object component and said background object component, based on said region specifying information;

wherein said processing means process at least one of said foreground object component and said background object component.

80. An image processing method for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising:

a region specifying step for specifying, based on said input image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a

background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a processing step for processing said pixel data for said mixed region specified by said region specifying means with a method different from a method for processing said non-mixed region.

81. An image processing method according to claim 80, wherein, in said region specifying step, said foreground region and said background region are further specified, and said region specifying information is output corresponding to the results of specifying.

82. An image processing method according to claim 80, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and region specifying information is output corresponding to the results of specifying.

83. An image processing method according to claim 80, further comprising a separating step for separating

said pixel data of said mixed region into said foreground object component and said background object component, based on said region specifying information;

wherein, in said processing step, at least one of said foreground object component and said background object component are processed.

84. A recording medium storing a computer-readable program for processing input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, said method comprising:

a region specifying step for specifying, based on said input image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a processing step for processing said pixel data for said mixed region specified by said region specifying means

with a method different form a method for processing said non-mixed region.

85. A recording medium according to claim 84, wherein, in said region specifying step, said foreground region and said background region are further specified, and said region specifying information is output corresponding to the results of specifying.

86. A recording medium according to claim 84, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and region specifying information is output corresponding to the results of specifying.

87. A recording medium according to claim 84, said program further comprising a separating step for separating said pixel data of said mixed region into said foreground object component and said background object component, based on said region specifying information;

wherein, in said processing step, at least one of said foreground object component and said background object component are processed.

88. A program for causing a computer, which processes input image data made up of a predetermined number of pieces of pixel data obtained by an image-taking device having a predetermined number of pixels having time-integration effects, to execute:

a region specifying step for specifying, based on said input image data, at least one of a mixed region made up of a mixture of a foreground object component configuring foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

a processing step for processing said pixel data for said mixed region specified by said region specifying means with a method different from a method for processing said non-mixed region.

89. A program according to claim 88, wherein, in said region specifying step, said foreground region and said background region are further specified, and said region specifying information is output corresponding to the results of specifying.

90. A program according to claim 88, wherein, in said region specifying step, a covered background region and an uncovered background region are further specified, and region specifying information is output corresponding to the results of specifying.

91. A program according to claim 88, further comprising a separating step for separating said pixel data of said mixed region into said foreground object component and said background object component, based on said region specifying information;

wherein, in said processing step, at least one of said foreground object component and said background object component are processed.

92. An image-taking device, comprising:

image-taking means for outputting a subject image taken by an image-taking device having a predetermined number of pixels having time-integration effects as image data made up of a predetermined number of pieces of pixel data;

region specifying means for specifying, based on said image data, at least one of a mixed region made up of a mixture of a foreground object component configuring

foreground objects and a background object component configuring background objects, and a non-mixed region made up of one of a foreground region made up of said foreground object component and a background region made up of a background object component configuring said background objects, and outputting region specifying information corresponding to the results of specifying; and

processing means for processing said pixel data for said mixed region specified by said region specifying means with a method different from a method for processing said non-mixed region.

93. An image-taking device according to claim 92, wherein said region specifying means further specify said foreground region and said background region, and output said region specifying information corresponding to the results of specifying.

94. An image-taking device according to claim 92, wherein said region specifying means further specify a covered background region and an uncovered background region, and output said region specifying information corresponding to the results of specifying.

95. An image-taking device according to claim 92, further comprising separating means for separating said pixel data of said mixed region into said foreground object component and said background object component, based on said region specifying information;

wherein said processing means process at least one of said foreground object component and said background object component.

ABSTRACT

The present invention allows an image to be processed corresponding to the mixture of a background image and an image of a moving object. A region specifying unit specifies a mixed region wherein foreground object components making up foreground objects and background object components making up background objects are mixed, and a non-mixed region configured of one of foreground object components making up foreground objects or background object components making up background objects, and outputs region information corresponding to the results of specifying. A region processing unit 5001 processes input images for each of the regions specified by the region information. The present invention can be applied to image processing devices for processing images.