DESCRIPTION

IMAGE PROCESSING APPARATUS AND METHOD, AND IMAGE-CAPTURING APPARATUS

Technical Field

The present invention relates to image processing apparatuses and methods, and image-capturing apparatuses, and more particularly, to an image processing apparatus and method, and an image-capturing apparatus in which a difference between a signal detected by a sensor and the real world is taken into consideration.

Background Art

A technique for detecting incidents occurring in the real world by a sensor and for processing sampled data output from the image sensor is widely used.

For example, motion blur occurs in an image obtained by capturing an object moving in front of a predetermined stationary background with a video camera if the moving speed is relatively high.

However, when an object is moving in front of a stationary background, not only does motion blur caused by the mixture of the moving object itself occur, but also the mixture of the background image and the object image occurs. Hitherto, the processing of the mixture state of the

background image and the moving object has not been considered.

Disclosure of Invention

The present invention has been made in view of the above-described background. Accordingly, it is an object of the present invention to enable the separation of a background image and an object image according to the mixture state.

According to one aspect of the present invention, there is provided an image processing apparatus for performing image-processing on image data which is formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function, the image processing apparatus comprises area specifying means for specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, the area specifying means for specifying, in a second period of time corresponding to one screen

subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and the area specifying means for specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving; mixture-ratio detection means for detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and foreground/background separation means for separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components based on the mixture ratio, and for generating a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

In one embodiment, the area specifying means may temporarily store three frames, which are consecutively input, and the area specifying means may specify, in the

first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, as the uncovered background area corresponding to the designated frame, and the area specifying means may specify, in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame, is moving, as the foreground area corresponding to the designated frame, and may specify, in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, as the background area corresponding to the designated frame, and the area specifying means may specify, in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one

frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, as the covered background area corresponding to the designated frame.

According to another aspect of the present invention, there is provided an image processing method for performing image-processing on image data which is formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function, the image processing method comprises an area specifying step of specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, the area specifying step of specifying, in a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and the area specifying step of specifying, in a third period of time corresponding to one screen

subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving; a mixture-ratio detection step of detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and a foreground/background separation step of separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components based on the mixture ratio so as to generate a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

In one embodiment, in the area specifying step, three frames, which are consecutively input, may be temporarily stored, and in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary,

may be specified as the uncovered background area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame, is moving, may be specified as the foreground area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, may be specified as the background area corresponding to the designated frame, and in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, may be specified as the covered background area corresponding to the designated frame.

According to yet another aspect of the present invention, there is provided a recording medium in which a

computer-readable program is recorded, the program being used for performing image-processing on image data which is formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function, the program comprises an area specifying step of specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, the area specifying step of specifying, in a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and the area specifying step of specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving; a mixture-ratio detection step

of detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and a foreground/background separation step of separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components based on the mixture ratio so as to generate a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

In one embodiment, in the area specifying step, three frames, which are consecutively input, may be temporarily stored, and in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, may be specified as the uncovered background area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination

result for the designated frame and a frame, which is one frame after the designated frame, is moving, may be specified as the foreground area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, may be specified as the background area corresponding to the designated frame, and in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, may be specified as the covered background area corresponding to the designated frame.

According to yet another aspect of the present invention, there is provided a program for allowing a computer which performs image-processing on image data formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function to execute: an area specifying step of specifying, in a first period of

time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of the image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, the area specifying step of specifying, in a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and the area specifying step of specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving; a mixture-ratio detection step of detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and a foreground/background separation step of separating the pixel data of the pixels belonging to the uncovered background area and to the

covered background area into the foreground object components and the background object components based on the mixture ratio so as to generate a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

In one embodiment, in the area specifying step, three frames, which are consecutively input, may be temporarily stored, and in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, may be specified as the uncovered background area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame, is moving, may be specified as the foreground area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame

is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, may be specified as the background area corresponding to the designated frame, and in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, may be specified as the covered background area corresponding to the designated frame.

According to yet another aspect of the present invention, there is provided an image-capturing apparatus comprises: image-capturing means for performing image-processing on image data which is formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function; area specifying means for specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of the image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in

a direction in which the foreground object is moving, the area specifying means for specifying, in a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and the area specifying means for specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving; mixture-ratio detection means for detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and foreground/background separation means for separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components based on the mixture ratio, and for generating a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

In another embodiment, the area specifying means may temporarily store three frames, which are consecutively input, and the area specifying means may specify, in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, as the uncovered background area corresponding to the designated frame, and the area specifying means may specify, in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame, is moving, as the foreground area corresponding to the designated frame, and may specify, in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, as the background area corresponding to the designated frame, and the area specifying means may specify, in the third period of time, an area in which a

determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, as the covered background area corresponding to the designated frame.

In a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of the image data and background object components forming a background object of the designated frame are mixed is specified, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving. In a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components are specified. In a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed is specified, the covered background area being formed at a leading end in a direction in which the foreground object is moving. A mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the

covered background area is detected. The pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components are separated based on the mixture ratio so as to generate a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

With this arrangement, the background image and the object image can be separated.

Brief Description of the Drawings

Fig. 1 is a diagram illustrating an embodiment of an image processing apparatus according to the present invention.

Fig. 2 is a block diagram illustrating the image processing apparatus.

Fig. 3 illustrates the image capturing performed by a sensor.

Fig. 4 illustrates the arrangement of pixels.

Fig. 5 illustrates the operation of a detection device.

Fig. 6A illustrates an image obtained by image-capturing an object corresponding to a moving foreground and an object corresponding to a stationary background.

Fig. 6B illustrates a model of an image obtained by image-capturing an object corresponding to a moving foreground and an object corresponding to a stationary background.

Fig. 7 illustrates a background area, a foreground area, a mixed area, a covered background area, and an uncovered background area.

Fig. 8 illustrates a model obtained by expanding in the time direction the pixel values of pixels aligned side-by-side in an image obtained by image-capturing an object corresponding to a stationary foreground and an the object corresponding to a stationary background.

Fig. 9 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 10 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 11 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 12 illustrates an example in which pixels in a foreground area, a background area, and a mixed area are extracted.

Fig. 13 illustrates the relationships between pixels

and a model obtained by expanding the pixel values in the time direction.

Fig. 14 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 15 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 16 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 17 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 18 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 19 is a flowchart illustrating the processing for adjusting the amount of motion blur.

Fig. 20 is a block diagram illustrating the configuration of an area specifying unit 103.

Fig. 21 illustrates an image when an object corresponding to a foreground is moving.

Fig. 22 illustrates a model in which pixel values are expanded in the time direction and the period corresponding

to the shutter time is divided.

Fig. 23 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 24 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 25 illustrates the conditions for determining the area.

Fig. 26 illustrates an example of the result obtained by specifying the area by the area specifying unit 103.

Fig. 27 illustrates an example of the result obtained by specifying the area by the area specifying unit 103.

Fig. 28 is a flowchart illustrating the area specifying processing.

Fig. 29 is a flowchart illustrating the area specifying processing.

Fig. 30 is a block diagram illustrating an example of the configuration of a mixture-ratio calculator 104.

Fig. 31 illustrates an example of the ideal mixture ratio α.

Fig. 32 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 33 illustrates a model in which pixel values are

expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 34 illustrates the approximation using the correlation of foreground components.

Fig. 35 illustrates the relationship among C, N, and P.

Fig. 36 is a block diagram illustrating the configuration of an estimated-mixture-ratio processor 401.

Fig. 37 illustrates an example of the estimated mixture ratio.

Fig. 38 is a block diagram illustrating another configuration of the mixture-ratio calculator 104.

Fig. 39 is a flowchart illustrating the processing for calculating the mixture ratio.

Fig. 40 is a flowchart illustrating the processing for calculating the estimated mixture ratio.

Fig. 41 illustrates a straight line for approximating the mixture ratio α.

Fig. 42 illustrates a plane for approximating the mixture ratio α.

Fig. 43 illustrates the relationships of the pixels in a plurality of frames when the mixture ratio α is calculated.

Fig. 44 is a block diagram illustrating another configuration of the mixture-ratio estimation processor 401.

Fig. 45 illustrates an example of the estimated mixture ratio.

Fig. 46 is a flowchart illustrating the mixture-ratio estimating processing by using a model corresponding to a covered background area.

Fig. 47 is a block diagram illustrating an example of the configuration of a foreground/background separator 105.

Fig. 48A illustrates an input image, a foreground component image, and a background component image.

Fig. 48B illustrates a model of an input image, a foreground component image, and a background component image.

Fig. 49 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 50 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 51 illustrates a model in which pixel values are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 52 is a block diagram illustrating an example of the configuration of a separating portion 601.

Fig. 53A illustrates an example of a separated foreground component image.

Fig. 53B illustrates an example of a separated background component image.

Fig. 54 is a flowchart illustrating the processing for

separating a foreground and a background.

Fig. 55 is a block diagram illustrating an example of the configuration of a motion-blur adjusting unit 106.

Fig. 56 illustrates the unit of processing.

Fig. 57 illustrates a model in which the pixel values of a foreground component image are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 58 illustrates a model in which the pixel values of a foreground component image are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 59 illustrates a model in which the pixel values of a foreground component image are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 60 illustrates a model in which the pixel values of a foreground component image are expanded in the time direction and the period corresponding to the shutter time is divided.

Fig. 61 illustrates an example of another configuration of the motion-blur adjusting unit 106.

Fig. 62 is a flowchart illustrating the processing for adjusting the amount of motion blur contained in a foreground component image performed by the motion-blur

adjusting unit 106.

Fig. 63 is a block diagram illustrating an example of another configuration of the motion-blur adjusting unit 106.

Fig. 64 illustrates an example of a model in which the relationships between pixel values and foreground components are indicated.

Fig. 65 illustrates the calculation of foreground components.

Fig. 66 illustrates the calculation of foreground components.

Fig. 67 is a flowchart illustrating the processing for eliminating motion blur contained in a foreground.

Fig. 68 is a block diagram illustrating another configuration of the function of the image processing apparatus.

Fig. 69 illustrates the configuration of a synthesizer 1001.

Fig. 70 is a block diagram illustrating still another configuration of the function of the image processing apparatus.

Fig. 71 is a block diagram illustrating the configuration of a mixture-ratio calculator 1101.

Fig. 72 is a block diagram illustrating the configuration of a foreground/background separator 1102.

Fig. 73 is a block diagram illustrating still another

configuration of the function of the image processing apparatus.

Fig. 74 illustrates the configuration of a synthesizer 1201.

Best Mode for Carrying Out the Invention

Fig. 1 is a block diagram illustrating the configuration of an embodiment of an image processing apparatus according to the present invention. A CPU (Central Processing Unit) 21 executes various types of processing according to programs stored in a ROM (Read Only Memory) 22 or in a storage unit 28. Programs executed by the CPU 21 and data are stored in a RAM (Random Access Memory) 23 as required. The CPU 21, the ROM 22, and the RAM 23 are connected to each other by a bus 24.

An input/output interface 25 is also connected to the CPU 21 via the bus 24. An input unit 26, which is formed of a keyboard, a mouse, a microphone, and so on, and an output unit 27, which is formed of a display, a speaker, and so on, are connected to the input/output interface 25. The CPU 21 executes various types of processing in response to a command input from the input unit 26. The CPU 21 then outputs an image or sound obtained as a result of the processing to the output unit 27.

The storage unit 28 connected to the input/output

interface 25 is formed of, for example, a hard disk, and stores programs executed by the CPU 21 and various types of data. A communication unit 29 communicates with an external device via the Internet or another network. In this example, the communication unit 29 serves as an obtaining unit for obtaining an output of a sensor.

Alternatively, a program may be obtained via the communication unit 29 and stored in the storage unit 28.

A drive 30 connected to the input/output interface 25 drives a magnetic disk 51, an optical disc 52, a magneto-optical disk 53, a semiconductor memory 54, or the like, when such a recording medium is attached to the drive 30, and obtains a program or data stored in the corresponding medium. The obtained program or data is transferred to the storage unit 28 and stored therein if necessary.

Fig. 2 is a block diagram illustrating the image processing apparatus.

It does not matter whether the individual functions of the image processing apparatus are implemented by hardware or software. That is, the block diagrams of this specification may be hardware block diagrams or software functional block diagrams.

In this specification, an image to be captured corresponding to an object in the real world is referred to as an image object.

An input image supplied to the image processing apparatus is supplied to an object extracting unit 101, an area specifying unit 103, a mixture-ratio calculator 104, and a foreground/background separator 105.

The object extracting unit 101 extracts a rough image object corresponding to a foreground object contained in the input image, and supplies the extracted image object to a motion detector 102. The object extracting unit 101 detects, for example, an outline of the foreground image object contained in the input image so as to extract a rough image object corresponding to the foreground object.

The object extracting unit 101 extracts a rough image object corresponding to a background object contained in the input image, and supplies the extracted image object to the motion detector 102. The object extracting unit 101 extracts a rough image object corresponding to the background object from, for example, the difference between the input image and the extracted image object corresponding to the foreground object.

Alternatively, for example, the object extracting unit 101 may extract the rough image object corresponding to the foreground object and the rough image object corresponding to the background object from the difference between the background image stored in a built-in background memory and the input image.

The motion detector 102 calculates a motion vector of the roughly extracted image object corresponding to the foreground object according to a technique, such as block matching, gradient, phase correlation, or pel-recursive technique, and supplies the calculated motion vector and the motion-vector positional information (which is information for specifying the positions of the pixels corresponding to the motion vector) to a motion-blur adjusting unit 106.

The motion vector output from the motion detector 102 contains information corresponding to the amount of movement v.

The motion detector 102 may output the motion vector of each image object, together with the pixel positional information for specifying the pixels of the image object, to the motion-blur adjusting unit 106.

The amount of movement v is a value indicating a positional change in an image corresponding to a moving object in units of the pixel pitch. For example, if an object image corresponding to a foreground is moving such that it is displayed at a position four pixels away from a reference frame when it is positioned in the subsequent frame, the amount of movement v of the object image corresponding to the foreground is 4.

The object extracting unit 101 and the motion detector 102 are needed when adjusting the amount of motion blur

corresponding to a moving object.

The area specifying unit 103 determines to which of a foreground area, a background area, or a mixed area each pixel of the input image belongs, and supplies information indicating to which area each pixel belongs (hereinafter referred to as "area information") to the mixture-ratio calculator 104, the foreground/background separator 105, and the motion-blur adjusting unit 106.

The mixture-ratio calculator 104 calculates the mixture ratio corresponding to the pixels contained in a mixed area (hereinafter referred to as the "mixture ratio α") based on the input image, the motion vector and the positional information thereof supplied from the motion detector 102, and the area information supplied from the area specifying unit 103, and supplies the mixture ratio α to the foreground/background separator 105.

The mixture ratio α is a value indicating the ratio of the image components corresponding to the background object (hereinafter also be referred to as "background components") to the pixel value as expressed by equation (3), which is shown below.

The foreground/background separator 105 separates the input image into a foreground component image formed of only the image components corresponding to the foreground object (hereinafter also be referred to as "foreground components")

and a background component image formed of only the background components based on the area information supplied from the area specifying unit 103 and the mixture ratio α supplied from the mixture-ratio calculator 104, and supplies the foreground component image to the motion-blur adjusting unit 106 and a selector 107. The separated foreground component image may be set as the final output. A more precise foreground and background can be obtained compared to a known method in which only a foreground and a background are specified without considering the mixed area.

The motion-blur adjusting unit 106 determines the unit of processing indicating at least one pixel contained in the foreground component image based on the amount of movement v obtained from the motion vector and based on the area information. The unit of processing is data that specifies a group of pixels to be subjected to the motion-blur adjustments.

Based on the amount by which the motion blur is to be adjusted, which is input into the image processing apparatus, the foreground component image supplied from the foreground/background separator 105, the motion vector and the positional information thereof supplied from the motion detector 102, and the unit of processing, the motion-blur adjusting unit 106 adjusts the amount of motion blur contained in the foreground component image by removing,

decreasing, or increasing the motion blur contained in the foreground component image. The motion-blur adjusting unit 106 then outputs the foreground component image in which amount of motion blur is adjusted to the selector 107. It is not essential that the motion vector and the positional information thereof be used.

Motion blur is a distortion contained in an image corresponding to a moving object caused by the movement of an object to be captured in the real world and the image-capturing characteristics of the sensor.

The selector 107 selects one of the foreground component image supplied from the foreground/background separator 105 and the foreground component image in which the amount of motion blur is adjusted supplied from the motion-blur adjusting unit 106 based on, for example, a selection signal reflecting a user's selection, and outputs the selected foreground component image.

An input image supplied to the image processing apparatus is discussed below with reference to Figs. 3 through 18.

Fig. 3 illustrates image capturing performed by a sensor. The sensor is formed of, for example, a CCD (Charge-Coupled Device) video camera provided with a CCD area sensor, which is a solid-state imaging device. An object 111 corresponding to a foreground in the real world

moves, for example, horizontally from the left to the right, between an object 112 corresponding to a background and the sensor.

The sensor captures the image of the object 111 corresponding to the foreground together with the image of the object 112 corresponding to the background. The sensor outputs the captured image in units of frames. For example, the sensor outputs an image having 30 frames per second. The exposure time of the sensor can be 1/30 second. The exposure time is a period from when the sensor starts converting input light into electrical charge until when the conversion from the input light to the electrical charge is finished. The exposure time is also referred to as a "shutter time".

Fig. 4 illustrates the arrangement of pixels. In Fig. 4, A through I indicate the individual pixels. The pixels are disposed on a plane of a corresponding image. One detection device corresponding to each pixel is disposed on the sensor. When the sensor performs image capturing, each detection device outputs a pixel value of the corresponding pixel forming the image. For example, the position of the detection device in the X direction corresponds to the horizontal direction on the image, while the position of the detection device in the Y direction corresponds to the vertical direction on the image.

As shown in Fig. 5, the detection device, which is, for example, a CCD, converts input light into electrical charge during a period corresponding to a shutter time, and stores the converted electrical charge. The amount of charge is almost proportional to the intensity of the input light and the period for which the light is input. The detection device sequentially adds the electrical charge converted from the input light to the stored electrical charge during the period corresponding to the shutter time. That is, the detection device integrates the input light during the period corresponding to the shutter time and stores the electrical charge corresponding to the amount of integrated light. It can be considered that the detection device has an integrating function with respect to time.

The electrical charge stored in the detection device is converted into a voltage value by a circuit (not shown), and the voltage value is further converted into a pixel value, such as digital data, and is output. Accordingly, each pixel value output from the sensor is a value projected on a linear space, which is a result of integrating a certain three-dimensional portion of the object corresponding to the foreground or the background with respect to the shutter time.

The image processing apparatus extracts significant information embedded in the output signal, for example, the

mixture ratio α, by the storage operation of the sensor. The image processing apparatus adjusts the amount of distortion, for example, the amount of motion blur, caused by the mixture of the foreground image object itself. The image processing apparatus also adjusts the amount of distortion caused by the mixture of the foreground image object and the background image object.

Fig. 6A illustrates an image obtained by capturing a moving object corresponding to a foreground and a stationary object corresponding to a background. Fig. 6B illustrates an image obtained by capturing a moving object corresponding to a foreground and a stationary object corresponding to a background.

Fig. 6A illustrates an image obtained by capturing a moving object corresponding to a foreground and a stationary object corresponding to a background. In the example shown in Fig. 6A, the object corresponding to the foreground is moving horizontally from the left to the right with respect to the screen.

Fig. 6B illustrates a model obtained by expanding pixel values corresponding to one line of the image shown in Fig. 6A in the time direction. The horizontal direction shown in Fig. 6B corresponds to the spatial direction X in Fig. 6A.

The values of the pixels in the background area are formed only from the background components, that is, the

image components corresponding to the background object. The values of the pixels in the foreground area are formed only from the foreground components, that is, the image components corresponding to the foreground object.

The values of the pixels of the mixed area are formed from the background components and the foreground components. Since the values of the pixels in the mixed area are formed from the background components and the foreground components, it may be referred to as a "distortion area". The mixed area is further classified into a covered background area and an uncovered background area.

The covered background area is a mixed area at a position corresponding to the leading end in the direction in which the foreground object is moving, where the background components are gradually covered with the foreground over time.

In contrast, the uncovered background area is a mixed area corresponding to the trailing end in the direction in which the foreground object is moving, where the background components gradually appear over time.

As discussed above, the image containing the foreground area, the background area, or the covered background area or the uncovered background area is input into the area specifying unit 103, the mixture-ratio calculator 104, and the foreground/background separator 105 as the input image.

Fig. 7 illustrates the background area, the foreground area, the mixed area, the covered background area, and the uncovered background area discussed above. In the areas corresponding to the image shown in Fig. 6A, the background area is a stationary portion, the foreground area is a moving portion, the covered background area of the mixed area is a portion that changes from the background to the foreground, and the uncovered background area of the mixed area is a portion that changes from the foreground to the background.

Fig. 8 illustrates a model obtained by expanding in the time direction the pixel values of the pixels aligned side-by-side in the image obtained by capturing the image of the object corresponding to the stationary foreground and the image of the object corresponding to the stationary background. For example, as the pixels aligned side-by-side, pixels arranged in one line on the screen can be selected.

The pixel values indicated by F01 through F04 shown in Fig. 8 are values of the pixels corresponding to the object of the stationary foreground. The pixel values indicated by B01 through B04 shown in Fig. 8 are values of the pixels corresponding to the object of the stationary background.

The vertical direction in Fig. 8 corresponds to time, and time elapses from the top to the bottom in Fig. 8 in the vertical direction in Fig. 8. The position at the top side

of the rectangle in Fig. 8 corresponds to the time at which the sensor starts converting input light into electrical charge, and the position at the bottom side of the rectangle in Fig. 8 corresponds to the time at which the conversion from the input light into the electrical charge is finished. That is, the distance from the top side to the bottom side of the rectangle in Fig. 8 corresponds to the shutter time.

The pixels shown in Fig. 8 are described below assuming that, for example, the shutter time is equal to the frame size.

The horizontal direction in Fig. 8 corresponds to the spatial direction X in Fig. 6A. More specifically, in the example shown in Fig. 8, the distance from the left side of the rectangle indicated by "F01" in Fig. 8 to the right side of the rectangle indicated by "B04" is eight times the pixel pitch, i.e., eight consecutive pixels.

When the foreground object and the background object are stationary, the light input into the sensor does not change during the period corresponding to the shutter time.

The period corresponding to the shutter time is divided into two or more portions of equal periods. For example, if the number of virtual divided portions is 4, the model shown in Fig. 8 can be represented by the model shown in Fig. 9. The number of virtual divided portions can be set according to the amount of movement v of the object corresponding to

the foreground within the shutter time. For example, the number of virtual divided portions is set to 4 when the amount of movement v is 4, and the period corresponding to the shutter time is divided into four portions.

The uppermost line in Fig. 9 corresponds to the first divided period from when the shutter has opened. The second line in Fig. 11 corresponds to the second divided period from when the shutter has opened. The third line in Fig. 11 corresponds to the third divided period from when the shutter has opened. The fourth line in Fig. 11 corresponds to the fourth divided period from when the shutter has opened.

The shutter time divided in accordance with the amount of movement v is also hereinafter referred to as the "shutter time/v".

When the object corresponding to the foreground is stationary, the light input into the sensor does not change, and thus, the foreground component F01/v is equal to the value obtained by dividing the pixel value F01 by the number of virtual divided portions. Similarly, when the object corresponding to the foreground is stationary, the foreground component F02/v is equal to the value obtained by dividing the pixel value F02 by the number of virtual divided portions, the foreground component F03/v is equal to the value obtained by dividing the pixel value F03 by the

number of virtual divided portions, and the foreground component F04/v is equal to the value obtained by dividing the pixel value F04 by the number of virtual divided portions.

When the object corresponding to the background is stationary, the light input into the sensor does not change, and thus, the background component B01/v is equal to the value obtained by dividing the pixel value B01 by the number of virtual divided portions. Similarly, when the object corresponding to the background is stationary, the background component B02/v is equal to the value obtained by dividing the pixel value B02 by the number of virtual divided portions, the background component B03/v is equal to the value obtained by dividing the pixel value B03 by the number of virtual divided portions, and the background component B04/v is equal to the value obtained by dividing the pixel value B04 by the number of virtual divided portions.

More specifically, when the object corresponding to the foreground is stationary, the light corresponding to the foreground object input into the sensor does not change during the period corresponding to the shutter time. Accordingly, the foreground component F01/v corresponding to the first portion of the shutter time/v from when the shutter has opened, the foreground component F01/v

corresponding to the second portion of the shutter time/v from when the shutter has opened, the foreground component F01/v corresponding to the third portion of the shutter time/v from when the shutter has opened, and the foreground component F01/v corresponding to the fourth portion of the shutter time/v from when the shutter has opened become the same value. The same applies to F02/v through F04/v, as in the case of F01/v.

When the object corresponding to the background is stationary, the light corresponding to the background object input into the sensor does not change during the period corresponding to the shutter time. Accordingly, the background component B01/v corresponding to the first portion of the shutter time/v from when the shutter has opened, the background component B01/v corresponding to the second portion of the shutter time/v from when the shutter has opened, the background component B01/v corresponding to the third portion of the shutter time/v from when the shutter has opened, and the background component B01/v corresponding to the fourth portion of the shutter time/v from when the shutter has opened become the same value. The same applies to B02/v through B04/v.

A description is given of the case in which the object corresponding to the foreground is moving and the object corresponding to the background is stationary.

Fig. 10 illustrates a model obtained by expanding in the time direction the pixel values of the pixels in one line, including a covered background area, when the object corresponding to the foreground is moving to the right in Fig. 10. In Fig. 10, the amount of movement v is 4. Since one frame is a short period, it can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity. In Fig. 10, the object image corresponding to the foreground is moving such that it is positioned four pixels to the right with respect to a reference frame when it is displayed in the subsequent frame.

In Fig. 10, the pixels from the leftmost pixel to the fourth pixel belong to the foreground area. In Fig. 10, the pixels from the fifth pixel to the seventh pixel from the left belong to the mixed area, which is the covered background area. In Fig. 10, the rightmost pixel belongs to the background area.

The object corresponding to the foreground is moving such that it gradually covers the object corresponding to the background over time. Accordingly, the components contained in the pixel values of the pixels belonging to the covered background area change from the background components to the foreground components at a certain time during the period corresponding to the shutter time.

For example, the pixel value M surrounded by the thick

frame in Fig. 10 is expressed by equation (1) below.

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

For example, the fifth pixel from the left contains a background component corresponding to one portion of the shutter time/v and foreground components corresponding to three portions of the shutter time/v, and thus, the mixture ratio α of the fifth pixel from the left is 1/4. The sixth pixel from the left contains background components corresponding to two portions of the shutter time/v and foreground components corresponding to two portions of the shutter time/v, and thus, the mixture ratio α of the sixth pixel from the left is 1/2. The seventh pixel from the left contains background components corresponding to three portions of the shutter time/v and a foreground component corresponding to one portion of the shutter time/v, and thus, the mixture ratio α of the fifth pixel from the left is 3/4.

It can be assumed that the object corresponding to the foreground is a rigid body, and the foreground object is moving with constant velocity such that it is displayed four pixels to the right in the subsequent frame. Accordingly, for example, the foreground component F07/v of the fourth pixel from the left in Fig. 10 corresponding to the first portion of the shutter time/v from when the shutter has opened is equal to the foreground component of the fifth pixel from the left in Fig. 10 corresponding to the second

portion of the shutter time/v from when the shutter has opened. Similarly, the foreground component F07/v is equal to the foreground component of the sixth pixel from the left in Fig. 10 corresponding to the third portion of the shutter time/v from when the shutter has opened, and the foreground component of the seventh pixel from the left in Fig. 10 corresponding to the fourth portion of the shutter time/v from when the shutter has opened.

It can be assumed that the object corresponding to the foreground is a rigid body, and the foreground object is moving with constant velocity such that it is displayed four pixels to the right in the subsequent frame. Accordingly, for example, the foreground component F06/v of the third pixel from the left in Fig. 10 corresponding to the first portion of the shutter time/v from when the shutter has opened is equal to the foreground component of the fourth pixel from the left in Fig. 10 corresponding to the second portion of the shutter time/v from when the shutter has opened. Similarly, the foreground component F06/v is equal to the foreground component of the fifth pixel from the left in Fig. 10 corresponding to the third portion of the shutter time/v from when the shutter has opened, and the foreground component of the sixth pixel from the left in Fig. 10 corresponding to the fourth portion of the shutter time/v from when the shutter has opened.

It can be assumed that the object corresponding to the foreground is a rigid body, and the foreground object is moving with constant velocity such that it is displayed four pixels to the right in the subsequent frame. Accordingly, for example, the foreground component F05/v of the second pixel from the left in Fig. 10 corresponding to the first portion of the shutter time/v from when the shutter has opened is equal to the foreground component of the third pixel from the left in Fig. 10 corresponding to the second portion of the shutter time/v from when the shutter has opened. Similarly, the foreground component F05/v is equal to the foreground component of the fourth pixel from the left in Fig. 10 corresponding to the third portion of the shutter time/v from when the shutter has opened, and the foreground component of the fifth pixel from the left in Fig. 10 corresponding to the fourth portion of the shutter time/v from when the shutter has opened.

It can be assumed that the object corresponding to the foreground is a rigid body, and the foreground object is moving with constant velocity such that it is displayed four pixels to the right in the subsequent frame. Accordingly, for example, the foreground component F04/v of the left most pixel in Fig. 10 corresponding to the first portion of the shutter time/v from when the shutter has opened is equal to the foreground component of the second pixel from the left

in Fig. 10 corresponding to the second portion of the shutter time/v from when the shutter has opened. Similarly, the foreground component F04/v is equal to the foreground component of the third pixel from the left in Fig. 10 corresponding to the third portion of the shutter time/v from when the shutter has opened, and the foreground component of the fourth pixel from the left in Fig. 10 corresponding to the fourth portion of the shutter time/v from when the shutter has opened.

Since the foreground area corresponding to the moving object contains motion blur as discussed above, it can also be referred to as a "distortion area".

Fig. 11 illustrates a model obtained by expanding in the time direction the pixel values of the pixels in one line including an uncovered background area when the object corresponding to the foreground is moving to the right in Fig. 11. In Fig. 11, the amount of movement v is 4. Since one frame is a short period, it can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity. In Fig. 11, the object image corresponding to the foreground is moving to the right such that it is positioned four pixels to the right with respect to a reference frame when it is displayed in the subsequent frame.

In Fig. 11, the pixels from the leftmost pixel to the

fourth pixel belong to the background area. In Fig. 11, the pixels from the fifth pixel to the seventh pixels from the left belong to the mixed area, which is an uncovered background area. In Fig. 11, the rightmost pixel belongs to the foreground area.

The object corresponding to the foreground which covers the object corresponding to the background is moving such that it is gradually removed from the object corresponding to the background over time. Accordingly, the components contained in the pixel values of the pixels belonging to the uncovered background area change from the foreground components to the background components at a certain time of the period corresponding to the shutter time.

For example, the pixel value M' surrounded by the thick frame in Fig. 11 is expressed by equation (2).

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

For example, the fifth pixel from the left contains background components corresponding to three portions of the shutter time/v and a foreground component corresponding to one shutter portion of the shutter time/v, and thus, the mixture ratio α of the fifth pixel from the left is 3/4. The sixth pixel from the left contains background components corresponding to two portions of the shutter time/v and foreground components corresponding to two portions of the shutter time/v, and thus, the mixture ratio α of the sixth

pixel from the left is 1/2. The seventh pixel from the left contains a background component corresponding to one portion of the shutter time/v and foreground components corresponding to three portions of the shutter time/v, and thus, the mixture ratio α of the seventh pixel from the left is 1/4.

When equations (1) and (2) are generalized, the pixel value M can be expressed by equation (3):

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

where α is the mixture ratio, B indicates a pixel value of the background, and Fi/v designates a foreground component.

It can be assumed that the object corresponding to the foreground is a rigid body, which is moving with constant velocity, and the amount of movement is 4. Accordingly, for example, the foreground component F01/v of the fifth pixel from the left in Fig. 11 corresponding to the first portion of the shutter time/v from when the shutter has opened is equal to the foreground component of the sixth pixel from the left in Fig. 11 corresponding to the second portion of the shutter time/v from when the shutter has opened. Similarly, the foreground component F01/v is equal to the foreground component of the seventh pixel from the left in Fig. 11 corresponding to the third portion of the shutter time/v from when the shutter has opened, and the foreground

component of the eighth pixel from the left in Fig. 11 corresponding to the fourth portion of the shutter time/v from when the shutter has opened.

It can be assumed that the object corresponding to the foreground is a rigid body, which is moving with constant velocity, and the amount of movement v is 4. Accordingly, for example, the foreground component F02/v of the sixth pixel from the left in Fig. 11 corresponding to the first portion of the shutter time/v from when the shutter has opened is equal to the foreground component of the seventh pixel from the left in Fig. 11 corresponding to the second portion of the shutter time/v from when the shutter has opened. Similarly, the foreground component F02/v is equal to the foreground component of the eighth pixel from the left in Fig. 11 corresponding to the third portion of the shutter time/v from when the shutter has opened.

It can be assumed that the object corresponding to the foreground is a rigid body, which is moving with constant velocity, and the amount of movement v is 4. Accordingly, for example, the foreground component F03/v of the seventh pixel from the left in Fig. 11 corresponding to the first portion of the shutter time/v from when the shutter has opened is equal to the foreground component of the eighth pixel from the left in Fig. 11 corresponding to the second portion of the shutter time/v from when the shutter has

opened.

It has been described with reference to Figs. 9 through 11 that the number of virtual divided portions is 4. The number of virtual divided portions corresponds to the amount of movement v. Generally, the amount of movement v corresponds to the moving speed of the object corresponding to the foreground. For example, if the object corresponding to the foreground is moving such that it is displayed four pixels to the right with respect to a certain frame when it is positioned in the subsequent frame, the amount of movement v is set to 4. The number of virtual divided portions is set to 4 in accordance with the amount of movement v. Similarly, when the object corresponding to the foreground is moving such that it is displayed six pixels to the left with respect to a certain frame when it is positioned in the subsequent frame, the amount of movement v is set to 6, and the number of virtual divided portions is set to 6.

Figs. 12 and 13 illustrate the relationship of the foreground area, the background area, and the mixed area which consists of a covered background or an uncovered background, which are discussed above, to the foreground components and the background components corresponding to the divided periods of the shutter time.

Fig. 12 illustrates an example in which pixels in the

foreground area, the background area, and the mixed area are extracted from an image containing a foreground corresponding to an object moving in front of a stationary background. In the example shown in Fig. 12, the object corresponding to the foreground indicated by A is horizontally moving with respect to the screen.

Frame #n+1 is a frame subsequent to frame #n, and frame #n+2 is a frame subsequent to frame #n+1.

Pixels in the foreground area, the background area, and the mixed area are extracted from one of frames #n through #n+2, and the amount of movement v is set to 4. A model obtained by expanding the pixel values of the extracted pixels in the time direction is shown in Fig. 13.

Since the object corresponding to the foreground is moving, the pixel values in the foreground area are formed of four different foreground components corresponding to the shutter time/v. For example, the leftmost pixel of the pixels in the foreground area shown in Fig. 13 consists of F01/v, F02/v, F03/v, and F04/v. That is, the pixels in the foreground contain motion blur.

Since the object corresponding to the background is stationary, light input into the sensor corresponding to the background during the shutter time does not change. In this case, the pixel values in the background area do not contain motion blur.

The pixel values in the mixed area consisting of a covered background area or an uncovered background area are formed of foreground components and background components.

A description is given below of a model obtained by expanding in the time direction the pixel values of the pixels which are aligned side-by-side in a plurality of frames and which are located at the same positions when the frames are overlapped when the image corresponding to the object is moving. For example, when the image corresponding to the object is moving horizontally with respect to the screen, pixels aligned on the screen can be selected as the pixels aligned side-by-side.

Fig. 14 illustrates a model obtained by expanding in the time direction the pixels which are aligned side-by-side in three frames of an image obtained by capturing an object corresponding to a stationary background and which are located at the same positions when the frames are overlapped. Frame #n is the frame subsequent to frame #n-1, and frame #n+1 is the frame subsequent to frame #n. The same applies to the other frames.

The pixel values B01 through B12 shown in Fig. 14 are pixel values corresponding to the stationary background object. Since the object corresponding to the background is stationary, the pixel values of the corresponding pixels in frame #n-1 through frame #n+1 do not change. For example,

the pixel in frame #n and the pixel in frame #n+1 located at the corresponding position of the pixel having the pixel value B05 in frame #n-1 have the pixel value B05.

Fig. 15 illustrates a model obtained by expanding in the time direction the pixels which are aligned side-by-side in three frames of an image obtained by capturing an object corresponding to a foreground that is moving to the right in Fig. 15 together with an object corresponding to a stationary background and which are located at the same positions when the frames are overlapped. The model shown in Fig. 15 contains a covered background area.

In Fig. 15, it can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity, and that it is moving such that it is displayed four pixels to the right in the subsequent frame. Accordingly, the amount of movement v is 4, and the number of virtual divided portions is 4.

For example, the foreground component of the leftmost pixel of frame #n-1 in Fig. 15 corresponding to the first portion of the shutter time/v from when the shutter has opened is F12/v, and the foreground component of the second pixel from the left in Fig. 15 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F12/v. The foreground component of the third pixel from the left in Fig. 15 corresponding to the third

portion of the shutter time/v from when the shutter has opened and the foreground component of the fourth pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened are F12/v.

The foreground component of the leftmost pixel of frame #n-1 in Fig. 15 corresponding to the second portion of the shutter time/v from when the shutter has opened is F11/v. The foreground component of the second pixel from the left in Fig. 15 corresponding to the third portion of the shutter time/v from when the shutter has opened is also F11/v. The foreground component of the third pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is F11/v.

The foreground component of the leftmost pixel of frame #n-1 in Fig. 15 corresponding to the third portion of the shutter time/v from when the shutter has opened is F10/v. The foreground component of the second pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is also F10/v. The foreground component of the leftmost pixel of frame #n-1 in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is F09/v.

Since the object corresponding to the background is stationary, the background component of the second pixel

from the left of frame #n-1 in Fig. 15 corresponding to the first portion of the shutter time/v from when the shutter has opened is B01/v. The background components of the third pixel from the left of frame #n-1 in Fig. 15 corresponding to the first and second portions of the shutter time/v from when the shutter has opened are B02/v. The background components of the fourth pixel from the left of frame #n-1 in Fig. 15 corresponding to the first through third portions of the shutter time/v from when the shutter has opened are B03/v.

In frame #n-1 in Fig. 15, the leftmost pixel from the left belongs to the foreground area, and the second through fourth pixels from the left belong to the mixed area, which is a covered background area.

The fifth through twelfth pixels from the left of frame #n-1 in Fig. 15 belong to the background area, and the pixel values thereof are B04 through B11, respectively.

The first through fifth pixels from the left in frame #n in Fig. 15 belong to the foreground area. The foreground component in the shutter time/v in the foreground area of frame #n is any one of F05/v through F12/v.

It can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity, and that it is moving such that the foreground image is displayed four pixels to the right in the subsequent frame.

Accordingly, the foreground component of the fifth pixel from the left of frame #n in Fig. 15 corresponding to the first portion of the shutter time/v from when the shutter has opened is F12/v, and the foreground component of the sixth pixel from the left in Fig. 15 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F12/v. The foreground component of the seventh pixel from the left in Fig. 15 corresponding to the third portion of the shutter time/v from when the shutter has opened and the foreground component of the eighth pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened are F12/v.

The foreground component of the fifth pixel from the left of frame #n in Fig. 15 corresponding to the second portion of the shutter time/v from when the shutter has opened is F11/v. The foreground component of the sixth pixel from the left in Fig. 15 corresponding to the third portion of the shutter time/v from when the shutter has opened is also F11/v. The foreground component of the seventh pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is F11/v.

The foreground component of the fifth pixel from the left of frame #n in Fig. 15 corresponding to the third

portion of the shutter time/v from when the shutter has opened is F10/v. The foreground component of the sixth pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is also F10/v. The foreground component of the fifth pixel from the left of frame #n in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is F09/v.

Since the object corresponding to the background is stationary, the background component of the sixth pixel from the left of frame #n in Fig. 15 corresponding to the first portion of the shutter time/v from when the shutter has opened is B05/v. The background components of the seventh pixel from the left of frame #n in Fig. 15 corresponding to the first and second portions of the shutter time/v from when the shutter has opened are B06/v. The background components of the eighth pixel from the left of frame #n in Fig. 15 corresponding to the first through third portion of the shutter time/v from when the shutter has opened are B07/v.

In frame #n in Fig. 15, the sixth through eighth pixels from the left belong to the mixed area, which is a covered background area.

The ninth through twelfth pixels from the left of frame #n in Fig. 15 belong to the background area, and the pixel

values thereof are B08 through B11, respectively.

The first through ninth pixels from the left in frame #n+1 in Fig. 15 belong to the foreground area. The foreground component in the shutter time/v in the foreground area of frame #n+1 is any one of F01/v through F12/v.

It can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity, and that it is moving such that the foreground image is displayed four pixels to the right in the subsequent frame. Accordingly, the foreground component of the ninth pixel from the left of frame #n+1 in Fig. 15 corresponding to the first portion of the shutter time/v from when the shutter has opened is F12/v, and the foreground component of the tenth pixel from the left in Fig. 15 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F12/v. The foreground component of the eleventh pixel from the left in Fig. 15 corresponding to the third portion of the shutter time/v from when the shutter has opened and the foreground component of the twelfth pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened are F12/v.

The foreground component of the ninth pixel from the left of frame #n+1 in Fig. 15 corresponding to the second portion of the shutter time/v from when the shutter has

opened is F11/v. The foreground component of the tenth pixel from the left in Fig. 15 corresponding to the third portion of the shutter time/v from when the shutter has opened is also F11/v. The foreground component of the eleventh pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is F11/v.

The foreground component of the ninth pixel from the left of frame #n+1 in Fig. 15 corresponding to the third portion of the shutter time/v from when the shutter has opened is F10/v. The foreground component of the tenth pixel from the left in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is also F10/v. The foreground component of the ninth pixel from the left of frame #n+1 in Fig. 15 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is F09/v.

Since the object corresponding to the background is stationary, the background component of the tenth pixel from the left of frame #n+1 in Fig. 15 corresponding to the first portion of the shutter time/v from when the shutter has opened is B09/v. The background components of the eleventh pixel from the left of frame #n+1 in Fig. 15 corresponding to the first and second portions of the shutter time/v from when the shutter has opened are B10/v. The background

components of the twelfth pixel from the left of frame #n+1 in Fig. 15 corresponding to the first through third portion of the shutter time/v from when the shutter has opened are B11/v.

In frame #n+1 in Fig. 15, the tenth through twelfth pixels from the left belong to the mixed area, which is a covered background area.

Fig. 16 is a model of an image obtained by extracting the foreground components from the pixel values shown in Fig. 15.

Fig. 17 illustrates a model obtained by expanding in the time direction the pixels which are aligned side-by-side in three frames of an image obtained by capturing an object corresponding to a foreground that is moving to the right in Fig. 17 together with an object corresponding to a stationary background and which are located at the same positions when the frames are overlapped. The model shown in Fig. 17 contains an uncovered background area.

In Fig. 17, it can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity, and that it is moving such that it is displayed four pixels to the right in the subsequent frame. Accordingly, the amount of movement v is 4.

For example, the foreground component of the leftmost pixel of frame #n-1 in Fig. 17 corresponding to the first

portion of the shutter time/v from when the shutter has opened is F13/v, and the foreground component of the second pixel from the left in Fig. 17 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F13/v. The foreground component of the third pixel from the left in Fig. 17 corresponding to the third portion of the shutter time/v from when the shutter has opened and the foreground component of the fourth pixel from the left in Fig. 17 corresponding to the fourth portion of the shutter time/v from when the shutter has opened are F13/v.

The foreground component of the second pixel from the left of frame #n-1 in Fig. 17 corresponding to the first portion of the shutter time/v from when the shutter has opened is F14/v. The foreground component of the third pixel from the left in Fig. 17 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F14/v. The foreground component of the third pixel from the left in Fig. 17 corresponding to the first portion of the shutter time/v from when the shutter has opened is F15/v.

Since the object corresponding to the background is stationary, the background components of the leftmost pixel of frame #n-1 in Fig. 17 corresponding to the second through fourth portions of the shutter time/v from when the shutter

has opened are B25/v. The background components of the second pixel from the left of frame #n-1 in Fig. 17 corresponding to the third and fourth portions of the shutter time/v from when the shutter has opened are B26/v. The background component of the third pixel from the left of frame #n-1 in Fig. 17 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is B27/v.

In frame #n-1 in Fig. 17, the leftmost pixel through the third pixel belong to the mixed area, which is an uncovered background area.

The fourth through twelfth pixels from the left of frame #n-1 in Fig. 17 belong to the foreground area. The foreground component of the frame is any one of F13/v through F24/v.

The leftmost pixel through the fourth pixel from the left of frame #n in Fig. 17 belong to the background area, and the pixel values thereof are B25 through B28, respectively.

It can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity, and that it is moving such that it is displayed four pixels to the right in the subsequent frame. Accordingly, the foreground component of the fifth pixel from the left of frame #n in Fig. 17 corresponding to the first portion of the shutter time/v from when the shutter has opened is F13/v,

and the foreground component of the sixth pixel from the left in Fig. 17 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F13/v. The foreground component of the seventh pixel from the left in Fig. 17 corresponding to the third portion of the shutter time/v from when the shutter has opened and the foreground component of the eighth pixel from the left in Fig. 17 corresponding to the fourth portion of the shutter time/v from when the shutter has opened are F13/v.

The foreground component of the sixth pixel from the left of frame #n in Fig. 17 corresponding to the first portion of the shutter time/v from when the shutter has opened is F14/v. The foreground component of the seventh pixel from the left in Fig. 17 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F14/v. The foreground component of the eighth pixel from the left in Fig. 17 corresponding to the first portion of the shutter time/v from when the shutter has opened is F15/v.

Since the object corresponding to the background is stationary, the background components of the fifth pixel from the left of frame #n in Fig. 17 corresponding to the second through fourth portions of the shutter time/v from when the shutter has opened are B29/v. The background components of the sixth pixel from the left of frame #n in

Fig. 17 corresponding to the third and fourth portions of the shutter time/v from when the shutter has opened are B30/v. The background component of the seventh pixel from the left of frame #n in Fig. 17 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is B31/v.

In frame #n in Fig. 17, the fifth pixel through the seventh pixel from the left belong to the mixed area, which is an uncovered background area.

The eighth through twelfth pixels from the left of frame #n in Fig. 17 belong to the foreground area. The value in the foreground area of frame #n corresponding to the period of the shutter time/v is any one of F13/v through F20/v.

The leftmost pixel through the eighth pixel from the left of frame #n+1 in Fig. 17 belong to the background area, and the pixel values thereof are B25 through B32, respectively.

It can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity, and that it is moving such that it is displayed four pixels to the right in the subsequent frame. Accordingly, the foreground component of the ninth pixel from the left of frame #n+1 in Fig. 17 corresponding to the first portion of the shutter time/v from when the shutter has opened is F13/v,

and the foreground component of the tenth pixel from the left in Fig. 17 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F13/v. The foreground component of the eleventh pixel from the left in Fig. 17 corresponding to the third portion of the shutter time/v from when the shutter has opened and the foreground component of the twelfth pixel from the left in Fig. 17 corresponding to the fourth portion of the shutter time/v from when the shutter has opened are F13/v.

The foreground component of the tenth pixel from the left of frame #n+1 in Fig. 17 corresponding to the first portion of the shutter time/v from when the shutter has opened is F14/v. The foreground component of the eleventh pixel from the left in Fig. 17 corresponding to the second portion of the shutter time/v from when the shutter has opened is also F14/v. The foreground component of the twelfth pixel from the left in Fig. 17 corresponding to the first portion of the shutter time/v from when the shutter has opened is F15/v.

Since the object corresponding to the background is stationary, the background components of the ninth pixel from the left of frame #n+1 in Fig. 17 corresponding to the second through fourth portions of the shutter time/v from when the shutter has opened are B33/v. The background components of the tenth pixel from the left of frame #n+1 in

Fig. 17 corresponding to the third and fourth portions of the shutter time/v from when the shutter has opened are B34/v. The background component of the eleventh pixel from the left of frame #n+1 in Fig. 17 corresponding to the fourth portion of the shutter time/v from when the shutter has opened is B35/v.

In frame #n+1 in Fig. 17, the ninth through eleventh pixels from the left in Fig. 17 belong to the mixed area, which is an uncovered background area.

The twelfth pixel from the left of frame #n+1 in Fig. 17 belongs to the foreground area. The foreground component in the shutter time/v in the foreground area of frame #n+1 is any one of F13 through F16, respectively.

Fig. 18 illustrates a model of an image obtained by extracting the foreground components from the pixel values shown in Fig. 17.

Referring back to Fig. 2, the area specifying unit 103 specifies flags indicating to which of a foreground area, a background area, a covered background area, or an uncovered background area the individual pixels of the input image belong by using the pixel values of a plurality of frames, and supplies the flags to the mixture-ratio calculator 104 and the motion-blur adjusting unit 106 as the area information.

The mixture-ratio calculator 104 calculates the mixture

ratio α for each pixel contained in the mixed area based on the pixel values of a plurality of frames and the area information, and supplies the calculated mixture ratio α to the foreground/background separator 105.

The foreground/background separator 105 extracts the foreground component image consisting of only the foreground components based on the pixel values of a plurality of frames, the area information, and the mixture ratio α, and supplies the foreground component image to the motion-blur adjusting unit 106.

The motion-blur adjusting unit 106 adjusts the amount of motion blur contained in the foreground component image based on the foreground component image supplied from the foreground/background separator 105, the motion vector supplied from the motion detector 102, and the area information supplied from the area specifying unit 103, and then outputs the foreground component image in which motion blur is adjusted.

The processing for adjusting the amount of motion blur performed by the image processing apparatus is described below with reference to the flowchart of Fig. 19. In step S11, the area specifying unit 103 executes area specifying processing, based on an input image, for generating area information indicating to which of a foreground area, a background area, a covered background area, or an uncovered

background area each pixel of the input image belongs. Details of the area specifying processing are given below. The area specifying unit 103 supplies the generated area information to the mixture-ratio calculator 104.

In step S11, the area specifying unit 103 may generate, based on the input image, area information indicating to which of the foreground area, the background area, or the mixed area (regardless of whether each pixel belongs to a covered background area or an uncovered background area) each pixel of the input image belongs. In this case, the foreground/background separator 105 and the motion-blur adjusting unit 106 determine based on the direction of the motion vector whether the mixed area is a covered background area or an uncovered background area. For example, if the input image is disposed in the order of the foreground area, the mixed area, and the background area in the direction of the motion vector, it is determined that the mixed area is a covered background area. If the input image is disposed in the order of the background area, the mixed area, and the foreground area in the direction of the motion vector, it is determined that the mixed area is an uncovered background area.

In step S12, the mixture-ratio calculator 104 calculates the mixture ratio α for each pixel contained in the mixed area based on the input image and the area

information. Details of the mixture ratio calculating processing are given below. The mixture-ratio calculator 104 supplies the calculated mixture ratio α to the foreground/background separator 105.

In step S13, the foreground/background separator 105 extracts the foreground components from the input image based on the area information and the mixture ratio α, and supplies the foreground components to the motion-blur adjusting unit 106 as the foreground component image.

In step S14, the motion-blur adjusting unit 106 generates, based on the motion vector and the area information, the unit of processing that indicates the positions of consecutive pixels disposed in the moving direction and belonging to any of the uncovered background area, the foreground area, and the covered background area, and adjusts the amount of motion blur contained in the foreground components corresponding to the unit of processing. Details of the processing for adjusting the amount of motion blur are given below.

In step S15, the image processing apparatus determines whether the processing is finished for the whole screen. If it is determined that the processing is not finished for the whole screen, the process proceeds to step S14, and the processing for adjusting the amount of motion blur for the foreground components corresponding to the unit of

processing is repeated.

If it is determined in step S15 that the processing is finished for the whole screen, the processing is completed.

In this manner, the image processing apparatus is capable of adjusting the amount of motion blur contained in the foreground by separating the foreground and the background. That is, the image processing apparatus is capable of adjusting the amount of motion blur contained in sampled data indicating the pixel values of the foreground pixels.

The configuration of each of the area specifying unit 103, the mixture-ratio calculator 104, the foreground/background separator 105, and the motion-blur adjusting unit 106 is described below.

Fig. 20 is a block diagram illustrating an example of the configuration of the area specifying unit 103.

A frame memory 201 stores an input image in units of frames. The frame memory 201 stores frame #n-1, which is the frame one frame before frame #n, frame #n, and frame #n+1, which is the frame one frame after frame #n.

A stationary/moving determining portion 202-1 reads the pixel value of a designated pixel of frame #n in which the area to which the pixel belongs is determined, and reads the pixel value of the pixel of frame #n-1 located at the same position as the designated pixel of frame #n from the frame

memory 201, and calculates the absolute value of the difference between the pixel values. The stationary/moving determining portion 202-1 determines whether the absolute value of the difference between the pixel value of frame #n and the pixel value of frame #n-1 is greater than a preset threshold Th. If it is determined that the absolute value of the difference between the pixel values is greater than the threshold Th, a stationary/moving determination indicating "moving" is supplied to an area determining portion 203. If it is determined that the absolute value of the difference between the pixel value of the pixel of frame #n and the pixel value of the pixel of frame #n-1 is smaller than or equal to the threshold Th, the stationary/moving determining portion 202-1 supplies a stationary/moving determination indicating "stationary" to the area determining portion 203.

A stationary/moving determining portion 202-2 reads the pixel value of a designated pixel of frame #n in which the area to which the pixel belongs is determined, and reads the pixel value of the pixel of frame #n+1 located at the same position as the designated pixel of frame #n from the frame memory 201, and calculates the absolute value of the difference between the pixel values. The stationary/moving determining portion 202-2 determines whether the absolute value of the difference between the pixel value of frame

#n+1 and the pixel value of frame #n is greater than a preset threshold Th. If it is determined that the absolute value of the difference between the pixel values is greater than the threshold Th, a stationary/moving determination indicating "moving" is supplied to the area determining portion 203. If it is determined that the absolute value of the difference between the pixel value of the pixel of frame #n+1 and the pixel value of the pixel of frame #n is smaller than or equal to the threshold Th, the stationary/moving determining portion 202-2 supplies a stationary/moving determination indicating "stationary" to the area determining portion 203.

When the stationary/moving determination supplied from the stationary/moving determining portion 202-1 indicates "stationary" and when the stationary/moving determination supplied from the stationary/moving determining portion 202-2 indicate "stationary", the area determining portion 203 determines that the designated pixel of frame #n belongs to the stationary area, and sets a flag indicating that the pixel belongs to the stationary area in the address corresponding to the designated pixel of frame #n in a determining-flag-storing frame memory 204.

When the stationary/moving determination supplied from the stationary/moving determining portion 202-1 indicates "moving" or when the stationary/moving determination

supplied from the stationary/moving determining portion 202-2 indicate "moving", the area determining portion 203 determines that the designated pixel of frame #n belongs to the moving area, and sets a flag that the pixel belongs to the moving area in the address corresponding to the designated pixel of frame # in the determining-flag-storing frame memory 204.

When the stationary/moving determination supplied from the stationary/moving determining portion 202-1 indicates "stationary" and when the stationary/moving determination supplied from the stationary/moving determining portion 202-2 indicates "moving", the area determining portion 203 determines that the designated pixel of frame #n+1 belongs to a covered background area, and sets a flag indicating that the designated pixel belongs to a covered background area in the address corresponding to the designated pixel of frame #n+1 in the determining-flag-storing frame memory 204.

When the stationary/moving determination supplied from the stationary/moving determining portion 202-1 indicates "moving" or when the stationary/moving determination supplied from the stationary/moving determining portion 202-2 indicates "stationary", the area determining portion 203 determines that the designated pixel of frame #n-1 belongs to uncovered background area, and sets a flag indicating that the designated pixel belongs to an uncovered background

area in the address corresponding to the designated pixel of frame #n-1 in the determining-flag-storing frame memory 204.

The flag, which is set in the determining-flag-storing frame memory 204 by the area determining portion 203 is, for example, a 2-bit flag. When the flag is "00", it indicates a stationary area. When the flag is "01", it indicates an uncovered background area. When the flag is "10", it indicates a covered background area. When the flag is "11", it indicates a moving area.

The determining-flag-storing frame memory 204 individually stores 2-bit flags associated with the pixels, i.e., the flag indicating the area of the designated pixel in frame #n-1, the flag indicating the area of the designated pixel in frame #n, and the flag indicating the area of the designated pixel in frame #n+1.

When the area specifying unit 103 finishes the determination of the areas of one frame, the determining-flag-storing frame memory 204 outputs, as area information, the flags of frame #n+1 in which the flags indicating the uncovered background area, the moving area, the stationary area, and the covered background area are set.

When the area specifying unit 103 finishes the determination of the areas of one frame, the determining-flag-storing frame memory 204 shifts the flags of frame #n in which the flags indicating the uncovered background area,

the moving area, and the stationary area are set to frame #n+1.

When the area specifying unit 103 finishes the determination of the areas of one frame, the determining-flag-storing frame memory 204 shifts the flag of frame #n-1 in which the flag indicating the uncovered background area is set to frame #n.

When the area specifying unit 103 finishes the determination of the areas of one frame, the determining-flag-storing frame memory 204 initializes frame #n-1.

That is, when the area specifying unit 103 starts to determine the areas of one frame, a flag is not set in frame #n-1 stored in the determining-flag-storing frame memory 204.

When the area specifying unit 103 starts to determine the areas of one frame, the flag indicating the uncovered background area is set in frame #n stored in the determining-flag-storing frame memory 204.

When the area specifying unit 103 starts to determine the areas of one frame, the flag indicating the uncovered background area, the flag indicating the stationary area, and the flag indicating the moving area are set in frame #n+1 stored in the determining-flag-storing frame memory 204.

Accordingly, the area determining portion 203 sets a flag indicating the stationary area or the moving area in frame #n, which is stored in the determining-flag-storing

frame memory 204, in which the flag indicating the uncovered background area is set.

The area determining portion 203 does not set a flag indicating the moving area when a flag indicating the uncovered background area or a flag indicating the covered background area is already set in the corresponding address of frame #n.

The area determining portion 203 sets a flag indicating the covered background area in frame #n+1, which is stored in the determining-flag-storing frame memory 204, in which the flag indicating the uncovered background area, the flag indicating the stationary area, and the flag indicating the moving area are set.

An example of the processing performed by the area specifying unit 103 is described below with reference to Figs. 21 through 25.

When the object corresponding to the foreground is moving, the position of the image corresponding to the object on the screen changes in every frame. As shown in Fig. 21, the image corresponding to the object located at the position indicated by Yn(x,y) in frame #n is positioned at Yn+1(x,y) in frame #n+1, which is subsequent to frame #n.

A model obtained by expanding in the time direction the pixel values of the pixels aligned side-by-side in the moving direction of the image corresponding to the

foreground object is shown in Fig. 22. For example, if the moving direction of the image corresponding to the foreground object is horizontal with respect to the screen, the model shown in Fig. 22 is a model obtained by expanding in the time direction the pixel values of the pixels disposed on a line side-by-side.

In Fig. 22, the line in frame #n is equal to the line in frame #n+1.

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

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

In the example shown in Fig. 22, since the foreground components contained in frame #n are moved by four pixels in frame #n+1, the amount of movement v is 4. The number of virtual divided portions is 4 in accordance with the amount

of movement v.

A description is now given of a change in pixel values of the pixels belonging to the mixed area in the frames before and after a designated frame.

In Fig. 23, the pixels belonging to a covered background area in frame #n+1 in which the background is stationary and the amount of movement v in the foreground is 4 are the fifteenth through seventeenth pixels from the left. Since the amount of movement v is 4, the fifteenth through seventeenth frames from the left in the previous frame #n contain only background components and belong to the background area. The fifteenth through seventeenth pixels from the left in frame #n-1, which is one before frame #n, contain only background components and belong to the background area.

Since the object corresponding to the background is stationary, the pixel value of the fifteenth pixel from the left in frame #n does not change from the pixel value of the fifteenth pixel from the left in frame #n-1. Similarly, the pixel value of the sixteenth pixel from the left in frame #n does not change from the pixel value of the sixteenth pixel from the left in frame #n-1, and the pixel value of the seventeenth pixel from the left in frame #n does not change from the pixel value of the seventeenth pixel from the left in frame #n-1.

That is, the pixels in frame #n and frame #n-1 corresponding to the pixels belonging to the covered background area in frame #n+1 consist of only background components, and the pixel values thereof do not change. Accordingly, the absolute value of the difference between the pixel values is almost 0. Thus, the stationary/moving determination made for the pixels in frame #n and frame #n-1 corresponding to the pixels belonging to the covered background area in frame #n+1 by the stationary/moving determining portion 202-1 is "stationary".

Since the pixels belonging to the covered background area in frame #n+1 contain foreground components, the pixel values thereof are different from those of frame #n consisting of only background components. Accordingly, the stationary/moving determination made for the pixels belonging to the mixed area in frame #n+1 and the corresponding pixels in frame #n by the stationary/moving determining portion 202-2 is "moving".

When the stationary/moving determination result indicating "moving" is supplied from the stationary/moving determining portion 202-2, and when the stationary/moving determination result indicating "stationary" is supplied from the stationary/moving determining portion 202-1, as discussed above, the area determining portion 203 determines that the corresponding pixels of frame #n+1 belong to a

covered background area.

In Fig. 24, in frame #n-1 in which the background is stationary and the amount of movement v in the foreground is 4, the pixels contained in an uncovered background area are the second through fourth pixels from the left. Since the amount of movement v is 4, the second through fourth pixels from the left in the subsequent frame #n contain only background components and belong to the background area. In frame #n+1, which is subsequent to frame #n, the second through fourth pixels from the left contain only background components and belong to the background area.

Since the object corresponding to the background is stationary, the pixel value of the second pixel from the left in frame #n+1 does not change from the pixel value of the second pixel from the left in frame #n. Similarly, the pixel value of the third pixel from the left in frame #n+1 does not change from the pixel value of the third pixel from the left in frame #n, and the pixel value of the fourth pixel from the left in frame #n+1 does not change from the pixel value of the fourth pixel from the left in frame #n.

That is, the pixels in frame #n and frame #n+1 corresponding to the pixels belonging to the uncovered background area in frame #n-1 consist of only background components, and the pixel values thereof do not change. Accordingly, the absolute value of the difference between

the pixel values is almost 0. Thus, the stationary/moving determination made for the pixels in frame #n and frame #n+1 corresponding to the pixels belonging to the uncovered background area in frame #n by the stationary/moving determining portion 202-2 is "stationary".

Since the pixels belonging to the uncovered background area in frame #n-1 contain foreground components, the pixel values thereof are different from those of frame #n consisting of only background components. Accordingly, the stationary/moving determination made for the pixels belonging to the mixed area in frame #n-1 and the corresponding pixels in frame #n by the stationary/moving determining portion 202-1 is "moving".

When the stationary/moving determination result indicating "moving" is supplied from the stationary/moving determining portion 202-1, and when the stationary/moving determination result indicating "stationary" is supplied from the stationary/moving determining portion 202-2, as discussed above, the area determining portion 203 determines that the corresponding pixels of frame #n-1 belong to an uncovered background area.

Fig. 25 illustrates determination conditions made by the area specifying unit 103. When the determination result for the pixel in frame #n-1 located at the same image position as a pixel in frame #n+1 to be processed and for

the pixel in frame #n located at the same position as the pixel in frame #n+1 is stationary, and when the determination result for the pixel in frame #n+1 and the pixel in frame #n located at the same image position as the pixel in frame #n+1 is moving, the area specifying unit 103 determines that the pixel in frame #n+1 belongs to a covered background area.

When the determination result for the pixel in frame #n and the pixel in frame #n-1 located at the same image position as the pixel in frame #n is stationary, and when the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same image position as the pixel in frame #n is stationary, the area specifying unit 103 determines that the pixel in frame #n belongs to the stationary area.

When the determination result for the pixel in frame #n and the pixel in frame #n-1 located at the same image position as the pixel in frame #n is moving, and when the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same image position as the pixel in frame #n is moving, the area specifying unit 103 determines that the pixel in frame #n belongs to the moving area.

When the determination result for the pixel in frame #n-1 and the pixel in frame #n located at the same image

position as the pixel in frame #n-1 is moving, and when the determination result for the pixel in frame #n located at the same image position as the pixel in frame #n-1 and the pixel in frame #n+1 located at the same image position as the pixel in frame #n-1 is stationary, the area specifying unit 103 determines that the pixel in frame #n-1 belongs to an uncovered background area.

As discussed above, the area specifying unit 103 specifies the foreground area, the background area, the covered background area, and the uncovered background area. The area specifying unit 103 requires the time corresponding to three frames for specifying the foreground area, the background area, the covered background area, and the uncovered background area for one frame.

Fig. 26 illustrates an example of the area determination result obtained by the area specifying unit 103. In the input image corresponding to the result shown in Fig. 26, the foreground object is moving from the left to the right in the drawing.

It is seen that the covered background area is observed in the direction in which the foreground object is moving (right side of Fig. 26), and the uncovered background area is observed in the direction opposite to the direction in which the foreground object is moving (left side of Fig. 26).

Fig. 27 is an enlarged view illustrating the top left

portion of the foreground object in the determination result shown in Fig. 26.

Since the foreground object is moving to the right in Fig. 27, it is seen in Fig. 27 that the covered background area indicated by A in Fig. 27 is positioned at the right side of the foreground area indicated by B in Fig. 27, and the uncovered background area indicated by C in Fig. 27 is positioned at the left side of the foreground area. In Fig. 27, D indicates the background area.

The area specifying processing performed by the area specifying unit 103 is described below with reference to the flowcharts of Figs. 28 and 29. In step S201, the frame memory 201 obtains an image of frame #n-1, which is to be determined, through frame #n+1.

In step S202, the stationary/moving determining portion 202-1 determines whether the determination result for the pixel in frame #n-1 and the pixel in frame #n located at the same position is stationary. If it is determined that the determination result is stationary, the process proceeds to step S203 in which the stationary/moving determining portion 202-2 determines whether the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same position is stationary.

If it is determined in step S203 that the determination result for the pixel in frame #n and the pixel in frame #n+1

located at the same position is stationary, the process proceeds to step S204. In step S204, the area determining portion 203 sets "00", which indicates that the pixel to be processed belongs to the stationary area, in the corresponding address of frame #n stored in the determining-flag-storing frame memory 204. The process then proceeds to step S205.

If it is determined in step S202 that the determination result for the pixel in frame #n-1 and the pixel in frame #n located at the same position is moving, or if it is determined in step S203 that the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same position is moving, the pixel to be processed does not belong to a stationary area. Accordingly, the processing of step S204 is skipped, and the process proceeds to step S205.

In step S205, the stationary/moving determining portion 202-1 determines whether the determination result for the pixel in frame #n-1 and the pixel in frame #n located at the same position is moving. If it is determined that the determination result is moving, the process proceeds to step S206 in which the stationary/moving determining portion 202-2 determines whether the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same position is moving.

If it is determined in step S206 that the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same position is moving, the process proceeds to step S207. In step S207, the area determining portion 203 determines based on the flag of frame #n stored in the determining-flag-storing frame memory 204 whether the corresponding pixel has already been determined to be the uncovered background area. If it is found that the corresponding pixel has not been determined to be the uncovered background area, the process proceeds to step S208.

In step S208, the area determining portion 203 sets "11", indicating that the pixel belongs to the moving area, in the corresponding address of frame #n in stored in the determining-flag-storing frame memory 204. The process then proceeds to step S209.

If it is determined in step S205 that the determination result for the pixel in frame #n-1 and the pixel in frame #n located at the same position is stationary, or if it is determined in step S206 that the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same position is stationary, or if is found in step S207 that the corresponding pixel has already been determined to be the uncovered background area, the pixel in frame #n does not belong to a moving area. Accordingly, the processing of step S208 is skipped, and the process proceeds to step S209.

In step S209, the stationary/moving determining portion 202-1 determines whether the determination result for the pixel in frame #n-1 and the pixel in frame #n at the same position is moving is stationary. If it is determined that the determination result is stationary, the process proceeds to step S210. In step S210, the stationary/moving determining portion 202-2 determines whether the determination result for the pixel in frame #n and the pixel for frame #n+1 at the same position is moving.

If it is determined in step S210 that the determination result for the pixel in frame #n and the pixel in frame #n+1 at the same position is moving, the process proceeds to step S211. In step S211, the area determining portion 203 sets "10", indicating that the pixel belongs to the covered background area, in the corresponding address in frame #n+1 stored in the determining-flag-storing frame memory 204, and the process then proceeds to step S212.

If it is determined in step S209 that the determination result for the pixel in frame #n-1 and the pixel in frame #n located at the same position is moving, or if it is determined in step S210 that the pixel in frame #n and the pixel in frame #n+1 located at the same position is stationary, the pixel in frame #n+1 does not belong to a covered background area. Accordingly, the processing of step S211 is skipped, and the process proceeds to step S212.

In step S212, the stationary/moving determining portion 202-1 determines whether the determination result for the pixel in frame #n-1 and the pixel in frame #n located at the same position is moving. If it is determined in step S212 that the determination result is moving, the process proceeds to step S213 in which the stationary/moving determining portion 202-2 determines whether the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same position is stationary.

If it is determined in step S213 that the determination result for the pixel in frame #n and the pixel in frame #n+1 located at the same position is stationary, the process proceeds to step S214. In step S214, the area determining portion 203 sets "01", which indicates that the pixel to be processed belongs to an uncovered background area, in the corresponding address of frame #n-1 stored in the determining-flag-storing frame memory 204. The process then proceeds to step S215.

If it is determined in step S212 that the determination result for the pixel in frame #n-1 and the pixel in frame #n located at the same position is stationary, or if it is determined in step S213 that the determination result for the pixel in frame #n and the pixel in frame #n+1 is moving, the pixel in frame #n-1 does not belong to an uncovered background area. Accordingly, the processing of step S214

is skipped, and the process proceeds to step S215.

In step S215, the area specifying unit 103 determines whether the areas of all the pixels are specified. If it is determined that the areas of all the pixels are not yet specified, the process returns to step S202, and the area specifying processing is repeated for the remaining pixels.

If it is determined in step S215 that the areas of all the pixels are specified, the process proceeds to step S216. In step S216, the determining-flag-storing frame memory 204 outputs the flag of frame #n+1 indicating the foreground area, the background area, the covered background area, or the uncovered background area as area information.

In step S217, the determining-flag-storing frame memory 204 shifts the flag of frame #n to frame #n+1.

In step S218, the determining-flag-storing frame memory 204 shifts the flag of frame #n-1 to frame #n.

In step S219, the determining-flag-storing frame memory 204 initializes frame #n-1, and the process is completed.

As discussed above, the area specifying unit 103 is capable of generating area information indicating to which of the moving area, the stationary area, the uncovered background area, or the covered background area each of the pixels contained in a frame belongs.

The area specifying unit 103 may apply logical OR to the area information corresponding to the uncovered

background area and the area information corresponding to the covered background area so as to generate area information corresponding to the mixed area, and then may generate area information consisting of flags indicating to which of the moving area, the stationary area, or the mixed area the individual pixels contained in the frame belong.

When the object corresponding to the foreground has a texture, the area specifying unit 103 is able to specify the moving area more precisely.

The area specifying unit 103 is able to output the area information indicating the moving area as the area information indicating the foreground area, and outputs the area information indicating the stationary area as the area information indicating the background area.

As discussed above, the area specifying unit 103 is capable of generating area information indicating to which of the moving area, the stationary area, the uncovered background area, or the covered background area each of the pixels contained in a frame belongs. The area specifying unit 103 is able to generate area information with a relatively small memory space.

Fig. 30 is a block diagram illustrating an example of the configuration of the mixture-ratio calculator 104. An estimated-mixture-ratio processor 401 calculates an estimated mixture ratio for each pixel by calculating a

model of a covered background area based on the input image, and supplies the calculated estimated mixture ratio to a mixture-ratio determining portion 403.

An estimated-mixture-ratio processor 402 calculates an estimated mixture ratio for each pixel by calculating a model of an uncovered background area based on the input image, and supplies the calculated estimated mixture ratio to the mixture-ratio determining portion 403.

Since it can be assumed that the object corresponding to the foreground is moving with constant velocity within the shutter time, the mixture ratio α of the pixels belonging to a mixed area exhibits the following characteristics. That is, the mixture ratio α linearly changes according to the positional change in the pixels. If the positional change in the pixels is one-dimensional, a change in the mixture ratio α can be represented linearly. If the positional change in the pixels is two-dimensional, a change in the mixture ratio α can be represented on a plane.

Since the period of one frame is short, it can be assumed that the object corresponding to the foreground is a rigid body moving with constant velocity.

The gradient of the mixture ratio α is inversely proportional to the amount of movement v within the shutter time of the foreground.

An example of the ideal mixture ratio α is shown in Fig.

31. The gradient l of the ideal mixture ratio α in the mixed area can be represented by the reciprocal of the amount of movement v.

As shown in Fig. 31, the ideal mixture ratio α has the value of 1 in the background area, the value of 0 in the foreground area, and the value of greater than 0 and smaller than 1 in the mixed area.

In the example shown in Fig. 32, the pixel value C06 of the seventh pixel from the left in frame #n can be indicated by equation (4) by using the pixel value P06 of the seventh pixel from the left in frame #n-1.

$$\begin{aligned} C06 &= B06 / v + B06 / v + F01 / v + F02 / v \\ &= P06 / v + P06 / v + F01 / v + F02 / v \\ &= 2 / v \cdot P06 + \sum_{i=1}^{2} Fi / v \end{aligned} \quad (4)$$

In equation (4), the pixel value C06 is indicated by a pixel value M of the pixel in the mixed area, while the pixel value P06 is indicated by a pixel value B of the pixel in the background area. That is, the pixel value M of the pixel in the mixed area and the pixel value B of the pixel in the background area can be represented by equations (5) and (6), respectively.

$$M = C06 \quad (5)$$

$$B = P06 \quad (6)$$

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

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

As discussed above, the pixel value C in the designated frame #n is considered as the pixel value in the mixed area, while the pixel value P of frame #n-1 prior to frame #n is considered as the pixel value in the background area. Accordingly, equation (3) indicating the mixture ratio α can be represented by equation (7):

$$C = \alpha \bullet P+f \qquad (7)$$

where f in equation (7) indicates the sum of the foreground components $\Sigma_i Fi/v$ contained in the designated pixel. The variables contained in equation (7) are two factors, i.e., the mixture ratio α and the sum f of the foreground components.

Similarly, a model obtained by expanding in the time direction the pixel values in which the amount of movement is 4 and the number of virtual divided portions is 4 in an uncovered background area is shown in Fig. 33.

As in the representation of the covered background area, in the uncovered background area, the pixel value C of the designated frame #n is considered as the pixel value in the mixed area, while the pixel value N of frame #n+1 subsequent to frame #n is considered as the background area. Accordingly, equation (3) indicating the mixture ratio α can be represented by equation (8).

$$C = \alpha \bullet N+f \qquad (8)$$

The embodiment has been described, assuming that the background object is stationary. However, equations (4) through (8) can be applied to the case in which the background object is moving by using the pixel value of a pixel located corresponding to the amount of movement v of the background. It is now assumed, for example, in Fig. 32 that the amount of movement v of the object corresponding to the background is 2, and the number of virtual divided portions is 2. In this case, when the object corresponding to the background is moving to the right in Fig. 32, the pixel value B of the pixel in the background area in equation (6) is represented by a pixel value P04.

Since equations (7) and (8) each contain two variables, the mixture ratio α cannot be determined without modifying the equations. Generally, an image has a strong spatial correlation, and accordingly, pixels located in close proximity with each other have almost the same pixel values.

Since the foreground components have a spatially strong correlation, the equation is modified so that the sum f of the foreground components can be deduced from the previous or subsequent frame, thereby determining the mixture ratio α.

The pixel value Mc of the seventh pixel from the left in frame #n in Fig. 34 can be expressed by equation (9).

$$Mc = \frac{2}{v} \cdot B06 + \sum_{i=11}^{12} Fi / v \qquad (9)$$

The first term 2/v of the right side in equation (9) corresponds to the mixture ratio α. The second term of the right side in equation (9) can be expressed by equation (10) by utilizing the pixel value in the subsequent frame #n+1.

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

It is now assumed that equation (11) holds true by utilizing the spatial correlation of the foreground component.

$$F=F05=F06=F07=F08=F09=F10=F11=F12 \qquad (11)$$

Equation (10) can be modified into equation (12) by utilizing equation (11).

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

As a result, β can be expressed by equation (13).

$$\beta = 2/4 \qquad (13)$$

If it is assumed that the foreground components in the mixed area are equal, as indicated by equation (11), equation (14) can hold true for all the pixels in the mixed area because of the internal ratio.

$$\beta = 1-\alpha \qquad (14)$$

If equation (14) holds true, equation (7) can be developed into equation (15).

$$
\begin{aligned}
C &= \alpha \cdot P + f \\
&= \alpha \cdot P + (1 - \alpha) \cdot \sum_{i=\gamma}^{\gamma+v-1} Fi / v \qquad (15) \\
&= \alpha \cdot P + (1 - \alpha) \cdot N
\end{aligned}
$$

Similarly, if equation (14) holds true, equation (8) can be developed into equation (16).

$$
\begin{aligned}
C &= \alpha \cdot N + f \\
&= \alpha \cdot N + (1 - \alpha) \cdot \sum_{i=\gamma}^{\gamma+v-1} Fi / v \qquad (16) \\
&= \alpha \cdot N + (1 - \alpha) \cdot P
\end{aligned}
$$

In equations (15) and (16), since C, N, and P are known pixel values, the variable contained in equations (15) and (16) is only the mixture ratio α. The relationship among C, N, and P in equations (15) and (16) is shown in Fig. 35. C is the pixel value of the designated pixel in frame #n for which the mixture ratio α is calculated. N is the pixel value of the pixel in frame #n+1 located at the position spatially corresponding to the designated pixel. P is the pixel value of the pixel in frame #n-1 located at the position spatially corresponding to the designated pixel.

Accordingly, since one variable is contained in each of equations (15) and (16), the mixture ratio α is calculated by utilizing the pixels in the three frames. The condition for solving the correct mixture ratio α by solving equations (15) and (16) is as follows. In the image object having the same foreground components in the mixed area, i.e., in the image object of the foreground which is captured when the

foreground object is stationary, the pixel values of the consecutive pixels positioned at the boundary of the image object corresponding to the moving direction of the foreground object, the number of pixels being two times the amount of movement v, must be constant.

As discussed above, the mixture ratio α of the pixels belonging to the covered background area is calculated by equation (17), and the mixture ratio α of the pixels belonging to the uncovered background area is calculated by equation (18).

$$\alpha = (C-N)/(P-N) \quad (17)$$

$$\alpha = (C-P)/(N-P) \quad (18)$$

Fig. 36 is a block diagram illustrating the configuration of the estimated-mixture-ratio processor 401. A frame memory 421 stores an input image in the units of frames, and supplies the frame subsequent to the frame which is input as the input image to a frame memory 422 and a mixture-ratio calculator 423.

A frame memory 422 stores an input image in the units of frames, and supplies the frame subsequent to the frame supplied from the frame memory 421 to the mixture-ratio calculator 423.

Accordingly, when frame #n+1 is input into the mixture-ratio calculator 423 as the input image, the frame memory 421 supplies frame #n to the mixture-ratio calculator 423,

and the frame memory 422 supplies frame #n-1 to the mixture-ratio calculator 423.

The mixture-ratio calculator 423 calculates the estimated mixture ratio of the designated pixel by solving equation (17) based on the pixel value C of the designated pixel in frame #n, the pixel value N of the pixel in frame #n+1 located at the position corresponding to the position of the designated pixel, and the pixel value P of the pixel #n-1 located at the position corresponding to the position of the designated pixel, and outputs the calculated estimated mixture ratio. For example, when the background is stationary, the mixture-ratio calculator 423 calculates the estimated mixture ratio of the designated pixel based on the pixel value C of the designated pixel in frame #n, the pixel value N of the pixel in frame #n+1 located at the same position as the designated pixel, and the pixel value P of the pixel in frame #n-1 located at the same position as the designated pixel, and outputs the calculated estimated mixture ratio.

In this manner, the estimated-mixture-ratio calculator 401 calculates the estimated mixture ratio based on the input image, and supplies it to the mixture-ratio determining portion 403.

The estimated-mixture-ratio calculator 401 calculates the estimated mixture ratio of the designated pixel by

solving equation (17). The operation of the estimated-mixture-ratio calculator 402 is similar to that of the estimated-mixture-ratio calculator 401, except that the estimated-mixture-ratio calculator 402 calculates a different estimated mixture ratio of the designated pixel by solving equation (18). Thus, an explanation of the estimated-mixture-ratio calculator 402 is omitted.

Fig. 37 illustrates an example of the estimated mixture ratio calculated by the estimated-mixture-ratio processor 401. The estimated mixture ratio shown in Fig. 37 is the result represented by one line when the amount of movement v of the foreground object moving with constant velocity is 11.

It is seen, as shown in Fig. 31, that the estimated mixture ratio changes almost linearly in the mixed area.

Referring back to Fig. 30, the mixture-ratio determining portion 403 sets the mixture ratio α based on the area information supplied from the area specifying unit 103 and indicating to which of the foreground area, the background area, the covered background area, or the uncovered background area the pixel for which the mixture ratio α is to be calculated belongs. The mixture-ratio determining portion 403 sets the mixture ratio α to 0 when the corresponding pixel belongs to the foreground area, and sets the mixture ratio α to 1 when the corresponding pixel belongs to the background area. When the corresponding

pixel belongs to the covered background area, the mixture-ratio determining portion 403 sets the mixture ratio α to the estimated mixture ratio supplied from the estimated-mixture-ratio processor 401. When the corresponding pixel belongs to the uncovered background area, the mixture-ratio determining portion 403 sets the mixture ratio α to the estimated mixture ratio supplied from the estimated-mixture-ratio processor 402. The mixture-ratio determining portion 403 outputs the mixture ratio α which has been set based on the area information.

Fig. 38 is a block diagram illustrating another configuration of the mixture-ratio calculator 104. A selector 441 supplies a pixel belonging to the covered background area and the corresponding pixels in the previous and subsequent frames to an estimated-mixture-ratio processor 442 based on the area information supplied from the area specifying unit 103. The selector 441 supplies a pixel belonging to the uncovered background area and the corresponding pixels in the previous and subsequent frames to an estimated-mixture-ratio processor 443 based on the area information supplied from the area specifying unit 103.

The estimated-mixture-ratio processor 442 calculates the estimated mixture ratio of the designated pixel belonging to the covered background area by the calculation expressed in equation (17) based on the pixel values input

from the selector 441, and supplies the calculated estimated mixture ratio to a selector 444.

The estimated-mixture-ratio processor 443 calculates the estimated mixture ratio of the designated pixel belonging to the uncovered background area by the calculation expressed in equation (18) based on the pixel values input from the selector 441, and supplies the calculated estimated mixture ratio to the selector 444.

Based on the area information supplied from the area specifying unit 103, the selector 444 selects the estimated mixture ratio 0 and sets it as the mixture ratio α when the designated pixel belongs to the foreground area, and selects the estimated mixture ratio 1 and sets it as the mixture ratio α when the designated pixel belongs to the background area. When the designated pixel belongs to the covered background area, the selector 444 selects the estimated mixture ratio supplied from the estimated-mixture-ratio processor 442 and sets it as the mixture ratio α. When the designated pixel belongs to the uncovered background area, the selector 444 selects the estimated mixture ratio supplied from the estimated-mixture-ratio processor 443 and sets it as the mixture ratio α. The selector 444 then outputs the mixture ratio α which has been selected and set based on the area information.

As discussed above, the mixture-ratio calculator 104

configured as shown in Fig. 38 is able to calculate the mixture ratio α for each pixel contained in the image, and outputs the calculated mixture ratio α.

The calculation processing for the mixture ratio α performed by the mixture-ratio calculator 104 configured as shown in Fig. 30 is discussed below with reference to the flowchart of Fig. 39. In step S401, the mixture-ratio calculator 104 obtains area information supplied from the area specifying unit 103. In step S402, the estimated-mixture-ratio processor 401 executes the processing for estimating the mixture ratio by using a model corresponding to a covered background area, and supplies the estimated mixture ratio to the mixture-ratio determining portion 403. Details of the processing for estimating the mixture ratio are discussed below with reference to the flowchart of Fig. 40.

In step S403, the estimated-mixture-ratio processor 402 executes the processing for estimating the mixture ratio by using a model corresponding to an uncovered background area, and supplies the estimated mixture ratio to the mixture-ratio determining portion 403.

In step S404, the mixture-ratio calculator 104 determines whether the mixture ratios have been estimated for the whole frame. If it is determined that the mixture ratios have not yet been estimated for the whole frame, the

process returns to step S402, and the processing for estimating the mixture ratio for the subsequent pixel is executed.

If it is determined in step S404 that the mixture ratios have been estimated for the whole frame, the process proceeds to step S405. In step S405, the mixture-ratio determining portion 403 sets the mixture ratio based on the area information supplied from the area specifying unit 103 and indicating to which of the foreground area, the background area, the covered background area, or the uncovered background area the pixel for which the mixture ratio α is to be calculated belongs. The mixture-ratio determining portion 403 sets the mixture ratio α to 0 when the corresponding pixel belongs to the foreground area, and sets the mixture ratio α to 1 when the corresponding pixel belongs to the background area. When the corresponding pixel belongs to the covered background area, the mixture-ratio determining portion 403 sets the estimated mixture ratio supplied from the estimated-mixture-ratio processor 401 as the mixture ratio α. When the corresponding pixel belongs to the uncovered background area, the mixture-ratio determining portion 403 sets the estimated mixture ratio supplied from the estimated-mixture-ratio processor 402 as the mixture ratio α. The processing is then completed.

As discussed above, the mixture-ratio calculator 104 is

able to calculate the mixture ratio α, which indicates a feature quantity corresponding to each pixel, based on the area information supplied from the area specifying unit 103, and the input image.

The processing for calculating the mixture ratio α performed by the mixture-ratio calculator 104 configured as shown in Fig. 38 is similar to that discussed with reference to the flowchart of Fig. 39, and an explanation thereof is thus omitted.

A description is now given of, with reference to the flowchart of Fig. 40, the mixture-ratio estimating processing by using a model corresponding to the covered background area in step S402 of Fig. 39.

In step S421, the mixture-ratio calculator 423 obtains the pixel value C of the designated pixel in frame #n from the frame memory 421.

In step S422, the mixture-ratio calculator 423 obtains from the frame memory 422 the pixel value P of the pixel in frame #n-1 corresponding to the designated pixel contained in the input image.

In step S423, the mixture-ratio calculator 423 obtains the pixel value N of the pixel in frame #n+1 corresponding to the designated pixel contained in the input image.

In step S424, the mixture-ratio calculator 423 calculates the estimated mixture ratio based on the pixel

value C of the designated pixel in frame #n, the pixel value P of the pixel in frame #n-1, and the pixel value N of the pixel in frame #n+1.

In step S425, the mixture-ratio calculator 423 determines whether the processing for calculating the estimated mixture ratio is finished for the whole frame. If it is determined that the processing for calculating the estimated mixture ratio is not finished for the whole frame, the process returns to step S421, the processing for calculating the estimated mixture ratio for the subsequent pixel is repeated.

If it is determined in step S425 that the processing for calculating the estimated mixture ratio for the whole frame is finished, the processing is completed.

As discussed above, the estimated-mixture-ratio processor 401 is able to calculate the estimated mixture ratio based on the input image.

The mixture-ratio estimating processing performed by using a model corresponding to the uncovered background area in step S403 of Fig. 39 is similar to the processing indicated by the flowchart of Fig. 40 performed by using a model corresponding to the uncovered background area, and an explanation thereof is thus omitted.

The estimated-mixture-ratio processor 442 and the estimated-mixture-ratio processor 443 shown in Fig. 38

calculate the estimated mixture ratios by performing processing similar to that of the flowchart of Fig. 40, and an explanation thereof is thus omitted.

The embodiment has been described, assuming that the object corresponding to the background is stationary. However, the above-described processing for determining the mixture ratio α can be applied even if the image corresponding to the background area contains motion. For example, if the image corresponding to the background area is uniformly moving, the estimated-mixture-ratio processor 401 shifts the overall image in accordance with the motion of the background, and performs processing in a manner similar to the case in which the object corresponding to the background is stationary. If the image corresponding to the background area contains locally different motions, the estimated-mixture-ratio processor 401 selects the pixels corresponding to the motions as the corresponding pixels belonging to the mixed area, and executes the above-described processing.

The estimated-mixture ratio calculator 104 may execute only the mixture-ratio estimating processing for all the pixels by using a model corresponding to the covered background area so as to output the calculated estimated mixture ratio as the mixture ratio α. In this case, the mixture ratio α indicates the ratio of the background

components for the background components of the pixels belonging to the covered background area, and indicates the ratio of the foreground components for the pixels belonging to the uncovered background area. For the pixels belonging to the uncovered background area, the absolute value of the difference between the mixture ratio α and 1 is calculated, and the calculated absolute value is set as the mixture ratio α. Then, the image processing apparatus is able to determine the mixture ratio α indicating the ratio of the background components for the pixels belonging to the uncovered background area.

Similarly, the mixture-ratio calculator 104 may execute only the mixture-ratio estimating processing for all the pixels by using a model corresponding to the uncovered background area so as to output the calculated estimated mixture ratio as the mixture ratio α.

The mixture-ratio calculator 104 that calculates the mixture ratio α by utilizing the characteristic in which the mixture ratio α linearly changes is discussed below.

As discussed above, since equations (7) and (8) each contain two variables, the mixture ratio α cannot be determined without modifying the equations.

The mixture ratio α linearly changes in accordance with a change in the position of the pixels because the object corresponding to the foreground is moving with constant

velocity. By utilizing this characteristic, an equation in which the mixture ratio α and the sum f of the foreground components are approximated in the spatial direction can hold true. By utilizing a plurality of sets of the pixel values of the pixels belonging to the mixed area and the pixel values of the pixels belonging to the background area, the equations in which the mixture ratio α and the sum f of the foreground components are approximated are solved.

When a change in the mixture ratio α is approximated as a straight line, the mixture ratio α can be expressed by equation (19).

$$\alpha = il+p \qquad (19)$$

In equation (19), i indicates the spatial index when the position of the designated pixel is set to 0, l designates the gradient of the straight line of the mixture ratio α, and p designates the intercept of the straight line of the mixture ratio α and also indicates the mixture ratio α of the designated pixel. In equation (19), the index i is known, and the gradient l and the intercept p are unknown.

The relationship among the index i, the gradient l, and the intercept p is shown in Fig. 41. In Fig. 41, white dots indicate a pixel to be processed, and black dots indicate pixels adjacent to the pixel to be processed.

By approximating the mixture ratio α as equation (19), a plurality of different mixture ratios α for a plurality of

pixels can be expressed by two variables. In the example shown in Fig. 41, the five mixture ratios for five pixels are expressed by the two variables, i.e., the gradient l and the intercept p.

When the mixture ratio α is approximated in the plane shown in Fig. 42, equation (19) is expanded into the plane by considering the movement v corresponding to the two directions, i.e., the horizontal direction and the vertical direction of the image, and the mixture ratio α can be expressed by equation (20).

$$\alpha = jm+kq+p \qquad (20)$$

In equation (20), j is the index in the horizontal direction and k is the index in the vertical direction when the position of the designated pixel is 0. In equation (20), m designates the horizontal gradient of the mixture ratio α in the plane, and q indicates the vertical gradient of the mixture ratio α in the plane. In equation (20), p indicates the intercept of the mixture ratio α in the plane.

For example, in frame #n shown in Fig. 32, equations (21) through (23) can hold true for C05 through C07, respectively.

$$C05 = \alpha 05 \bullet B05/v+f05 \qquad (21)$$

$$C06 = \alpha 06 \bullet B06/v+f06 \qquad (22)$$

$$C07 = \alpha 07 \bullet B07/v+f07 \qquad (23)$$

Assuming that the foreground components positioned in

close proximity with each other are equal to each other, i.e., that F01 through F03 are equal, equation (24) holds true by replacing F01 through F03 by fc.

$$f(x) = (1-\alpha(x))\bullet Fc \qquad (24)$$

In equation (24), x indicates the position in the spatial direction.

When $\alpha(x)$ is replaced by equation (20), equation (24) can be expressed by equation (25).

$$\begin{aligned} f(x) &= (1-(jm+kq+p))\bullet Fc \\ &= j\bullet(-m\bullet Fc)+k\bullet(-q\bullet Fc)+((1-p)\bullet Fc) \\ &= js+kt+u \qquad (25) \end{aligned}$$

In equation (25), $(-m\bullet Fc)$, $(-q\bullet Fc)$, and $(1-p)\bullet Fc$ are replaced, as expressed by equations (26) through (28), respectively.

$$s = -m\bullet Fc \qquad (26)$$

$$t = -q\bullet Fc \qquad (27)$$

$$u = (1-p)\bullet Fc \qquad (28)$$

In equation (25), j is the index in the horizontal direction and k is the index in the vertical direction when the position of the designated pixel is 0.

As discussed above, since it can be assumed that the object corresponding to the foreground is moving with constant velocity within the shutter period, and that the foreground components positioned in close proximity with each other are uniform, the sum of the foreground components

can be approximated by equation (25).

When the mixture ratio α is approximated by a straight line, the sum of the foreground components can be expressed by equation (29).

$$f(x) = is+u \qquad (29)$$

By replacing the mixture ratio α and the sum of the foreground components in equation (9) by using equations (20) and (25), the pixel value M can be expressed by equation (30).

$$\begin{aligned} M &= (jm+kq+p)\bullet B+js+kt+u \\ &= jB\bullet m+kB\bullet q+B\bullet p+j\bullet s+k\bullet t+u \qquad (30) \end{aligned}$$

In equation (30), unknown variables are six factors, such as the horizontal gradient m of the mixture ratio α in the plane, the vertical gradient q of the mixture ratio α in the plane, and the intercepts of the mixture ratio α in the plane, p, s, t, and u.

The pixel value M and the pixel value B are set in normal equation (30) in accordance with the pixels close to the designated pixel, and then, a plurality of normal equations in which the pixel value M and the pixel value B are set are solved by the method of least squares, thereby calculating the mixture ratio α.

It is now assumed, for example, that the horizontal index j of the designated pixel is set to 0, and the vertical index k of the designated pixel is set to 0. In

this case, when the pixel value M or the pixel value B is set in the normal equation expressed by equation (30) for 3×3 pixels located in the proximity with the designated pixel, equations (31) through (39) are obtained.

$$M_{-1,-1} = (-1)\bullet B_{-1,-1}\bullet m+(-1)\bullet B_{-1,-1}\bullet q+B_{-1,-1}\bullet p+(-1)\bullet s+(-1)\bullet t+u \quad (31)$$

$$M_{0,-1} = (0)\bullet B_{0,-1}\bullet m+(-1)\bullet B_{0,-1}\bullet q+B_{0,-1}\bullet p+(0)\bullet s+(-1)\bullet t+u \quad (32)$$

$$M_{+1,-1} = (+1)\bullet B_{+1,-1}\bullet m+(-1)\bullet B_{+1,-1}\bullet q+B_{+1,-1}\bullet p+(+1)\bullet s+(-1)\bullet t+u \quad (33)$$

$$M_{-1,0} = (-1)\bullet B_{-1,0}\bullet m+(0)\bullet B_{-1,0}\bullet q+B_{-1,0}\bullet p+(-1)\bullet s+(0)\bullet t+u \quad (34)$$

$$M_{0,0} = (0)\bullet B_{0,0}\bullet m+(0)\bullet B_{0,0}\bullet q+B_{0,0}\bullet p+(0)\bullet s+(0)\bullet t+u \quad (35)$$

$$M_{+1,0} = (+1)\bullet B_{+1,0}\bullet m+(0)\bullet B_{+1,0}\bullet q+B_{+1,0}\bullet p+(+1)\bullet s+(0)\bullet t+u \quad (36)$$

$$M_{-1,+1} = (-1)\bullet B_{-1,+1}\bullet m+(+1)\bullet B_{-1,+1}\bullet q+B_{-1,+1}\bullet p+(-1)\bullet s+(+1)\bullet t+u \quad (37)$$

$$M_{0,+1} = (0)\bullet B_{0,+1}\bullet m+(+1)\bullet B_{0,+1}\bullet q+B_{0,+1}\bullet p+(0)\bullet s+(+1)\bullet t+u \quad (38)$$

$$M_{+1,+1} = (+1)\bullet B_{+1,+1}\bullet m+(+1)\bullet B_{+1,+1}\bullet q+B_{+1,+1}\bullet p+(+1)\bullet s+(+1)\bullet t+u \quad (39)$$

Since the horizontal index j of the designated pixel is 0, and the vertical index k of the designated pixel is 0, the mixture ratio α of the designated pixel is equal to the value when j is 0 and k is 0 in equation (20), i.e., the mixture ratio α is equal to the intercept p in equation (20).

Accordingly, based on the nine equations, i.e., equations (31) through (39), the horizontal gradient m, the vertical gradient q, and the intercepts p, s, t, and u are calculated by the method of least squares, and the intercept p is output as the mixture ratio α.

A specific process for calculating the mixture ratio α by applying the method of least squares is as follows.

When the index i and the index k are expressed by a single index x, the relationship among the index i, the index k, and the index x can be expressed by equation (40).

$$x = (j+1) \bullet 3 + (k+1) \qquad (40)$$

It is now assumed that the horizontal gradient m, the vertical gradient q, and the intercepts p, s, t, and u are expressed by variables w0, w1, w2, w3, w4, and w5, respectively, and jB, kB, B, j, k and l are expressed by a0, a1, a2, a3, a4, and a5, respectively. In consideration of the error ex, equations (31) through (39) can be modified into equation (41).

$$Mx = \sum_{y=0}^{5} ay \cdot wy + ex \qquad (41)$$

In equation (41), x is any one of the integers from 0 to 8.

Equation (42) can be found from equation (41).

$$ex = Mx - \sum_{y=0}^{5} ay \cdot wy \qquad (42)$$

Since the method of least squares is applied, the square sum E of the error is defined as follows, as expressed by equation (43).

$$E = \sum_{x=0}^{8} ex^2 \qquad (43)$$

In order to minimize the error, the partial differential value of the variable Wv with respect to the

square sum E of the error should be 0. v is any one of the integers from 0 to 5. Thus, wy is determined so that equation (44) is satisfied.

$$\begin{aligned}\frac{\partial E}{\partial Wv} &= 2 \cdot \sum_{x=0}^{8} ex \cdot \frac{\partial ex}{\partial Wv} \\ &= 2 \cdot \sum_{x=0}^{8} ex \cdot av = 0\end{aligned} \tag{44}$$

By substituting equation (42) into equation (44), equation (45) is obtained.

$$\sum_{x=0}^{8} (av \cdot \sum_{y=0}^{5} ay \cdot Wy) = \sum_{x=0}^{8} av \cdot Mx \tag{45}$$

For example, the sweep-out method (Gauss-Jordan elimination) is applied to the normal equations consisting of six equations obtained by substituting one of the integers from 0 to 5 into v in equation (45), thereby obtaining wy. As stated above, w0 is the horizontal gradient m, w1 is the vertical gradient q, w2 is the intercept p, w3 is s, w4 is t, and w5 is u.

As discussed above, by applying the method of least squares to the equations in which the pixel value M and the pixel value B are set, the horizontal gradient m, the vertical gradient q, and the intercepts p, s, t, and u can be determined.

A description has been given with reference to equations (31) through (39), by assuming that the pixel value of the pixel contained in the mixed area is M, and the

pixel value of the pixel contained in the background area is B. In this case, it is necessary to set normal equations for each of the cases where the designated pixel is contained in the covered background area, or the designated pixel is contained in the uncovered background area.

For example, if the mixture ratio α of the pixel contained in the covered background area in frame #n shown in Fig. 32 is determined, C04 through C08 of the pixels in frame #n and the pixel values P04 through P08 of the pixels in frame #n-1 are set in the normal equations.

If the mixture ratio α of the pixels contained in the uncovered background area in frame #n shown in Fig. 33 is determined, C28 through C32 of the pixels in frame #n and the pixel values N28 through N32 of the pixels in frame #n+1 are set in the normal equations.

Moreover, if, for example, the mixture ratio α of the pixel contained in the covered background area shown in Fig. 43 is calculated, the following equations (46) through (54) are set. In Fig. 43, white dots indicate pixels of the background, and black dots indicate pixels of the mixed area. The pixel value of the pixel for which the mixture ratio α is calculated is Mc5.

$$Mc1 = (-1)\bullet Bc1\bullet m+(-1)\bullet Bc1\bullet q+Bc1\bullet p+(-1)\bullet s+(-1)\bullet t+u \quad (46)$$

$$Mc2 = (0)\bullet Bc2\bullet m+(-1)\bullet Bc2\bullet q+Bc2\bullet p+(0)\bullet s+(-1)\bullet t+u \quad (47)$$

$$Mc3 = (+1)\bullet Bc3\bullet m+(-1)\bullet Bc3\bullet q+Bc3\bullet p+(+1)\bullet s+(-1)\bullet t+u \quad (48)$$

$$Mc4 = (-1)\bullet Bc4\bullet m+(0)\bullet Bc4\bullet q+Bc4\bullet p+(-1)\bullet s+(0)\bullet t+u \quad (49)$$

$$Mc5 = (0)\bullet Bc5\bullet m+(0)\bullet Bc5\bullet q+Bc5\bullet p+(0)\bullet s+(0)\bullet t+u \quad (50)$$

$$Mc6 = (+1)\bullet Bc6\bullet m+(0)\bullet Bc6\bullet q+Bc6\bullet p+(+1)\bullet s+(0)\bullet t+u \quad (51)$$

$$Mc7 = (-1)\bullet Bc7\bullet m+(+1)\bullet Bc7\bullet q+Bc7\bullet p+(-1)\bullet s+(+1)\bullet t+u \quad (52)$$

$$Mc8 = (0)\bullet Bc8\bullet m+(+1)\bullet Bc8\bullet q+Bc8\bullet p+(0)\bullet s+(+1)\bullet t+u \quad (53)$$

$$Mc9 = (+1)\bullet Bc9\bullet m+(+1)\bullet Bc9\bullet q+Bc9\bullet p+(+1)\bullet s+(+1)\bullet t+u \quad (54)$$

When the mixture ratio α of the pixel contained in the covered background area in frame #n is calculated, the pixel values Bc1 through Bc9 of the pixels of the background area in frame #n-1 in equations (46) through (54), respectively, corresponding to the pixels in frame #n are used.

If, for example, the mixture ratio α of the pixel contained in the uncovered background area shown in Fig. 43 is calculated, the following equations (55) through (63) are set. The pixel value of the pixel for which the mixture ratio α is calculated is Mu5.

$$Mu1 = (-1)\bullet Bu1\bullet m+(-1)\bullet Bu1\bullet q+Bu1\bullet p+(-1)\bullet s+(-1)\bullet t+u \quad (55)$$

$$Mu2 = (0)\bullet Bu2\bullet m+(-1)\bullet Bu2\bullet q+Bu2\bullet p+(0)\bullet s+(-1)\bullet t+u \quad (56)$$

$$Mu3 = (+1)\bullet Bu3\bullet m+(-1)\bullet Bu3\bullet q+Bu3\bullet p+(+1)\bullet s+(-1)\bullet t+u \quad (57)$$

$$Mu4 = (-1)\bullet Bu4\bullet m+(0)\bullet Bu4\bullet q+Bu4\bullet p+(-1)\bullet s+(0)\bullet t+u \quad (58)$$

$$Mu5 = (0)\bullet Bu5\bullet m+(0)\bullet Bu5\bullet q+Bu5\bullet p+(0)\bullet s+(0)\bullet t+u \quad (59)$$

$$Mu6 = (+1)\bullet Bu6\bullet m+(0)\bullet Bu6\bullet q+Bu6\bullet p+(+1)\bullet s+(0)\bullet t+u \quad (60)$$

$$Mu7 = (-1)\bullet Bu7\bullet m+(+1)\bullet Bu7\bullet q+Bu7\bullet p+(-1)\bullet s+(+1)\bullet t+u \quad (61)$$

$$Mu8 = (0)\bullet Bu8\bullet m+(+1)\bullet Bu8\bullet q+Bu8\bullet p+(0)\bullet s+(+1)\bullet t+u \quad (62)$$

$$Mu9 = (+1)\bullet Bu9\bullet m+(+1)\bullet Bu9\bullet q+Bu9\bullet p+(+1)\bullet s+(+1)\bullet t+u \quad (63)$$

When the mixture ratio α of the pixel contained in the uncovered background area in frame #n is calculated, the pixel values Bu1 through Bu9 of the pixels of the background area in frame #n+1 in equations (55) through (63), respectively, corresponding to the pixels in frame #n are used.

Fig. 44 is a block diagram illustrating the configuration of the estimated-mixture-ratio processor 401. An image input into the estimated-mixture-ratio processor 401 is supplied to a delay portion 501 and an adder 502.

A delay circuit 501 delays the input image for one frame, and supplies the image to the adder 502. When frame #n is supplied as the input image to the adder 502, the delay circuit 501 supplies frame #n-1 to the adder 502.

The adder 502 sets the pixel value of the pixel adjacent to the pixel for which the mixture ratio α is calculated, and the pixel value of frame #n-1 in the normal equation. For example, the adder 502 sets the pixel values Mc1 through Mc9 and the pixel values Bc1 through Bc9 in the normal equations based on equations (46) through (54), respectively. The adder 502 supplies the normal equations in which the pixel values are set to a calculator 503.

The calculator 503 determines the estimated mixture ratio by solving the normal equations supplied from the adder 502 by, for example, a sweep-out method, and outputs

the determined estimated mixture ratio.

In this manner, the estimated-mixture-ratio processor 401 is able to calculate the estimated mixture ratio based on the input image, and supplies it to the mixture-ratio determining portion 403.

The estimated-mixture-ratio processor 402 is configured similar to the estimated-mixture-ratio processor 401, and an explanation thereof is thus omitted.

Fig. 45 illustrates an example of the estimated mixture ratio calculated by the estimated-mixture-ratio processor 401. The estimated mixture ratio shown in Fig. 45 is the result represented by one line and obtained by performing the calculation by generating equations in units of 7x7-pixel blocks when the movement v of the foreground corresponding to the object moving with constant velocity is 11.

The estimated mixture ratio changes almost linearly in the mixed area, as shown in Fig. 44.

A description is now given, with reference to the flowchart of Fig. 46, of the mixture-ratio estimating processing performed by the estimated-mixture-ratio processor 401 by using a model of the covered background area shown in Fig. 44.

In step S521, the adder 502 sets the pixel value contained in the input image and the pixel value contained

in the image supplied from the delay circuit 501 in a normal equation corresponding to a model of the covered background area.

In step S522, the estimated-mixture-ratio processor 401 determines whether the setting of the target pixels is finished. If it is determined that the setting of the target pixels is not finished, the process returns to step S521, and the processing for setting the pixel values in the normal equation is repeated.

If it is determined in step S522 that the setting for the target pixels is finished, the process proceeds to step S523. In step S523, a calculator 503 calculates the estimated mixture ratio based on the normal equations in which the pixels values are set, and outputs the calculated mixture ratio.

As discussed above, the estimated-mixture-ratio processor 401 shown in Fig. 44 is able to calculate the estimated mixture ratio based on the input image.

The mixture-ratio estimating processing by using a model corresponding to the uncovered background area is similar to the processing indicated by the flowchart of Fig. 46 by using the normal equations corresponding to a model of the uncovered background area, and an explanation thereof is thus omitted.

The embodiment has been described, assuming that the

object corresponding to the background is stationary. However, the above-described mixture-ratio calculation processing can be applied even if the image corresponding to the background area contains motion. For example, if the image corresponding to the background area is uniformly moving, the estimated-mixture-ratio processor 401 shifts the overall image in accordance with this motion, and performs processing in a manner similar to the case in which the object corresponding to the background is stationary. If the image corresponding to the background area contains locally different motions, the estimated-mixture-ratio processor 401 selects the pixels corresponding to the motions as the pixels belonging to the mixed area, and executes the above-described processing.

As discussed above, the mixture ratio calculator 102 is able to calculate the mixture ratio α, which is the feature quantity corresponding to each pixel, based on the area information supplied from the area specifying unit 101 and input image.

By using the mixture ratio α, it is possible to separate the foreground components and the background components contained in the pixel value while maintaining the information of the motion blur contained in the image corresponding to the moving object.

If the image is synthesized based on the mixture ratio

α, it is possible to create an image containing motion blur that matches the speed of the moving object and that faithfully reflects the real world.

The foreground/background separator 105 is discussed below. Fig. 47 is a block diagram illustrating an example of the configuration of the foreground/background separator 105. The input image supplied to the foreground/background separator 105 is supplied to a separating portion 601, a switch 602, and a switch 604. The area information supplied from the area specifying unit 103 and indicating the information of the covered background area and the uncovered background area is supplied to the separating portion 601. The area information indicating the foreground area is supplied to the switch 602. The area information indicating the background area supplied to the switch 604.

The mixture ratio α supplied from the mixture-ratio calculator 104 is supplied to the separating portion 601.

The separating portion 601 separates the foreground components from the input image based on the area information indicating the covered background area, the area information indicating the uncovered background area, and the mixture ratio α, and supplies the separated foreground components to a synthesizer 603. The separating portion 601 also separates the background components from the input image, and supplies the separated background components to a

synthesizer 605.

The switch 602 is closed when a pixel corresponding to the foreground is input based on the area information indicating the foreground area, and supplies only the pixels corresponding to the foreground contained in the input image to the synthesizer 603.

The switch 604 is closed when a pixel corresponding to the background is input based on the area information indicating the background area, and supplies only the pixels corresponding to the background contained in the input image to the synthesizer 605.

The synthesizer 603 synthesizes a foreground component image based on the foreground components supplied from the separating portion 601 and the pixels corresponding to the foreground supplied from the switch 602, and outputs the synthesized foreground component image. Since the foreground area and the mixed area do not overlap, the synthesizer 603 applies, for example, logical OR to the foreground components and the foreground pixels, thereby synthesizing the foreground component image.

In the initializing processing executed at the start of the synthesizing processing for the foreground component image, the synthesizer 603 stores an image whose pixel values are all 0 in a built-in frame memory. Then, in the synthesizing processing for the foreground component image,

the synthesizer 603 stores the foreground component image (overwrites the previous image by the foreground component image). Accordingly, 0 is stored in the pixels corresponding to the background area in the foreground component image output from the synthesizer 603.

The synthesizer 605 synthesizes a background component image based on the background components supplied from the separating portion 601 and the pixels corresponding to the background supplied from the switch 604, and outputs the synthesized background component image. Since the background area and the mixed area do not overlap, the synthesizer 605 applies, for example, logical OR to the background components and the background pixels, thereby synthesizing the background component image.

In the initializing processing executed at the start of the synthesizing processing for the background component image, the synthesizer 605 stores an image whose pixel values are all 0 in a built-in frame memory. Then, in the synthesizing processing for the background component image, the synthesizer 605 stores the background component image (overwrites the previous image by the background component image). Accordingly, 0 is stored in the pixels corresponding to the foreground area in the background component image output from the synthesizer 605.

Fig. 48A illustrates the input image input into the

foreground/background separator 105 and the foreground component image and the background component image output from the foreground/background separator 105. Fig. 48B illustrates a model of the input image input into the foreground/background separator 105 and the foreground component image and the background component image output from the foreground/background separator 105.

Fig. 48A is a schematic diagram of an image to be displayed, and Fig. 48B is a model in which pixels for one line corresponding to the image shown in Fig. 48A and containing pixels belonging to the foreground area, pixels belonging to the background area, and pixels belonging to the mixed area are expanded in the time direction.

As shown in Figs. 48A and 48B, the background component image output from the foreground/background separator 105 consists of the pixels belonging to the background area and the background components contained in the pixels of the mixed area.

As shown in Figs. 48A and 48B, the foreground component image output from the foreground/background separator 105 consists of the pixel belonging to the foreground area and the foreground components contained in the pixels of the mixed area.

The pixel values of the pixels in the mixed area are separated into the background components and the foreground

components by the foreground/background separator 105. The separated background components form the background component image together with the pixels belonging to the background area. The separated foreground components form the foreground component image together with the pixels belonging to the foreground area.

As discussed above, in the foreground component image, the pixel values of the pixels corresponding to the background area are set to 0, and significant pixel values are set in the pixels corresponding to the foreground area and the pixels corresponding to the mixed area. Similarly, in the background component image, the pixel values of the pixels corresponding to the foreground area are set to 0, and significant pixel values are set in the pixels corresponding to the background area and the pixels corresponding to the mixed area.

A description is given below of the processing executed by the separating portion 601 for separating the foreground components and the background components from the pixels belonging to the mixed area.

Fig. 49 illustrates a model of an image indicating foreground components and background components in two frames including a foreground object moving from the left to the right in Fig. 49. In the model of the image shown in Fig. 49, the amount of movement v is 4, and the number of

virtual divided portions is 4.

In frame #n, the leftmost pixel and the fourteenth through eighteenth pixels from the left consist of only the background components and belong to the background area. In frame #n, the second through fourth pixels from the left contain the background components and the foreground components, and belong to the uncovered background area. In frame #n, the eleventh through thirteenth pixels from the left contain background components and foreground components, and belong to the covered background area. In frame #n, the fifth through tenth pixels from the left consist of only the foreground components, and belong to the foreground area.

In frame #n+1, the first through fifth pixels from the left and the eighteenth pixel from the left consist of only the background components, and belong to the background area. In frame #n+1, the sixth through eighth pixels from the left contain background components and foreground components, and belong to the uncovered background area. In frame #n+1, the fifteenth through seventeenth pixels from the left contain background components and foreground components, and belong to the covered background area. In frame #n+1, the ninth through fourteenth pixels from the left consist of only the foreground components, and belong to the foreground area.

Fig. 50 illustrates the processing for separating the foreground components from the pixels belonging to the

covered background area. In Fig. 50, $\alpha 1$ through $\alpha 18$ indicate mixture ratios of the individual pixels of frame #n. In Fig. 50, the fifteenth through seventeenth pixels from the left belong to the covered background area.

The pixel value C15 of the fifteenth pixel from the left in frame #n can be expressed by equation (64):

$$\begin{aligned} C15 &= B15/v+F09/v+F08/v+F07/v \\ &= \alpha 15 \bullet B15+F09/v+F08/v+F07/v \\ &= \alpha 15 \bullet P15+F09/v+F08/v+F07/v \qquad (64) \end{aligned}$$

where $\alpha 15$ indicates the mixture ratio of the fifteenth pixel from the left in frame #n, and P15 designates the pixel value of the fifteenth pixel from the left in frame #n-1.

The sum f15 of the foreground components of the fifteenth pixel from the left in frame #n can be expressed by equation (65) based on equation (64).

$$\begin{aligned} f15 &= F09/v+F08/v+F07/v \\ &= C15-\alpha 15 \bullet P15 \qquad (65) \end{aligned}$$

Similarly, the sum f16 of the foreground components of the sixteenth pixel from the left in frame #n can be expressed by equation (66), and the sum f17 of the foreground components of the seventeenth pixel from the left in frame #n can be expressed by equation (67).

$$f16 = C16-\alpha 16 \bullet P16 \qquad (66)$$

$$f17 = C17-\alpha 17 \bullet P17 \qquad (67)$$

In this manner, the foreground components fc contained

in the pixel value C of the pixel belonging to the covered background area can be expressed by equation (68):

$$fc = C-\alpha \bullet P \qquad (68)$$

where P designates the pixel value of the corresponding pixel in the previous frame.

Fig. 51 illustrates the processing for separating the foreground components from the pixels belonging to the uncovered background area. In Fig. 51, α1 through α18 indicate mixture ratios of the individual pixels of frame #n. In Fig. 51, the second through fourth pixels from the left belong to the uncovered background area.

The pixel value C02 of the second pixel from the left in frame #n can be expressed by equation (69):

$$\begin{aligned} C02 &= B02/v+B02/v+B02/v+F01/v \\ &= \alpha 2 \bullet B02+F01/v \\ &= \alpha 2 \bullet N02+F01/v \qquad (69) \end{aligned}$$

where α2 indicates the mixture ratio of the second pixel from the left in frame #n, and N02 designates the pixel value of the second pixel from the left in frame #n+1.

The sum f02 of the foreground components of the second pixel from the left in frame #n can be expressed by equation (70) based on equation (69).

$$\begin{aligned} f02 &= F01/v \\ &= C02-\alpha 2 \bullet N02 \qquad (70) \end{aligned}$$

Similarly, the sum f03 of the foreground components of

the third pixel from the left in frame #n can be expressed by equation (71), and the sum f04 of the foreground components of the fourth pixel from the left in frame #n can be expressed by equation (72).

$$f03 = C03-\alpha 3 \bullet N03 \quad (71)$$

$$f04 = C04-\alpha 4 \bullet N04 \quad (72)$$

In this manner, the foreground components fu contained in the pixel value C of the pixel belonging to the uncovered background area can be expressed by equation (73):

$$fu = C-\alpha \bullet N \quad (73)$$

where N designates the pixel value of the corresponding pixel in the subsequent frame.

As discussed above, the separating portion 601 is able to separate the foreground components from the pixels belonging to the mixed area and the background components from the pixels belonging to the mixed area based on the information indicating the covered background area and the information indicating the uncovered background area contained in the area information, and the mixture ratio α for each pixel.

Fig. 52 is a block diagram illustrating an example of the configuration of the separating portion 601 for executing the above-described processing. An image input into the separating portion 601 is supplied to a frame memory 621, and the area information indicating the covered

background area and the uncovered background area supplied from the mixture-ratio calculator 104 and the mixture ratio α are supplied to a separation processing block 622.

The frame memory 621 stores the input images in units of frames. When a frame to be processed is frame #n, the frame memory 621 stores frame #n-1, which is the frame one frame before frame #n, frame #n, and frame #n+1, which is the frame one frame after frame #n.

The frame memory 621 supplies the corresponding pixels in frame #n-1, frame #n, and frame #n+1 to the separation processing block 622.

The separation processing block 622 applies the calculations discussed with reference to Figs. 50 and 51 to the pixel values of the corresponding pixels in frame #n-1, frame #n, and frame #n+1 supplied from the frame memory 621 based on the area information indicating the covered background area and the uncovered background area and the mixture ratio α so as to separate the foreground components and the background components from the pixels belonging to the mixed area in frame #n, and supplies them to a frame memory 623.

The separation processing block 622 is formed of an uncovered area processor 631, a covered area processor 632, a synthesizer 633, and a synthesizer 634.

A multiplier 641 of the uncovered area processor 631

multiplies the pixel value of the pixel in frame #n+1 supplied from the frame memory 621 by the mixture ratio α, and outputs the resulting pixel value to a switch 642. The switch 642 is closed when the pixel of frame #n (corresponding to the pixel in frame #n+1) supplied from the frame memory 621 belongs to the uncovered background area, and supplies the pixel value multiplied by the mixture ratio α supplied from the multiplier 641 to a calculator 643 and the synthesizer 634. The value obtained by multiplying the pixel value of the pixel in frame #n+1 by the mixture ratio α output from the switch 642 is equivalent to the background components of the pixel value of the corresponding pixel in frame #n.

The calculator 643 subtracts the background components supplied from the switch 642 from the pixel value of the pixel in frame #n supplied from the frame memory 621 so as to obtain the foreground components. The calculator 643 supplies the foreground components of the pixel in frame #n belonging to the uncovered background area to the synthesizer 633.

A multiplier 651 of the covered area processor 632 multiplies the pixel value of the pixel in frame #n-1 supplied from the frame memory 621 by the mixture ratio α, and outputs the resulting pixel value to a switch 652. The switch 652 is closed when the pixel of frame #n

(corresponding to the pixel in frame #n-1) supplied from the frame memory 621 belongs to the covered background area, and supplies the pixel value multiplied by the mixture ratio α supplied from the multiplier 651 to a calculator 653 and the synthesizer 634. The value obtained by multiplying the pixel value of the pixel in frame #n-1 by the mixture ratio α output from the switch 652 is equivalent to the background components of the pixel value of the corresponding pixel in frame #n.

The calculator 653 subtracts the background components supplied from the switch 652 from the pixel value of the pixel in frame #n supplied from the frame memory 621 so as to obtain the foreground components. The calculator 653 supplies the foreground components of the pixel in frame #n belonging to the covered background area to the synthesizer 633.

The synthesizer 633 combines the foreground components of the pixels belonging to the uncovered background area and supplied from the calculator 643 with the foreground components of the pixels belonging to the covered background area and supplied from the calculator 653, and supplies the synthesized foreground components to the frame memory 623.

The synthesizer 634 combines the background components of the pixels belonging to the uncovered background area and supplied from the switch 642 with the background components

of the pixels belonging to the covered background area and supplied from the switch 652, and supplies the synthesized background components to the frame memory 623.

The frame memory 623 stores the foreground components and the background components of the pixels in the mixed area of frame #n supplied from the separation processing block 622.

The frame memory 623 outputs the stored foreground components of the pixels in the mixed area in frame #n and the stored background components of the pixels in the mixed area in frame #n.

By utilizing the mixture ratio α, which indicates the feature quantity, the foreground components and the background components contained in the pixel values can be completely separated.

The synthesizer 603 combines the foreground components of the pixels in the mixed area in frame #n output from the separating portion 601 with the pixels belonging to the foreground area so as to generate a foreground component image. The synthesizer 605 combines the background components of the pixels in the mixed area in frame #n output from the separating portion 601 with the pixels belonging to the background area so as to generate a background component image.

Fig. 53A illustrates an example of the foreground

component image corresponding to frame #n in Fig. 49. The leftmost pixel and the fourteenth pixel from the left consist of only the background components before the foreground and the background are separated, and thus, the pixel values are set to 0.

The second and fourth pixels from the left belong to the uncovered background area before the foreground and the background are separated. Accordingly, the background components are set to 0, and the foreground components are maintained. The eleventh through thirteenth pixels from the left belong to the covered background area before the foreground and the background are separated. Accordingly, the background components are set to 0, and the foreground components are maintained. The fifth through tenth pixels from the left consist of only the foreground components, which are thus maintained.

Fig. 53B illustrates an example of the background component image corresponding to frame #n in Fig. 49. The leftmost pixel and the fourteenth pixel from the left consist of only the background components before the foreground and the background are separated, and thus, the background components are maintained.

The second through fourth pixels from the left belong to the uncovered background area before the foreground and the background are separated. Accordingly, the foreground

components are set to 0, and the background components are maintained. The eleventh through thirteenth pixels from the left belong to the covered background area before the foreground and the background are separated. Accordingly, the foreground components are set to 0, and the background components are maintained. The fifth through tenth pixels from the left consist of only the foreground components, and thus, the pixel values are set to 0.

The processing for separating the foreground and the background executed by the foreground/background separator 105 is described below with reference to the flowchart of Fig. 54. In step S601, the frame memory 621 of the separating portion 601 obtains an input image, and stores frame #n for which the foreground and the background are separated together with the previous frame #n-1 and the subsequent frame #n+1.

In step S602, the separation processing block 622 of the separating portion 601 obtains area information supplied from the mixture-ratio calculator 104. In step S603, the separation processing block 622 of the separating portion 601 obtains the mixture ratio α supplied from the mixture-ratio calculator 104.

In step S604, the uncovered area processor 631 extracts the background components from the pixel values of the pixels belonging to the uncovered background area supplied

from the frame memory 621 based on the area information and the mixture ratio α.

In step S605, the uncovered area processor 631 extracts the foreground components from the pixel values of the pixels belonging to the uncovered background area supplied from the frame memory 621 based on the area information and the mixture ratio α.

In step S606, the covered area processor 632 extracts the background components from the pixel values of the pixels belonging to the covered background area supplied from the frame memory 621 based on the area information and the mixture ratio α.

In step S607, the covered area processor 632 extracts the foreground components from the pixel values of the pixels belonging to the covered background area supplied from the frame memory 621 based on the area information and the mixture ratio α.

In step S608, the synthesizer 633 combines the foreground components of the pixels belonging to the uncovered background area extracted in the processing of step S605 with the foreground components of the pixels belonging to the covered background area extracted in the processing of step S607. The synthesized foreground components are supplied to the synthesizer 603. The synthesizer 603 further combines the pixels belonging to the

foreground area supplied via the switch 602 with the foreground components supplied from the separating portion 601 so as to generate a foreground component image.

In step S609, the synthesizer 634 combines the background components of the pixels belonging to the uncovered background area extracted in the processing of step S604 with the background components of the pixels belonging to the covered background area extracted in the processing of step S606. The synthesized background components are supplied to the synthesizer 605. The synthesizer 605 further combines the pixels belonging to the background area supplied via the switch 604 with the background components supplied from the separating portion 601 so as to generate a background component image.

In step S610, the synthesizer 603 outputs the foreground component image. In step S611, the synthesizer 605 outputs the background component image. The processing is then completed.

As discussed above, the foreground/background separator 105 is able to separate the foreground components and the background components from the input image based on the area information and the mixture ratio α, and outputs the foreground component image consisting of only the foreground components and the background component image consisting of only the background components.

Adjustments of the amount of motion blur of the foreground component image are described below.

Fig. 55 is a block diagram illustrating an example of the configuration of the motion-blur adjusting unit 106. The motion vector and the positional information thereof supplied from the motion detector 102 are supplied to a unit-of-processing determining portion 801 and a model-forming portion 802, and a calculator 805. The area information supplied from the area specifying unit 103 is supplied to the unit-of-processing determining portion 801. The foreground component image supplied from the foreground/background separator 105 is supplied to an adder 804.

The unit-of-processing determining portion 801 generates the unit of processing based on the motion vector and the positional information thereof, and the area information, and supplies the generated unit of processing to the model-forming portion 802 and the adder 804.

As indicated by A in Fig. 56, for example, the unit of processing generated by the unit-of-processing determining portion 801 indicates consecutive pixels disposed in the moving direction starting from the pixel corresponding to the covered background area of the foreground component image until the pixel corresponding to the uncovered background area, or indicates consecutive pixels disposed in

the moving direction starting from the pixel corresponding to the uncovered background area until the pixel corresponding to the covered background area. The unit of processing is formed of two pieces of data which indicate, for example, the upper left point (which is the position of the leftmost or the topmost pixel in the image designated by the unit of processing) and the lower right point.

The model-forming portion 802 forms a model based on the motion vector and the input unit of processing. More specifically, for example, the model-forming portion 802 may store in advance a plurality of models in accordance with the number of pixels contained in the unit of processing, the number of virtual divided portions of the pixel value in the time direction, and the number of foreground components for each pixel. The model-forming portion 802 then may select the model in which the correlation between the pixel values and the foreground components is designated, such as that in Fig. 57, based on the unit of processing and the number of virtual divided portions of the pixel value in the time direction.

It is now assumed, for example, that the number of pixels corresponding to the unit of processing is 12, and that the amount of movement v within the shutter time is 5. Then, the model-forming portion 802 sets the number of virtual divided portions to 5, and selects a model formed of

eight types of foreground components so that the leftmost 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 pixel 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.

Instead of selecting a model from the prestored models, the model-forming portion 802 may generate a model based on the motion vector and the unit of processing when the motion vector and the unit of processing are supplied.

The model-forming portion 802 supplies the selected model to an equation generator 803.

The equation generator 803 generates an equation based on the model supplied from the model-forming portion 802. A description is given below, with reference to the model of the foreground component image shown in Fig. 57, of an

equation generated by the equation generator 803 when the number of foreground components is 8, the number of pixels corresponding to the unit of processing is 12, the amount of movement v is 5, and the number of virtual divided portions is 5.

When the foreground components contained in the foreground component image corresponding to the shutter time/v are F01/v through F08/v, the relationships between F01/v through F08/v and the pixel values C01 through C12 can be expressed by equations (74) through (85).

$$C01 = F01/v \quad (74)$$

$$C02 = F02/v+F01/v \quad (75)$$

$$C03 = F03/v+F02/v+F01v \quad (76)$$

$$C04 = F04/v+F03/v+F02/v+F01v \quad (77)$$

$$C05 = F05/v+F04/v+F03/v+F02/v+F01v \quad (78)$$

$$C06 = F06/v+F05/v+F04/v+F03/v+F02/v \quad (79)$$

$$C07 = F07/v+F06/v+F05/v+F04/v+F03/v \quad (80)$$

$$C08 = F08/v+F07/v+F06/v+F05/v+F04/v \quad (81)$$

$$C09 = F08/v+F07/v+F06/v+F05/v \quad (82)$$

$$C10 = F08/v+F07/v+F06/v \quad (83)$$

$$C11 = F08/v+F07/v \quad (84)$$

$$C12 = F08/v \quad (85)$$

The equation generator 803 generates an equation by modifying the generated equations. The equations generated by the equation generator 803 are indicated by equations

(86) though (97).

$$C01 = 1 \bullet F01/v + 0 \bullet F02/v + 0 \bullet F03/v + 0 \bullet F04/v + 0 \bullet F05/v + 0 \bullet F06/v + 0 \bullet F07/v + 0 \bullet F08/v \quad (86)$$

$$C02 = 1 \bullet F01/v + 1 \bullet F02/v + 0 \bullet F03/v + 0 \bullet F04/v + 0 \bullet F05/v + 0 \bullet F06/v + 0 \bullet F07/v + 0 \bullet F08/v \quad (87)$$

$$C03 = 1 \bullet F01/v + 1 \bullet F02/v + 1 \bullet F03/v + 0 \bullet F04/v + 0 \bullet F05/v + 0 \bullet F06/v + 0 \bullet F07/v + 0 \bullet F08/v \quad (88)$$

$$C04 = 1 \bullet F01/v + 1 \bullet F02/v + 1 \bullet F03/v + 1 \bullet F04/v + 0 \bullet F05/v + 0 \bullet F06/v + 0 \bullet F07/v + 0 \bullet F08/v \quad (89)$$

$$C05 = 1 \bullet F01/v + 1 \bullet F02/v + 1 \bullet F03/v + 1 \bullet F04/v + 1 \bullet F05/v + 0 \bullet F06/v + 0 \bullet F07/v + 0 \bullet F08/v \quad (90)$$

$$C06 = 0 \bullet F01/v + 1 \bullet F02/v + 1 \bullet F03/v + 1 \bullet F04/v + 1 \bullet F05/v + 1 \bullet F06/v + 0 \bullet F07/v + 0 \bullet F08/v \quad (91)$$

$$C07 = 0 \bullet F01/v + 0 \bullet F02/v + 1 \bullet F03/v + 1 \bullet F04/v + 1 \bullet F05/v + 1 \bullet F06/v + 1 \bullet F07/v + 0 \bullet F08/v \quad (92)$$

$$C08 = 0 \bullet F01/v + 0 \bullet F02/v + 0 \bullet F03/v + 1 \bullet F04/v + 1 \bullet F05/v + 1 \bullet F06/v + 1 \bullet F07/v + 1 \bullet F08/v \quad (93)$$

$$C09 = 0 \bullet F01/v + 0 \bullet F02/v + 0 \bullet F03/v + 0 \bullet F04/v + 1 \bullet F05/v + 1 \bullet F06/v + 1 \bullet F07/v + 1 \bullet F08/v \quad (94)$$

$$C10 = 0 \bullet F01/v + 0 \bullet F02/v + 0 \bullet F03/v + 0 \bullet F04/v + 0 \bullet F05/v + 1 \bullet F06/v + 1 \bullet F07/v + 1 \bullet F08/v \quad (95)$$

$$C11 = 0 \bullet F01/v + 0 \bullet F02/v + 0 \bullet F03/v + 0 \bullet F04/v + 0 \bullet F05/v + 0 \bullet F06/v + 1 \bullet F07/v + 1 \bullet F08/v \quad (96)$$

$$C12 = 0 \bullet F01/v + 0 \bullet F02/v + 0 \bullet F03/v + 0 \bullet F04/v + 0 \bullet F05/v + 0 \bullet F06/v + 0 \bullet F07/v + 1 \bullet F08/v \quad (97)$$

Equations (86) through (97) can be expressed by equation (98).

$$Cj = \sum_{i=01}^{08} aij \cdot Fi / v \qquad (98)$$

In equation (98), j designates the position of the pixel. In this example, j has one of the values from 1 to 12. In equation (98), i designates the position of the foreground value. In this example, i has one of the values from 1 to 8. In equation (98), aij has the value 0 or 1 according to the values of i and j.

Equation (98) can be expressed by equation (99) in consideration of the error.

$$Cj = \sum_{i=01}^{08} aij \cdot Fi / v + ej \qquad (99)$$

In equation (99), ej designates the error contained in the designated pixel Cj.

Equation (99) can be modified into equation (100).

$$ej = Cj - \sum_{i=01}^{08} aij \cdot Fi / v \qquad (100)$$

In order to apply the method of least squares, the square sum E of the error is defined as equation (101).

$$E = \sum_{j=01}^{12} ej^2 \qquad (101)$$

In order to minimize the error, the partial differential value using the variable Fk with respect to the

square sum E of the error should be 0. Fk is determined so that equation (102) is satisfied.

$$\frac{\partial E}{\partial Fk} = 2 \cdot \sum_{j=01}^{12} ej \cdot \frac{\partial ej}{\partial Fk}$$
$$= 2 \cdot \sum_{j=01}^{12} \{ (Cj - \sum_{i=01}^{08} aij \cdot Fi / v) \cdot (-akj / v) = 0 \quad (102)$$

In equation (102), since the amount of movement v is a fixed value, equation (103) can be deduced.

$$\sum_{j=01}^{12} akj \cdot (Cj - \sum_{i=01}^{08} aij \cdot Fi / v) = 0 \quad (103)$$

To expand equation (103) and transpose the terms, equation (104) can be obtained.

$$\sum_{j=01}^{12} (akj \cdot \sum_{i=01}^{08} aij \cdot Fi) = v \sum_{j=01}^{12} akj \cdot Cj \quad (104)$$

Equation (104) is expanded into eight equations by substituting the individual integers from 1 to 8 into k in equation (104). The obtained eight equations can be expressed by one matrix equation. This equation is referred to as a "normal equation".

An example of the normal equation generated by the equation generator 803 based on the method of least squares is indicated by equation (105).

$$\begin{bmatrix} 5 & 4 & 3 & 2 & 1 & 0 & 0 & 0 \\ 4 & 5 & 4 & 3 & 2 & 1 & 0 & 0 \\ 3 & 4 & 5 & 4 & 3 & 2 & 1 & 0 \\ 2 & 3 & 4 & 5 & 4 & 3 & 2 & 1 \\ 1 & 2 & 3 & 4 & 5 & 4 & 3 & 2 \\ 0 & 1 & 2 & 3 & 4 & 5 & 4 & 3 \\ 0 & 0 & 1 & 2 & 3 & 4 & 5 & 4 \\ 0 & 0 & 0 & 1 & 2 & 3 & 4 & 5 \end{bmatrix} \begin{bmatrix} F01 \\ F02 \\ F03 \\ F04 \\ F05 \\ F06 \\ F07 \\ F08 \end{bmatrix} = v \cdot \begin{bmatrix} \sum_{i=08}^{12} Ci \\ \sum_{i=07}^{11} Ci \\ \sum_{i=06}^{10} Ci \\ \sum_{i=05}^{09} Ci \\ \sum_{i=04}^{08} Ci \\ \sum_{i=03}^{07} Ci \\ \sum_{i=02}^{06} Ci \\ \sum_{i=01}^{05} Ci \end{bmatrix} \qquad (105)$$

When equation (105) is expressed by A□F=v□C, C, A, and v are known, and F is unknown. A and v are known when the model is formed, while C becomes known when the pixel value is input in the addition processing.

By calculating the foreground components according to the normal equation based on the method of least squares, the error contained in the pixel C can be distributed.

The equation generator 803 supplies the normal equation generated as discussed above to the adder 804.

The adder 804 sets, based on the unit of processing supplied from the unit-of-processing determining portion 801, the pixel value C contained in the foreground component image in the matrix equation supplied from the equation

generator 803. The adder 804 supplies the matrix in which the pixel value C is set to a calculator 805.

The calculator 805 calculates the foreground component Fi/v from which motion blur is eliminated by the processing based on a solution, such as a sweep-out method (Gauss-Jordan elimination), so as to obtain Fi corresponding to i indicating one of the integers from 1 to 8, which is the pixel value from which motion blur is eliminated. The calculator 805 then outputs the foreground component image consisting of the pixel values Fi without motion blur, such as that in Fig. 58, to a motion-blur adder 806 and a selector 807.

In the foreground component image without motion blur shown in Fig. 58, the reason for setting F01 through F08 in C03 through C10, respectively, is not to change the position of the foreground component image with respect to the screen. However, F01 through F08 may be set in any desired positions.

The motion-blur adder 806 is able to adjust the amount of motion blur by adding the amount v' by which motion blur is adjusted, which is different from the amount of movement v, for example, the amount v' by which motion blur is adjusted, which is one half the value of the amount of movement v, or the amount v' by which motion blur is adjusted, which is irrelevant to the amount of movement v. For example, as shown in Fig. 59, the motion-blur adder 806

divides the foreground pixel value Fi without motion blur by the amount v' by which motion blur is adjusted so as to obtain the foreground component Fi/v'. The motion-blur adder 806 then calculates the sum of the foreground components Fi/v', thereby generating the pixel value in which the amount of motion blur is adjusted. For example, when the amount v' by which motion blur is adjusted is 3, the pixel value C02 is set to (F01)/v', the pixel value C3 is set to (F01+F02)/v', the pixel value C04 is set to (F01+F02+F03)/v', and the pixel value C05 is set to (F02+F03+F04)/v'.

The motion-blur adder 806 supplies the foreground component image in which the amount of motion blur is adjusted to a selector 807.

The selector 807 selects one of the foreground component image without motion blur supplied from the calculator 805 and the foreground component image in which the amount of motion blur is adjusted supplied from the motion-blur adder 806 based on a selection signal reflecting a user's selection, and outputs the selected foreground component image.

As discussed above, the motion-blur adjusting unit 106 is able to adjust the amount of motion blur based on the selection signal and the amount v' by which motion blur is adjusted.

Also, for example, when the number of pixels corresponding to the unit of processing is 8, and the amount of movement v is 4, as shown in Fig. 60, the motion-blur adjusting unit 106 generates a matrix equation expressed by equation (106).

$$\begin{bmatrix} 4 & 3 & 2 & 1 & 0 \\ 3 & 4 & 3 & 2 & 1 \\ 2 & 3 & 4 & 3 & 2 \\ 1 & 2 & 3 & 4 & 3 \\ 0 & 1 & 2 & 3 & 4 \end{bmatrix} \begin{bmatrix} F01 \\ F02 \\ F03 \\ F04 \\ F05 \end{bmatrix} = v \cdot \begin{bmatrix} \sum_{i=05}^{08} Ci \\ \sum_{i=04}^{07} Ci \\ \sum_{i=03}^{06} Ci \\ \sum_{i=02}^{05} Ci \\ \sum_{i=01}^{04} Ci \end{bmatrix} \qquad (106)$$

In this manner, the motion-blur adjusting unit 106 calculates Fi, which is the pixel value in which the amount of motion blur is adjusted, by setting up the equation in accordance with the length of the unit of processing. Similarly, for example, when the number of pixels contained in the unit of processing is 100, the equation corresponding to 100 pixels is generated so as to calculate Fi.

Fig. 61 illustrates an example of another configuration of the motion-blur adjusting unit 106. The same elements as those shown in Fig. 55 are designated with like reference numerals, and an explanation thereof is thus omitted.

Based on a selection signal, a selector 821 directly

supplies an input motion vector and a positional signal thereof to the unit-of-processing determining portion 801 and the model-forming portion 802. Alternatively, the selector 821 may substitute the magnitude of the motion vector by the amount v' by which motion blur is adjusted, and then supplies the motion vector and the positional signal thereof to the unit-of-processing determining portion 801 and the model-forming unit 802.

With this arrangement, the unit-of-processing determining portion 801 through the calculator 805 of the motion-blur adjusting unit 106 shown in Fig. 61 are able to adjust the amount of motion blur in accordance with the amount of movement v and the amount v' by which motion blur is adjusted. For example, when the amount of movement is 5, and the amount v' by which motion blur is adjusted is 3, the unit-of-processing determining portion 801 through the calculator 805 of the motion-blur adjusting unit 106 shown in Fig. 61 execute computation on the foreground component image in which the amount of movement v is 5 shown in Fig. 57 according to the model shown in Fig. 59 in which the amount v' by which motion blur is adjusted is 3. As a result, the image containing motion blur having the amount of movement v of (amount of movement v)/(amount v' by which motion blur is adjusted) = 5/3, i.e., about 1.7 is obtained. In this case, the calculated image does not contain motion

blur corresponding to the amount of movement v of 3. Accordingly, it should be noted that the relationship between the amount of movement v and the amount v' by which motion blur is adjusted is different from the result of the motion-blur adder 806.

As discussed above, the motion-blur adjusting unit 106 generates the equation in accordance with the amount of movement v and the unit of processing, and sets the pixel values of the foreground component image in the generated equation, thereby calculating the foreground component image in which the amount of motion blur is adjusted.

The processing for adjusting the amount of motion blur contained in the foreground component image executed by the motion-blur adjusting unit 106 is described below with reference to the flowchart of Fig. 62.

In step S801, the unit-of-processing determining portion 801 of the motion-blur adjusting unit 106 generates the unit of processing based on the motion vector and the area information, and supplies the generated unit of processing to the model-forming portion 802.

In step S802, the model-forming portion 802 of the motion-blur adjusting unit 106 selects or generates the model in accordance with the amount of movement v and the unit of processing. In step S803, the equation generator 803 generates the normal equation based on the selected

model.

In step S804, the adder 804 sets the pixel values of the foreground component image in the generated normal equation. In step S805, the adder 804 determines whether the pixel values of all the pixels corresponding to the unit of processing are set. If it is determined that the pixel values of all the pixels corresponding to the unit of processing are not yet set, the process returns to step S804, and the processing for setting the pixel values in the normal equation is repeated.

If it is determined in step S805 that the pixel values of all the pixels corresponding to the unit of processing are set, the process proceeds to step S806. In step S806, the calculator 805 calculates the pixel values of the foreground in which the amount of motion blur is adjusted based on the normal equation in which the pixel values are set supplied from the adder 804. The processing is then completed.

As discussed above, the motion-blur adjusting unit 106 is able to adjust the amount of motion blur of the foreground image containing motion blur based on the motion vector and the area information.

That is, it is possible to adjust the amount of motion blur contained in the pixel values, that is, contained in sampled data.

Fig. 63 is a block diagram illustrating another example of the configuration of the motion-blur adjusting unit 106. The motion vector and the positional information thereof supplied from the motion detector 102 are supplied to a unit-of-processing determining portion 901 and an adjusting portion 905. The area information supplied from the area specifying unit 103 is supplied to the unit-of-processing determining portion 901. The foreground component image supplied from the foreground/background separator 105 is supplied to a calculator 904.

The unit-of-processing determining portion 901 generates the unit of processing based on the motion vector and the positional information thereof and the area information, and supplies the generated unit of processing to a model-forming portion 902 together with the motion vector.

The model-forming portion 902 forms a model based on the motion vector and the input unit of processing. More specifically, for example, the model-forming portion 902 prestores a plurality of models corresponding to the number of pixels contained in the unit of processing, the number of virtual divided portions of a pixel value in the time direction, and the number of foreground components of each pixel, and selects a model indicating the relationship between the pixel values and the foreground components, such

as that shown in Fig. 64, based on the unit of processing and the number of virtual divided portions of a pixel value in the time direction.

For example, when the number of pixels corresponding to the unit of processing is 12, and when the amount of movement v is 5, the model-forming portion 902 selects a model having the number of virtual divided portions of 5 and consisting of, on the whole, eight foreground components. In the selected model, the leftmost 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 pixel.

Instead of selecting a model from prestored models, the model-forming portion 902 may generate a model when the

motion vector and the unit of processing are supplied, based on the motion vector and the unit of processing.

An equation generator 903 generates an equation based on the model supplied from the model-forming portion 902.

A description is now given, with reference to the models of foreground component images shown in Figs. 64 through 66, of an example of the equation generated by the equation generator 903 when the number of foreground components is 8, the number of pixels corresponding to the unit of processing is 12, and the amount of movement v is 5.

When the foreground components contained in the foreground component image corresponding to the shutter time/v are F01/v through F08/v, the relationships between F01/v through F08/v and pixel values C01 through C12 can be expressed by equations (74) through (85), as stated above.

By considering the pixel values C12 and C11, the pixel value C12 contains only the foreground component F08/v, as expressed by equation (107), and the pixel value C11 consists of the product sum of the foreground component F08/v and the foreground component F07/v. Accordingly, the foreground component F07/v can be found by equation (108).

$$F08/v = C12 \quad (107)$$

$$F07/v = C11-C12 \quad (108)$$

Similarly, by considering the foreground components contained in the pixel values C10 through C01, the

foreground components F06/v through F01/v can be found by equations (109) through (114), respectively.

$$F06/v = C10-C11 \quad (109)$$

$$F05/v = C09-C10 \quad (110)$$

$$F04/v = C08-C09 \quad (111)$$

$$F03/v = C07-C08+C12 \quad (112)$$

$$F02/v = C06-C07+C11-C12 \quad (113)$$

$$F01/v = C05-C06+C10-C11 \quad (114)$$

The equation generator 903 generates the equations for calculating the foreground components by the difference between the pixel values, as indicated by the examples of equations (107) through (114). The equation generator 903 supplies the generated equations to the calculator 904.

The calculator 904 sets the pixel values of the foreground component image in the equations supplied from the equation generator 903 so as to obtain the foreground components based on the equations in which the pixel values are set. For example, when equations (107) through (114) are supplied from the equation generator 903, the calculator 904 sets the pixel values C05 through C12 in equations (107) through (114).

The calculator 904 calculates the foreground components based on the equations in which the pixel values are set. For example, the calculator 904 calculates the foreground components F01/v through F08/v, as shown in Fig. 65, based

on the calculations of equations (107) through (114) in which the pixel values C05 through C12 are set. The calculator 904 supplies the foreground components F01/v through F08/v to the adjusting portion 905.

The adjusting portion 905 multiplies the foreground components supplied from the calculator 904 by the amount of movement v contained in the motion vector supplied from the unit-of-processing determining portion 901 so as to obtain the foreground pixel values from which motion blur is eliminated. For example, when the foreground components F01/v through F08/v are supplied from the calculator 904, the adjusting portion 905 multiples each of the foreground components F01/v through F08/v by the amount of movement v, i.e., 5, so as to obtain the foreground pixel values F01 through F08 from which motion blur is eliminated, as shown in Fig. 66.

The adjusting portion 905 supplies the foreground component image consisting of the foreground pixel values without motion blur calculated as described above to a motion-blur adder 906 and a selector 907.

The motion-blur adder 906 is able to adjust the amount of motion blur by using the amount v' by which motion blur is adjusted, which is different from the amount of movement v, for example, the amount v' by which motion blur is adjusted, which is one half the value of the amount of

movement v, or the amount v' by which motion blur is adjusted, which is irrelevant to the amount of movement v. For example, as shown in Fig. 59, the motion-blur adder 906 divides the foreground pixel value Fi without motion blur by the amount v' by which motion blur is adjusted so as to obtain the foreground component Fi/v'. The motion-blur adder 906 then calculates the sum of the foreground components Fi/v', thereby generating the pixel value in which the amount of motion blur is adjusted. For example, when the amount v' by which motion blur is adjusted is 3, the pixel value C02 is set to (F01)/v', the pixel value C3 is set to (F01+F02)/v', the pixel value C04 is set to (F01+F02+F03)/v', and the pixel value C05 is set to (F02+F03+F04)/v'.

The motion-blur adder 906 supplies the foreground component image in which the amount of motion blur is adjusted to the selector 907.

The selector 907 selects either the foreground component image without motion blur supplied from the adjusting portion 905 or the foreground component image in which the amount of motion blur is adjusted supplied from the motion-blur adder 906 based on a selection signal reflecting a user's selection, and outputs the selected foreground component image.

As discussed above, the motion-blur adjusting unit 106

is able to adjust the amount of motion blur based on the selection signal and the amount v' by which motion blur is adjusted.

The processing for adjusting the amount of motion blur of the foreground executed by the motion-blur adjusting unit 106 configured as shown in Fig. 63 is described below with reference to the flowchart of Fig. 67.

In step S901, the unit-of-processing determining portion 901 of the motion-blur adjusting unit 106 generates the unit of processing based on the motion vector and the area information, and supplies the generated unit of processing to the model-forming portion 902 and the adjusting portion 905.

In step S902, the model-forming portion 902 of the motion-blur adjusting unit 106 selects or generates the model according to the amount of movement v and the unit of processing. In step S903, the equation generator 903 generates, based on the selected or generated model, the equations for calculating the foreground components by the difference between the pixel values of the foreground component image.

In step S904, the calculator 904 sets the pixel values of the foreground component image in the generated equations, and extracts the foreground components by using the difference between the pixel values based on the equations

in which the pixel values are set. In step S905, the calculator 904 determines whether all the foreground components corresponding to the unit of processing have been extracted. If it is determined that all the foreground components corresponding to the unit of processing have not been extracted, the process returns to step S904, and the processing for extracting the foreground components is repeated.

If it is determined in step S905 that all the foreground components corresponding to the unit of processing have been extracted, the process proceeds to step S906. In step S906, the adjusting portion 905 adjusts each of the foreground components F01/v through F08/v supplied from the calculator 904 based on the amount of movement v so as to obtain the foreground pixel values F01/v through F08/v from which motion blur is eliminated.

In step S907, the motion-blur adder 906 calculates the foreground pixel values in which the amount of motion blur is adjusted, and the selector 907 selects the image without motion blur or the image in which the amount of motion blur is adjusted, and outputs the selected image. The processing is then completed.

As described above, the motion-blur adjusting unit 106 configured as shown in Fig. 63 is able to more speedily adjust motion blur of the foreground image containing motion

blur according to simpler computations.

A known technique for partially eliminating motion blur, such as a Wiener filter, is effective when being used in the ideal state, but is not sufficient for an actual image quantized and containing noise. In contrast, it is proved that the motion-blur adjusting unit 106 configured as shown in Fig. 63 is sufficiently effective for an actual image quantized and containing noise. It is thus possible to eliminate motion blur with high precision.

As discussed above, the image processing apparatus configured as shown in Fig. 2 is able to adjust the amount of motion blur contained in the input image.

Fig. 68 is a block diagram illustrating another configuration of the function of the image processing apparatus.

The elements similar to those shown in Fig. 2 are designated with like reference numerals, and an explanation thereof is thus omitted.

The area specifying unit 103 supplies area information to the mixture-ratio calculator 104 and a synthesizer 1001.

The mixture-ratio calculator 104 supplies the mixture ratio α to the foreground/background separator 105 and the synthesizer 1001.

The foreground/background separator 105 supplies the foreground component image to the synthesizer 1001.

The synthesizer 1001 combines a certain background image with the foreground component image supplied from the foreground/background separator 105 based on the mixture ratio α supplied from the mixture-ratio calculator 104 and the area information supplied from the area specifying unit 103, and outputs the synthesized image in which the certain background image and the foreground component image are combined.

Fig. 69 illustrates the configuration of the synthesizer 1001. A background component generator 1021 generates a background component image based on the mixture ratio α and a certain background image, and supplies the background component image to a mixed-area-image synthesizing portion 1022.

The mixed-area-image synthesizing portion 1022 combines the background component image supplied from the background component generator 1021 with the foreground component image so as to generate a mixed-area synthesized image, and supplies the generated mixture-area synthesized image to an image synthesizing portion 1023.

The image synthesizer 1023 combines the foreground component image, the mixed-area synthesized image supplied from the mixed-area-image synthesizing portion 1022, and the certain background image based on the area information so as to generate a synthesized image, and outputs it.

As discussed above, the synthesizer 1001 is able to combine the foreground component image with a certain background image.

The image obtained by combining a foreground component image with a certain background image based on the mixture ratio α, which is the feature quantity, appears more natural compared to an image obtained by simply combining pixels.

Fig. 70 is a block diagram illustrating still another configuration of the function of the image processing apparatus for adjusting the amount of motion blur. The image processing apparatus shown in Fig. 2 sequentially performs the area-specifying operation and the calculation for the mixture ratio α. In contrast, the image processing apparatus shown in Fig. 70 simultaneously performs the area-specifying operation and the calculation for the mixture ratio α.

The functional elements similar to those in the block diagram of Fig. 2 are designated with like reference numerals, and an explanation thereof is thus omitted.

An input image is supplied to a mixture-ratio calculator 1101, a foreground/background separator 1102, the area specifying unit 103, and the object extracting unit 101.

The mixture-ratio calculator 1101 calculates, based on the input image, the estimated mixture ratio when it is assumed that each pixel contained in the input image belongs

to the covered background area, and the estimated mixture ratio when it is assumed that each pixel contained in the input image belongs to the uncovered background area, and supplies the estimated mixture ratios calculated as described above to the foreground/background separator 1102.

Fig. 71 is a block diagram illustrating an example of the configuration of the mixture-ratio calculator 1101.

An estimated-mixture-ratio processor 401 shown in Fig. 71 is the same as the estimated-mixture-ratio processor 401 shown in Fig. 30. An estimated-mixture-ratio processor 402 shown in Fig. 71 is the same as the estimated-mixture-ratio processor 402 shown in Fig. 30.

The estimated-mixture-ratio processor 401 calculates the estimated mixture ratio for each pixel by the computation corresponding to a model of the covered background area based on the input image, and outputs the calculated estimated mixture ratio.

The estimated-mixture-ratio processor 402 calculates the estimated mixture ratio for each pixel by the computation corresponding to a model of the uncovered background area based on the input image, and outputs the calculated estimated mixture ratio.

The foreground/background separator 1102 generates the foreground component image from the input image based on the estimated mixture ratio calculated when it is assumed that

the pixel belongs to the covered background area supplied from the mixture-ratio calculator 1101, the estimated mixture ratio calculated when it is assumed that the pixel belongs to the uncovered background area supplied from the mixture-ratio calculator 1101, and the area information supplied from the area specifying unit 103, and supplies the generated foreground component image to the motion-blur adjusting unit 106 and the selector 107.

Fig. 72 is a block diagram illustrating an example of the configuration of the foreground/background separator 1102.

The elements similar to those of the foreground/background separator 105 shown in Fig. 47 are indicated by like reference numerals, and an explanation thereof is thus omitted.

A selector 1121 selects, based on the area information supplied from the area specifying unit 103, either the estimated mixture ratio calculated when it is assumed that the pixel belongs to the covered background area supplied from the mixture-ratio calculator 1101 or the estimated mixture ratio calculated when it is assumed that the pixel belongs to the uncovered background area supplied from the mixture-ratio calculator 1101, and supplies the selected estimated mixture ratio to the separating portion 601 as the mixture ratio α.

The separating portion 601 extracts the foreground components and the background components from the pixel values of the pixels belonging to the mixed area based on the mixture ratio α supplied from the selector 1121 and the area information, and supplies the extracted foreground components to the synthesizer 603 and also supplies the foreground components to the synthesizer 605.

The separating portion 601 can be configured similarly to the counterpart shown in Fig. 52.

The synthesizer 603 synthesizes the foreground component image and outputs it. The synthesizer 605 synthesizes the background component image and outputs it.

The motion-blur adjusting unit 106 shown in Fig. 70 can be configured similarly to the counterpart shown in Fig. 2. The motion-blur adjusting unit 106 adjusts the amount of motion blur contained in the foreground component image supplied from the foreground/background separator 1102 based on the area information and the motion vector, and outputs the foreground component image in which the amount of motion blur is adjusted.

The selector 107 shown in Fig. 70 selects the foreground component image supplied from the foreground/background separator 1102 or the foreground component image in which the amount of motion blur is adjusted supplied from the motion-blur adjusting unit 106

based on, for example, a selection signal reflecting a user's selection, and outputs the selected foreground component image.

As discussed above, the image processing apparatus shown in Fig. 70 is able to adjust the amount of motion blur contained in an image corresponding to a foreground object of the input image, and outputs the resulting foreground object image. As in the first embodiment, the image processing apparatus shown in Fig. 70 is able to calculate the mixture ratio α, which is embedded information, and outputs the calculated mixture ratio α.

Fig. 73 is a block diagram illustrating another configuration of the function of the image processing apparatus for combining a foreground component image with a certain background image. The image processing apparatus shown in Fig. 68 serially performs the area-specifying operation and the calculation for the mixture ratio α. In contrast, the image processing apparatus shown in Fig. 73 performs the area-specifying operation and the calculation for the mixture ratio α in a parallel manner.

The functional elements similar to those indicated by the block of Fig. 70 are indicated by like reference numerals, and an explanation thereof is thus omitted.

The mixture-ratio calculator 1101 shown in Fig. 73 calculates, based on the motion vector and the positional

information thereof and the input image, the estimated mixture ratio when it is assumed that each pixel contained in the input image belongs to the covered background area, and the estimated mixture ratio when it is assumed that each pixel contained in the input image belongs to the uncovered background area, and supplies the estimated mixture ratios calculated as described above to the foreground/background separator 1102 and a synthesizer 1201.

The foreground/background separator 1102 shown in Fig. 73 generates the foreground component image from the input image based on the estimated mixture ratio calculated when it is assumed that the pixel belongs to the covered background area supplied from the mixture-ratio calculator 1101, the estimated mixture ratio calculated when it is assumed that the pixel belongs to the uncovered background area supplied from the mixture-ratio calculator 1101, and the area information supplied from the area specifying unit 103, and supplies the generated foreground component image to the synthesizer 1201.

The synthesizer 1201 combines a certain background image with the foreground component image supplied from the foreground/background separator 1102 based on the estimated mixture ratio calculated when it is assumed that the pixel belongs to the covered background area supplied from the mixture-ratio calculator 1101, the estimated mixture ratio

calculated when it is assumed that the pixel belongs to the uncovered background area supplied from the mixture-ratio calculator 1101, and the area information supplied from the area specifying unit 103, and outputs the synthesized image in which the background image and the foreground component image are combined.

Fig. 74 illustrates the configuration of the synthesizer 1201. The functional elements similar to those of the block diagram of Fig. 69 are designated with like reference numerals, and explanation thereof is thus omitted.

A selector 1221 selects, based on the area information supplied from the area specifying unit 103, either the estimated mixture ratio calculated when it is assumed that the pixel belongs to the covered background area supplied from the mixture-ratio calculator 1101 or the estimated mixture ratio calculated when it is assumed that the pixel belongs to the uncovered background area supplied from the mixture-ratio calculator 1101, and supplies the selected estimated mixture ratio to the background component generator 1021 as the mixture ratio α.

The background component generator 1021 shown in Fig. 74 generates a background component image based on the mixture ratio α supplied from the selector 1221 and a certain background image, and supplies the background component image to the mixed-area-image synthesizing portion

1022.

The mixed-area-image synthesizing portion 1022 shown in Fig. 74 combines the background component image supplied from the background component generator 1021 with the foreground component image so as to generate a mixed-area synthesized image, and supplies the generated mixed-area synthesized image to the image synthesizing portion 1023.

The image synthesizing portion 1023 combines the foreground component image, the mixed-area synthesized image supplied from the mixed-area-image synthesizing portion 1022, and the background image based on the area information so as to generate a synthesized image and outputs it.

In this manner, the synthesizer 1201 is able to combine the foreground component image with a certain background image.

The invention has been discussed above by setting the mixture ratio α to the ratio of the background components contained in the pixel values. However, the mixture ratio α may be set to the ratio of the foreground components contained in the pixel values.

The invention has been discussed above by setting the moving direction of the foreground object to the direction from the left to the right. However, the moving direction is not restricted to the above-described direction.

In the above description, a real-space image having a

three-dimensional space and time axis information is projected onto a time space having a two-dimensional space and time axis information by using a video camera. However, the present invention is not restricted to this example, and can be applied to the following case. When a greater amount of first information in one-dimensional space is projected onto a smaller amount of second information in a two-dimensional space, distortion generated by the projection can be corrected, significant information can be extracted, or a more natural image can be synthesized.

The sensor is not restricted to a CCD, and may be another type of sensor, such as a solid-state imaging device, for example, a BBD (Bucket Brigade Device), a CID (Charge Injection Device), a CPD (Charge Priming Device) or a CMOS (Complementary Mental Oxide Semiconductor). Also, the sensor does not have to be a sensor in which detection devices are arranged in a matrix, and may be a sensor in which detection devices are arranged in one line.

A recording medium in which a program for performing the signal processing of the present invention is recorded may be formed of a removable medium in which the program is recorded, which is distributed for providing the program to a user separately from the computer, as shown in Fig. 1, such as the magnetic disk 51 (including a floppy (registered trade name) disk), the optical disc 52 (CD-ROM (Compact

Disc-Read Only Memory) and a DVD (Digital Versatile Disc)), the magneto-optical disk (including MD (Mini-Disc) (registered trade name)), or the semiconductor memory 54. The recording medium may also be formed of the ROM 22 or a hard disk contained in the storage unit 28 in which the program is recorded, such recording medium being provided to the user while being prestored in the computer.

The steps forming the program recorded in a recording medium may be executed chronologically according to the orders described in the specification. However, they do not have to be executed in a time-series manner, and they may be executed concurrently or individually.

Industrial Applicability

According to the present invention, it is possible to separate a background image and an object image according to the mixture state.

CLAIMS

1. An image processing apparatus for performing image-processing on image data which is formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function, said image processing apparatus comprising:

area specifying means for specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of the image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, said area specifying means for specifying, in a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and said area specifying means for specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in

a direction in which the foreground object is moving;

mixture-ratio detection means for detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and

foreground/background separation means for separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components based on the mixture ratio, and for generating a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

2. An image processing apparatus according to claim 1, wherein said area specifying means temporarily stores three frames, which are consecutively input, and said area specifying means specifies, in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, as the uncovered background area corresponding to the designated frame, and said area specifying means

specifies, in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame, is moving, as the foreground area corresponding to the designated frame, and specifies, in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, as the background area corresponding to the designated frame, and said area specifying means specifies, in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, as the covered background area corresponding to the designated frame.

3. An image processing method for performing image-processing on image data which is formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time

integrating function, said image processing method comprising:

an area specifying step of specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of the image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, said area specifying step of specifying, in a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and said area specifying step of specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving;

a mixture-ratio detection step of detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered

background area and in the covered background area; and

a foreground/background separation step of separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components based on the mixture ratio so as to generate a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

4. An image processing method according to claim 3, wherein in said area specifying step, three frames, which are consecutively input, are temporarily stored, and in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, is specified as the uncovered background area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame,

is moving, is specified as the foreground area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, is specified as the background area corresponding to the designated frame, and in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, is specified as the covered background area corresponding to the designated frame.

5. A recording medium in which a computer-readable program is recorded, said program being used for performing image-processing on image data which is formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function, said program comprising:

an area specifying step of specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components

forming a foreground object of a designated frame of the image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, said area specifying step of specifying, in a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and said area specifying step of specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving;

a mixture-ratio detection step of detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and

a foreground/background separation step of separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object

components based on the mixture ratio so as to generate a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

6. A recording medium according to claim 5, wherein in said area specifying step, three frames, which are consecutively input, are temporarily stored, and in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, is specified as the uncovered background area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame, is moving, is specified as the foreground area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated

frame and the frame, which is one frame after the designated frame, is stationary, is specified as the background area corresponding to the designated frame, and in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, is specified as the covered background area corresponding to the designated frame.

7. A program for allowing a computer which performs image-processing on image data formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function to execute:

an area specifying step of specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of the image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, said area specifying step of specifying, in a second period of time corresponding to one screen subsequent to the first

period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and said area specifying step of specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving;

a mixture-ratio detection step of detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and

a foreground/background separation step of separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components based on the mixture ratio so as to generate a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

8. A program according to claim 7, wherein in said area specifying step, three frames, which are consecutively input,

are temporarily stored, and in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, is specified as the uncovered background area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame, is moving, is specified as the foreground area corresponding to the designated frame, and in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, is specified as the background area corresponding to the designated frame, and in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame,

and a frame, which is two frames after the designated frame, is stationary, is specified as the covered background area corresponding to the designated frame.

9. An image-capturing apparatus comprising:

image-capturing means for performing image-processing on image data which is formed of a predetermined number of pixel data obtained by an image-capturing device including a predetermined number of pixels and having a time integrating function;

area specifying means for specifying, in a first period of time corresponding to one screen, an uncovered background area in which foreground object components forming a foreground object of a designated frame of the image data and background object components forming a background object of the designated frame are mixed, the uncovered background area being formed at a trailing end in a direction in which the foreground object is moving, said area specifying means for specifying, in a second period of time corresponding to one screen subsequent to the first period of time, a foreground area consisting of only the foreground object components and a background area consisting of only the background object components, and said area specifying means for specifying, in a third period of time corresponding to one screen subsequent to the second period of time, a covered background area in which the foreground object

components and the background object components are mixed, the covered background area being formed at a leading end in a direction in which the foreground object is moving;

mixture-ratio detection means for detecting a mixture ratio indicating a ratio of the foreground object components and the background object components in the uncovered background area and in the covered background area; and

foreground/background separation means for separating the pixel data of the pixels belonging to the uncovered background area and to the covered background area into the foreground object components and the background object components based on the mixture ratio, and for generating a foreground component image consisting of only the foreground object components and a background component image consisting of only the background component image in the designated frame.

10. An image-capturing apparatus according to claim 9, wherein said area specifying means temporarily stores three frames, which are consecutively input, and said area specifying means specifies, in the first period of time, an area in which a determination result for a frame, which is two frames before the designated frame and a frame, which is one frame before the designated frame, is moving, and a determination result for the frame, which is one frame before the designated frame, and the designated frame is

stationary, as the uncovered background area corresponding to the designated frame, and said area specifying means specifies, in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is moving, and a determination result for the designated frame and a frame, which is one frame after the designated frame, is moving, as the foreground area corresponding to the designated frame, and specifies, in the second period of time, an area in which a determination result for the frame, which is one frame before the designated frame, and the designated frame is stationary, and a determination result for the designated frame and the frame, which is one frame after the designated frame, is stationary, as the background area corresponding to the designated frame, and said area specifying means specifies, in the third period of time, an area in which a determination result for the designated pixel and the frame, which is one frame after the designated frame, is moving, and a determination result for the frame, which is one frame after the designated frame, and a frame, which is two frames after the designated frame, is stationary, as the covered background area corresponding to the designated frame.