interpolation in the direction of the detected dominant edge require a plurality of rather complex calculations such as divisions, which increases the complexity and reduces the easiness of implementation of the coding and/or decoding. In a lot of applications, it is necessary that at least the decoder (image decoding apparatus) has as low complexity as possible. In particular, employment in devices with a limited power supply and/or processing methods requires low-complexity implementations of an encoder and/or a decoder.

[0013] Embodiments~~The present invention has been conceived to solve the problems, and the aim~~ of the present invention~~ is to~~ provide a spatial prediction method that can reduce complexity of the spatial prediction.

[Solution to Problem]

[0013a] According to a first aspect, there is provided a spatial prediction method for spatially predicting a pixel value at each pixel position within a current block included in an image, the method comprising: deriving, using a processor, an integer slope indicating an integer value of a slope; determining a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and predicting, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

[0013b] According to a second aspect, there is provided a method for decoding an image coded per block, the method comprising: predicting a pixel value at each pixel position within a current block to be decoded, using the above spatial prediction method to generate a predicted block; obtaining a prediction error block; and adding the predicted block to the prediction error block.

[0013c] According to a third aspect, there is provided a method for coding an image per block, the method comprising: predicting a pixel value at each pixel position within a current block to be coded, using the above spatial prediction method to generate a predicted block; and subtracting the predicted block from the current block.

[0013d] According to a fourth aspect, there is provided a spatial prediction device that spatially predicts a pixel value at each pixel position within a current block included in an image, the device comprising: a deriving unit configured to derive an integer slope indicating an integer value of a slope; a determining unit configured to determine a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and a prediction unit configured to predict, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

[0013e] According to a fifth aspect, there is provided an image decoding apparatus that decodes an image coded per block, the apparatus comprising: the above spatial prediction device that predicts a pixel value at each pixel position within a current block to be decoded, to generate a predicted block; and an adding unit configured to obtain a prediction error block and add the predicted block to the prediction error block.

[0013f] According to a sixth aspect, there is provided an image coding apparatus that codes an image per block, the apparatus comprising: the above spatial prediction device that predicts a pixel value at each pixel position within a current block to be coded, to generate a predicted block; and a subtracting unit configured to subtract the predicted block from the current block.

[0013g] According to a seventh aspect, there is provided a non-transitory computer-readable recording medium on which a program for spatially predicting a pixel value at each pixel position within a current block included in an image is recorded, the program causing a computer to execute: deriving an integer slope indicating an integer value of a slope; determining a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and predicting, for each of the pixel positions, the pixel value at the pixel position based

on a pixel value interpolated in the sub-pel position determined for the pixel position.

[0013h] According to an eighth aspect, there is provided a non-transitory computer-readable recording medium on which an image decoding program for decoding an image coded per block is recorded, the program causing a computer to execute: predicting a pixel value at each pixel position within a current block to be decoded, using the program recorded on the above recording medium to generate a predicted block; obtaining a prediction error block; and adding the predicted block to the prediction error block.

[0013i] According to a ninth aspect, there is provided a non-transitory computer-readable recording medium on which an image coding program for coding an image per block is recorded, the program causing a computer to execute: predicting a pixel value at each pixel position within a current block to be coded, using the program recorded on the above recording medium to generate a predicted block; and subtracting the predicted block from the current block.

[0013j] According to a tenth aspect, there is provided an integrated circuit that spatially predicts a pixel value at each pixel position within a current block included in an image, the circuit comprising: a deriving unit configured to derive an integer slope indicating an integer value of a slope; a determining unit configured to determine a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and a prediction unit configured to predict, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

[0013k] According to an eleventh aspect, there is provided an image decoding integrated circuit that decodes an image coded per block, the circuit comprising: the above integrated circuit that predicts a pixel value at each pixel position within a current block to be decoded, to generate a predicted block; and an adding unit

configured to obtain a prediction error block and add the predicted block to the prediction error block.

[0013l] According to a twelfth aspect, there is provided an image coding integrated circuit that codes an image per block, the circuit comprising: the above integrated circuit that predicts a pixel value at each pixel position within a current block to be coded, to generate a predicted block; and a subtracting unit configured to subtract the predicted block from the current block.

[0014] Disclosed herein is~~In order to achieve the aim,~~ a spatial prediction method~~according to an aspect of the present invention is a spatial prediction method~~ for spatially predicting a pixel value at each pixel position within a current block included in an image, and the method includes: detecting an edge that overlaps the current block by obtaining a horizontal gradient and a vertical gradient between pixels within a block adjacent to the current block; calculating an integer slope based on at least one of the horizontal gradient and the vertical gradient, the integer slope indicating an integer value of a slope of the detected edge; determining a sub-pel position for each of the pixel positions within the current block, the sub-pel position being an intersection between (i) a line that has the calculated integer slope and passes through the pixel position and (ii) a boundary of the adjacent block; and predicting, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position, wherein the boundary of the adjacent block is a row or a column that is closest to the current block, among a plurality of rows or a plurality of columns of pixels included in the adjacent block.

[0015] Thereby, the integer slope of the edge that overlaps the current block (edge entering the current block) is first calculated, and the sub-pel position corresponding to each of the pixel positions

within the current block is determined according to the integer slope. Here, the sub-pel position for each of the pixel positions within the current block can be determined using the integer slope, without a division. Thus, the division can be prevented for each of the pixel positions within the current block. In other words, it is possible to prevent for each of the pixel positions within the current block (i) multiplication of the coordinate value horizontal or the vertical to the pixel position, by one of the horizontal component and the vertical component of the edge, and (ii) division of the result of the multiplication by the other of the horizontal component and the vertical component. As a result, even when calculation of the integer slope of the edge requires a division only once, the division for each of the pixel positions within the current block can be prevented, and the complexity of the spatial prediction can be reduced. In other words, complex operations can be suppressed.

[0016] In other words, the spatial prediction method according to an embodiment~~aspect~~ of the present invention is characterized by calculating an integer slope of the detected edge solely for the current block based on at least one of a vertical gradient and a horizontal gradient, and determining an intersection of the line of the integer slope and a row or a column of the boundary pixels in the neighboring blocks.

[0017] Furthermore, in the calculating, the one of the horizontal gradient and the vertical gradient may be scaled by a *c*-th power of 2, and the integer slope may be calculated using the scaled one of the horizontal gradient and the vertical gradient, *c* being a positive integer, and in the determining, the sub-pel position for the pixel position may be calculated by multiplying the integer slope generated by the scaling by a coordinate value horizontal or vertical to the pixel position to be predicted within the current block.

[0018] Since the integer slope is calculated by scaling one of the vertical gradient and the horizontal gradient by a *c*-th power of 2, the precision of the integer slope can be increased by the scaling when the integer slope is calculated by a division in which a value indicating a gradient to be scaled is used as the number to be divided (numerator). Furthermore, since scaling by a *c*-th power of 2 is

be appropriately interpolated.

[0028] Furthermore, in the calculating, the integer slope may be calculated solely for the current block, and in the determining, the sub-pel position may be determined for each of the pixel positions within the current block, using the integer slope that is common to the pixel positions.

[0029] Since one integer slope is calculated for the current block, the computation load can be suppressed.

[0030] Embodiments of t~~T~~he present invention can be implemented not only as such a spatial prediction method but also as an apparatus and an integrated circuit each of which predicts a space by the spatial prediction method, as a program causing a computer to predict a space according to the spatial prediction method, and as a recording medium that stores the program. Furthermore, embodiments of the present invention can be also implemented as an image coding apparatus and an integrated circuit each of which codes an image using the space predicted by the spatial prediction method, an image coding method for coding the image as such, a program causing a computer to code the image according to the image coding method, and a recording medium that stores the program. Furthermore, embodiments of the present invention can be also implemented as an image decoding apparatus and an integrated circuit each of which decodes an image using the space predicted by the spatial prediction method, an image decoding method for decoding the image as such, a program causing a computer to decode the image according to the image decoding method, and a recording medium that stores the program.

[0031] Disclosed herein~~A spatial prediction device according to an aspect of the present invention~~ is a spatial prediction device that spatially predicts a pixel value at each pixel position within a current block included in an image, and the device includes: a detection unit configured to detect an edge that overlaps the current block by obtaining a horizontal gradient and a vertical gradient between pixels within a block adjacent to the current block; a calculation unit configured to calculate an integer slope based on at least one of the horizontal gradient and the vertical gradient, the integer slope indicating an

gradient (Gy) and the vertical gradient (Gx) used as the divisor exceeds the *b*-th power of 2, the calculation unit may be configured to scale the one of the horizontal gradient and the vertical gradient by shifting bits of the value to the right to obtain the result of the division using, as a divisor, a value indicating the scaled one of the horizontal gradient and the vertical gradient.

[0036] Furthermore, the calculation unit may be configured to calculate the integer slope by dividing a value indicating one of the horizontal gradient (Gy) and the vertical gradient (Gx) by a value indicating the other of the horizontal gradient and the vertical gradient, and the prediction unit may be configured to set weights according to a distance, in the boundary, between the sub-pel position determined for the pixel position and each of full-pel positions adjacent to the sub-pel position, and interpolate the pixel value at the sub-pel position by setting a corresponding one of the weights to each pixel value of the full-pel positions and calculating a weighted average of the pixel values.

[0037] Furthermore, the calculation unit may be configured to calculate the integer slope solely for the current block, and the determining unit may be configured to determine the sub-pel position for each of the pixel positions within the current block, using the integer slope that is common to the pixel positions.

[Advantageous Effects of Invention]

[0038] The spatial prediction method according to embodiments of the present invention can reduce the complexity of spatial prediction.

[Brief Description of Drawings]

[0039]

[FIG. 1] FIG. 1 schematically illustrates eight directional prediction modes used for the subblocks of 4 x 4 pixels.

[FIG. 2] FIG. 2 is a block diagram of an image coding apparatus according to Embodiment 1 of the present invention.

[FIG. 3] FIG. 3 is a block diagram of an image decoding apparatus according to Embodiment 1.

[FIG. 4A] FIG. 4A illustrates an edge vector and its projections into the orthogonal axes X and Y according to Embodiment 1.

[CLAIMS]

[Claim 1] A spatial prediction method for spatially predicting a pixel value at each pixel position within a current block included in an image, the method comprising:

calculating an integer slope based on at least one of a horizontal gradient and a vertical gradient each of which is indicated by a mode number, the integer slope indicating an integer value of a slope;

determining a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and

predicting, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

[Claim 2] The spatial prediction method according to Claim 1,

wherein in the calculating, the one of the horizontal gradient and the vertical gradient is scaled by a c-th power of 2, and the integer slope is calculated using the scaled one of the horizontal gradient and the vertical gradient, c being a positive integer, and

in the determining, the sub-pel position for the pixel position is calculated by multiplying the integer slope generated by the scaling by a coordinate value horizontal or vertical to the pixel position to be predicted within the current block.

[Claim 3] The spatial prediction method according to Claim 2, further comprising

calculating the value of c using a function of the one of the

horizontal gradient and the vertical gradient.

[Claim 4] The spatial prediction method according to one of Claims 1 to 3,

wherein in the calculating, a result of a division is obtained with reference to a division table stored in a memory, and the integer slope is calculated using the obtained result of the division, the division using, as a divisor, a value indicating the one of the horizontal gradient and the vertical gradient, and the division table indicating, for each predetermined value, the predetermined value and a result of a division using the predetermined value as a divisor.

[Claim 5] The spatial prediction method according to Claim 4,

wherein a maximum value of the predetermined value indicated in the division table is a *b*-th power of 2, *b* being an integer, and

in the calculating, when the value indicating the one of the horizontal gradient and the vertical gradient used as the divisor exceeds the *b*-th power of 2, the one of the horizontal gradient and the vertical gradient is scaled by shifting bits of the value to the right to obtain the result of the division using, as a divisor, a value indicating the scaled one of the horizontal gradient and the vertical gradient.

[Claim 6] The spatial prediction method according to one of Claims 1 to 5,

wherein in the calculating, the integer slope is calculated by dividing a value indicating one of the horizontal gradient and the vertical gradient by a value indicating the other of the horizontal gradient and the vertical gradient,

when the pixel value at each of the pixel positions within the current block is predicted, weights are set according to a distance, in the boundary, between the sub-pel position determined for the pixel position and each of full-pel positions adjacent to the sub-pel position, and

the pixel value at the sub-pel position is interpolated by setting a corresponding one of the weights to each pixel value of the full-pel positions and calculating a weighted average of the pixel values.

[Claim 7] The spatial prediction method according to one of Claims 1 to 6,

wherein in the calculating, the integer slope is calculated solely for the current block, and

in the determining, the sub-pel position is determined for each of the pixel positions within the current block, using the integer slope that is common to the pixel positions.

[Claim 8] A method for decoding an image coded per block, the method comprising:

predicting a pixel value at each pixel position within a current block to be decoded, using the spatial prediction method according to one of Claims 1 to 7 to generate a predicted block;

obtaining a prediction error block; and

adding the predicted block to the prediction error block.

[Claim 9] A method for coding an image per block, the method comprising:

predicting a pixel value at each pixel position within a current block to be coded, using the spatial prediction method according to one of Claims 1 to 7 to generate a predicted block; and

subtracting the predicted block from the current block.

[Claim 10] A spatial prediction device that spatially predicts a pixel value at each pixel position within a current block included in an image, the device comprising:

a calculation unit configured to calculate an integer slope

based on at least one of a horizontal gradient and a vertical gradient each of which is indicated by a mode number, the integer slope indicating an integer value of a slope;

a determining unit configured to determine a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and

a prediction unit configured to predict, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

[Claim 11] An image decoding apparatus that decodes an image coded per block, the apparatus comprising:

the spatial prediction device according to Claim 10 that predicts a pixel value at each pixel position within a current block to be decoded, to generate a predicted block; and

an adding unit configured to obtain a prediction error block and add the predicted block to the prediction error block.

[Claim 12] An image coding apparatus that codes an image per block, the apparatus comprising:

the spatial prediction device according to Claim 10 that predicts a pixel value at each pixel position within a current block to be coded, to generate a predicted block; and

a subtracting unit configured to subtract the predicted block from the current block.

[Claim 13] A program for spatially predicting a pixel value at each pixel position within a current block included in an image, the program causing a computer to execute:

calculating an integer slope based on at least one of a horizontal gradient and a vertical gradient each of which is indicated by a mode number, the integer slope indicating an integer value of a slope;

determining a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and

predicting, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

[Claim 14] An image decoding program for decoding an image coded per block, the program causing a computer to execute:

predicting a pixel value at each pixel position within a current block to be decoded, using the program according to Claim 13 to generate a predicted block;

obtaining a prediction error block; and

adding the predicted block to the prediction error block.

[Claim 15] An image coding program for coding an image per block, the program causing a computer to execute:

predicting a pixel value at each pixel position within a current block to be coded, using the program according to Claim 13 to generate a predicted block; and

subtracting the predicted block from the current block.

[Claim 16] An integrated circuit that spatially predicts a pixel value at each pixel position within a current block included in an image, the circuit comprising:

a calculation unit configured to calculate an integer slope based on at least one of a horizontal gradient and a vertical gradient each of which is indicated by a mode number, the integer slope indicating an integer value of a slope;

a determining unit configured to determine a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and

a prediction unit configured to predict, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

[Claim 17] An image decoding integrated circuit that decodes an image coded per block, the circuit comprising:

the integrated circuit according to Claim 16 that predicts a pixel value at each pixel position within a current block to be decoded, to generate a predicted block; and

an adding unit configured to obtain a prediction error block and add the predicted block to the prediction error block.

[Claim 18] An image coding integrated circuit that codes an image per block, the circuit comprising:

the integrated circuit according to Claim 16 that predicts a pixel value at each pixel position within a current block to be coded, to generate a predicted block; and

a subtracting unit configured to subtract the predicted block from the current block.

Claims:

1. A spatial prediction method for spatially predicting a pixel value at each pixel position within a current block included in an image, the method comprising:

deriving, using a processor, an integer slope indicating an integer value of a slope;

determining a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and

predicting, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

2. The spatial prediction method according to claim 1,

wherein in the deriving, one of a horizontal gradient and a vertical gradient is scaled by a c-th power of 2, and the integer slope is derived using the scaled one of the horizontal gradient and the vertical gradient, c being a positive integer, and

in the determining, the sub-pel position for the pixel position is derive by multiplying the integer slope generated by the scaling by a coordinate value horizontal or vertical to the pixel position to be predicted within the current block.

3. The spatial prediction method according to claim 2, further comprising

deriving the value of c using a function of the one of the horizontal gradient and the vertical gradient.

4. The spatial prediction method according to claim 1,

wherein in the deriving, a result of a division is obtained with reference to a division table stored in a memory, and the integer slope is derived using

the obtained result of the division, the division using, as a divisor, a value indicating one of a horizontal gradient and a vertical gradient, and the division table indicating, for each predetermined value, the predetermined value and a result of a division using the predetermined value as a divisor.

5. The spatial prediction method according to claim 4,

wherein a maximum value of the predetermined value indicated in the division table is a b-th power of 2, b being an integer, and

in the deriving, when the value indicating the one of the horizontal gradient and the vertical gradient used as the divisor exceeds the b-th power of 2, the one of the horizontal gradient and the vertical gradient is scaled by shifting bits of the value to the right to obtain the result of the division using, as a divisor, a value indicating the scaled one of the horizontal gradient and the vertical gradient.

6. The spatial prediction method according to claim 1,

wherein in the deriving, the integer slope is derived by dividing a value indicating one of a horizontal gradient and a vertical gradient by a value indicating the other of the horizontal gradient and the vertical gradient,

when the pixel value at each of the pixel positions within the current block is predicted, weights are set according to a distance, in the boundary, between the sub-pel position determined for the pixel position and each of full-pel positions adjacent to the sub-pel position, and

the pixel value at the sub-pel position is interpolated by setting a corresponding one of the weights to each pixel value of the full-pel positions and deriving a weighted average of the pixel values.

7. The spatial prediction method according to claim 1,

wherein in the deriving, the integer slope is derived solely for the current block, and

in the determining, the sub-pel position is determined for each of the pixel positions within the current block, using the integer slope that is common to the pixel positions.

8. A method for decoding an image coded per block, the method comprising:

predicting a pixel value at each pixel position within a current block to be decoded, using the spatial prediction method according to claim 1 to generate a predicted block;

obtaining a prediction error block; and

adding the predicted block to the prediction error block.

9. A method for coding an image per block, the method comprising:

predicting a pixel value at each pixel position within a current block to be coded, using the spatial prediction method according to claim 1 to generate a predicted block; and

subtracting the predicted block from the current block.

10. The spatial prediction method according to claim 1,

wherein the sub-pel position is determined for each column or each row of the current block.

11. A spatial prediction device that spatially predicts a pixel value at each pixel position within a current block included in an image, the device comprising:

a deriving unit configured to derive an integer slope indicating an integer value of a slope;

a determining unit configured to determine a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and

a prediction unit configured to predict, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

12. An image decoding apparatus that decodes an image coded per block, the apparatus comprising:

the spatial prediction device according to claim 11 that predicts a pixel value at each pixel position within a current block to be decoded, to generate a predicted block; and

an adding unit configured to obtain a prediction error block and add the predicted block to the prediction error block.

13. An image coding apparatus that codes an image per block, the apparatus comprising:

the spatial prediction device according to claim 11 that predicts a pixel value at each pixel position within a current block to be coded, to generate a predicted block; and

a subtracting unit configured to subtract the predicted block from the current block.

14. A non-transitory computer-readable recording medium on which a program for spatially predicting a pixel value at each pixel position within a current block included in an image is recorded, the program causing a computer to execute:

deriving an integer slope indicating an integer value of a slope;

determining a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and

predicting, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

15. A non-transitory computer-readable recording medium on which an image decoding program for decoding an image coded per block is recorded, the program causing a computer to execute:

predicting a pixel value at each pixel position within a current block to be decoded, using the program recorded on the recording medium according to claim 14 to generate a predicted block;

obtaining a prediction error block; and

adding the predicted block to the prediction error block.

16. A non-transitory computer-readable recording medium on which an image coding program for coding an image per block is recorded, the program causing a computer to execute:

predicting a pixel value at each pixel position within a current block to be coded, using the program recorded on the recording medium according to claim 14 to generate a predicted block; and

subtracting the predicted block from the current block.

17. An integrated circuit that spatially predicts a pixel value at each pixel position within a current block included in an image, the circuit comprising:

a deriving unit configured to derive an integer slope indicating an integer value of a slope;

a determining unit configured to determine a sub-pel position that is an intersection between (i) a line of the integer slope that passes through the pixel position within the current block and (ii) a boundary of a block adjacent to the current block; and

a prediction unit configured to predict, for each of the pixel positions, the pixel value at the pixel position based on a pixel value interpolated in the sub-pel position determined for the pixel position.

18. An image decoding integrated circuit that decodes an image coded per block, the circuit comprising:

the integrated circuit according to claim 17 that predicts a pixel value at each pixel position within a current block to be decoded, to generate a predicted block; and

an adding unit configured to obtain a prediction error block and add the predicted block to the prediction error block.

19. An image coding integrated circuit that codes an image per block, the circuit comprising:

the integrated circuit according to claim 17 that predicts a pixel value at each pixel position within a current block to be coded, to generate a predicted block; and

a subtracting unit configured to subtract the predicted block from the current block.