Description

A requirement has arisen in recent years for high-quality reproduction of both printed images and step gradation images (for example an image representing a continuous-tone image as a plurality of step gradation density values) by utilizing a bi-level type of display device such as a gas plasma dot-matrix display which is inherently capable of generating only two levels of display density. This is achieved by generating a spatial gray scale display image. However problems are presented by the prior art methods proposed for implementing such reproduction.

With such a bi-level display device, each picture element generated by the display can be set (e.g. as an element of a dot matrix) in either a light or a dark state. There have been various proposals for implementing pseudo-continuous tone reproduction by such display devices by employing a spatial gray scale, which are based on setting a relatively high proportion of picture elements of the display in the light state within a display region which is to represent a light (i.e. low-density) region of the original image, and a high proportion in the dark state in the case of a dark (i.e. high-density) region of the original image.

The most well-known method of providing such pseudo-continuous tone reproduction is the dither technique, whereby a step gradation representation of a continuous tone image is reproduced on the basis of numbers of dots within each of predetermined areas of the continuous tone image, by utilizing a dither matrix. Threshold values of the dither matrix are compared with the level of an input signal, one picture element at a time, to thereby execute bi-level image conversion processing. However this method has the disadvantage that the step gradation reproduction characteristic and the resolution of the image that is obtained will both depend directly upon the size of the dither matrix, and have a mutually incompatible relationship. Moreover with the dither technique, it is difficult to avoid the generation of moire patterns, particularly when printed images are reproduced.

A method has been proposed in the prior art which is highly effective in overcoming these problems of the dither method. This is the "error diffusion" method, which has been proposed by R. Floyd and L. Steinberg under the title "An Adaptive Algorithm for Spatial Gray Scale", published in the SID 75 Digest, pp 36-37. The basic principles of the proposed method are as follows. To determine whether a picture element of the input signal is to be displayed at the dark or at the light level in the image generated by the bi-level display device, the corresponding level of the input image signal is compared with a threshold value, and a light/dark decision thereby made. The density value (i.e. completely dark or completely light) which is thereby determined for that picture element will in general be in error with respect to the desired density of that element, i.e. with respect to the density of the corresponding picture element in the original image. This error is referred to in the following as the bi-level conversion error. However with the error diffusion method, the effect of this error are substantially reduced by modifying (in accordance with the value of the error) the respective values of desired density to be subsequently used in processing respective ones of a specific set of picture elements which are positioned peripherally adjacent to the object picture element, and have not yet been processed. This modification is performed by apportioning the value of error obtained for that object picture element among these peripheral picture elements, with the error being apportioned in accordance with predetermined fixed factors. Such factors are referred to in the following as apportionment factors.

The term "object picture element" as used herein has the significance of a picture element which is currently being processed, to determine a corresponding bi-level display image value, with data being utilized in that processing which have been obtained beforehand during processing of preceding picture elements.

The error diffusion method is superior to the dither method with regard to image resolution and the reproduction characteristic for a step gradation source image, and enables the degree of generation of moire patterns to be made very small even when a printed image is being reproduced. However in the case of reproduction of an image which has only small amounts of changes in density, such as a computer-generated image having areas of extremely uniform density, the error diffusion method produces regions of texture in the reproduced image. This texture is inherent to the error diffusion method, and for this reason the error diffusion method has not been widely adopted. The reason for generation of this texture is that a fixed relationship is continuously maintained between an object picture element and the aforementioned set of picture elements which are disposed peripherally adjacent to the object picture element, and fixed values are also maintained for the respective proportions by which the bi-level conversion error of the object picture element is apportioned among these peripheral picture elements.

Furthermore, if it is attempted to produce a practical type of digital computation processing circuit for implementing this prior art error diffusion method, it is found that the sum of the aforementioned error apportionment values which are generated during processing of each picture element is not equal to the

corresponding bi-level error which is computed for that picture element. This is due to inevitable inaccuracies which arise in the process of computing these error apportionment values, due to discarding of low-significance bits of certain computation results. As a result, the entire bi-level error is not correctly apportioned among the picture elements which are peripherally adjacent to the object picture element, so that all of the possible step gradation density levels of the input signal cannot be properly reproduced in the final image. This is especially true when the input signal level represents a high value or a low value of image density, and hence the range of step gradation image density values which can be reproduced by the prior art error diffusion method is made narrow.

It is a further disadvantage of the prior art is that a plurality of respectively different computations must be executed consecutively in order to process each picture element, so that it is difficult to achieve a high speed of image processing.

It is an objective of the present invention to provide an image signal processing apparatus which overcomes the disadvantages of the prior art error diffusion method described above, and which provides a display image having high resolution and an excellent step gradation reproduction characteristic, with only very small amounts of moire pattern being produced even when the source image is a printed image, and with no texture being generated even in image regions which are of highly uniform density.

The present invention relates to an image signal processing apparatus for receiving an input signal comprising successive digital level values each representing a step gradation density level of a corresponding picture element of a source image, to produce a bi-level image signal by sequentially converting these level values to corresponding bi-level values in respective processing steps, with an error between the bi-level value derived for each of the picture elements and a required density level for that picture element being apportioned among a set of peripherally adjacent picture elements which have not yet been processed.

According to the present invention there is provided an image signal processing apparatus for sequentially processing input level values representing respective density levels of picture elements to produce corresponding bi-level values, including

error memory means for holding an accumulated error for an object picture element in one of a set of memory locations respectively corresponding to said object picture element and to a set of picture elements which have not yet been processed and are peripherally adjacent to said object picture element,

input correction means for adding an input level value of said object picture element to said accumulated error for said object picture element to thereby produce a corrected input level value,

bi-level conversion means for comparing said corrected input level value with a predetermined level value to thereby determine a bi-level value for said object picture element, and

difference computation means for obtaining a bi-level error which is a difference between said corrected input level value and said bi-level value determined for said object picture element, characterised in that it further comprises

apportionment factor generating means for generating apportionment factors for apportioning said bi-level error among said set of picture elements which have not yet been processed and are positioned at the periphery of said object picture element;

error apportionment value computing means for computing, based on said bi-level error of said object picture element and on said apportionment factors, a set of error apportionment values respectively corresponding to said set of picture elements which have not yet been processed and are positioned at the periphery of said object picture element;

residual error computing means for deriving a residual error which is equal to a difference between said bi-level error and a sum total of said error apportionment values; and

error updating means for combining said set of apportionment values with said residual error, adding respective ones of a set of results obtained thereby to respective accumulated error values which have been stored previously at respectively corresponding locations in said error memory means, and for storing addition results obtained thereby in said error memory means as updated accumulated error values.

In a preferred embodiment of the invention, reapportionment correction is performed of the error apportionment values which respectively correspond to the set of unprocessed picture elements positioned at the periphery of the object picture element, to compensate for a residual error which is the difference between the bi-level error of the object picture element and the sum total of the error apportionment values respectively corresponding to the set of unprocessed picture elements positioned at the periphery of the object picture element. It is thereby ensured that the sum total of the error apportionment values of these peripheral picture elements is equal to the bi-level error, enabling an improved step density gradation reproduction characteristic to be achieved in image regions of high density or low density, while in addition the generation of moire patterns is suppressed.

In a second preferred embodiment, a residual error which is the difference between a bi-level error and the sum total of the error apportionment values for the set of unprocessed picture elements positioned at the periphery of the object picture element, derived during processing of the object picture element, is utilized for correction during the next picture element processing operation, such that the aforementioned sum total is made equal to the bi-level error. This enables an improved continuous tone reproduction characteristic to be attained in image regions of high density or low density, and also is effective in suppressing the generation of moire pattern.

In a third preferred embodiment, the n least significant bits of the bi-level error E_{xy} are apportioned to one of the set of unprocessed picture elements positioned at the periphery of the object picture element, while the bi-level error E_{xy} with the n least significant bits thereof reset to zero is apportioned, in accordance with respective error apportionment factors, among other ones of these peripheral picture elements. As a result, the sum total of the error apportionment values for these peripheral picture elements can be made identical to the bi-level error for the object picture element, to thereby achieve an improvement in the step gradation reproduction characteristic of the reproduced image when the input signal level to the apparatus represents an image region having a low value of density or a high value of density, while in addition the generation of moire patterns is effectively suppressed.

The present invention will be further described hereinafter with reference to the following description of exemplary embodiments and the accompanying drawings, in which:

Fig. 1 is a conceptual block circuit diagram of a first embodiment of an image signal processing apparatus according to the present invention;

Figs 2(a) and 2(b) are block circuit diagrams to respectively show details of essential blocks in two different implementations of the first embodiment;

Fig. 3 is a conceptual block circuit diagram of a second embodiment of an image signal processing apparatus according to the present invention;

Figs. 4(a) and 4(b) are block circuit diagrams respectively showing details of essential blocks shown in Fig. 3;

Fig. 5 is a conceptual block circuit diagram of a third embodiment of an image signal processing apparatus according to the present invention; and

Fig. 6 is a block circuit diagram showing details of essential blocks shown in Fig. 5.

Fig. 1 is a general block diagram showing the essential components of a first embodiment of an image signal processing apparatus according to the present invention.

Numeral 104 denotes an input terminal to which is applied an input image signal I_{xy} consisting of successive digital values constituting respective level values, each representing a step gradation density level of a corresponding picture element of a source image. The input image signal is derived by successively sampling the source image in units of picture elements, i.e. by successively sampling picture elements along each of a successively selected lines of picture elements, each line being aligned in a direction referred to in the following as the x-direction, the lines being successively arranged along a direction perpendicular thereto (referred to in the following as the y-direction), so that each picture element can be defined by x and y-coordinates. The apparatus functions to produce a bi-level output value P_{xy} in response to each input level value I_{xy}, from an output terminal 106 by sequentially converting the input level values in respective processing steps. The bi-level output values that are thus produced can each represent either of two values, designated as 0 and R in the following, corresponding to a low and a high density (i.e. light and dark state) respectively of a bi-level display image produced on the basis of these bi-level values. An error between the bi-level value derived for a picture element and the density level which is actually appropriate for that picture element (defined as described hereinafter) is apportioned among a set of peripherally adjacent picture elements which have not yet been processed.

In Fig. 1, the display coordinates of an object picture element (i.e. a picture element for which image processing is currently being executed to generate a corresponding bi-level output value) are designated as (x,y). Reference numeral 101 denotes an error memory section, used to store values of accumulated error as described hereinafter. Numeral 103 denotes a location in the error memory section 101 in which is stored the accumulated error value for the object picture element, the object picture element position being indicated by the * symbol, and numeral 102 denotes a storage region of error memory 101 containing a set of memory locations respectively corresponding to positions of a set of picture elements (designated as A, B, C and D) that have not yet been processed and are positioned adjacent to the periphery of the object picture element. Each picture element is processed during an interval of fixed duration, synchronized with a sync signal. The picture element at position A is processed to generate a corresponding bi-level value immediately following processing of the object picture element, i.e. processing of successive picture elements takes place (in the x-direction) from left to right as seen in Fig. 1, and picture element positions D,

C and B will be successively processed during scanning of the next line of picture elements, i.e. after one line shift in the y-direction has occurred.

Numeral 105 denotes an adder which amends the input signal level I_{xy} by adding thereto an accumulated error S_{xy} (whose value is determined by a combination of accumulated error values as described hereinafter) to produce a corrected input level I'_{xy} for the object picture element, i.e. $I'_{xy} = I_{xy} + S_{xy}$. Numeral 107 denotes a terminal to which is applied a threshold level which in this embodiment is equal to R/2, and 108 denotes a device such as a comparator, for executing bi-level conversion of the input level I'_{xy}, by comparing the level I'_{xy} with the fixed threshold value R/2, to produce as output a bi-level value P_{xy} at the R level if $I'_{xy} > R/2$, and otherwise producing P_{xy} at the 0 level. Numeral 109 denotes a subtractor, for computing a difference between the corrected input level I'_{xy} and the output bi-level value P_{xy} to thereby derive a bi-level conversion error E_{xy} (i.e. $E_{xy} = I'_{xy} - P_{xy}$) for the object picture element.

The components described above, and their functions, might be envisaged on the basis of the published matter concerning the error diffusion method described hereinabove. The novel features of this embodiment of the present invention reside in an error apportionment value computation section 110, an apportionment factor generating section 111, an error updating section 112, a residual error computation section 113 and an apportionment value computation section 114, which are described in detail in the following.

The apportionment factor generating section 111 has stored therein beforehand a set of apportionment factors K_A to K_D, and supplies these apportionment factors to the error apportionment value computation section 110, for apportioning the bi-level error E_{xy} of the object picture element among the picture element positions A to D of the peripheral picture element region 102.

The error apportionment value computation section 110 operates in synchronism with a sync signal which is synchronized with the intervals of processing successive picture elements, and utilizes the bi-level error E_{xy} for the object picture element (produced from the difference computation section 109) and the apportionment factors K_A to K_D to derive a set of error apportionment values G_A to G_D for the picture element positions A, B, C and D within the peripheral picture element region 102, employing equations (1) below.

$$\left.\begin{aligned} G_A &= K_A \times E_{xy} \\ G_B &= K_B \times E_{xy} \\ G_C &= K_C \times E_{xy} \\ G_D &= K_D \times E_{xy} \end{aligned}\right\} \quad \cdots\cdots\cdots (1)$$

The error apportionment value computation section 110 supplies these error apportionment values G_A to G_B to the error updating section 112 and the residual error computation section 113.

The residual error computation section 113 functions to derive, using equation (2) below, a residual error J_B which is the difference between the bi-level error E_{xy} and the sum total of the error apportionment values G_A to G_D.

$$J_B = E_{xy} - \sum_{*=A}^{D} G_* \quad \cdots\cdots\cdots (2)$$

In addition, the residual error J_{xy} is multiplied by each of the factors A_A to A_D, as shown in equations (5) below, to derive respective residual apportionment values RZ_A to RZ_D.

$$\left.\begin{aligned} RZ_A &= A_A \times J_{xy} \\ RZ_B &= A_B \times J_{xy} \\ RZ_C &= A_C \times J_{xy} \\ RZ_D &= A_D \times J_{xy} \end{aligned}\right\} \quad \cdots\cdots(3)$$

The residual apportionment values RZ_A to RZ_D thus obtained are output to the apportionment value computation section 114 (described hereinafter), which functions to add the error apportionment values G_A to G_D from the error apportionment value computation section 110 to the residual apportionment values RZ_A to RZ_D respectively, and to output the results as respective apportionment values H_A to H_D, to the error updating section 112. The error updating section 112 operates in synchronism with the aforementioned sync signal, and receives the apportionment values H_A to H_D from the apportionment value computation section 114, reads out a set of accumulated errors S_A', S_B', S_C',S_D' which had been derived and stored in the memory device 101 during previously executed picture element processing operations at locations respectively corresponding to the picture elements of positions A, B, C and D in the peripheral picture element region 102 of error memory section 101, and derives new values of accumulated error S_A to S_D by utilizing equations (4) below.

$$\left.\begin{aligned} S_A &= S_A' + H_A \\ S_B &= H_B \\ S_C &= S_C' + H_C \\ S_D &= S_D' + H_D \end{aligned}\right\} \quad \cdots\cdots(4)$$

In addition, the error updating section 112 performs updating processing by writing into the error memory section 101 the new values of accumulated error S_A to S_D, at locations respectively corresponding to the picture element positions A to D.

Fig. 2(a) shows specific configurations for the error apportionment value computation section 110, the apportionment factor generating section 111, the error updating section 112, the residual error computation section 113 and the apportionment value computation section 114 respectively shown in Fig. 1.

In Fig. 2(a), the apportionment factor generating section 111 incorporates a memory section 201 having stored therein beforehand (prior to the commencement of image processing) a set of apportionment factors K_A to K_D. The memory section 201 can consist for example of a ROM (read-only memory) into which the apportionment values K_A to K_D have been written beforehand.

The error apportionment value computation section 110 includes a set of multipliers 202a to 202d, for deriving the respective products of the bi-level error E_{xy} and each of the apportionment factors K_A to K_D, as the error apportionment values G_A to G_D. These error apportionment values are supplied to the apportionment value computation section 114 and the residual error computation section 113.

The residual error computation section 113 computes a value of residual error J_{xy}, which is the difference (derived by a subtractor 204) between the bi-level error E_{xy} and the sum total of the error apportionment values G_A to G_D from the error apportionment value computation section 110 (this sum being derived by adders 203a to 203c). The residual error J_{xy} is supplied to a residual apportionment value computation section 205, which includes a memory having a table of values stored therein, which contains the set of residual factors A_A to A_D of equation (3) above, and multipliers for multiplying the residual error J_{xy} by each of these residual factors obtained from the table of values. The residual apportionment value generating section 205 thereby produces a set of residual apportionment values RZ_A to RZ_D in accordance with the residual error J_{xy}, which are used by the apportionment value computation section 114 for apportioning the residual error J_{xy} among the peripheral picture element positions A to D respectively.

The apportionment value computation section 114 adds the error apportionment values G_A to G_D from the error apportionment value computation section 110 to the residual apportionment values RZ_A to RZ_D

respectively, in a set of adders 206a to 206d, and thereby produced respective apportionment values H_A to H_D as outputs, which are applied to the error updating section 112.

The error updating section 112 operates in synchronism with a sync signal 215 which is applied to a sync input terminal 107 and constitutes the sync signal described hereinabove which is synchronized with successive picture element processing intervals. The error updating section 112 functions to add (in an adder 208a) the apportionment value H_A to the accumulated error S'_A corresponding to the picture element position A, which has been derived in a previously executed picture element processing operation and stored in the error memory section 101, and stores the result of the addition temporarily in an internal register 209a (R_A) to be used as the accumulated error S_{xy} in the next picture element processing operation (i.e. the operation in which the picture element of position A in region 102 becomes the object picture element, and is processed). The apportionment value H_B which is produced in the current picture element processing step, during processing of the object picture element, is temporarily stored (i.e. to be read out in the succeeding picture element processing interval) in an internal register 209b (R_B) as the accumulated error S_B for the picture element position B. The apportionment value H_C is added (in an adder 208b) to the data S_B' which had been temporarily stored in the internal register 209b during the preceding picture element processing operation, and the result is stored in an internal register 209c (R_C) as the accumulated error S_C for the picture element position C. The apportionment value H_D is added to data S_C' which had been temporarily stored in an internal register 209c (R_C) during processing of the preceding picture element, and the result is stored in a memory unit of the error memory section 101 at a location corresponding to the picture element position D, as the accumulated error S_D for that picture element position.

It can be seen that with the configuration for the error updating section 112 described above, the only accessing of the memory unit in the memory section 101 consists of read-out access corresponding to the picture element position A and write-in access corresponding to the picture element position D. Each of the internal registers 209a etc. can be configured as simple latch circuits, for example. Thus, the memory section 101 can be easily implemented.

Fig. 2(b) shows another specific configuration for the apportionment factor generating section 111, the error apportionment value computation section 110, residual error computation section 113 and memory section 205, which can be utilized if the following values are adopted for the apportionment factors which apportion the bi-level error E_{xy} among the the set of unprocessed picture elements positioned at the periphery of the object picture element:

$$K_{ij} = \begin{bmatrix} & * & 8/16 \\ 2/16 & 4/16 & 2/16 \end{bmatrix} \quad \cdots\cdots\cdots (5)$$

In the above, i and j denote respective coordinates along the horizontal and vertical directions, considering the set of positions in region 102 and the object picture element position, as a matrix array. In Fig. 2(b), the only blocks which differ from those of Fig. 2(a) are the residual error computation section 113 and error updating section 112 which are described in the following, while the apportionment value computation section 114 of the arrangement shown in Fig. 2(a) is eliminated.

In the embodiment of Fig. 2(b), the bi-level error E_{xy} is a digital value consisting of more than three bits. The residual error computation section 113 contains a line selector 210 which extracts the three least significant bits of the data representing E_{xy}, and reapportions these bits as residual apportionment values RV_A, RV_C and RV_D.

The error updating section 112 is substantially identical to that of Fig. 2(a), however the adders 208a, 208b and 208c which compute the new accumulated errors S_A to S_D, are different in that a "carry" input terminal (designated as C) of each of these adders is utilized. The new accumulated errors S_A to S_D are obtained by adding the error apportionment values G_A to G_D to respective ones of the accumulated errors S_A', S_C' and S_D' which were derived during previous picture element processing operations, and to the residual apportionment values RV_A, RV_C and RV_D respectively from the residual error computation section 113. Each of the residual apportionment values RV_A, RV_C and RV_D consists of a single data bit, these being respectively applied to the "carry" input terminals C of the adders 208a, 208b and 208c. This enables the apportionment value computation section 114 shown in Fig. 2(a) to be eliminated.

In this way, a practical circuit can be implemented, by utilizing the apportionment factor values set out in equation (6) above, whereby the computation operations and circuits can be substantially simplified by comparison with the system of Fig. 2(a).

With the first embodiment of the present invention, as described above, a bi-level error of an object picture element is apportioned as error apportionment values among a set of picture elements which are peripherally adjacent to that object picture element, with a residual error (which is the difference between the bi-level error and the sum total of the error apportionment values) being derived and reapportioned as a set of residual apportionment values. As a result, a problem which arises with a digital computation type of processing circuit for practical implementation of the error diffusion method, i.e. the problem of deterioration of the continuous tone reproduction characteristic when the input signal level represents a low image density or a high image density, is substantially overcome.

Fig. 3 is a general block diagram of a second embodiment of an image signal processing apparatus according to the present invention. The essential feature of this embodiment, as for the first embodiment, is that of elimination of the effects of an error resulting from digital computation of the error apportionment values by which the bi-level error E_{xy} of the object picture element is apportioned among a set of peripherally adjacent picture element positions, i.e. a residual error whereby the sum total of these error apportionment values is not equal to the value of the bi-level error. In Fig. 3, each of blocks 101 to 111 is essentially identical to the correspondingly numbered block in Fig. 1, described hereinabove, so that further description of these will be omitted. The features of the second embodiment which are different from those of the first embodiment reside in an error updating section 112 and a residual error computation section 113, described in the following.

The residual error computation section 113 functions to derive, using equation (6) below, the residual error J_B which is the difference between the sum total of the error apportionment values G_A to G_D and the bi-level error E_{xy}.

$$J_B = E_{xy} - \sum_{*=A}^{D} G_* \quad \cdots\cdots(6)$$

The residual error J_B is supplied to the error updating section 112. The error updating section 112 functions in synchronism with a sync signal (synchronized with successive picture element processing operations, as described for the first embodiment) to receive the error apportionment values G_A to G_D from the error apportionment value computation section 110 and the residual error J_B from the residual error computation section 113 and to read out accumulated errors S_A', S_C', S_D' which were obtained in previously executed picture element processing operations and stored in a memory unit at locations corresponding to the picture element positions A, C, D in the error memory section 101, and derives new values of accumulated errors S_A to S_D by using equations (7) below.

$$\left.\begin{aligned} S_A &= S_A' + G_A \\ S_B &= J_B + G_B \\ S_C &= S_C' + G_C \\ S_D &= S_D' + G_D \end{aligned}\right\} \quad \cdots\cdots(7)$$

In addition, the error updating section 112 performs updating processing by writing into the error memory section 101 the new accumulated errors S_A to S_D, at locations respectively corresponding to the picture element positions A to D.

In the above description the residual error J_B is obtained by using equations (7) on the basis of picture element position B within the peripheral picture element region 102. However it would be equally possible to use any of the other picture element positions A, B, C or D within that region for this purpose. In the following, it will be assumed that the picture element position B is used in equations (7).

It should also be noted that it would be equally possible to temporarily store the residual error J_B within an internal register, and to read out this residual error at the time of processing the next picture element

and add the residual error to the error apportionment value for any one of the picture element positions A', B', C' or D'.

Fig. 4(a) shows a specific configuration for the error apportionment value computation section 110, the apportionment factor generating section 111, the error updating section 112 and the residual error computation section 113. With this configuration, the residual error J_B is temporarily stored in an internal register, to be used in computing a value of accumulated error for the peripheral picture element position B, as described in the following.

The apportionment factor generating section 111 includes a memory section 201 having stored therein beforehand (i.e. prior to the commencement of image processing) a set of apportionment factors K_A to K_D. The memory section 201 can consist for example of a ROM (read-only memory).

The error apportionment value computation section 110 derives the respective products of the bi-level error E_{xy} and each of the apportionment factors K_A to K_D (by a set of multipliers 201a to 201d) as the error apportionment values G_A to G_D, and outputs these error apportionment values to the error updating section 112 and the residual error computation section 113.

The residual error computation section 113 computes the residual error J_B, which is the difference (computed by a subtractor 204) between the bi-level error E_{xy} and the sum total of the error apportionment values G_A to G_D from the error apportionment value computation section 110 (computed by a set of adders 203a to 203c) and temporarily stores the result in an internal register 401 (R_J), until the succeeding picture element processing operation. A residual error J_B' which had been derived and stored in the internal register 401 at the time of processing the preceding picture element is outputted at this time to the error updating section 112.

The error updating section 112 operates in synchronism with a sync signal 214, applied to a sync input terminal 207, which is synchronized with successive picture element processing operations, and adds (by an adder 402a) the error apportionment value G_A to the accumulated error S_A' for the picture element position A, read out from the error memory section 101, and temporarily stores the result in an internal register 403a (R_A) to be used as the accumulated error S_{xy} during processing of the succeeding picture element. In addition, the accumulated error for picture element position B is added (by an adder 402b) to the residual error J_B' which was temporarily stored in the residual error computation section 113 during processing of the preceding picture element, and stores the result as an accumulated error S_B in the internal register 403b (R_B). The error apportionment value G_C is added (by an adder 402c) to the data which had similarly been stored in the internal register 403b (R_B), and the result is temporarily stored in the internal register 403c (R_C) as the accumulated error S_C for the picture element position C. The error apportionment value G_D is added (by an adder 402d) to the data which had been temporarily stored in the internal register 403c (R_C), and the result is stored at a location in a memory unit of the error memory section 101 corresponding to the picture element position D, as the accumulated error S_D for the picture element position D.

Thus, as for the first embodiment, the only accessing of the memory unit of the memory section 101 consists of read-out access corresponding to the picture element position A and write-in access corresponding to the picture element position D, so that a practical apparatus can be readily configured.

Fig. 4(b) shows a specific configuration for the residual error computing section 113, for the case in which the apportionment factors K_{ij} for apportioning the bi-level error E_{xy} among the picture elements which are peripherally adjacent to the object picture element are respectively determined to be as follows:

$$K_{ij} = \begin{bmatrix} & * & 8/16 \\ 2/16 & 4/16 & 2/16 \end{bmatrix} \quad \ldots(8)$$

In Fig. 4(b) a bi-level error E_{xy}' consists of the least significant three bits of the bi-level error E_{xy}, and is inputted to a decoder 411 which thereby produces as output the residual error J_B as a 2-bit data value. The relationships between the values of E_{xy}' and J_B established by this decoder 411 are as shown in the following table.

E_{xy}'	J_B
111	3
110	2
101	2
100	1
011	2
010	1
001	1
000	0

The residual error J_B is temporarily stored in a register 412 and is read out during processing of the next picture element, as the residual error J_B'. In this way, by using a set of apportionment factors as specified in equation (8), a practical circuit configuration can be realized without the need for complex computations.

With the second embodiment of the present invention, as described in the above, a bi-level error of an object picture element is apportioned as error apportionment values among a set of picture elements which are peripherally adjacent to that object picture element, with the difference between the bi-level error and the sum total of the error apportionment values being derived during each picture element processing operation and used for correction to compensate for that error during a succeeding picture element processing operation. As a result, the problem which arises with a processing circuit having a digital computation type of processing circuit for practical implementation of the error diffusion method, i.e. the problem which arises with respect to the continuous tone reproduction characteristic for input signal levels representing low values of image density or high values of density due to the effects of the error, is substantially eliminated.

Fig. 5 is a conceptual block diagram of a third embodiment of an image signal processing apparatus according to the present invention. In Fig. 5, numerals 101 to 109 denote blocks which are similar to the correspondingly numbered blocks in the embodiment shown in Fig. 1, so that further description of these will be omitted. The circuit of Fig. 5 differs from that of Fig. 1 with respect to the respective configurations of the apportionment value computation section 114, apportionment factor generating section 111, error updating section 112 and bi-level error apportioning section, which will be described in detail in the following.

The bi-level error E_{xy} is obtained as a digital value composed of more than n bits, where n is a fixed integer. The bi-level error apportionment section 115 functions to extract the n least significant bits of E_{xy} and output these n bits as a bi-level error E_{xyl} to the error updating section 112, and also sets each of the n least significant bits of the bi-level error E_{xy} to zero and outputs the resultant converted value of E_{xy} as a bi-level error E_{xyu} to the apportionment value computation section 114.

The apportionment factor generating section 111 has stored therein beforehand a set of apportionment factors for a set of unprocessed picture elements positioned at the periphery of the object picture element, and outputs these apportionment factors K_A to K_D to the apportionment value computation section 114, for apportioning the bi-level error E_{xyu} among these picture elements A to D within the peripheral picture element region 102.

The apportionment value computation section 114 operates in synchronism with a sync signal which is synchronized with successive picture element processing intervals, and utilizes the bi-level error E_{xyu} for the object picture element (produced from the bit apportioning section 109) and the apportionment factors K_A to K_D to derive a set of error apportionment values G_A to G_D for the picture element positions A, B, C and D within the peripheral picture element region 102 of the error memory section 101, employing equations (9) given below.

$$\left.\begin{aligned} G_A &= K_A \times E_{xyu} \\ G_B &= K_B \times E_{xyu} \\ G_C &= K_C \times E_{xyu} \\ G_D &= K_D \times E_{xyu} \end{aligned}\right\} \quad \cdots\cdots\cdots(9)$$

The apportionment value computation section 114 thereby produces the error apportionment values G_A to G_D as outputs, and supplies these to the error updating section 112.

The error updating section 112 operates in synchronism with the aforementioned sync signal, and functions to derive new values of accumulated error S_A to S_D respectively corresponding to the picture element positions A, B, C, D within the peripheral picture element region 102 of the error memory section 101, based on the error apportionment values G_A to G_D, accumulated error values S_A', S_C' and S_D' which were derived and stored in previously executed processing operations, and the bi-level error E_{xyl} produced from the bi-level error apportioning section 115, by employing equations (10) below:

$$\left.\begin{aligned} S_A &= S_A' + G_A \\ S_B &= E_{xyl} + G_B \\ S_C &= S_C' + G_C \\ S_D &= S_D' + G_D \end{aligned}\right\} \quad \cdots\cdots\cdots(10)$$

In this embodiment, the bi-level error E_{xyl} is added to the error apportionment value for picture element position B of the peripheral picture element region 102. However it would be equally possible to add E_{xyl} to any one of error apportionment values for the respective picture element positions A, B, C or D. In the following it will be assumed that picture element position B is utilized.

Fig. 6 shows specific configurations for the apportionment value computation section 114, the apportionment factor generating section 111, the error updating section 112 and the bi-level error apportioning section 115. In this embodiment, the bi-level error E_{xyl} is applied to the picture element position B, as described in the following.

The apportionment factor generating section 111 includes a memory section 201 having stored therein beforehand (i.e. prior to the commencement of image processing) a set of apportionment factors K_A to K_D. The memory section 201 can consist for example of a ROM (read-only memory) having the apportionment factors written therein.

The bi-level error apportioning section 115 includes a bit apportioning section 601 which functions to reset the n least significant bits of the bi-level error E_{xy} to logic "0", with the resultant converted value of E_{xy} being outputted as the bi-level error E_{xyu} to the error apportionment value computation section 114, and a bit apportioning section 602 which functions to extract the n least significant bits of the bi-level error E_{xy} and to output these as the bi-level error E_{xyl} to the error updating section 112.

The apportionment value computation section 114 multiplies each of the apportionment factors K_A to K_D by the bi-level error E_{xyu} in a set of multipliers 603a to 603c, to thereby derive the error apportionment values G_A to G_D, and outputs these to the error updating section 112.

The error updating section 112 operates in synchronism with a sync signal 214 applied to a sync input terminal 207 which is synchronized with successive picture element processing intervals, and adds the error apportionment value G_A to the accumulated error S_A' for the picture element position A, read out from the error memory section 101 (this addition being executed by an adder 604a), and temporarily stores the result in an internal register 605a (R_A) to be used as the accumulated error S_{xy} during processing of the succeeding picture element. The accumulated error for picture element position B is obtained by adding the bi-level error E_{xyl} from the bi-level error computation section 115 to the error apportionment value G_B for picture element position B (by an adder 604b), and storing the result as an accumulated error S_B in the internal register 605b (R_B), until the next processing interval. The error apportionment value G_C is added by

an adder 604c to the data which had been temporarily stored in the internal register 605b (R_B) at the time of processing the preceding picture element, and the result is stored in the internal register 605c (R_C) as the accumulated error S_C for the picture element position C, until the next processing interval. The error apportionment value G_D is added by an adder 604d to the data which had similarly been temporarily stored in the internal register 605c (R_C), and the result is stored at a memory location in the error memory section 101 corresponding to the picture element position D, as the accumulated error S_D for that picture element position.

Due to the configuration for the error updating section 112 described above, the only accessing of the memory in the memory section 101 consists of read-out access corresponding to the picture element position A and write-in access corresponding to the picture element position B, so that a practical apparatus can be easily implemented.

With the third embodiment of the present invention, as described in the above, the n least significant bits of the bi-level error E_{xy} are extracted and apportioned to one of the picture element positions which is peripherally adjacent to the object picture element position, while in addition these n least significant bits of the bi-level error E_{xy} are reset to logic "0" and the resultant value is apportioned among each of the remaining peripheral picture element positions in accordance with the respective apportionment factors for these positions. As a result, this embodiment effectively eliminates the effects of an error which arises due to the effects of discarding low-significance bits of the bi-level error E_{xy} during computation of the error apportionment values G_A to G_D. Thus, the effective sum total of the error apportionment values used for apportioning the bi-level error E_{xy} of the object picture element among the picture element positions peripherally adjacent thereto is made identical to that bi-level error. The embodiment thereby enables a practical integer computation type of processing circuit for implementing the error diffusion method to be realized, by considerably improving the step gradation reproduction characteristic for input signal levels which represent image regions of low density or high density.

Claims

1. An image signal processing apparatus for sequentially processing input level values representing respective density levels of picture elements to produce corresponding bi-level values, including

error memory means (101) for holding an accumulated error (S_{XY}) for an object picture element in one of a set of memory locations respectively corresponding to said object picture element and to a set of picture elements which have not yet been processed and are peripherally adjacent to said object picture element,

input correction means (105) for adding an input level value of said object picture element to said accumulated error (S_{XY}) for said object picture element to thereby produce a corrected input level value,

bi-level conversion means (108) for comparing said corrected input level value with a predetermined level value to thereby determine a bi-level value (P_{xy}) for said object picture element, and

difference computation means (109) for obtaining a bi-level error (E_{XY}) which is a difference between said corrected input level value and said bi-level value determined for said object picture element, characterised in that it further comprises

apportionment factor generating means (111) for generating apportionment factors for apportioning said bi-level error among said set of picture elements which have not yet been processed and are positioned at the periphery of said object picture element;

error apportionment value computing means (110) for computing, based on said bi-level error of said object picture element and on said apportionment factors, a set of error apportionment values (G_A,..., G_D) respectively corresponding to said set of picture elements which have not yet been processed and are positioned at the periphery of said object picture element;

residual error computing means (113) for deriving a residual error which is equal to a difference between said bi-level error and a sum total of said error apportionment values; and

error updating means (112) for combining said set of apportionment values with said residual error, adding respective ones of a set of results obtained thereby to respective accumulated error values which have been stored previously at respectively corresponding locations in said error memory means, and for storing addition results obtained thereby in said error memory means as updated accumulated error values.

2. An image signal processing apparatus according to claim 1, wherein said error updating means comprises means (402b) for adding a predetermined one of said error apportionment values to said

an adder 604c to the data which had been temporarily stored in the internal register 605b (R_B) at the time of processing the preceding picture element, and the result is stored in the internal register 605c (R_C) as the accumulated error S_C for the picture element position C, until the next processing interval. The error apportionment value G_D is added by an adder 604d to the data which had similarly been temporarily stored in the internal register 605c (R_C), and the result is stored at a memory location in the error memory section 101 corresponding to the picture element position D, as the accumulated error S_D for that picture element position.

Due to the configuration for the error updating section 112 described above, the only accessing of the memory in the memory section 101 consists of read-out access corresponding to the picture element position A and write-in access corresponding to the picture element position B, so that a practical apparatus can be easily implemented.

With the third embodiment of the present invention, as described in the above, the n least significant bits of the bi-level error E_{xy} are extracted and apportioned to one of the picture element positions which is peripherally adjacent to the object picture element position, while in addition these n least significant bits of the bi-level error E_{xy} are reset to logic "0" and the resultant value is apportioned among each of the remaining peripheral picture element positions in accordance with the respective apportionment factors for these positions. As a result, this embodiment effectively eliminates the effects of an error which arises due to the effects of discarding low-significance bits of the bi-level error E_{xy} during computation of the error apportionment values G_A to G_D. Thus, the effective sum total of the error apportionment values used for apportioning the bi-level error E_{xy} of the object picture element among the picture element positions peripherally adjacent thereto is made identical to that bi-level error. The embodiment thereby enables a practical integer computation type of processing circuit for implementing the error diffusion method to be realized, by considerably improving the step gradation reproduction characteristic for input signal levels which represent image regions of low density or high density.

Claims

1. An image signal processing apparatus for sequentially processing input level values representing respective density levels of picture elements to produce corresponding bi-level values, including

error memory means (101) for holding an accumulated error (S_{XY}) for an object picture element in one of a set of memory locations respectively corresponding to said object picture element and to a set of picture elements which have not yet been processed and are peripherally adjacent to said object picture element,

input correction means (105) for adding an input level value of said object picture element to said accumulated error (S_{XY}) for said object picture element to thereby produce a corrected input level value,

bi-level conversion means (108) for comparing said corrected input level value with a predetermined level value to thereby determine a bi-level value (P_{xy}) for said object picture element, and

difference computation means (109) for obtaining a bi-level error (E_{XY}) which is a difference between said corrected input level value and said bi-level value determined for said object picture element, characterised in that it further comprises

apportionment factor generating means (111) for generating apportionment factors for apportioning said bi-level error among said set of picture elements which have not yet been processed and are positioned at the periphery of said object picture element;

error apportionment value computing means (110) for computing, based on said bi-level error of said object picture element and on said apportionment factors, a set of error apportionment values (G_A,..., G_D) respectively corresponding to said set of picture elements which have not yet been processed and are positioned at the periphery of said object picture element;

residual error computing means (113) for deriving a residual error which is equal to a difference between said bi-level error and a sum total of said error apportionment values; and

error updating means (112) for combining said set of apportionment values with said residual error, adding respective ones of a set of results obtained thereby to respective accumulated error values which have been stored previously at respectively corresponding locations in said error memory means, and for storing addition results obtained thereby in said error memory means as updated accumulated error values.

2. An image signal processing apparatus according to claim 1, wherein said error updating means comprises means (402b) for adding a predetermined one of said error apportionment values to said

residual error and supplying a resultant sum value to said means for deriving the accumulated error.

3. An image signal processing apparatus according to claim 1, wherein said residual error computation means (113) comprises:
means (203a, 203b, 203c) for computing said sum total of said error apportionment values; and
means (204) for subtracting said bi-level value from said sum total to obtain said residual error.

4. An image signal processing apparatus according to claim 1, wherein said residual error computation means (113) comprises decoder means (411) coupled to receive a predetermined set of low-order bits extending from a least significant bit of said bi-level error, for producing a decoded set of bits that is predetermined in accordance with a combination of states of said low-order bits, as said residual error.

5. An image signal processing apparatus according to claim 1, wherein said residual error computation means (113) is constituted by bi-level error apportionment means (115) for extracting a predetermined set of low-order bits (E_{XYL}) extending from a least significant bit of said bi-level error and for supplying said set of low-order bits to said error updating means (112) as said residual error, and wherein said bi-level error apportionment means resets all of said set of low-order bits of said bi-level error to zero and supplies a resultant bi-level error (E_{XYU}) to said error apportionment value computation means (114) for use in deriving said error apportionment values.

6. An image signal processing apparatus according to claim 1, wherein said residual error computation means (113) comprises means (203a, 203b, 203c) for computing a sum total of said error apportionment values, means (204) for subtracting said bi-level value from said sum total to obtain said residual error, and means (205) for apportioning said residual error as a set of residual error apportionment values (RZ_A,...RZ_B) by utilizing respective factors which have been predetermined for respective ones of said set of unprocessed picture elements positioned at the periphery of the object picture element, and further comprising:
apportionment value computing means (114) for computing respective apportionment values (H_A,....H_D) for said set of unprocessed picture elements positioned at the periphery of the object picture element, by adding to each of said error apportionment values (G_A,....G_D) a corresponding one of said residual error apportionment values (RZ_A,....,RZ_D);
wherein said apportionment values (H_A,....H_D) are supplied to said error updating means (112) for use in executing said updating processing.

7. An image signal processing apparatus according to claim 1, wherein said residual error computation means (113) comprises bit selector means (210) for extracting respective ones of a predetermined set of low-order bits of said bi-level error, with said set of low-order bits constituting said bi-level error, and wherein said error updating means (112) includes adder means (208a, 208b, 208c) for separately adding said extracted low-order bits to respective predetermined ones of said error apportionment values (G_A,...G_D) during execution of said updating processing.

Patentansprüche

1. Bildsignal-Verarbeitungseinrichtung zum aufeinanderfolgenden Verarbeiten von jeweilige Dichtewerte von Bildelementen darstellenden Eingangssignal-Pegelwerten zu entsprechenden zweipegeligen Werten, mit
einer Fehlerspeichereinrichtung (101), die einen Summenfehler (S_{XY}) für ein Ziel-Bildelement in einer von einem Satz von Speicherstellen speichert, die jeweils dem Ziel-Bildelement und einem Satz von Bildelementen entsprechen, die noch nicht verarbeitet wurden und die periphär an das Ziel-Bildelement angrenzen,
einer Eingangssignalkorrektureinrichtung (105), die einen Eingangssignal-Pegelwert für das Ziel-Bildelement mit dem Summenfehler (S_{XY}) für das Ziel-Bildelement addiert, um dadurch einen korrigierten Eingangssignal-Pegelwert zu erzeugen,
einer Zweipegel-Umsetzeinrichtung (108), die den korrigierten Eingangssignal-Pegelwert mit einem vorbestimmten Pegelwert vergleicht, um dadurch einen zweipegeligen Wert (P_{XY}) für das Ziel-Bildelement zu bestimmen, und
einer Differenzrecheneinrichtung (109) zum Ermitteln eines zweipegeligen Fehlers (E_{XY}), der eine Differenz zwischen dem korrigierten Eingangssignal-Pegelwert und dem für das Ziel-Bildelement

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bestimmten zweipegeligen Wert ist,
ferner gekennzeichnet durch
eine Verteilungsfaktor-Erzeugungseinrichtung (111), die Verteilungsfaktoren für das Verteilen des zweipegeligen Fehlers auf den Satz von Bildelementen erzeugt, die noch nicht verarbeitet wurden und die an der Peripherie des Ziel-Bildelements liegen,
eine Fehlerverteilungswert-Recheneinrichtung (110), die aufgrund des zweipegeligen Fehlers für das Ziel-Bildelement und der Verteilungsfaktoren einen Satz von Fehlerverteilungswerten (G_A,..., G_D) berechnet, welche jeweils dem Satz von Bildelementen entsprechen, die noch nicht verarbeitet wurden und die an der Peripherie des Ziel-Bildelements liegen,
eine Restfehler-Recheneinrichtung (113) zum Ableiten eines Restfehlers, der gleich einer Differenz zwischen dem zweipegeligen Fehler und einer Gesamtsumme der Fehlerverteilungswerte ist, und
eine Fehlerfortschreibeeinrichtung (112), die den Satz von Verteilungswerten mit dem Restfehler kombiniert, jeweils eines von einem Satz von dadurch enthaltenen Ergebnissen mit jeweiligen Summenfehlerwerten addiert, die zuvor an jeweils entsprechenden Stellen in der Fehlerspeichereinrichtung gespeichert wurden, und die dadurch erhaltenen Additionsergebnisse in der Fehlerspeichereinrichtung als fortgeschriebene Summenfehlerwerte speichert.

2. Bildsignal-Verarbeitungseinrichtung nach Anspruch 1, in der die Fehlerfortschreibeeinrichtung eine Einrichtung (402b) aufweist, die einen vorbestimmten der Fehlerverteilungswerte zu dem Restfehler addiert und den sich ergebenden Summenwert der Einrichtung zum Ableiten des Summenfehlers zuführt.

3. Bildsignal-Verarbeitungseinrichtung nach Anspruch 1, in der die Restfehler-Recheneinrichtung (113) eine Einrichtung (203a, 203b, 203c) zum Berechnen der Gesamtsumme der Fehlerverteilungswerte und eine Einrichtung (204) aufweist, die den zweipegeligen Wert von der Gesamtsumme subtrahiert, um den Restfehler zu erhalten.

4. Bildsignal-Verarbeitungseinrichtung nach Anspruch 1, in der die Restfehler-Recheneinrichtung (113) eine Decodiereinrichtung (411) aufweist, die zur Aufnahme eines vorbestimmten Satzes von wertniedrigen Bits von einem wertniedrigsten Bit des zweipegeligen Fehlers weg geschaltet ist, um als Restfehler einen decodierten Bitsatz zu erzeugen, der entsprechend einer Kombination von Zuständen der wertniedrigen Bits vorbestimmt ist.

5. Bildsignal-Verarbeitungseinrichtung nach Anspruch 1, in der die Restfehler-Recheneinrichtung (113) durch eine Zweipegel-Fehlerverteilungseinrichtung (115) gebildet ist, die einen vorbestimmten Satz wertniedriger Bits (E_{XYL}) von einem wertniedrigsten Bit des zweipegeligen Fehlers weg herausgreift und den Satz wertniedriger Bits der Fehlerfortschreibeeinrichtung (112) als Restfehler zuführt, und in der die Zweipegel-Fehlerverteilungseinrichtung den ganzen Satz wertniedriger Bits des zweipegeligen Fehlers auf null rücksetzt und einen sich ergebenden zweipegeligen Fehler (E_{XYU}) der Fehlerverteilungswert-Recheneinrichtung (114) für das Ableiten der Fehlerverteilungswerte zuführt.

6. Bildsignal-Verarbeitungseinrichtung nach Anspruch 1, in der die Restfehler-Recheneinrichtung (113) eine Einrichtung (203a, 203b, 203c) zum Berechnen einer Gesamtsumme der Fehlerverteilungswerte, eine Einrichtung (204), die den zweipegeligen Wert von der Gesamtsumme subtrahiert, um den Restfehler zu erhalten, und eine Einrichtung (205) aufweist, die den Restfehler als einen Satz von Restfehler-Verteilungswerten (RZ_A,...RZ_B) unter Anwendung jeweiliger Faktoren verteilt, die für jeweilige des Satzes der in der Peripherie des Ziel-Bildelements liegenden unverarbeiteten Bildelemente vorbestimmt wurden,
und die ferner eine Verteilungswert-Recheneinrichtung (114) aufweist, die für den Satz der an der Peripherie des Ziel-Bildelements liegenden unverarbeiteten Bildelemente jeweilige Verteilungswerte (H_A,..., H_D) durch Addieren eines jeden der Fehlerverteilungswerte (G_A,...G_D) zu einem entsprechenden der Restfehler-Verteilungswerte (RZ_A,..., RZ_D) berechnet,
wobei die Verteilungswerte (H_A,..., H_D) der Fehlerfortschreibeeinrichtung (112) zum Ausführen des Fortschreibevorgangs zugeführt werden.

7. Bildsignal-Verarbeitungseinrichtung nach Anspruch 1, in der die Restfehler-Recheneinrichtung (113) eine Bitwähleinrichtung (210) aufweist, die jeweilige Bits aus einem vorbestimmten Satz der wertniedrigen Bits des zweipegeligen Fehlers herausgreift, wobei der Satz wertniedriger Bits den zweipegeligen

Fehler bildet, und in der die Fehlerfortschreibeeinrichtung (112) eine Addiereinrichtung (208a, 208b, 208c) enthält, die während des Ausführens des Fortschreibevorgangs auf gesonderte Weise die herausgegriffenen wertniedrigen Bits mit jeweils vorbestimmten der Fehlerverteilungswerte (G_A,..., G_D) addiert.

Revendications

1. Appareil de traitement de signaux d'image pour traiter de façon séquentielle des valeurs de niveau d'entrée représentant des niveaux de densité respectifs d'éléments d'image pour produire des valeurs bi-niveaux correspondants, comprenant :

un moyen (101) de mémorisation d'erreur destiné à contenir une erreur cumulée (S_{XY}) relative à un élément d'image objet dans un endroit d'un ensemble d'endroits de mémorisation correspondant respectivement audit élément d'image objet et à un ensemble d'éléments d'image qui n'ont pas encore été traités et qui sont périphériquement contigus audit élément d'image objet,

un moyen (105) de correction d'entrée pour ajouter une valeur de niveau d'entrée dudit élément d'image objet à ladite erreur cumulée (S_{XY}) relative audit élément d'image objet de manière à produire ainsi une valeur de niveau d'entrée corrigée,

un moyen (108) de conversion bi-niveau pour comparer la valeur de niveau d'entrée corrigée avec une valeur de niveau prédéterminée de manière à déterminer ainsi une valeur bi-niveau (P_{XY}) relative audit élément d'image objet, et

un moyen 109) de calcul de différence pour obtenir une erreur bi-niveau (E_{XY}) qui représente la différence entre la valeur de niveau d'entrée corrigée et la valeur bi-niveau déterminée pour ledit élément d'image objet, caractérisé en ce qu'il comprend, en outre :

un moyen (111) de génération de facteur de répartition pour engendrer des facteurs de répartition destinés à répartir ladite erreur bi-niveau parmi ledit ensemble d'éléments d'image qui n'ont pas encore été traités et qui se trouvent à la périphérie de l'élément d'image objet;

un moyen (110) de calcul de valeur de répartition d'erreur pour calculer, en se basant sur l'erreur bi-niveau de l'élément d'image objet et sur les facteurs de répartition, un ensemble de valeurs de répartition d'erreur (G_A,..., G_D) correspondant respectivement audit ensemble d'éléments d'image qui n'ont pas encore été traités et qui se trouvent à la périphérie dudit élément d'image considéré;

un moyen (113) de calcul d'erreur résiduelle pour calculer une erreur résiduelle qui est égale à la différence entre l'erreur bi-niveau et la somme totale des valeurs de répartition d'erreur; et

un moyen (112) de remise à jour d'erreur pour combiner ledit ensemble de valeurs de répartition avec ladite erreur résiduelle, ajouter les résultats respectifs d'un ensemble de résultats obtenus de cette manière aux valeurs d'erreur cumulées respectives qui ont été mémorisées antérieurement à des endroits respectivement correspondants dans ledit moyen de mémorisation d'erreur, et stocker les résultats de l'addition obtenus de cette manière dans ledit moyen de mémorisation d'erreur en tant que valeurs d'erreur cumulées remises à jour.

2. Appareil de traitement de signaux d'image selon la revendication 1, dans lequel le moyen de remise à jour d'erreur comprend un moyen (402b) pour ajouter une valeur prédéterminée desdites valeurs de répartition d'erreur à l'erreur résiduelle et fournir une valeur de somme résultante audit moyen servant à calculer l'erreur cumulée.

3. Appareil de traitement de signaux d'image selon la revendication 1, dans lequel le moyen (113) de calcul d'erreur résiduelle comprend :

des moyens (203a, 203b, 203c) destinés à calculer ledit total cumulé des valeurs de répartition d'erreur; et

un moyen (204) pour soustraire ladite valeur bi-niveau de la somme totale pour obtenir l'erreur résiduelle précitée.

4. Appareil de traitement de signaux d'image selon la revendication 1, dans lequel le moyen (113) de calcul d'erreur résiduelle comprend un moyen de décodage (411) couplé de manière à recevoir un ensemble prédéterminé de bits d'ordre inférieur augmentant depuis un bit le moins significatif de l'erreur bi-niveau, pour produire un ensemble décodé de bits qui est prédéterminé en fonction d'une combinaison d'état desdits bits d'ordre inférieur, en tant qu'erreur résiduelle précitée.

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5. Appareil de traitement de signaux d'image selon la revendication 1, dans lequel le moyen (113) de calcul d'erreur résiduelle est constitué par un moyen (115) de répartition d'erreur bi-niveau destiné à extraire l'ensemble prédéterminé de bits d'ordre inférieur (E_{XYL}) augmentant à partir d'un bit le moins significatif de l'erreur bi-niveau pour fournir l'ensemble de bits d'ordre inférieur au moyen (112) de remise à jour d'erreur en tant qu'erreur résiduelle précitée, et dans lequel le moyen de répartition d'erreur bi-niveau remet à zéro tout l'ensemble de bits d'ordre inférieur de l'erreur bi-niveau et fournit une erreur bi-niveau résultante (E_{XYU}) au moyen (114) de calcul de valeur de répartition d'erreur destiné à être utilisé pour calculer les valeurs de répartition d'erreur.

6. Appareil de traitement de signaux d'image selon la revendication 1, dans lequel le moyen (113) de calcul d'erreur résiduelle comprend des moyens (203a, 203b, 203c) destinés à calculer un total cumulé des valeurs de répartition d'erreur, un moyen (204) pour soustraire la valeur bi-niveau précitée du total cumulé pour obtenir l'erreur résiduelle, et un moyen (205) pour répartir ladite erreur résiduelle comme un ensemble de valeur de répartition d'erreur résiduelle (RZ_A,....RZ_B) en utilisant des facteurs respectifs qui ont été prédéterminés pour des éléments respectifs dudit ensemble d'éléments d'image non traités situés à la périphérie de l'élément d'image objet, et comprenant en outre :

un moyen (114) de calcul de valeur de répartition pour calculer des valeurs de répartition respectives (H_A,....H_D) relatives à l'ensemble précité d'éléments d'image non traités situés à la périphérie de l'élément d'image objet, en ajoutant à chaque valeur de répartition d'erreur (G_A,....G_D) une valeur correspondante desdites valeurs de répartition d'erreur résiduelle (RZA,...., RZD);

dans lequel les valeurs de répartition précitées (H_A,....H_D) sont fournies au moyen (112) de remise à jour d'erreur destiné à être utilisé pour exécuter le traitement de remise à jour précitée.

7. Appareil de traitement de signaux d'image selon la revendication 1, dans lequel le moyen (113) de calcul d'erreur résiduelle comprend un moyen (210) de sélection de bits pour extraire les bits respectifs d'un ensemble prédéterminé de bits d'ordre inférieur de l'erreur bi-niveau, ledit ensemble de bits d'ordre inférieur constituant l'erreur bi-niveau, et dans lequel le moyen (112) de remise à jour d'erreur comprend un moyen d'addition (208a, 208b, 208c) destiné à ajouter séparément les bits d'ordre inférieur extraits aux valeurs prédéterminées respectives desdites valeurs de répartition d'erreur (G_A,....G_D) pendant l'exécution du traitement de remise à jour.