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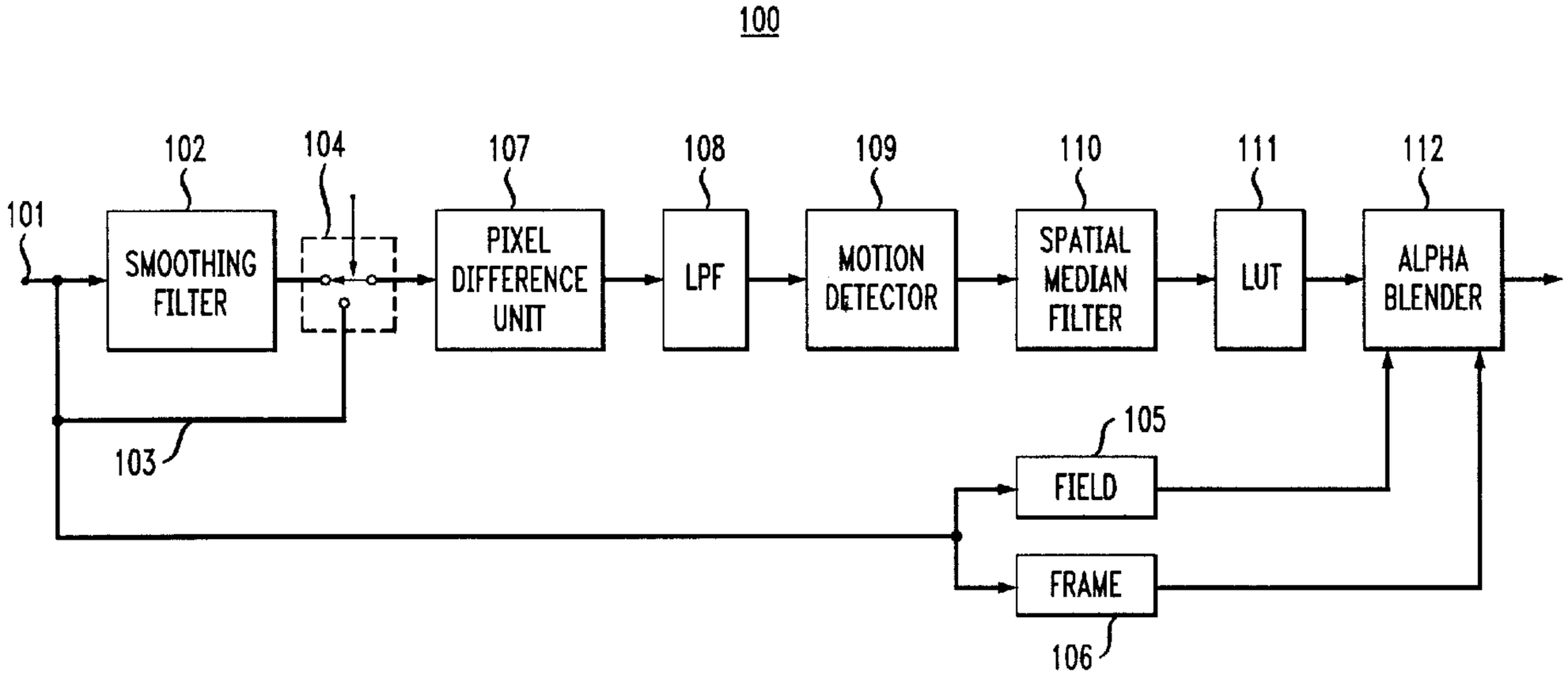
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(54) Titre : METHODE ET APPAREIL DE DESENTRELACEMENT D'IMAGES VIDEO
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(57) Abrégé/Abstract:
De-interlacing is effected by determining the motion at each missing pixel and, then, interpolating the missing tines to convert an interlaced field to a progressive frame. The interpolation employed for luminance is determined through motion detection. If motion is detected in the image field based interpolation is used and if no motion of the image is detected frame interpolation is used. Specifically, the interpolation is determined by employing a motion metric. The motion metric at a missing pixel is defined by using a prescribed combination of pixel luminance value differences. A spatial median filter is then used to remove objectionable noise from the pixel luminance value differences and to fill in so-called "holes" in the image. Indeed, the spatial median filter can be considered as providing a measure of the overall effect of all pixels that make up the object of the image.

H Jiang 10-20-9

METHOD AND APPARATUS FOR DE-INTERLACING VIDEO IMAGES

Abstract

De-interlacing is effected by determining the motion at each missing pixel and, then, interpolating the missing lines to convert an interlaced field to a progressive frame. The interpolation employed for luminance is determined through motion detection. If motion is detected in the image field based interpolation is used and if no motion of the image is detected frame interpolation is used. Specifically, the interpolation is determined by employing a motion metric. The motion metric at a missing pixel is defined by using a prescribed combination of pixel luminance value differences. A spatial median filter is then used to remove objectionable noise from the pixel luminance value differences and to fill in so-called "holes" in the image. Indeed, the spatial median filter can be considered as providing a measure of the overall effect of all pixels that make up the object of the image.

METHOD AND APPARATUS FOR DE-INTERLACING VIDEO IMAGES

Related Applications

This application claims the priority of the corresponding provisional application, Serial No. 60/192,294, filed March 27, 2000. United States Patent application Serial No. (H. Jiang Case 11) was filed concurrently herewith.

Technical Field

This invention relates to video images and, more particularly, to the conversion of an interlaced field to a progressive frame.

Background of the Invention

Arrangements are known for converting interlaced video fields to progressive video frames through interpolation of so-called missing lines. One known arrangement of particular interest is disclosed in U. S. Patent 4,989,090 issued to J.J. Campbell et al. on January 29, 1991. This arrangement includes a video pixel interpolator that generates so-called interpolation pixels from incoming image pixels for use in a television image scan line doubler. The interpolator includes a temporal median filter that generates an interpolation pixel by selecting the median one of a plurality of temporal pixel samples. The reason for using the temporal median filter is so that a switch over from frame interpolation to field interpolation can take place at a higher motion threshold for the pixel. The switch over at a higher motion threshold is necessary in the Campbell et al. apparatus because of a high noise level there are no gaps in the motion values between moving and still pixels. Consequently, it would be difficult to determine whether or not the image at the pixel depicts motion, but for the use of the temporal filter. Unfortunately, the use of the temporal median filter in the Campbell et al. apparatus has only minor affects in the result. The purpose of using the temporal median filter is to allow the use of field interpolation even during higher motion values so that no objectionable aliases will be caused in the image by frame interpolation. However, at motion values when objectionable aliases would occur, the

use of the temporal filter in the Campbell et al. apparatus still yields frame interpolation and, therefore, it does not remove the objectionable aliases.

Summary of the Invention

These and other problems and limitations of prior de-interlacing arrangements are overcome by determining the motion at each missing pixel and, then, interpolating the missing lines to convert an interlaced field to a progressive frame. The interpolation employed for luminance is determined through motion detection. If motion is detected in the image, field based interpolation is used and if no motion of the image is detected, frame interpolation is used.

Specifically, the interpolation is determined by employing a motion metric. The motion metric at a missing pixel is defined by using a prescribed combination of pixel luminance value differences. A spatial median filter is then used to remove objectionable noise from the pixel luminance value differences and to fill in so-called "holes" in the image. Indeed, the spatial median filter can be considered as providing a measure of the overall effect of all pixels that make up the object of the image.

In a specific embodiment of the invention, a nine point spatial median filter is used to filter the noise from the pixel luminance value differences while continuing to preserve the motion or the stillness of the image.

In still another embodiment of the invention a look-up table is used to determine a "weight" parameter, i.e., blending factor, for frame based or field based interpolations.

A technical advantage of the invention is that it makes a correct decision regarding the motion state of the image rather than merely providing a so-called "fix" for erroneous decisions.

Brief Description of the Drawing

FIG. 1 shows, in simplified block diagram form, details of a de-interlacer in accordance with the invention;

FIG. 2 graphically illustrates missing lines in interlaced fields useful in describing the invention;

FIG. 3 is a graphical representation of a number of fields useful in describing taking the luminance differences of pixels;

FIG. 4 shows, in simplified form, a nine-point spatial median filter that may be employed in practicing the invention; and

FIG. 5 is a graphical representation of a look up table including weights, i.e., blending factors, that may be used in the interpolation employed in the invention.

Detailed Description

FIG. 1 shows, in simplified block diagram form, details of a de-interlacer in accordance with the invention. The process of de-interlacing is to interpolate missing lines in an interlaced image field.

Specifically, an image to be de-interlaced is supplied to input 101 and, then, to smoothing filter 102, via bypass 103 to a terminal of controllable switch 104, field interpolation unit 105 and frame interpolation unit 106. Smoothing filter 102 is employed to remove or reduce the noise level of the incoming image to remove its adverse effects on a motion metric to be generated and may not be required in all applications of the invention. In this example, a simple 1-2-1 horizontal filter may be used for this purpose. It should be noted that the smoothing filter 102 is employed only to compute the motion metric. After the weights α are computed, as described below, smoothing filter 102 is by-passed via bypass103 and controllable switch 104, and the subsequent interpolation is done on the original images.

Briefly, FIG. 2 shows two interlaced fields where "X" indicates existing lines and "O" indicates missing lines useful in describing interpolation.

Broadly, interpolation for luminance is effected by using motion detection. If an image is found to be still, frame based interpolation is used. That is, the luminance value of the missing pixel "C_0" is taken to be the value at the missing pixel in the early field, namely,

$C_0 = C_{-1}$. This is realized in frame interpolation unit 106.

If the image is moving, i.e., has motion, then field-based interpolation is used. That is, the luminance value of the missing pixel "C_0" is taken to be the average of the luminance values of pixels in the same field above and below the missing pixel, namely, $C_0 = \frac{(N_0 + S_0)}{2}$. This is realized in field interpolation unit 105.

In general, the motion of an image is characterized by a quantity, i.e., weight or blending factor, α, where $0 \le \alpha \le 1$, and the interpolation is given by, $C_0 = \alpha \frac{(N_0 + S_0)}{2} + (1-\alpha) C_{-1}$. This is realized in alpha blender 112 in conjunction with a blending factor α from look up table 111 and the above-noted expressions from field interpolation unit 105 and frame interpolation unit 106.

The interpolation of chrominance is always field based.

Motion detection is accomplished by taking the luminance value differences of pixels of prescribed fields via pixel difference unit 107, as shown in FIG. 3. In this example, to determine the motion for a missing pixel, five pixel luminance value differences are obtained by pixel difference unit 107 in accordance with prescribed criteria as follows:

$$\Delta_c = |C_1 - C_{-1}|;$$

$$\Delta_n = |N_0 - N_{-2}|;$$

$$\Delta_s = |S_0 - S_{-2}|;$$

$$\Delta_a = \left| \frac{N_0 + S_0}{2} - \frac{N_{-2} + S_{-2}}{2} \right|; \text{ and}$$

$$\Delta_b = |C_{-1} - C_{-3}|.$$

In the above expressions, C_1 represents the luminance value of the corresponding pixel in field f_1, C_0, N_0 and S_0 are in field f_0, C_{-1} is in field f_{-1}, N_{-2} and S_{-2} are in field f_{-2} and C_{-3} is in field f_{-3}. It should be noted that only four image fields are used in determining the pixel luminance value differences and, hence, the motion metric Δ.

The desired pixel luminance value differences are low pass filtered via low pass filter 108 to smooth them and the filtered versions are supplied to motion detector 109.

Motion detector 109 actually filters the pixel luminance value differences from pixel difference unit 107 to remove aliases occurring under motion conditions. Moreover, it should be noted that all the pixel luminance value differences noted above might not be used in determining the motion of the missing pixel. The motion metric Δ at a missing pixel may be defined by employing some combination of the obtained pixel luminance value differences, for example, by

$$\Delta = \max(\Delta_c, \Delta_a).$$

Other combinations of the pixel luminance value differences may also be used to obtain the motion metric at the missing pixel, for example,

$$\Delta = \max(\Delta_c, \min(\Delta_n, \Delta_s)),$$

is employed in motion detector 109 in this implementation. Note that the use of $\min(\Delta_n, \Delta_s)$ reduces the spreading of spurious motion in a vertical direction of the image. It is also important to note that our implementation is significantly simplified because the motion values are computed directly from the pixel luminance value differences employing the minimum and maximum value choices.

The effects of using other examples of combinations of pixel luminance value differences on the quality of images are now briefly discussed. To this end, motion metric $\Delta = \max(\Delta_c, \Delta_a)$ is considered the reference. All the following motion metrics will be compared with it. Indeed, this reference motion metric expression produces satisfactory results for most situations.

Consider motion metric $\Delta = \max(\Delta_c, \Delta_n, \Delta_s)$. This motion metric varies slightly from the reference and produces similar quality images.

Consider motion metric $\Delta = \max(\Delta_c, \min(\Delta_n, \Delta_s))$. This motion metric has the advantage of preserving very well the edge of a still region in an image. However it produces slightly more aliasing than the reference motion metric.

Consider motion metric $\Delta = \max(\Delta_c, \Delta_n, \Delta_s, \Delta_b)$. This motion metric has the advantage of removing more aliasing. However, disadvantages are that it causes a delayed motion and requires more memory.

Consider motion metric $\Delta = \max(\Delta_n, \Delta_s, \Delta_b)$. In motion metric $\Delta = \max(\Delta_c, \Delta_n, \Delta_s)$, the computation of Δ_c requires a delay of one field. This delay may cause the images to be out of synchronization with associated audio. Exclusion of Δ_c avoids this problem. However, disadvantages are also that it causes a delayed motion and requires more memory.

It should be noted that the order of spatial medium filter 110 and look-up table 111 could be exchanged.

In this example, the motion metrics Δ are computed by motion detector 109, filtered via spatial median filter 110 and, then, a look up table 111 is employed to obtain the weight, i.e., blending factor, α for the frame-based interpolation in frame interpolation unit 106 or field-based interpolation in field interpolation unit 105.

FIG. 4 shows, in simplified form, details of a so-called 9-point spatial median filter 110 that is advantageously used in practicing the invention. It is noted that the pixel luminance value difference is only a measure of the change in a single pixel. However, when considering whether an object in the image is moving or not all pixels of the object should be considered. The spatial median filter 110 can be thought of as measuring the overall effect of all pixels that make up the object. Additionally, since each individual pixel luminance value difference may be prone to random noise, use of spatial median filter 110 can also reduce the effects of the noise.

Referring to FIG. 4, it is seen that the 9-points (i.e., motion metrics Δ) are arranged into three groups of three points each, namely, a first group including motion metrics a, b and c, a second group including motion metrics d, e and f, and a third group including motion metrics g, h and j. The first group is supplied to sorter 401, the second group to sorter 402 and the third group to sorter 403. The motion metric Δ values are supplied from motion detector 109. Sorters 401, 402 and 403 each perform a complete

sort of their respective supplied groups, i.e., arrange the supplied motion metric values in either ascending or descending order. In the spatial median filter shown in FIG. 4 it is assumed that the motion metric values are arranged in ascending order. That is, $a_3 \geq a_2 \geq a_1$ and so on for the other values. Note that a sorter of three values requires three comparisons. Thus, the three sorters 401, 402 and 403 perform nine comparisons. The median of each group is determined to be the middle value motion metric in the sorted group. The three medians from sorters 401, 402 and 403, in this example, are a_2, b_2 and c_2, respectively, and are supplied to sorter 404. In turn, sorter 404 sorts the three medians a_2, b_2 and c_2. This requires another three comparisons. After sorting, the three medians a_2, b_2 and c_2, are assumed to be arranged in ascending order and are designated λ, β and γ, respectively, where $\lambda \leq \beta \leq \gamma$. Now the nine points of median filter 110 are reduced to five points by removing four points. The remaining five points include the median of the nine points. This reduction is realized by first identifying the group of three values whose median is λ. These values are labeled in ascending order as $d_1 \leq d_2 \leq d_3$. It is noted that these three values had been sorted in the prior sorting operations. Additionally, since d_2 is the median of the group, it has the same value as λ. It can be shown that both d_1 and d_2 can be removed from the nine points. Now label the three values having γ as its median in ascending order as $f_1 \leq f_2 \leq f_3$. Again, it is noted that f_2 has the same value as γ. It can be shown that the values f_2 and f_3 can be removed from the nine points. Thus, leaving five points including d_3, f_1 and a group of three values having β as its median that is labeled in ascending order as $e_1 \leq e_2 \leq e_3$. These remaining five values are divided into two groups and further sorted. One group includes d_3 and e_1 that after sorting via sorter 405 are labeled in ascending order as $g_1 \leq g_2$. This sorting requires only one comparison. The second group includes e_2, e_3 and f_1 that after sorting via sorter 406 are labeled in ascending order as $h_1 \leq h_2 \leq h_3$. This sorting only requires two

comparisons because e_2 and e_3 have already been sorted. Of the remaining five values g_1, g_2, h_1, h_2 and h_3, it can be shown that values g_1 and h_3 can be removed, leaving values g_2, h_1 and h_2. These remaining three values are sorted via sorter 407 and labeled in ascending order as $j_1 \leq j_2 \leq j_3$. This sorting takes only two comparisons because values h_1 and h_2 have already been sorted. The median value of the group from sorter 407 is the median of the nine points and is value j_2.

It should be noted that if so-called pipelining is used in the median filter 110, only one three point sorter is required for sorters 401, 402, 403 and 404 because the prior sorted results are stored for use in the subsequent sortings.

Moreover, the use of this unique spatial median filter 110 removes or reduces the effect of noise on the motion metric values without generating spurious "stillness" or motion. Furthermore, use of the spatial median filter in the invention enables the correct decision to be made regarding the motion state of an image rather than just providing a "fix" for erroneous decisions made in prior de-interlacing arrangements.

For further details of spatial median filter 110 see United States patent application Serial No. (Hong Jiang Case 11) filed concurrently herewith and assigned to the assignee of this patent application.

FIG. 5 is a graphical representation of a look up table including weights, i.e., blending factors, that may be used in the interpolation employed in the invention. In this example, the look up table is represented as a stretched sinusoidal curve, where α has 8-bit values. In certain applications, α may use fewer bits. It is noted that the curve shown in FIG. 5 has significant effects on the quality of the de-interlaced images. Shifting the curve to the left causes more pixels to be interpolated based on field, and therefore reducing aliasing. On the other hand, shifting the curve to the right may increase aliasing.

Thus, the look up table of FIG. 5 yields the weight, i.e., blending factor, α based on the supplied median motion metric Δ output from spatial median filter 110,

namely, median value j_2. Then, the weights, i.e., blending factors, α are supplied to alpha (α) blender 112. It should be noted that theoretically either the spatial median filter 110 or the look up table 111 could be applied first to the motion metric Δ.

In one example the blending factors for given motion metrics are as follows:

Motion Metric Value	**Blending Factor**
0	0
1	0
2	0
3	0
4	23/255
5	93/255
6	170/255
7	240/255
8	1 (255/255)

In this example, any motion metric value of less than 4 yields a blending factor α of 0 and any motion metric value of 8 or more yields a blending factor α of 1.

As indicated above, the blending factors α from look up table 111 are supplied to alpha blender 112 where they are employed with the field based interpolation factor from unit 105 and the frame based interpolation factor from unit 106.

It has been observed, however, that alpha blending may not be required in all applications of the invention. In such situations a hard switch from frame based interpolation to field based interpolation is sufficient for practical results. When employing such hard switching from frame based interpolation to field based interpolation a much simplified spatial median filter can be used. This hard switching is readily accomplished by employing a controllable selector to select either the output from frame interpolator 106 when the image is still, e.g., a motion metric value of less than 4 in this example, or the output from field interpolator 105 when there is motion in the image, i.e., a motion metric value of 4 or more in this example.

It is noted that interpolation for chrominance is always field based.

The above-described embodiments are, of course, merely illustrative of the principles of the invention. Indeed, numerous other methods or apparatus may be devised by those skilled in the art without departing from the spirit and scope of the invention.

CLAIMS:

1. Apparatus for use in a video image de-interlacer comprising:

a frame interpolator for yielding a frame based luminance value for a missing pixel by using frame based interpolation;

a field interpolator for yielding a field based luminance value for a missing pixel by using field based interpolation;

a luminance difference unit for obtaining luminance value differences of pixels in prescribed fields of an image in accordance with prescribed criteria;

a motion detector supplied with prescribed ones of said luminance value differences for generating a motion metric value at a missing pixel;

a spatial median filter supplied with at least three of said motion metric values for determining a median motion metric value; and

a controllable combiner supplied with said frame based luminance value and said field based luminance value and being responsive to a representation of said median motion metric value to controllably supply as an output a luminance value for said missing pixel.

2. The apparatus as defined in claim 1 wherein said spatial median filter is a nine-value spatial median filter.

3. The apparatus as defined in claim 1 wherein said combiner, in response to said representation of said median motion metric value indicating the image is still, outputs said frame based luminance value, and said combiner, in response to said representation of said median motion metric value indicating motion in the image, outputs said field based luminance value.

4. The apparatus as defined in claim 3 wherein said frame based luminance value is generated by said frame interpolator in accordance with $C_0 = C_{-1}$, where C_0 is the luminance value of the missing pixel in field f_0 and C_{-1} is the luminance value of a pixel corresponding to the missing pixel in a last prior field f_{-1} relative to field f_0, and said field based luminance value is generated by said field interpolator in accordance

with $C_0 = \frac{(N_0 + S_0)}{2}$, where N_0 is the luminance value of a pixel above of and in the same field f_0 as the missing pixel, and S_0 is the luminance value of a pixel below of and in the same field f_0 as the missing pixel .

5. The apparatus as defined in claim 1 wherein said luminance difference unit generates a plurality of prescribed luminance value differences of pixels in prescribed fields of the image, and said motion detector employs prescribed relationships of said luminance value differences to generate said motion metric value.

6. The apparatus as defined in claim 5 wherein said luminance difference unit generates a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, and generates at least a second luminance difference value in accordance with $\Delta_a = \left| \frac{N_0 + S_0}{2} - \frac{N_{-2} + S_{-2}}{2} \right|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel , N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel, and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

7. The apparatus as defined in claim 6 wherein said motion detector generates said motion metric value in accordance with $\Delta = \max(\Delta_c, \Delta_a)$, where Δ is said motion metric value.

8. The apparatus as defined in claim 5 wherein said luminance difference unit generates a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where

C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, generates a second luminance difference value in accordance with $\Delta_n = |N_0 - N_{-2}|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel and N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel, and generates at least a third luminance difference value in accordance with $\Delta_s = |S_0 - S_{-2}|$, where S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel .

9. The apparatus as defined in claim 8 wherein said motion detector generates said motion metric value in accordance with $\Delta = \max(\Delta_c, \min(\Delta_n, \Delta_s))$, where Δ is said motion metric value.

10. The apparatus as defined in claim 1 further including a look-up table including blending factor values related to said median motion metric values and being responsive to said median motion metric value from said spatial median filter for supplying as an output a corresponding blending factor value as said representation of said median motion metric value.

11. The apparatus as defined in claim 10 wherein said controllable combiner is responsive to said blending factor for supplying as an output a luminance value for said missing pixel in accordance with $C_0 = \alpha \frac{(N_0 + S_0)}{2} + (1-\alpha)C_{-1}$, where C_0 is the luminance value of the missing pixel in field f_0, C_{-1} is the luminance value of a pixel corresponding to the missing pixel in a last prior field f_{-1} relative to field f_0, N_0 is the luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is

the luminance value of a pixel below of and in the same field f_0 as the missing pixel and α is the blending factor.

12. The apparatus as defined in claim 11 wherein said luminance difference unit generates a plurality of prescribed luminance value differences of pixels in prescribed fields of the image, and said motion detector employs prescribed relationships of said luminance value differences to generate said motion metric value.

13. The apparatus as defined in claim 12 wherein said luminance difference unit generates a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, and generates at least a second luminance difference value in accordance with $\Delta_a = \left| \frac{N_0 + S_0}{2} - \frac{N_{-2} + S_{-2}}{2} \right|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel , N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel, and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

14. The apparatus as defined in claim 13 wherein said motion detector generates said motion metric value in accordance with $\Delta = \max(\Delta_c, \Delta_a)$, where Δ is said motion metric value.

15. The apparatus as defined in claim 10 wherein said luminance difference unit generates a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value

of a pixel corresponding to the missing pixel in field f_1, generates a second luminance difference value in accordance with $\Delta_n = |N_0 - N_{-2}|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel and N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel, and generates at least a third luminance difference value in accordance with $\Delta_s = |S_0 - S_{-2}|$, where S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

16. The apparatus as defined in claim 15 wherein said motion detector generates said motion metric value in accordance with $\Delta = \max(\Delta_c, \min(\Delta_n, \Delta_s))$, where Δ is said motion metric value.

17. Apparatus for use in a video image de-interlacer comprising:

a frame interpolator for yielding a frame based luminance value for a missing pixel by using frame based interpolation;

a field interpolator for yielding a field based luminance value for a missing pixel by using field based interpolation;

a luminance difference unit for obtaining luminance value differences of pixels in prescribed fields of an image in accordance with prescribed criteria;

a motion detector supplied with prescribed ones of said luminance value differences for generating a motion metric value at a missing pixel;

a look-up table including blending factor values related to said motion metric values and being responsive to supplied motion metric values for supplying as an output corresponding blending factor values;

a spatial median filter supplied with at least three of said blending factor values for determining a median motion metric value; and

a controllable combiner supplied with said frame based luminance value and said field based luminance value and being responsive to a said median blending factor value to controllably supply as an output a luminance value for said missing pixel.

18. The apparatus as defined in claim 17 wherein said spatial median filter is a nine-value spatial median filter.

19. The apparatus as defined in claim 17 wherein said combiner, in response to said representation of said median motion metric value indicating the image is still, outputs said frame based luminance value, and said combiner, in response to said representation of said median motion metric value indicating motion in the image, outputs said field based luminance value.

20. The apparatus as defined in claim 17 wherein said controllable combiner is responsive to said blending factor for supplying as an output a luminance value for said missing pixel in accordance with $C_0 = \alpha\frac{(N_0 + S_0)}{2} + (1-\alpha)C_{-1}$, where C_0 is the luminance value of the missing pixel in field f_0, C_{-1} is the luminance value of a pixel corresponding to the missing pixel in a last prior field f_{-1} relative to field f_0, N_0 is the luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is the luminance value of a pixel below of and in the same field f_0 as the missing pixel and α is the blending factor.

21. The apparatus as defined in claim 20 wherein said luminance difference unit generates a plurality of prescribed luminance value differences of pixels in prescribed fields of the image, and said motion detector employs prescribed relationships of said luminance value differences to generate said motion metric value.

22. The apparatus as defined in claim 21 wherein said luminance difference unit generates a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value

of a pixel corresponding to the missing pixel in field f_1, and generates at least a second luminance difference value in accordance with $\Delta_a = \left| \frac{N_0 + S_0}{2} - \frac{N_{-2} + S_{-2}}{2} \right|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel , N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel, and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

23. The apparatus as defined in claim 22 wherein said motion detector generates said motion metric value in accordance with $\Delta = \max(\Delta_c, \Delta_a)$, where Δ is said motion metric value.

24. The apparatus as defined in claim 21 wherein said luminance difference unit generates a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, generates a second luminance difference value in accordance with $\Delta_n = |N_0 - N_{-2}|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel and N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel, and generates at least a third luminance difference value in accordance with $\Delta_s = |S_0 - S_{-2}|$, where S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel .

25. The apparatus as defined in claim 24 wherein said motion detector generates said motion metric value in accordance with $\Delta = \max(\Delta_c, \min(\Delta_n, \Delta_s))$, where Δ is said motion metric value.

26. A method for use in a video image de-interlacer comprising the steps of:

frame interpolating to yield a frame based luminance value for a missing pixel by using frame based interpolation;

field interpolating to yield a field based luminance value for a missing pixel by using field based interpolation;

obtaining luminance value differences of pixels in prescribed fields of an image in accordance with prescribed criteria;

in response to prescribed ones of said luminance value differences, generating a motion metric value at a missing pixel;

spatial median filtering at least three of said motion metric values to determine a median motion metric value; and

controllably combining said frame based luminance value and said field based luminance value and in response to a representation of said median motion metric value controllably supplying as an output a luminance value for said missing pixel.

27. The method as defined in claim 26 wherein said step of spatial median filtering employs a nine-value spatial median filter.

28. The method as defined in claim 26 wherein said step of combining, in response to said representation of said median motion metric value indicating the image is still, outputs said frame based luminance value and, in response to said representation of said median motion metric value indicating motion in the image, outputs said field based luminance value.

29. The method as defined in claim 28 wherein said step of frame interpolating includes a step of generating said frame based luminance value in accordance with $C_0 = C_{-1}$, where C_0 is the luminance value of the missing pixel in field f_0 and C_{-1} is the luminance value of a pixel corresponding to the missing pixel in a last prior field

f_{-1} relative to field f_0, and said step of field interpolating includes a step of generating said field based luminance value in accordance with $C_0 = \frac{(N_0 + S_0)}{2}$, where N_0 is the luminance value of a pixel above of and in the same field f_0 as the missing pixel, and S_0 is the luminance value of a pixel below of and in the same field f_0 as the missing pixel.

30. The method as defined in claim 26 wherein said step of obtaining luminance value differences includes a step of generating a plurality of generating a motion metric value includes a step of employing prescribed relationships of said luminance value differences to generate said motion metric value.

31. The method as defined in claim 30 wherein said step of obtaining luminance value differences includes a step of generating a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, and a step of generating at least a second luminance difference value in accordance with $\Delta_a = \left| \frac{N_0 + S_0}{2} - \frac{N_{-2} + S_{-2}}{2} \right|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel , N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel, and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

32. The method as defined in claim 31 wherein said step of generating a motion metric value generates said motion metric value in accordance with $\Delta = \max(\Delta_c, \Delta_a)$, where Δ is said motion metric value.

33. The method as defined in claim 30 wherein said step of obtaining luminance value differences includes a step of generating a first luminance value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, a step of generating a second luminance difference value in accordance with $\Delta_n = |N_0 - N_{-2}|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel and N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel, and a step of generating at least a third luminance difference value in accordance with $\Delta_s = |S_0 - S_{-2}|$, where S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

34. The method as defined in claim 33 wherein said step of generating a motion metric value includes a step of generating said motion metric value in accordance with $\Delta = \max(\Delta_c, \min(\Delta_n, \Delta_s))$, where Δ is said motion metric value.

35. The method as defined in claim 26 further including a step of employing a look-up table including blending factor values related to said median motion metric values and, in response to a supplied median motion metric value, supplying as an output a corresponding blending factor value as said representation of said median motion metric value.

36. The method as defined in claim 35 wherein said step of controllably combining, in response to said blending factor, supplying as an output a luminance value for said missing pixel in accordance with $C_0 = \alpha\frac{(N_0 + S_0)}{2} + (1-\alpha)C_{-1}$, where C_0 is the luminance value of the missing pixel in field f_0, C_{-1} is the luminance value of a pixel corresponding to the missing pixel in a last prior field f_{-1} relative to field f_0, N_0 is the luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is the luminance value of a pixel below of and in the same field f_0 as the missing pixel and α is the blending factor.

37. The method as defined in claim 36 wherein said step of obtaining luminance value differences includes a step of generating a plurality of prescribed luminance value differences of pixels in prescribed fields of the image, and said step of generating a motion metric value includes a step of employing prescribed relationships of said luminance value differences to generate said motion metric value.

38. The method as defined in claim 37 wherein said step of obtaining luminance values differences includes a step of generating a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, and a step of generating at least a second luminance difference value in accordance with $\Delta_a = \left|\frac{N_0 + S_0}{2} - \frac{N_{-2} + S_{-2}}{2}\right|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel , N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel and S_{-2} is a luminance value of a pixel below

of the missing pixel, and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

39. The method as defined in claim 38 wherein said step of generating a motion metric value includes a step of generating said motion metric value in accordance with $\Delta = \max(\Delta_c, \Delta_a)$, where Δ is said motion metric value.

40. The method as defined in claim 35 wherein said step of obtaining luminance value differences includes a step of generating a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, a step of generating a second luminance difference value in accordance with $\Delta_n = |N_0 - N_{-2}|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel and N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel, and a step of generating at least a third luminance difference value in accordance with $\Delta_s = |S_0 - S_{-2}|$, where S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

41. The method as defined in claim 40 wherein said step of generating a motion metric value includes a step of generating said motion metric value in accordance with $\Delta = \max(\Delta_c, \min(\Delta_n, \Delta_s))$, where Δ is said motion metric value.

42. A method for use in a video image de-interlacer comprising the steps of:

frame interpolating to yield a frame based luminance value for a missing pixel by using frame based interpolation;

field interpolating to yield a field based luminance value for a missing pixel by using field based interpolation;

obtaining luminance value differences of pixels in prescribed fields of an image in accordance with prescribed criteria;

in response to prescribed ones of said luminance value differences, generating a motion metric value at a missing pixel;

in response to supplied motion metric values, utilizing a look-up table including blending factor values related to said motion metric values to supply as an output corresponding blending factor values;

spatial median filtering at least three of said blending factor values for determining a median blending factor value; and

controllably combining said frame based luminance value and said field based luminance value and in response to said median blending factor value controllably supplying as an output a luminance value for said missing pixel.

43. The method as defined in claim 42 wherein said spatial median filter is a nine-value spatial median filter.

44. The method as defined in claim 42 wherein said step of combining includes a step, responsive to said median blending factor value indicating the image is still, of outputting said frame based luminance value, and a step, responsive to said median blending factor value indicating motion in the image, of outputting said field based luminance value.

45. The method as defined in claim 42 wherein said step of combining includes a step, responsive to said median blending factor, of supplying as an output a luminance value for said missing pixel in accordance with $C_0 = \alpha\frac{(N_0 + S_0)}{2} + (1-\alpha)C_{-1}$, where C_0 is the luminance value of the missing pixel in field f_0, C_{-1} is the luminance value of a pixel corresponding to the missing pixel in a last prior field f_{-1} relative to field f_0, N_0 is the luminance value of a pixel above of and in the same field f_0 as the missing pixel,

S_0 is the luminance value of a pixel below of and in the same field f_0 as the missing pixel and α is the blending factor.

46. The method as defined in claim 45 wherein said step of obtaining luminance value differences includes a step of generating a plurality of prescribed luminance value differences of pixels in prescribed fields of the image, and said step of generating a motion metric value includes a step of employing prescribed relationships of said luminance value differences to generate said motion metric value.

47. The method as defined in claim 46 wherein said step of obtaining luminance value differences includes a step of generating a first luminance difference value in accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, and a step of generating at least a second luminance difference value in accordance with $\Delta_a = \left| \frac{N_0 + S_0}{2} - \frac{N_{-2} + S_{-2}}{2} \right|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel, S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel , N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel, and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

48. The method as defined in claim 47 wherein said step of generating a motion metric value includes a step of generating said motion metric value in accordance with $\Delta = \max(\Delta_c, \Delta_a)$, where Δ is said motion metric value.

49. The method as defined in claim 46 wherein said step of obtaining luminance value differences includes a step of generating a first luminance difference value in

accordance with $\Delta_c = |C_1 - C_{-1}|$, where C_{-1} is a luminance value of a pixel corresponding to the missing pixel in the last prior field f_{-1} relative to a field f_0 including the missing pixel and C_1 is a luminance value of a pixel corresponding to the missing pixel in field f_1, a step of generating a second luminance difference value in accordance with $\Delta_n = |N_0 - N_{-2}|$, where N_0 is a luminance value of a pixel above of and in the same field f_0 as the missing pixel and N_{-2} is a luminance value of a pixel above of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel, and a step of generating at least a third luminance difference value in accordance with $\Delta_s = |S_0 - S_{-2}|$, where S_0 is a luminance value of a pixel below of and in the same field f_0 as the missing pixel and S_{-2} is a luminance value of a pixel below of the missing pixel and in the second prior field f_{-2} relative to the field f_0 including the missing pixel.

50. The method as defined in claim 49 wherein said step of generating a motion metric value includes a step of generating said motion metric value in accordance with $\Delta = \max(\Delta_c, \min(\Delta_n, \Delta_s))$, where Δ is said motion metric value.

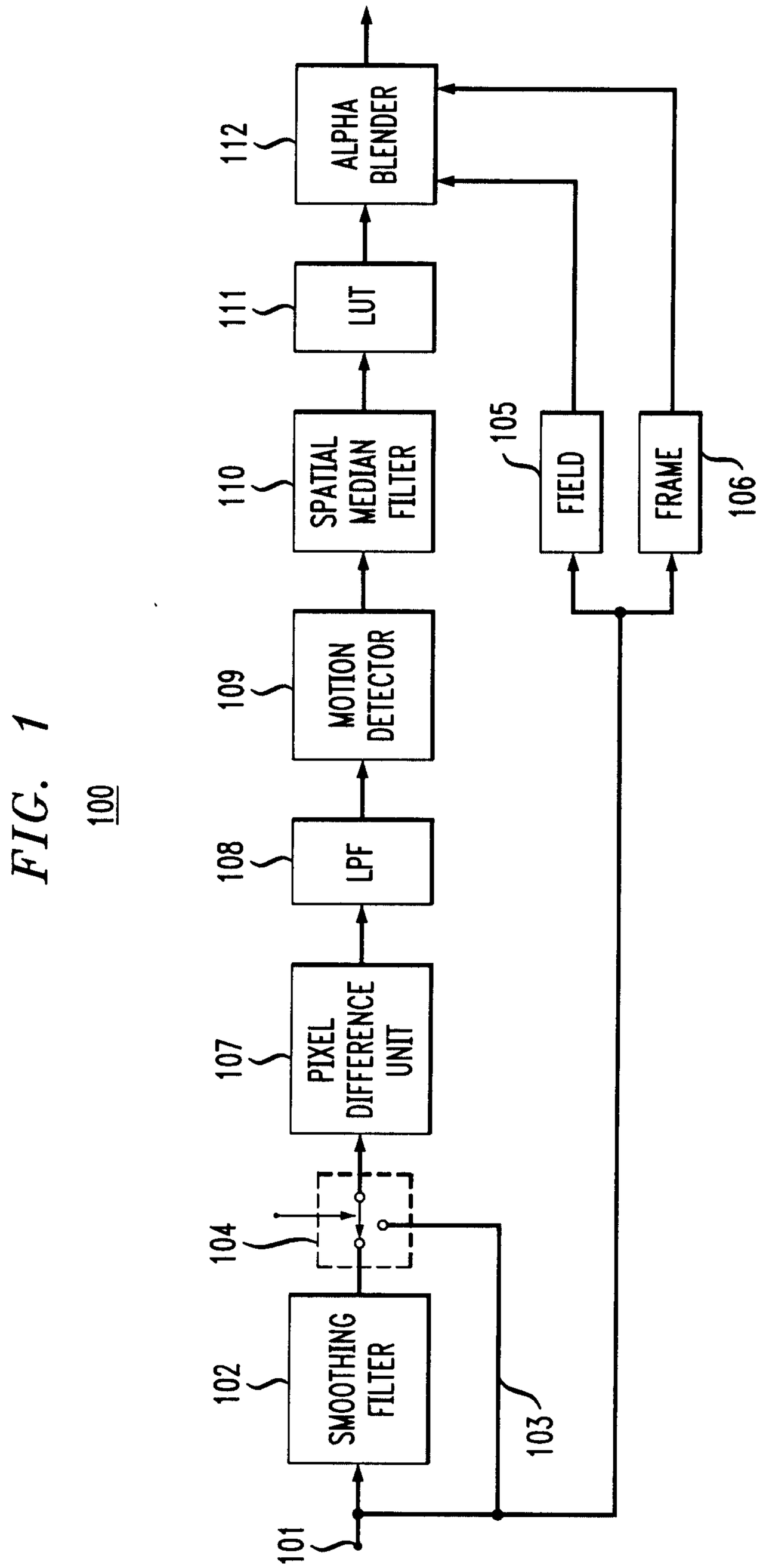

1
100
101
102
103
104
105
106
107
108
109
110
111
112
SMOOTHING FILTER
PIXEL DIFFERENCE UNIT
LPF
MOTION DETECTOR
SPATIAL MEDIAN FILTER
LUT
ALPHA BLENDER
FIELD
FRAME

FIG.

FIG. 2

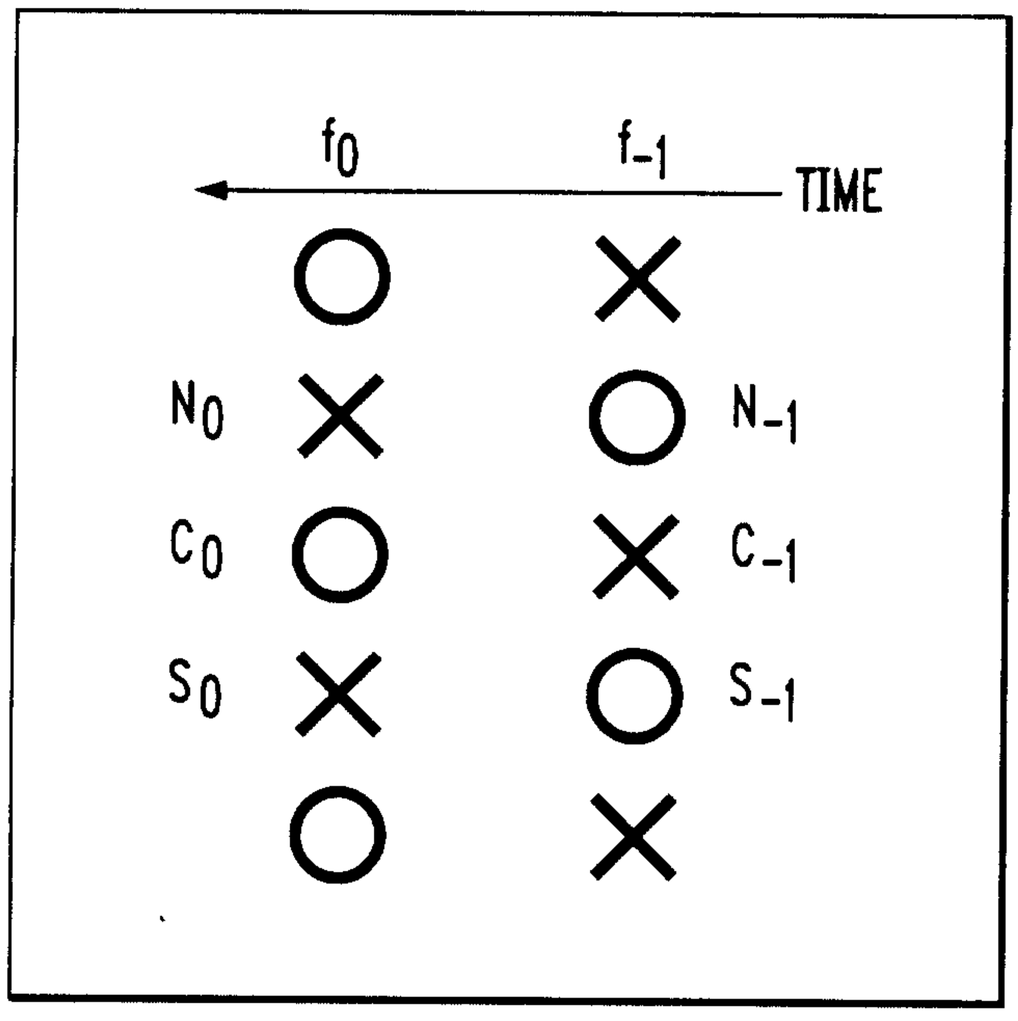

f_0
f_{-1}
TIME
N_0
N_{-1}
C_0
C_{-1}
S_0
S_{-1}

FIG. 3

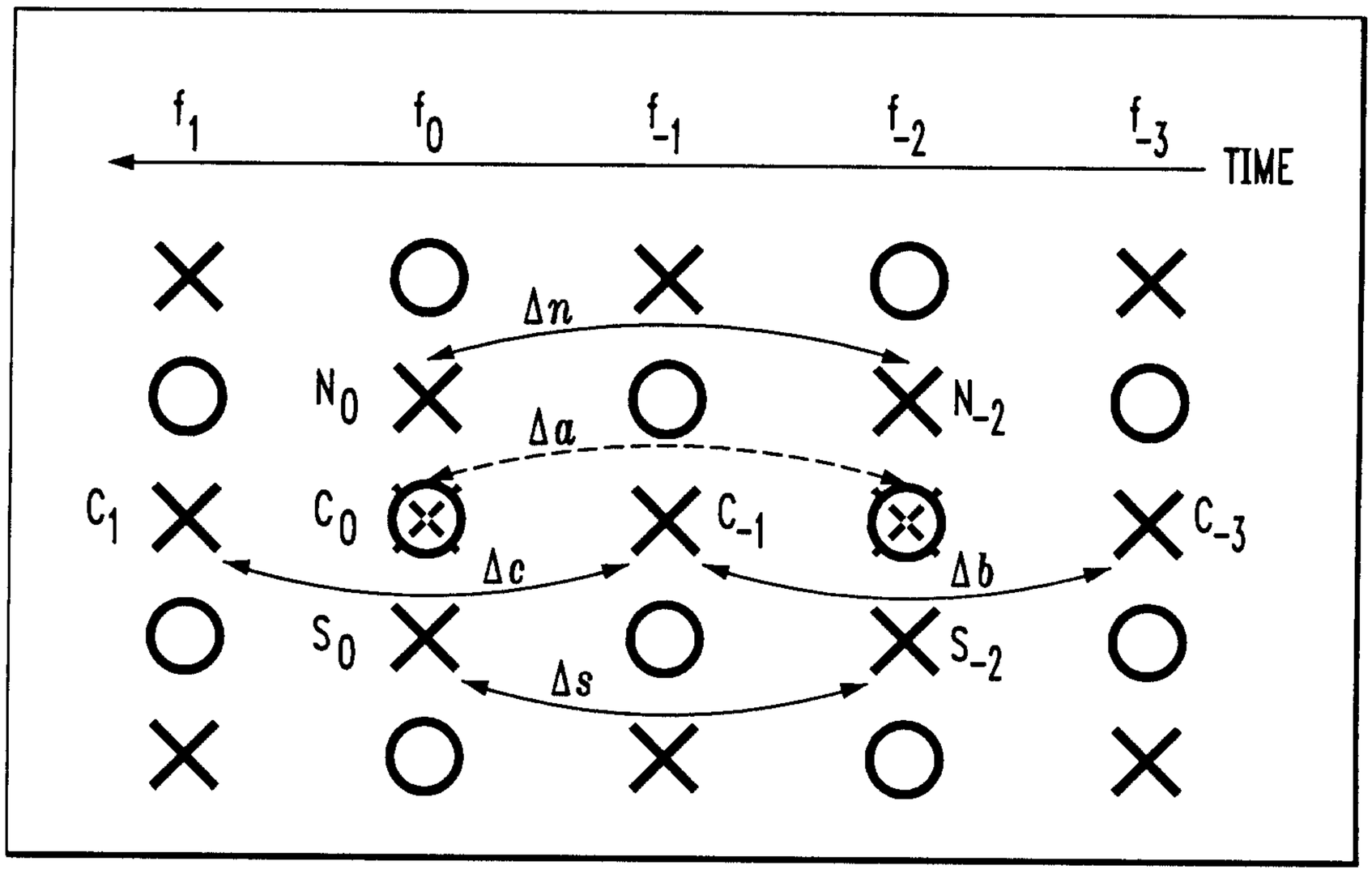

f_1
f_0
f_{-1}
f_{-2}
f_{-3}
TIME
Δn
N_0
N_{-2}
Δa
C_1
C_0
C_{-1}
C_{-3}
Δc
Δb
S_0
S_{-2}
Δs

FIG. 4

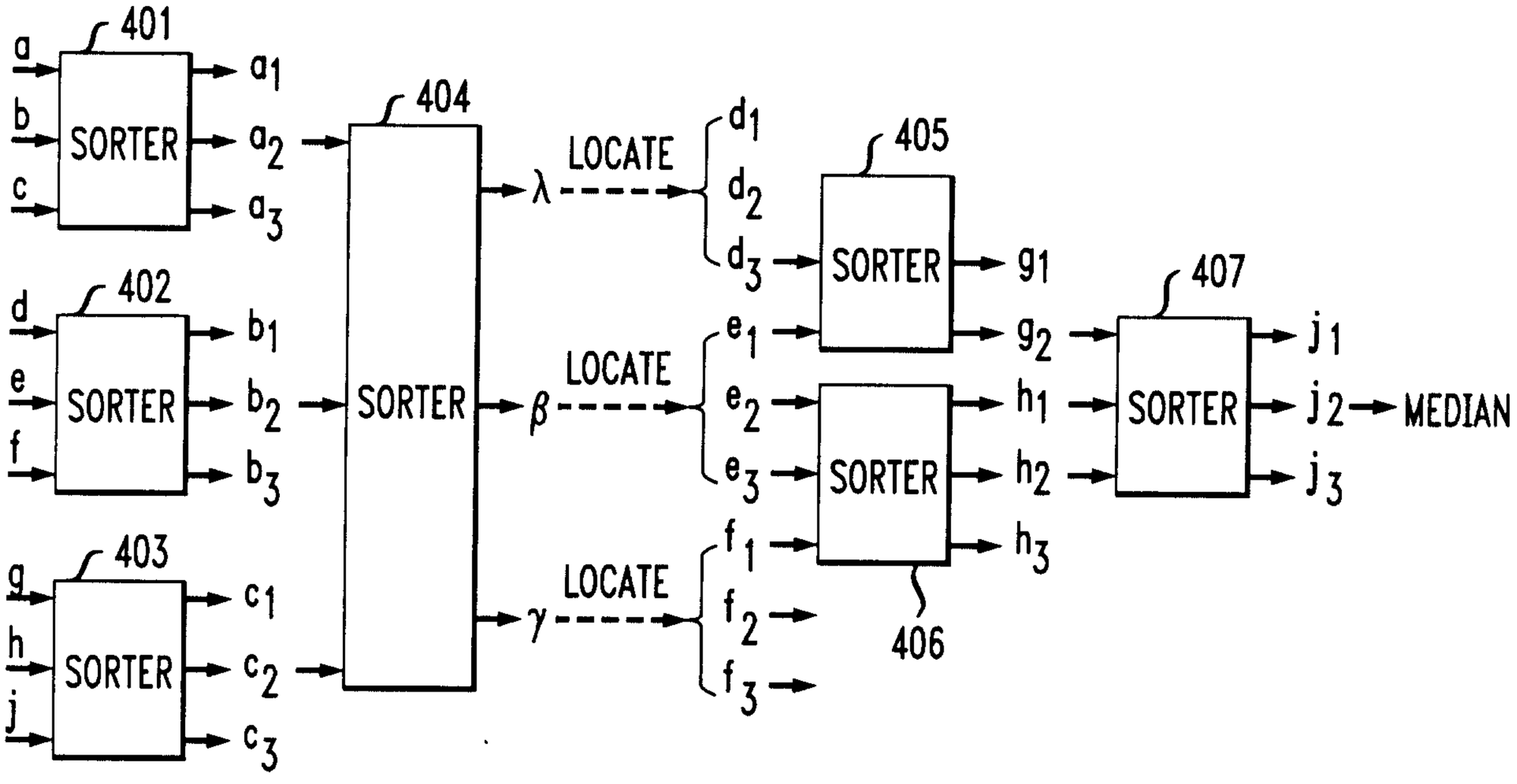
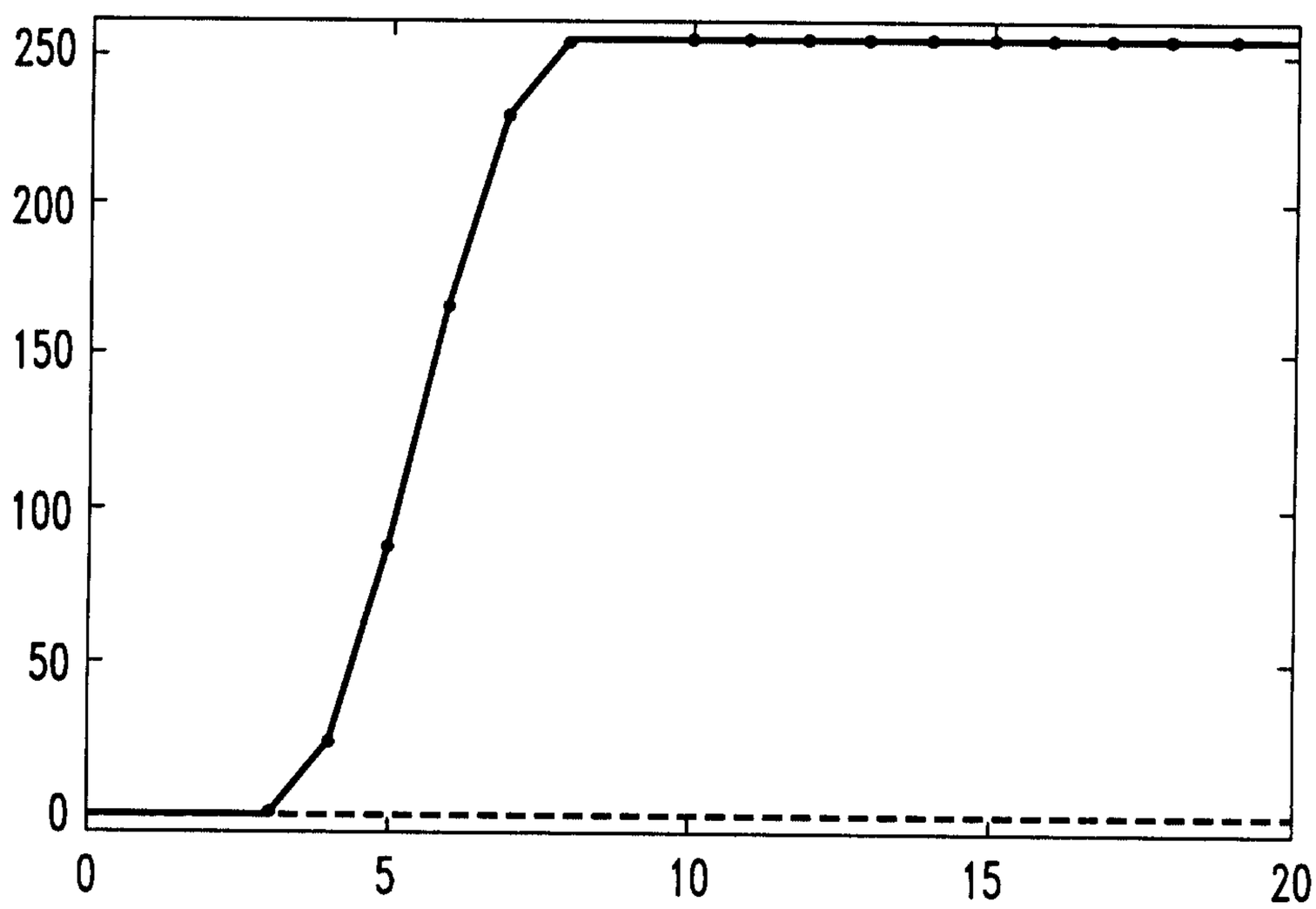
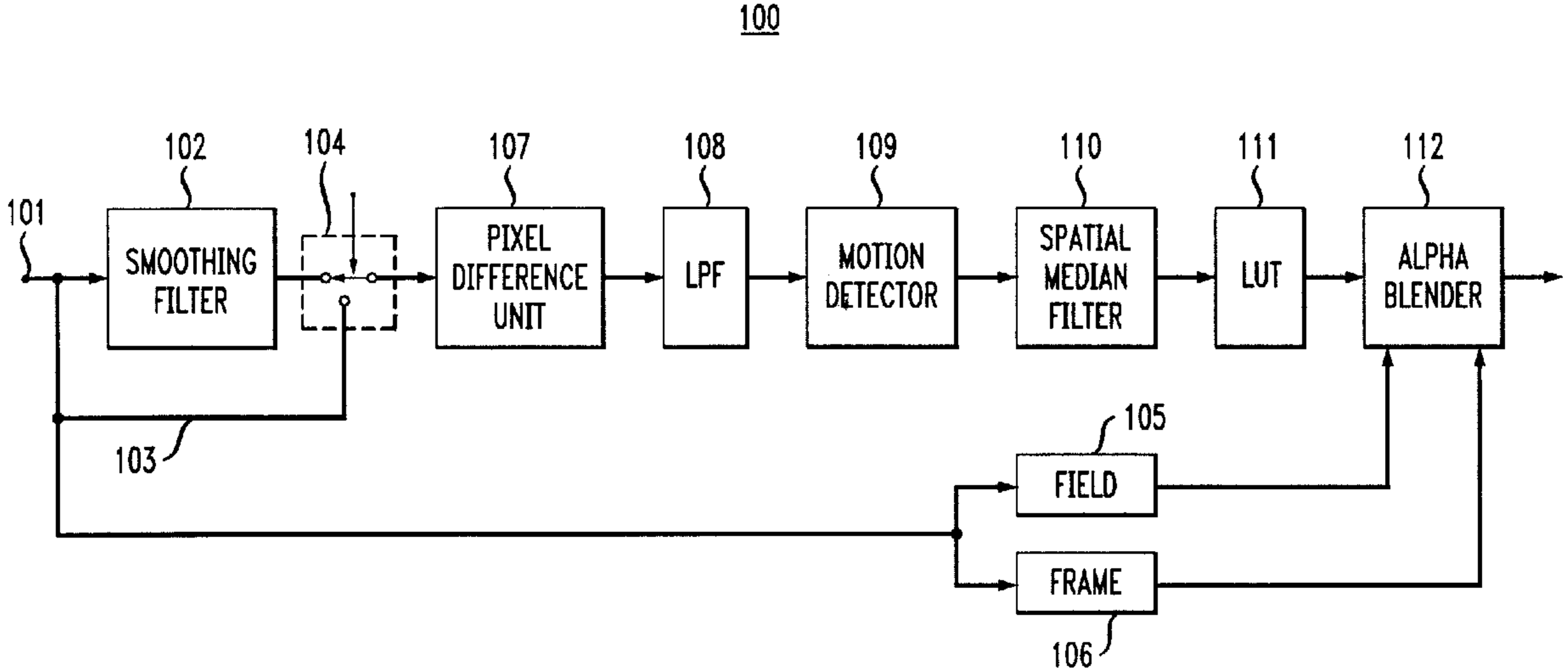

401
a
b
c
SORTER
a1
a2
a3
402
d
e
f
SORTER
b1
b2
b3
403
g
h
j
SORTER
c1
c2
c3
404
SORTER
λ
β
γ
LOCATE
LOCATE
LOCATE
d1
d2
d3
e1
e2
e3
f1
f2
f3
405
SORTER
406
SORTER
g1
g2
h1
h2
h3
407
SORTER
j1
j2
j3
MEDIAN

FIG. 5


250
200
150
100
50
0
0
5
10
15
20


100
101
102
SMOOTHING FILTER
104
103
107
PIXEL DIFFERENCE UNIT
108
LPF
109
MOTION DETECTOR
110
SPATIAL MEDIAN FILTER
111
LUT
112
ALPHA BLENDER
105
FIELD
FRAME
106