A method of stabilizing and registering a video image in multiple video fields of a video sequence provides accurate determination of the image change in magnification, rotation and translation between video fields, so that the video fields may be accurately corrected for these changes in the image in the video sequence. In a described embodiment, a key area of a key video field is selected which contains an image which it is desired to stabilize in a video sequence. The key area is subdivided into nested pixel blocks and the translation of each of the pixel blocks from the key video field to a new video field is determined as a precursor to determining change in magnification, rotation and translation of the image from the key video field to the new video field.

8 Claims, 6 Drawing Sheets
20 PRE-PROCESS VIDEO FRAMES

30 SUBDIVIDE KEY AREA

40 MASK KEY AREA

50 APPROXIMATE IMAGE TRANSLATION

60 DETERMINE TRANSLATION FOR EACH PIXEL BLOCK

70 DETERMINE CHANGE IN MAGNIFICATION

80 DETERMINE IMAGE ROTATION

90 DETERMINE IMAGE TRANSLATION

100 PRE-PROCESS SUBSEQUENT FIELD

FIG. 1
FIG. 2

22 EXTRACT VIDEO FIELDS FROM EACH VIDEO FRAME

24 INTERPOLATE TO FILL MISSING LINES IN EACH VIDEO FIELD

26 AVERAGE BRIGHTNESS VALUES OF EACH PIXEL

FIG. 3

32 SELECT KEY FIELD

34 SELECT KEY AREA

36 ADJUST KEY AREA

38 SUBDIVIDE INTO NESTED PIXEL BLOCKS
FIG. 4

42
EXCLUDE PIXEL BLOCKS NOT OF INTEREST

44
EXCLUDE FEATURELESS PIXEL BLOCKS

FIG. 5

52
CALCULATE CORRELATION COEFFICIENT BETWEEN KEY AREA AND CORRESPONDING AREA IN NEW FIELD

54
CALCULATE CORRELATION COEFFICIENT BETWEEN KEY AREA AND OTHER AREAS IN NEW FIELD

56
REFINE SEARCH

58
SELECT AREA IN NEW FIELD HAVING MAXIMUM CORRELATION TO KEY AREA
61 BEGIN WITH LARGEST PIXEL BLOCK SUBDIVISION

62 CALCULATE CORRELATION COEFFICIENT BETWEEN A PIXEL BLOCK OF KEY AREA AND CORRESPONDING PIXEL BLOCK IN NEW FIELD

63 SELECT PIXEL BLOCK IN NEW FIELD HAVING MAXIMUM CORRELATION TO THE PIXEL BLOCK OF KEY AREA

64 DETERMINE TRANSLATION FOR EACH PIXEL BLOCK

65 GO TO NEXT SMALLER PIXEL BLOCK SUBDIVISION

66 EXCLUDE PIXEL BLOCKS IN DATA MASK HAVING LOW CORRELATION

FIG. 6
FIG. 7

CALCULATE Δ HORIZONTAL TRANSLATION FOR PIXEL BLOCK ROW PAIRS

CALCULATE Δ VERTICAL TRANSLATION FOR PIXEL BLOCK COLUMN PAIRS

CALCULATE CHANGE IN MAGNIFICATION

FIG. 8

CALCULATE Δ HORIZONTAL TRANSLATION FOR PIXEL BLOCK COLUMN PAIRS

CALCULATE Δ VERTICAL TRANSLATION FOR PIXEL BLOCK ROW PAIRS

CALCULATE ROTATION
FIG. 9

92
CORRECT FOR MAGNIFICATION CHANGE

94
CORRECT FOR ROTATION

96
AVERAGE CORRECTED TRANSLATIONS OF INDIVIDUAL PIXEL BLOCKS

FIG. 10

102
DE-TRANSLATE IMAGE

104
DE-ROTATE IMAGE

106
DE-MAGNIFY IMAGE
VIDEO IMAGE STABILIZATION AND REGISTRATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of the filing date of provisional application Ser. No. 60/099,056, filed Aug. 26, 1998, and this application is a continuation of nonprovisional application Ser. No. 09/364,919 filed Jul. 26, 1999 now U.S. Pat. No. 6,439,822. The disclosures of these prior applications are incorporated herein by this reference.

ORIGIN OF THE INVENTION

This invention was made by employees of the United States Government and may be manufactured and used by or for the Government for Governmental purposes without the payment of royalties.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to video image processing methods and, in an embodiment described herein, more particularly provides a method of stabilizing and registering video images.

2. Description of Related Art

Techniques presently exist for stabilizing video images. These techniques typically function to reduce or eliminate image translation (i.e., displacement) horizontally and vertically in a video sequence. In general, these techniques are very limited in effectiveness, since they are not able to compensate for image rotation or dilation. In addition, these techniques are sensitive to the effects of parallax in which objects in the foreground and background are moving at different rates and/or directions. Furthermore, these techniques are typically able to determine image motion only to the nearest pixel.


From the foregoing, it can be seen that it would be quite desirable to provide a video image stabilization and registration technique which is more accurate than previous techniques, which is capable of compensating for image rotation and dilation, and which is capable of compensating for the effects of parallax.

SUMMARY OF THE INVENTION

In carrying out the principles of the present invention, in accordance with an embodiment thereof, a method is provided for stabilizing and registering video images. The method utilizes nested pixel blocks in accurately determining image translation, rotation and dilation in a video sequence.

In one aspect of the invention, displacement and dilation of an image from one video field to another in a video sequence are determined by choosing a key video field and selecting a key area of pixels within the key video field which contains the image. The key area is then subdivided into multiple levels of nested pixel blocks. Translation of the key area from the key field to a new video field is approximated by searching for an area in the new video field having a maximum correlation to the key area. The key area translation approximation is used as a starting point for determination of the translation of each of the pixel blocks in the largest pixel block subdivision from the key video field to the new video field. The translation of each of the pixel blocks in the largest pixel block subdivision is then used as a starting point for determination of the translation of each of the respective associated pixel blocks in the next smaller pixel block subdivision. This process is repeated until a determination of the translation of each of the pixel blocks in the smallest pixel block subdivision is made. Certain of the pixel blocks may be masked, for example, if a maximum correlation coefficient between one of the smallest pixel blocks and pixel blocks in the new video field is less than a predetermined value, in which case they are not considered in any subsequent calculations.

In another aspect of the present invention, translation, rotation and change in magnification of the key area from the key video field to the new video field is determined using the translations of each of the pixel blocks in the smallest pixel block subdivision. The change in magnification is determined by dividing each of relative horizontal and vertical displacements between pairs of pixel blocks by the respective horizontal and vertical distances between the pixel block pairs, and calculating a weighted average. The rotation is determined by dividing each of relative horizontal and vertical displacements between pairs of pixel blocks by respective vertical and horizontal distances between the pixel block pairs, and calculating a weighted average. The translation of the key area is determined by correcting the translation of each of the pixel blocks in the smallest pixel block subdivision for the change in magnification and rotation, and then averaging the pixel block translations. In the above process, further pixel blocks may be masked, for example, if a calculation produces a value which is significantly different from the average of multiple similarly calculated values.

In yet another aspect of the present invention, the change in magnification, rotation and translation of the key area from the key video field to the new video field is used to pre-process a subsequent video field for evaluation of the change in magnification, rotation and translation of the key area from the key video field to the subsequent video field. The change in magnification, rotation and translation of the key area from the key video field to a pre-processed subsequent video field is then added to the change in magnification, rotation and translation of the key area from the key video field to the new video field to thereby determine change in magnification, rotation and translation of the key area from the key video field to the subsequent video field.

These and other features, advantages, benefits and objects of the present invention will become apparent to one of ordinary skill in the art upon careful consideration of the detailed description of a representative embodiment of the invention hereinbelow and the accompanying drawings.
Therefore, in step corresponding other video field from its video frame.

In step 22, the video fields are extracted from each video frame. In the standard video format, one video field consists of even-numbered horizontal lines, and the other video field consists of odd-numbered horizontal lines, with these steps being performed for each video field in a video sequence, as described in further detail below.

When the video fields are separated out, each will have alternating blank lines therein, due to the absence of the corresponding other video field from its video frame. Therefore, in step 24, interpolation is used to fill in the missing lines in each video field. Video interpolation tech-

tiques are well known to those skilled in the art and will not be described further herein. Any such interpolation tech-

iques may be utilized in keeping with the principles of the present invention.

In step 26, each video field image is transformed into a gray-scale image by averaging together the red, green and blue brightness values of each pixel of the video field. Of course, step 20 could begin with a gray-scale (i.e., black and white in common parlance) video sequence, in which case step 26 would be unnecessary.

Step 30 is a key area subdividing step. This step produces groupings of pixels on multiple levels, such that each pixel group or block (other than the smallest size of pixel block) includes multiple smaller pixel blocks. In this sense, the pixel blocks are “nested” with respect to each other.

In step 32, a key field is selected. The key field is one of the video fields extracted in step 22. Preferably, the key field contains an image of interest, and at least a portion of that image displays an object, person, etc. which the objective is to stabilize in the video sequence. For example, if the video sequence shows an image of a moving car and it is desired to stabilize the video sequence so that the image of the car is relatively motionless, the key field will preferably be selected as one of the video fields which contains a relatively clear centralized image of the car. The key field may be any one of the video fields in the video sequence, e.g., at the beginning, middle or end of the video sequence.

In step 34, a key area within the key field is selected. Preferably, the key area is a rectangular array of pixels and contains the specific image of interest about which it is desired to stabilize the video sequence, with a minimum of background, foreground, extraneous images, etc. Using the above example, the key area would preferably contain the image of the car and little else. The key area may be any group of pixels in the key field. For use as an example in the following further description of the method 10, the key area may be a rectangular group of pixels which is 358 pixels wide by 242 pixels high.

In step 36, the key area is preferably adjusted so that it contains a convenient whole number multiple of the smallest pixel block size into which the key area is to be subdivided. Thus, the key area is adjusted so that it can be conveniently subdivided into progressively smaller blocks of pixels. Using the above example, and assuming that the smallest desired pixel block size is a 15x15 block of pixels, the next larger pixel block size is a 30x30 block of pixels and the largest pixel block size is a 60x60 block of pixels, the key area may be adjusted to a size of 360x240 pixels. It will be readily appreciated that an array of 360x240 pixels may be conveniently subdivided into 60x60 pixel blocks, further subdivided into 30x30 pixel blocks, and still further subdivided into 15x15 pixel blocks.

In step 38, the adjusted key area is subdivided into nested pixel blocks, that is, larger pixel blocks having smaller pixel blocks therein. Using the above example, there will be 24 of the 60x60 pixel blocks in the 360x240 adjusted key area, there will be 96 of the 30x30 pixel blocks (four 30x30 pixel blocks in each 60x60 pixel block) and there will be 384 of the 15x15 pixel blocks (four 15x15 pixel blocks in each 30x30 pixel block).

In this example, the pixel block subdivisions have been selected to be 15x15 as the smallest, 30x30 as the next larger, and 60x60 as the largest, the pixel blocks therein are square, there are three levels of pixel blocks, and each pixel block subdivision has four times the number of pixel blocks as the next larger pixel block subdivision. However, it is to
be clearly understood that other pixel block sizes, other pixel block shapes, other numbers of pixel block levels and other relationships between pixel block subdivisions may be used, without departing from the principles of the present invention. For instance, the smallest pixel block size could be 12x12, pixel blocks could be rectangular, but not square, there could be four levels of nested pixel blocks and one level could have nine times the number of pixel blocks as the next larger pixel block subdivision, while another level could have twelve times the number of pixel blocks as the next larger pixel block subdivision.

Step 40 is a data masking step in which selected pixel blocks are excluded from further consideration in the method. A data mask is constructed by producing an array of numbers in which each element of the array corresponds to one of the smallest pixel blocks of the key area. Using the above example of a 360x240 pixel key area and 15x15 smallest pixel blocks, the data mask would be a 24x16 array. An element of the array is set to 1 if the corresponding pixel block is to be included in further calculations, and the element is set to 0 if the corresponding pixel block is to be excluded from further calculations.

In step 42, an operator is permitted to manually exclude pixel blocks which are not of interest. Using the above example of a key area containing an image of a car, the key area may also include images of other objects, such as objects in the foreground, background, etc., which are not germane to the analysis. Computational economy and accuracy are enhanced when the pixel blocks containing these extraneous images are masked by changing the corresponding elements in the data mask array to 0.

In step 44, featureless pixel blocks are masked. This masking is done automatically and results when the scale of the variations in a pixel block are smaller than a predetermined value. The scale of the variations in a pixel block is given by the standard deviation of the average brightness level of each individual pixel in the pixel block. Recall that the average brightness level of each pixel was determined in step 26 above.

Step 50 provides an approximation of the translation (horizontal and vertical shift or displacement) of the key area from the key field to the new field in the video sequence. This approximation is used to aid in the search for translation of the progressively smaller pixel blocks, as described below.

In step 52, a correlation coefficient between the key area and a corresponding area in the new video field is calculated by a process known as cross-correlation. Such calculation of correlation coefficient between arrays of pixels is well known to those skilled in the art and results in a number which is related to the degree to which one array "matches" another array. Thus, the key area is cross-correlated with a corresponding area in the new video field, the corresponding area having the same shape and size as the key area and being located in the new field as the key area is located in the key field.

In step 54, the key area is cross-correlated with other areas in the new video field, with the centers of the other areas being displaced relative to the center of the corresponding area used in step 52. For example, correlation coefficients may be calculated for areas 10 pixels to the right, 10 pixels to the left, 10 pixels up and 10 pixels down relative to the corresponding area used in step 52. If a correlation coefficient between the key area and one of these other areas is greater than the correlation coefficient between the key area and the corresponding area found in step 52, then there is an indication that the image has translated in the direction of the area having the increased correlation coefficient. If the correlation coefficient between the key area and the corresponding area found in step 52 is greater than the correlation coefficient of each of the other areas, but one of the other areas has a correlation coefficient greater than the remainder of the other areas, then there is an indication that the image has translated in the direction of the other area having the maximum correlation coefficient, but is between the corresponding area and the other area having the maximum correlation coefficient.

In step 56, the search is refined based on the indications given by steps 52 and 54. Thus, the correlation coefficients calculated in steps 52 and 54 are used as a basis on which the search is refined. In general, the objective is to determine the area in the new field having the maximum correlation coefficient.

As depicted in FIG. 5, steps 54 and 56 are repeated, with correlation coefficients being calculated, the search refined, correlation coefficients calculated again, the search refined again, etc., until no further increase in correlation coefficient is achieved.

In step 58, the area in the new field having the maximum correlation to the key area is selected. This area is considered to be a rough approximation of the actual location of the image contained in the key area, as translated between the key field and the new field.

Step 60 is in large part a repeat of step 50, except that it is performed for each pixel block in each pixel block subdivision, beginning with the largest pixel block subdivision. As step 50 began with a calculation of correlation coefficient between the key area and the corresponding area in the new video field, step 60 begins with a calculation of correlation coefficient between one of the largest pixel blocks and a corresponding pixel block in the area selected in step 58. Using the above example, a 60x60 pixel block of the key area is first cross-correlated with a corresponding 60x60 pixel block in the area selected in step 58. The 60x60 pixel block of the key area is then cross-correlated with other 60x60 pixel blocks having respective centers which are displaced relative to the center of the corresponding 60x60 pixel block. The results of these calculations are then used to indicate the direction of translation of the 60x60 key area pixel block. The search is then refined and the process repeated to determine the translation of the 60x60 pixel block from the key area to the area selected in step 58 by finding the 60x60 pixel block having maximum correlation to the 60x60 key area pixel block. This process is then repeated for each of the other 60x60 pixel blocks in the key area, so that the translation of each 60x60 pixel block from the key field to the new field is determined.

Using the translation of its associated 60x60 pixel block as a first approximation, the translation of each 30x30 pixel block is determined. Then, using the translation of its associated 30x30 pixel block as a first approximation, the translation of each 15x15 pixel block is determined. Thus, step 60 of the method 10 progresses from the largest pixel block subdivision to the smallest pixel block subdivision, determining the translation of each pixel block within each subdivision, using the previously determined translation of the next larger associated pixel block as a starting point for determining the translation of each pixel block. Specific details of substeps 61-66 of step 60 are described in further detail below.

In step 61, the determination of each key field pixel block's translation begins with the largest pixel block sub-
division. Using the example given above, wherein the 360×240 pixel key area is first subdivided into 60x60 pixel blocks, further subdivided into 30x30 pixel blocks, and then further subdivided into 15×15 pixel blocks, the process of step 60 begins with the 60x60 pixel blocks. Of course, if other pixel block subdivisions are made, then the process of step 60 might begin with pixel blocks of another size. For instance, the key area could be initially subdivided into 40×40 pixel blocks, in which case step 61 would begin with 40x40 pixel blocks, instead of 60x60 pixel blocks.

In step 62, the correlation coefficient between a pixel block and the corresponding pixel block in the new field is calculated. For the largest pixel block subdivision, the corresponding pixel block in the new field is the pixel block of the key field translated the same as the key area translated from the key field to the new field. In this manner, the translation of the key area from the key field to the new field, as determined in step 50, is used as a first approximation of the translation of each of the largest pixel block subdivision pixel blocks. Using the above example, the correlation coefficient would be calculated for a 60×60 pixel block of the key area and a 60×60 pixel block of the new field translated the same relative to the 60×60 pixel block of the key area as its associated 60x60 pixel block translated from the key field to the new field.

In step 63, a search is performed for the pixel block in the new field having maximum correlation to the pixel block in the key area. This step is similar to steps 54, 56, and 58 described above, in which an area in the new field having maximum correlation to the key area is selected. In other words, step 63 is steps 54, 56, and 58 performed for an individual pixel block, rather than for the entire key area. Thus, correlation coefficients between the individual pixel block of the key area and pixel blocks displaced relative to the corresponding pixel block of the new field are calculated, the search is refined based on the results of these calculations, further correlation coefficients are calculated, etc., until the pixel block of the new field having the maximum correlation to the pixel block of the key area is determined.

In step 64, the translation of each pixel block is determined. Steps 62 and 63 have been described above as having been performed for a single pixel block of a pixel block subdivision. However, step 64 signifies that the translation of each pixel block in the pixel block subdivision is determined. This determination is made by performing steps 62 and 63 for each pixel block in the pixel block subdivision. Using the example given above, the key area contains 24 of the 60x60 pixel blocks. Thus, steps 62 and 63 would be performed 24 times for the largest pixel block subdivision, thereby permitting the translation of each of the 60x60 pixel blocks to be determined independently.

Note that it cannot be assumed that the pixel blocks are translated from the key field to the new field the same as the key area is translated from the key field to the new field, since rotation and change of magnification of the image from the key field to the new field may change the relative positionings of the pixel blocks. This is the reason the approximate translation of the key area from the key field to the new field as found in step 50 is used only as a starting point for determination of the translation of each pixel block of the largest pixel block subdivision.

In step 65, the process is advanced to the next smaller pixel block subdivision. Thus, after the translation of each pixel block in the largest pixel block subdivision is determined, the next smaller pixel block subdivision is evaluated to determine the translation of each pixel block therein. FIG. 6 shows that steps 62–65 are repeated, so that the translation of each pixel block in each pixel block subdivision is determined, progressing from the largest pixel block subdivision to the smallest pixel block subdivision.

Note that in step 62, when a correlation coefficient for a pixel block in a pixel block subdivision other than the largest pixel block subdivision is calculated, the corresponding pixel block in the new field is the pixel block of the key field translated the same as the associated pixel block of the next larger pixel block subdivision translated from the key field to the new field. In this manner, the translation of the associated next larger pixel block from the key field to the new field, as previously determined in step 64, is used as a first approximation of the translation of each of the pixel block subdivision pixel blocks. Using the above example, the correlation coefficient would be calculated for a 30×30 pixel block of the key area and a 30×30 pixel block of the new field translated the same relative to the 30×30 pixel block of the key area as its associated 60x60 pixel block translated from the key field to the new field.

After steps 62–65 have been performed for each pixel block subdivision (except that step 65 cannot be performed after the smallest pixel block subdivision has been evaluated), the result is that the translation of each pixel block in each pixel block subdivision has been determined. This result is very beneficial, since the translations of the smallest pixel blocks may now be used to more precisely determine the translation of the key area from the key field to the new field, and may further be used to determine rotation and dilation of the image between the key field and the new field.

However, it is recognized that the correlation between a pixel block of the key field and a pixel block of the new field may only be very low, due to a variety of reasons. For example, a particular pixel block of the new field which is a translated pixel block of the key area may be obscured due to the presence of an object in the image foreground. Thus, in step 66, a pixel block in the smallest pixel block subdivision is masked when its maximum correlation to pixel blocks in the new field, as determined in step 63, is below a predetermined value. For example, if the maximum calculated correlation coefficient for a pixel block in the smallest pixel block subdivision is less than 0.7, the pixel block may be excluded in the data mask described in step 40 above. If a pixel block is masked, it is not considered in any further calculations in the method 10.

Step 70 is a magnification determination step in which the change in magnification of the image from the key field to the new field is determined. Since step 66 provides a measure of the translation of each pixel block in the smallest pixel block subdivision from the key field to the new field, this information may be used to determine whether the pixel blocks have spread apart or contracted relative to each other, thereby permitting a calculation of the magnification change from the key field to the new field.

In step 72, the difference in horizontal translation is calculated for each pixel block row pair in the smallest pixel block subdivision. Using the example given above, for the 360×240 pixel key area and 15×15 pixel blocks in the smallest pixel block subdivision, there are twenty-four 15×15 pixel blocks in each row of the key area. The change in horizontal translation for each pair of pixel blocks, divided by the distance between the pixel block centers, is calculated for each row of the key area. This calculation gives the horizontal change in magnification for each pixel block pair.
For example, if a pixel block on a row moves to the left 10 pixels from the key field to the new field, while a pixel block 300 pixels away moves to the left 13 pixels from the key field to the new field, the horizontal change in magnification is 1% (a 3 pixel difference in horizontal translation over a 300 pixel distance). As described above, masked pixel blocks are excluded from these calculations.

In step 74, the difference in vertical translation is calculated for each pixel block column pair in the smallest pixel block subdivision. Using the example given above, for the 360x240 pixel key area and 15x15 pixel blocks in the smallest pixel block subdivision, there are sixteen 15x15 pixel blocks in each column of the key area. The difference in vertical translation for each pair of pixel blocks, divided by the distance between the pixel block centers, is calculated for each column of the key area. This calculation gives the vertical change in magnification for each pixel block pair, similar to the manner in which the horizontal change in magnification for pixel block pairs in the key area rows are calculated in step 72.

In step 76, the overall change in magnification of the image from the key field to the new field is calculated. A weighted average of the individual horizontal and vertical magnification changes determined in steps 72 and 74 is calculated, with the magnification changes for more widely spaced pixel block pairs being weighted more than those for relatively closely spaced pixel block pairs, since widely spaced apart pixel blocks are more sensitive to changes in magnification. Additionally, individual pixel block pair magnification changes may be excluded from the weighted average if their values are significantly different from the average, for example, a pixel block pair magnification change value may be excluded from the weighted average calculation if it is more than one standard deviation from the average, for example, a pixel block pair rotation calculation may be excluded from the weighted average calculation if it is more than one standard deviation from the average of the rotation calculations. In this manner, erroneous rotation calculations do not affect the weighted average.

Step 80 is an image rotation determination step. This step is somewhat similar to step 70 in that changes in translation of pixel block pairs from the key field to the new field are used to calculate rotation.

In step 82, the difference in horizontal translation is calculated for each pixel block pair in each of the smallest pixel block subdivision columns. The difference in horizontal translation for each pair of pixel blocks, divided by the distance between the pixel block centers, is calculated for each column of the key area. This calculation gives the rotation for each pixel block pair in each column. For example, if a pixel block in a column moved to the right 1 pixel while another pixel block 300 pixels away in the column moved to the left 2 pixels from the key field to the new field, the difference in horizontal translation would be 3 pixels and the rotation of the pixel block pair would be 0.57° (a 3 pixel difference in displacement over a 300 pixel distance gives an angle with a tangent of 3°/300, or an angle of 0.57°).

In step 84, the difference in vertical translation is calculated for each pixel block pair in each of the smallest pixel block subdivision rows. The difference in vertical translation for each pair of pixel blocks, divided by the distance between the pixel block centers, is calculated for each row of the key area. This calculation gives the rotation for each pixel block pair in each row.

In step 86, the overall rotation of the image from the key field to the new field is calculated. A weighted average of the individual pixel block pair rotations determined in steps 82 and 84 is calculated, with the rotations for more widely spaced apart pixel block pairs being weighted more than those for relatively closely spaced pixel block pairs, since widely spaced apart pixel blocks are more sensitive to rotation. Additionally, individual pixel block pair rotation calculations may be excluded from the weighted average if their values are significantly different from the average, for example, a pixel block pair rotation calculation may be excluded from the weighted average calculation if it is more than one standard deviation from the average of the rotation calculations. In this manner, erroneous rotation calculations do not affect the weighted average.

Step 90 is an image translation determination step. Recall that an approximation of the image translation from the key field to the new field was determined in step 50. However, since steps 60, 70 and 80 above have provided determinations of the individual translations of the smallest pixel block subdivision pixel blocks, the change in magnification of the image and the rotation of the key area from the key field to the new field, a precise determination of the key area translation may now be made.

In step 92, the translation determined in step 60 for each of the smallest pixel block subdivision pixel blocks is corrected for the change in magnification determined in step 70. This correction is performed by subtracting the horizontal and vertical translations of each of the pixel blocks which are due to the change in magnification from the key field to the new field from the overall horizontal and vertical translations of the respective pixel blocks as determined in step 60.

In step 94, the translation determined in step 60 for each of the smallest pixel block subdivision pixel blocks is further corrected for the rotation determined in step 80. This correction is performed by subtracting the horizontal and vertical translations of each of the pixel blocks which are due to the key area rotation from the key field to the new field from the overall horizontal and vertical translations of the respective pixel blocks as determined in step 60 and corrected for change in magnification in step 92.

In step 96, the overall horizontal and vertical translation for the center of the key area is calculated by averaging the individual horizontal and vertical translations of the smallest pixel block subdivision pixel blocks as corrected in steps 92 and 94. Here again, the data mask is used to exclude translation values from masked pixel blocks. Additionally, individual translation values may be excluded if their values are significantly different from the average.

Step 100 is a pre-processing step in which the results of steps 70, 80 and 90 are used to pre-process a subsequent field in the video sequence. In this manner, the subsequent field is placed in a condition in which it should more closely match the key field. The determinations of translation, rotation and magnification change of the key area from the key field to the new field are used to perform an initial de-translation, de-rotation and de-magnification of the subsequent field. It is to be clearly understood that use of the term "subsequent" herein to describe a video field does not necessarily signify that the video field is positioned later in the video sequence, but is used to signify that the video field is processed subsequently in the method 10. For example, a "subsequent" video field may actually be positioned earlier in time in a video sequence, since a video sequence may be processed from back to front (later to earlier in time), from the middle to either end, etc.

In step 102, the image contained in the subsequent field is de-translated, that is, it is translated horizontally and verti-
A method of stabilizing a video image of interest displayed in multiple video fields of a video sequence, the method comprising the steps of:

1. Subdividing a selected area of a first video field into nested pixel blocks including multiple levels of progressively smaller pixel block subdivisions, the area containing the video image; and
2. Determining horizontal and vertical translation of each of the pixel blocks in each of the pixel block subdivision levels from the first video field to a second video field.

The result of these steps is that, for each video field in the video sequence, a change in magnification, rotation and translation of the key area is determined. The video sequence may then be modified by de-magnifying, de-rotating and de-translating each video field in the video sequence, other than the key field, so that the image contained in the key area appears motionless and at the same magnification and orientation through the entire video sequence.

Of course, a person of ordinary skill in the art, upon a careful consideration of the above description of the method, would readily appreciate that modifications, additions, substitutions, deletions and other changes may be made to the method as described above and depicted in the accompanying drawings, which is but a single embodiment of the invention, and these changes are contemplated by the principles of the present invention. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the present invention being limited solely by the appended claims.

What is claimed is:

1. A method of stabilizing a video image of interest displayed in multiple video fields of a video sequence, the method comprising the steps of:

2. The method according to claim 1, further comprising the step of masking selected ones of the pixel blocks which are not of interest.

3. The method according to claim 1, further comprising the step of masking selected ones of the pixel blocks which have a scale of variations smaller than a predetermined value.

4. The method according to claim 1, further comprising the step of determining change in magnification of the image from the first video field to the second video field.

5. The method according to claim 1, further comprising the step of determining rotation of the image from the first video field to the second video field.

6. A method of stabilizing a video image of interest displayed in multiple video fields of a video sequence, the method comprising the steps of:

7. A method of stabilizing a video image of interest displayed in multiple video fields of a video sequence, the method comprising the steps of:

8. A method of stabilizing a video image of interest displayed in multiple video fields of a video sequence, the method comprising the steps of:

9. A method of stabilizing a video image of interest displayed in multiple video fields of a video sequence, the method comprising the steps of:

10. A method of stabilizing a video image of interest displayed in multiple video fields of a video sequence, the method comprising the steps of: