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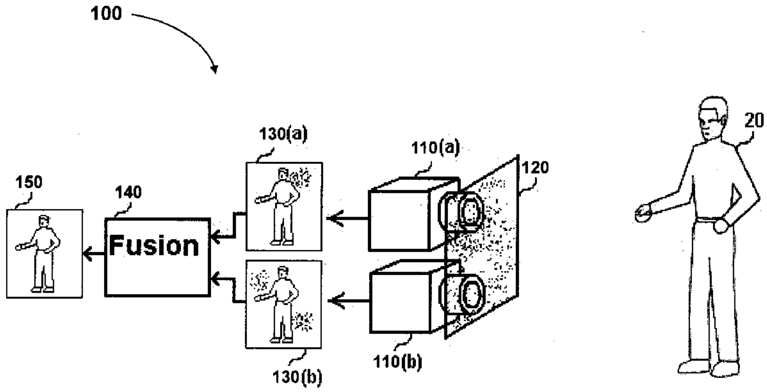

Fig 1

(57) Abstract: A computerized image acquisition system for reducing noise in an acquired image frame and methods of using thereof. The system includes multiple optical image acquisition devices, each having substantially the same field of view and aligned to view substantially the same scene. The system further includes an image fusion module, wherein at least two of the image acquisition devices synchronously acquire image frames, wherein correspondence is determined between the acquired image frames, wherein distorted pixels are determined in either of the corresponding image frames, and wherein the image fusion module fuses the corresponding image frames to form a fused image frame, wherein the determined distorted pixels are compensated for in the fused image frame.

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METHODS FOR COMPENSATING FOR LIGHT DISTORTIONS RELATED NOISE IN A CAMERA SYSTEM HAVING MULTIPLE IMAGE SENSORS

RELATED APPLICATION

The present application claims the benefit of US provisional application 61/167,226 filed on April 7th, 2009, the disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to imaging systems, and more particularly, the present invention relates to an imaging system with light distortions compensation system and methods.

BACKGROUND OF THE INVENTION AND PRIOR ART

An image frame acquired by an image sensor is generally subjected to light distortions caused by elements that block at least a portion of the light from reaching at least a portion of the image sensor array. The blocking elements can be dirt, glass defects and/or liquid such as rain drops, sun light rays dispersed towards the image sensor array after hitting dirt elements and other.

Typically, dirt causes at least partial blocking of the light and thereby blocked sensor array pixels sense less energy. Typically, glass defects and/or liquid such as rain drops, cause blurring effect on the acquire image frame. Typically, sun light rays dispersed towards the image sensor array causes high energy spot sensed by sensor array pixels.

There is therefore a need for and it would be advantageous to have a camera system with a noise cancelation device to undo at least a portion of the light distortions caused by elements that block at least a portion of the light from reaching at least a portion of the image sensor array.

SUMMARY OF THE INVENTION

According to teachings of the present invention, there is provided a computerized image acquisition system for reducing light distortions related noise in an acquired image frame. The system includes multiple optical image acquisition devices, each having substantially the same field of view (FOV), each configured to acquire one or more image frames and aligned to view substantially the same scene. The system further includes an image fusion module, wherein at least two of the image acquisition devices synchronously acquire image frames, wherein alignment offset parameters are determined between each pair of image acquisition devices, wherein correspondence is determined between the acquired image frames, wherein distorted pixels are determined in either of the corresponding image frames, and wherein the image fusion module fuses the corresponding image frames to form a fused image frame, wherein the determined distorted pixels are compensated for in the fused image frame. The correspondence is determined between image frames, acquired by a pair of the image acquisition devices substantially simultaneously, including by using the alignment offset parameters.

It should be noted that in general, the present invention is described, with no limitations, in terms of an image acquisition system having two image acquisition devices. But the present invention is not limited to two image acquisition devices, and in variations of the present invention, the image acquisition system can be similarly embodied with three image acquisition devices and more.

According to further teachings of the present invention, there is provided a method for reducing light distortions related noise in an acquired image frame by a computerized image acquisition system, the system including multiple optical image acquisition devices, optionally video cameras, each having substantially the same FOV and aligned to view substantially the same scene and each configured to acquire one or more image frames and aligned to view substantially the same scene. Preferably, each pair of image sensor arrays of adjacently disposed optical image acquisition devices are calibrated whereby obtaining alignment parameter between the adjacently disposed image sensor arrays of the pair.

The method includes the steps of:

a) acquiring image frames by at least two of the image acquisition devices;

b) determining corresponding image frames, acquired synchronously, including using the alignment offset parameters;

c) selecting a first image acquisition device from the image acquisition devices, and a second image acquisition device from the image acquisition devices;

d) selecting a pair of respective image frames from the corresponding image frames, the pair having a first image frame, acquired by the first image acquisition device, and a second image frame, acquired by the second image acquisition device, wherein the first image frame and the second image frame have been acquired substantially simultaneously;

e) determining distorted pixels in either of the corresponding image frames by comparing the corresponding image frames; and

f) fusing the corresponding image frames into a fused image frame, wherein the determined distorted pixels are compensated for, in the fused image frame.

In a first embodiment of the present invention, the determining of the distorted pixels includes the step of summing up the first image frame and the second image frame, thereby creating a noise integrated image frame. The first image frame is also subtracted from the second image frame to create a difference image frame. The next step is to compute the absolute value of each pixel in the difference image frame thereby creating a noise image frame. Finally, adding the noise image frame from the noise integrated image frame thereby creating the fused image frame.

Preferably, in other embodiments of the present invention, the methods of the present invention further includes the step of subdividing the respective image frames of the pair of respective image frames into respective, spatially symmetric, first and second groups of pixels, wherein the subdividing is performed before fusing the respective image frames. A group of pixels includes NXM pixels, wherein N and M are integers. In some variations of the present invention, both N and M are equal to 1. In other variations of the present invention, both N and M are the dimensions of the corresponding image frames.

In a second embodiment of the present invention, the determining of the distorted pixels includes the step of setting the first image frame to be a primary image frame and the second image frame to be a secondary image frame. Then, for each pair of respective primary and secondary groups of pixels from said respective subdivided primary and secondary image frame, calculating a differential signal to noise factor between the respective primary and secondary groups of pixels, thereby creating a differential noise group.

The fusing of the primary image frame from the secondary image frame is performed on each pair of respective group of pixels in the primary image frame and the secondary image frame, as follows: if the differential noise group is less than a pre selected threshold values, the value of the respective group of output pixels in the fused image frame is set to be the value of each respective pixel in said primary group of pixels. Else, the value of the respective group of output pixels in the fused image frame is set to be the values of each respective pixel in the secondary image frame.

In a third embodiment of the present invention, the determining of the distorted pixels includes, for each pair of respective first and second groups of pixels from said respective subdivided first and second image frame, calculating a differential signal to noise factor between the respective first and second groups of pixels, thereby creating a differential noise group.

The fusing of the first image frame from the second image frame is performed on each pair of respective group of pixels in the first image frame and the second image frame, as follows: determining a first weight factor based as a function of the differential noise group, calculating a first weighted group of pixels, wherein each first weighted pixel in the first weighted group of pixels is assigned the product of the value of the respective pixel value in the first group of pixels and the first weight factor, determining a second weight factor based as a function of the differential noise group, calculating a second weighted group of pixels, wherein each second weighted pixel in the second weighted group of pixels is assigned the product of the value of the respective pixel value in the second group of pixels and the second weight factor, and setting the value of the individual pixels in the respective group of output pixels in the fused image frame, to be the normalized sum of the respective individual values of the first weighted pixel and the second weighted.

In a forth embodiment of the present invention, the determining of the distorted pixels includes the step of computing the average values of each pair of respective pixels of the respective image frames. The fusing of the corresponding image frames includes the step of setting the value of the respective pixels in the fused image frame to be the computed average value. In variations of the present invention, the computed average pixel values are weighed average values, whereas each pixel of the pair is multiplied by a weight factor, whereas the sum of the weight factors of each pair is 100%.

In variations of the present invention, the method further includes selecting a first image frame to be the primary image frame and a second image frame to be the secondary image frame, wherein the fusing creates a first fused image frame. the method also includes selecting the first image frame to be the secondary image frame and the second image frame to be the primary image frame, wherein the fusing creates a second fused image frame. Then, a final fused image frame is computed by averaging the first fused image frame with the second fused image frame.

In variations of the present invention, the computation of the differential noise group includes the steps of summing up the value of the individual pixels in the first group of pixels, thereby obtaining a first energy sum, summing up the value of the individual pixels in the second group of pixels, thereby obtaining a second energy sum subtracting the second energy sum from the first energy sum, thereby obtaining an energy differential noise group, and assigning the value of the energy differential noise group to the differential noise group.

In other variations of the present invention, to determine blurry groups of pixels, the computation of the differential noise group includes the measurement of image sharpness for primary and secondary images and subtracting the second sharpness from the first sharpness values, thereby obtain an sharpness differential noise group, then assigning the value of the sharpness differential noise group to the differential noise group. The sharpness value calculated individually to first and second groups of pixels by applying a filter to the said group of pixels, thereby obtaining a filtered group of pixels, summing up the absolute values of the individual pixels of the said filtered group thereby determining the sharpness of the said group of pixels. In variations of the present invention the filter is a high pass filter. In other variations of the present invention the filter is a band pass filter.

In still other variations of the present invention, to determine at least partially saturated groups of pixels, the computation of the differential noise group includes the steps of counting the number of pixels greater than a pre determined threshold value in the first group of pixels, thereby obtaining a first hot spot value, counting the number of pixels greater than the pre determined threshold value in the second group of pixels, thereby obtaining a second hot spot value, subtracting the second hot spot value from the first hot spot value, thereby obtaining a hot spot differential noise group, and assigning the value of the hot spot differential noise group to the differential noise group.

In still other variations of the present invention, the computation of the differential noise group combines several algorithms with weight factors, wherein the combination includes the steps of computing an energy product of the energy differential noise group and a pre determined weight factor, computing a sharpness product of the sharpness differential noise group and a pre determined weight factor, computing a hot spot product of the hot spot differential noise group and a pre determined weight factor, and summing up the energy product, the sharpness product and the hot spot product, thereby obtaining the differential noise group. It should be noted that the pre determined weight factor can be threshold value, a multiplication factor value or any other factor. The pre determined weight factor can also be computed dynamically, preferably using a Kalman filter.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will become fully understood from the detailed description given herein below and the accompanying drawings, which are given by way of illustration and example only and thus not limitative of the present invention, and wherein:

FIG. 1 is a block diagram illustration of an imaging system having a noise reduction device for a camera system, according to embodiments of the present invention;

FIG. 2 is a block diagram illustration of an imaging system having a noise reduction device, according to variations of the present invention;

FIG. 3 schematically illustrates an embodiment of a computerized noise reduction device for a camera system, according to some variations of the present invention, configured to perform a methodology built into an image fusion module;

FIG. 4 schematically illustrates an embodiment of a computerized noise reduction device for a camera system, according to other variations of the present invention, configured to perform a methodology built into an image fusion module;

FIG. 5 schematically illustrates schematically illustrates an embodiment for detecting energy loss type of light obstruction, in a computerized noise reduction device for a camera system, according to variations of the present invention;

FIG. 6 schematically illustrates schematically illustrates an embodiment for detecting sharpness loss type of light distortion, in a computerized noise reduction device for a camera system, according to variations of the present invention; and

FIG. 7 schematically illustrates schematically illustrates an embodiment for detecting hot spots type of light distortion, in a computerized noise reduction device for a camera system, according to variations of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided, so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. The methods and examples provided herein are only illustrative and not intended to be limiting.

By way of introduction, a principal intention of the present invention includes providing a noise reduction device for a camera system having two or more image sensors. In particular, the noise reduction device compensates for light distortions caused by elements that block at least a portion of the light from reaching at least a portion of the image sensor array.

The methodology behind the noise reduction device of the present invention includes two basic phases: noise detection and noise distortion compensation. The noise detection phase is based on one or more of the following method:

a) Light blocking type of noise, caused by opaque or semi-opaque elements, causes reduction in the light energy reaching the image sensor array.

b) Blurring type of noise, caused by clear elements such as water drops, glass defects and the like, causes scattering of the incoming light energy and thereby blurring at least a portion of the image.

c) Hot spots type of noise, caused by a light source such as sun light rays dispersed towards the image sensor array and thereby, causing high energy spot sensed by sensor array pixels.

Therefore, the present invention provides means for detecting the different type of light related noise.

In the present invention, the distortion compensation phase is performed by fusing two (or more) image frames synchronously acquired by two (or more) image sensors aligned to view substantially the same scene. The fusion of the two image frames is based on one or more of the following:

a) Selecting the image frame determined as having less noise.

b) Selecting regions from respective regions in the image frames, determined as having less noise.

c) Averaging the two image frames.

d) Weigh averaging, wherein the weigh is computed of from respective regions in the image frames.

The distortion compensation phase may be performed on the whole image, on groups of pixels or on individual pixels. For energy related noise, image energy is computed and compared in corresponding images. For blurring related noise, high pass or band pass filters may be used to detect the noise.

Reference is made to Figure 1, which is a block diagram illustration of an exemplary imaging system having a light distortions related noise reduction device **100** for a camera system, according to embodiments of the present invention. Noise reduction device **100** includes two image acquisition devices **110a** and **110b**, each of which yields respective image frames **130a** and **130b**, and image fusion module **140** which yields a single output image frame **150**. Image acquisition devices **110** are configured to acquire one or more image frames and have substantially the same FOV, pointing substantially to the same distal object **20**. Each camera has different noise sources, such as glass **120** having light distorting element such as dirt, and other noise sources, yielding different distortions in the respective image frames **130**. Image fusion module **140** processes image frames **130** to yield a single output image frame **150**, in which the noise of both cameras is substantially removed.

It should be noted that image acquisition devices **110a** and **110b** are preferably aligned, preferably in sub-pixel accuracy, to ensure that image acquisition devices **110a** and **110b** are pointing substantially to the same distal object **20**.

In variations of the present invention, more than two image acquisition devices **110** are employed in the noise reduction camera system.

Image fusion module **140** may be embodied in various methods, to operatively yield an output image frame **150**.

Reference is now made to Figure 3, which schematically illustrates a first embodiment of a computerized noise reduction device **300** for a camera system, configured to perform a methodology built into an image fusion module **340**. In the example shown in Figure 3, protecting glass **120** is covered with dirt spots **122**, which dirt spots **122** at least partially block light from reaching image acquisition devices **110a** and **110b**. Image frames **130a** and **130b** include respective noisy regions **132a** and **132b**, which respective noisy regions **132a** and **132b** are substantially different in the two image frames (**130a** and **130b**).

The methodology of the first embodiment includes the following steps:

a) adding image frames **130a** and **130b** by sum unit **342**, to yield a noise integrated frame **346a**;
b) computing the difference between frame **130a** and **130b** (absolute value) to yield a noise frame **346a**; and
c) adding noise frame **346a** to noise integrated frame **346a** whereby creating an output image frame **350**, which output image frame **350** has noisy regions **132a** and **132b** substantially removed.

Preferably, in other embodiments of the present invention, the methods of the present invention further includes the step of subdividing the image frames **130a** and **130b** into respective groups of pixels, the respective groups of pixels being spatially symmetric, wherein a first group of pixels represents a selected group of pixels from image frame **130a** and wherein a second group of pixels represents a selected group of pixels from image frame **130b**, wherein the subdividing is performed before fusing the image frames **130a** and **130b**. A group of pixels includes NXM pixels, wherein N and M are integers. In some variations of the present invention, both N and M are equal to 1. In other variations of the present invention, both N and M are the dimensions of the corresponding image frames.

Reference is now made to Figure 4, which schematically illustrates a second embodiment of a computerized noise reduction device **400** for a camera system, configured to perform a methodology built into an image fusion module **440**. In the example shown in Figure 4, protecting glass **120** is covered with dirt spots **122,** which dirt spots **122** at least partially block light from reaching image acquisition devices **110a** and **110b**. Image frames **130a** and **130b** include respective noisy regions **132a** and **132b,** which respective noisy regions **132a** and **132b** are substantially different in the two image frames (**130a** and **130b**). In the example shown in Figure 4, image frames **130a** and **130b** are tessellated into 16 groups of pixels to form respective tessellated image frames **446a** and **446b**.

The methodology of the second embodiment includes the following steps:

a) selecting image frame **130a** as the primary image frame and image frame **130b** as the secondary image frame;
b) for each pair of respective primary and secondary groups of pixels from the respective subdivided primary image frames **130a** and secondary image frame **130b**, calculating a differential signal to noise factor between the respective primary and secondary groups of pixels, thereby creating a differential noise group; and
c) to fuse image frames **130a** and **130b,** for each pair of respective group of pixels, performs the following steps:
    i. if the differential noise group is less than a pre selected threshold values, the value of the respective group of output pixels in fused image frame **450** is set to be the value of each respective pixel in the primary group of pixels; else
    ii. the value of the respective group of output pixels in image frame **450** the fused image frame is set to be the values of each respective pixel in the primary group of pixels.

In a third embodiment includes the following steps:

a) for each pair of respective first and second groups of pixels from the respective subdivided first image frames **130a** and second image frame **130b**, calculating a differential signal to noise factor between the respective primary and secondary groups of pixels, thereby creating a differential noise group; and

b) to fuse image frames **130a** and **130b**, for each pair of respective group of pixels, performs the following steps:

   i. determining a first weight factor based as a function of the differential noise group ;

   ii. calculating a first weighted group of pixels, wherein each first weighted pixel in the first weighted group of pixels is assigned the product of the value of the respective pixel value in the first group of pixels and the first weight factor;

   iii. determining a second weight factor based as a function of the differential noise group;

   iv. calculating a second weighted group of pixels, wherein each second weighted pixel in the second weighted group of pixels is assigned the product of the value of the respective pixel value in the second group of pixels and the second weight factor; and

   v. individual pixels in the respective group of output pixels in image frame **150,** to be the normalized sum of the respective individual values of the first weighted pixel and the second weighted.

A variety of computation method can be performed to compute the differential noise group. Different methods are used to determine the noise that can be caused by the different light distorting elements such as dirt, water drops and other noise sources.

Reference is now made to Figure 5, which schematically illustrates an embodiment for detecting energy loss type of light obstruction, in a computerized noise reduction device **500** for a camera system, configured to perform a methodology built into an image fusion module **540**. In the example shown in Figure 5, protecting glass **120** is covered with dirt spots **122,** which dirt spots **122** at least partially block light from reaching image acquisition devices **110a** and **110b**. Image frames **130a** and **130b** include respective noisy regions **132a** and **132b,** which respective noisy regions **132a** and **132b** are substantially different in the two image frames (**130a** and **130b**). In the example shown in Figure 5, image frames **130a** and **130b** are tessellated into 16 groups of pixels to form respective tessellated image frames **546a** and **546b**.

To determine pixels with energy loss, the computation of the differential noise group includes the steps of summing up the values of the individual pixels in a first group of pixels **547a** by a computational unit **544a**, thereby obtaining a first energy sum; summing up the values of the individual pixels in a second group of pixels **547b** by a computational unit **544b**, thereby obtaining a second energy sum; subtracting the second energy sum from the first energy sum, thereby obtaining an energy differential noise group, and assigning the value of the energy differential noise group to the differential noise group.

Reference is now made to Figure 6, which schematically illustrates an embodiment for detecting sharpness loss type of light distortion, in a computerized noise reduction device **600** for a camera system, configured to perform a methodology built into an image fusion module **640**. In the example shown in Figure 6, protecting glass **120** is covered with blurring elements **122,** which rain drops spots **122** blur at least a portion of image frames **130a** and **130b**. Image frames **130a** and **130b** include respective noisy regions **132a** and **132b,** which respective noisy regions **132a** and **132b** are substantially different in the two image frames (**130a** and **130b**). In the example shown in Figure 6, image frames **130a** and **130b** are tessellated into 16 groups of pixels to form respective tessellated image frames **646a** and **646b**.

To determine blurry groups of pixels, the computation of the differential noise group includes the steps of applying a filter **642a** to a first group of pixels **647a**, thereby obtaining a first filtered group of pixels, summing up (by a computational unit **648a**) the absolute values (computed by a computational unit **644a**) of the individual pixels of the first filtered value thereby determining the sharpness of the first group of pixels. Then, applying a filter **642b** to a first group of pixels **647b**, thereby obtaining a second filtered group of pixels, summing up (by a computational unit **648b**) the absolute values (computed by a computational unit **644b**) of the individual pixels of the second filtered value thereby determining the sharpness of the second group of pixels. The following steps include subtracting the sharpness of the second group of pixels from the sharpness of the first group of pixels, thereby obtaining a sharpness differential noise group, and assigning the value of the sharpness differential noise group to the differential noise group. In variations of the present invention the filter is a high pass filter. In other variations of the present invention the filter is a band pass filter.

Reference is now made to Figure 7, which schematically illustrates an embodiment for detecting hot spots type of light distortion, in a computerized noise reduction device **700** for a camera system, configured to perform a methodology built into an image fusion module **740**. Image frames **130a** and **130b** include respective noisy regions **132a** and **132b,** which respective noisy regions **132a** and **132b** are substantially different in the two image frames (**130a** and **130b**). In the example shown in Figure 7, image frames **130a** and **130b** are tessellated into 16 groups of pixels to form respective tessellated image frames **746a** and **746b**.

To determine pixels with at least partially saturated groups of pixels, computation of the differential noise group includes the steps of counting the number of pixels greater than a pre determined threshold value (computed by a Comparator **742a**) in a first group of pixels **747a** by a counter **744a**, thereby obtaining a first hot spot value, counting the number of pixels greater than the pre determined threshold value (computed by a Comparator **742b**) in the second group of pixels **747b** by a counter **744b**, thereby obtaining a second hot spot value, subtracting the second hot spot value from the first hot spot value, thereby obtaining a hot spot differential noise group, and assigning the value of the hot spot differential noise group to the differential noise group.

In still other variations of the present invention, the computation of the differential noise group includes the steps of computing an energy product of the energy differential noise group and a pre determined weight factor, computing a sharpness product of the sharpness differential noise group and a pre determined weight factor, computing a hot spot product of the hot spot differential noise group and a pre determined weight factor, and summing up the energy product, the sharpness product and the hot spot product, thereby obtaining the differential noise group.

In a fourth embodiment, the methodology of image fusion module **140** includes the following steps:

a) setting the value of the individual pixels of output image frame **150** to be the average of the respective individual pixel values of image frames **130a** and **130b**.

In a fifth embodiment, the methodology of image fusion module **140** includes the following steps:

a) computing weighed value of each pair of corresponding pixels (or groups of pixels), whereas the sum of the weight factors of each pair is 100%.

b) setting the value of the individual pixels of output image frame **150** to be the weigh average of the respective individual pixel weighed values of image frames **130a** and **130b**.

In a sixth embodiment, the methodology of image fusion module **140** includes the following steps:

a) computing the energy of image frame **130a**;
b) computing the energy of image frame **130b**; and
c) determining:
    i. if the energy of image frame **130a** is less than the energy of image frame **130b**, setting the corresponding output image frame **150** to be image frame **130b**; else
    ii. setting the corresponding output image frame **150** to be image frame **130a**.

Reference is made to Figure 2, which is a block diagram illustration of an exemplary imaging system having noise reduction device **200**, according to variations of the present invention. As in system **100**, imaging system **200** includes two image acquisition devices **110a** and **110b** for acquiring respective image frames **130a** and **130b**. Both image acquisition devices **110** have substantially the same FOV and pointing substantially to the same distal object **20**. Imaging system **200** further includes an image sensor fusion module **140a** which fusion module selects valid pixels/groups-of-pixels from either image frames **130a** and **130b** to yield a single output image frame **150a**, an image fusion module **140b** which fusion module selects valid pixels/groups-of-pixels from either image frames **130a** and **130b** to yield a single output image frame

150b, an averaging module **240,** which averaging module averages image frames **150a** and **150b** to yield a single output image frame **250**.

In a seventh embodiment, the methodology of image fusion modules **140a, 140b** and averaging module **240** includes the following steps:

a) selecting image frame **130a** as the primary image frame and image frame **130b** as the secondary image frame, wherein fusing image frame **130a** and image frame **130b** creates a first fused image frame **150a**;
b) selecting image frame **130b** as the primary image frame and image frame **130a** as the secondary image frame, wherein fusing image frame **130a** and image frame **130b** creates a second fused image frame**150b**; and
c) averaging each pair of pixels from image frames **150a** and **150b** and setting the value of a corresponding final output pixel in image frame **250** to the computed average.

The invention being thus described in terms of embodiments and examples, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the claims.

WHAT IS CLAIMED IS:

1. In a computerized image acquisition system, including multiple optical image acquisition devices each having substantially the same field of view (FOV), each configured to acquire one or more image frames and aligned to view substantially the same scene, a method for reducing noise in an acquired image frame comprising the steps of:

a) acquiring image frames by at least two of said image acquisition devices;
b) determining corresponding image frames, acquired synchronously;
c) selecting a first image acquisition device from said image acquisition devices, and a second image acquisition device from said image acquisition devices;
d) selecting a pair of respective image frames from said corresponding image frames, said pair having a first image frame, acquired by said first image acquisition device, and a second image frame, acquired by said second image acquisition device, wherein said first image frame and said second image frame have been acquired substantially simultaneously;
e) determining distorted pixels in either of said respective image frames by comparing said respective image frames; and
f) fusing said respective image frames into a fused image frame, wherein said determined distorted pixels are compensated for, in said fused image frame.

2. The method as in claim 1, wherein said optical image acquisition devices are video cameras.

3. The method as in claim 1 further comprises a preliminary step of alignment between said first image acquisition device and said second image acquisition device, thereby obtaining alignment offset parameters, wherein said determining corresponding image frames includes using said alignment offset parameters.

4. The method as in claim 1, wherein said determining of said distorted pixels comprises the steps of:

a) adding said first image frame and said second image frame thereby creating a noise integrated image frame;

b) subtracting said first image frame from said second image frame thereby creating a difference image frame;
c) computing the absolute value of each pixel in said difference image frame thereby creating a noise image frame; and

wherein said fusing of said first image frame with said second image frame, comprises the step of:

a) adding said noise image frame from said noise integrated image frame thereby creating said fused image frame.

5. The method as in claim 1 further comprising the step of:

a) subdividing said respective image frames of said pair of respective image frames into respective, spatially symmetric, first and second groups of pixels, wherein said subdividing is performed before said fusing said respective image frames.

6. The method as in claim 5, wherein said group of pixels comprises one pixel.

7. The method as in claim 5, wherein said group of pixels comprises NXM pixels, wherein N and M are integers.

8. The method as in claim 7, wherein N and M are the dimensions of said respective image frames.

9. The method as in claim 5, wherein said determining of said distorted pixels comprises the steps of:

a) setting said first image frame to be a primary image frame and said second image frame to be a secondary image frame;
b) selecting a pair of respective primary and secondary groups of pixels from said respective subdivided primary and secondary image frame;
c) calculating a differential signal to noise factor between said respective primary and secondary groups of pixels, thereby creating a differential noise group; and
d) repeating steps (b) and (c) for each of said pair of respective primary and secondary groups of pixels, and

wherein said fusing of said primary image frame with said secondary image frame, comprises the steps of:

a) for each pair of respective first and second groups of pixels in said primary image frame and said secondary image frame:

i) if said differential noise group is less than a pre selected threshold value, setting the value of the individual pixels in the respective group of output pixels in said fused image frame to be the value of each respective pixel in said primary group of pixels; else

ii) setting the value of the individual pixels in the respective group of output pixels in said fused image frame to be the values of each respective pixel in said secondary group of pixels.

10. The method as in claim 5, wherein said determining of said distorted pixels comprises the steps of:

a) selecting a pair of respective first and second groups of pixels from said respective subdivided first and second image frame;
b) calculating of a differential signal to noise factor between said respective first and second groups of pixels, thereby creating a differential noise group; and
c) repeating steps (a) and (b) for each of said pair of respective primary and secondary groups of pixels, and

wherein said fusing of said first image frame with said second image frame, comprises the steps of:

a) for each pair of respective first and second groups of pixels in said first image frame and said second image frame:

i) determining a first weight factor based as a function of said differential noise group;

ii) calculating a first weighted group of pixels, wherein each first weighted pixel in said first weighted group of pixels is assigned the product of the value of the respective pixel value in said first group of pixels and said first weight factor;

iii) determining a second weight factor based as a function of said differential noise group;

iv) calculating a second weighted group of pixels, wherein each second weighted pixel in said second weighted group of pixels is assigned the product of the value of the respective pixel value in said second group of pixels and said second weight factor; and

v) setting the value of the individual pixels in the respective group of output pixels in said fused image frame, to be the normalized sum of the respective individual values of said first weighted pixel and said second weighted.

11. The method as in claims 9 and 10, wherein computing said differential noise group comprises the steps of:

a) summing up the value of the individual pixels in said first group of pixels, thereby obtaining a first energy sum;
b) summing up the value of the individual pixels in said second group of pixels, thereby obtaining a second energy sum;
c) subtracting said second energy sum from said first energy sum, thereby obtaining an energy differential noise group; and
d) assigning the value of said energy differential noise group to said differential noise group.

12. The method as in claims 9 and 10, wherein computing said differential noise group comprises the steps of:

a) applying a filter to said group of pixels said first group of pixels, thereby obtaining a first filtered group of pixels;
b) summing up the absolute values of the individual pixels of said first filtered value thereby determining the sharpness of said first group of pixels;
c) applying a filter to said group of pixels said second group of pixels, thereby obtaining a second filtered group of pixels;
d) summing up the absolute values of the individual pixels of said second filtered value thereby determining the sharpness of said second group of pixels;

e) subtracting said sharpness of said second group of pixels from said sharpness of said first group of pixels, thereby obtaining a sharpness differential noise group; and
f) assigning the value of said sharpness differential noise group to said differential noise group.

13. The method as in claim 12, wherein said filter is a high-pass filter.

14. The method as in claim 12, wherein said filter is a band-pass filter.

15. The method as in claims 9 and 10, wherein computing said differential noise group comprises the steps of:
a) counting the number of pixels greater than a pre determined threshold value in said first group of pixels, thereby obtaining a first hot spot value;
b) counting the number of pixels greater than said pre determined threshold value in said second group of pixels, thereby obtaining a second hot spot value;
c) subtracting said second hot spot value from said first hot spot value, thereby obtaining a hot spot differential noise group; and
d) assigning the value of said hot spot differential noise group to said differential noise group.

16. The method as in claims 11, 12 and 15, wherein computing said differential noise group comprises the step of:
a) computing an energy product of said energy differential noise group and a pre determined weight factor;
b) computing a sharpness product of said sharpness differential noise group and a pre determined weight factor;
c) computing a hot spot product of said hot spot differential noise group and a pre determined weight factor; and
d) summing up said energy product, said sharpness product and said hot spot product, thereby obtaining said differential noise group.

17. The method as in claim 16, wherein said pre determined weight factor is a threshold value.

18. The method as in claim 16, wherein said pre determined weight factor is a multiplication factor value.

19. The method as in claims 16 and 18, wherein said pre determined weight factor is computed dynamically.

20. The method as in claim 19, wherein said dynamically computed utilizes a Kalman filter.

21. The method as in claim 1, wherein said determining of said distorted pixels comprises the steps of:

a) computing the average values of each pair of respective pixels of said respective image frames, and

wherein said fusing of said respective image frames, comprises the step of:

a) setting the value of the respective pixels in said fused image frame to be said computed average pixel values.

22. The method as in claim 21, wherein said computed average pixel values are weighed average values.

23. The method as in claims 9, 10, 11, 12, 13, 14 15, 16, 17, 18, 19, 20, 21, 22, further comprising the steps of:

a) selecting a first image frame to be said primary image frame and a second image frame to be said secondary image frame, wherein said fusing creates a first fused image frame;
b) selecting said first image frame to be said secondary image frame and said second image frame to be said primary image frame, wherein said fusing creates a second fused image frame; and
c) averaging said first fused image frame with said second fused image frame, thereby creating a fused image frame.

24. A computerized image acquisition system for reducing noise in an acquired image frame, including multiple optical image acquisition devices, each having substantially the same FOV, each configured to acquire one or more image frames and aligned to view substantially the same scene, the system comprising:

a) an image fusion module,

wherein at least two of said image acquisition devices synchronously acquire image frames;
wherein alignment offset parameters are determined between said two image acquisition devices;
wherein correspondence is determined between image frames, acquired by a pair of said image acquisition devices substantially simultaneously, including by using said alignment offset parameters;
wherein distorted pixels are determined in either of said corresponding image frames; and
wherein said image fusion module fuses said corresponding image frames to form a fused image frame, wherein said determined distorted pixels are compensated for in said fused image frame.

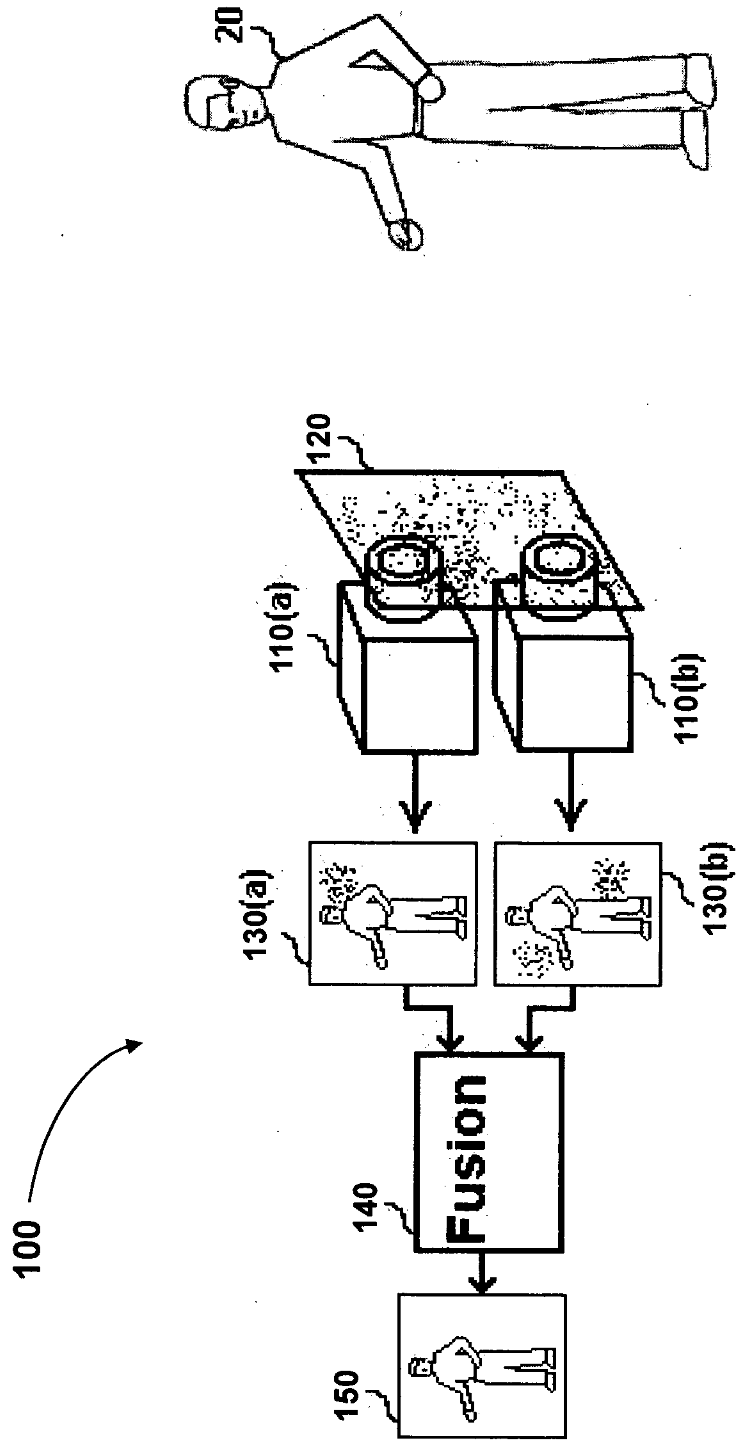

Fig 1

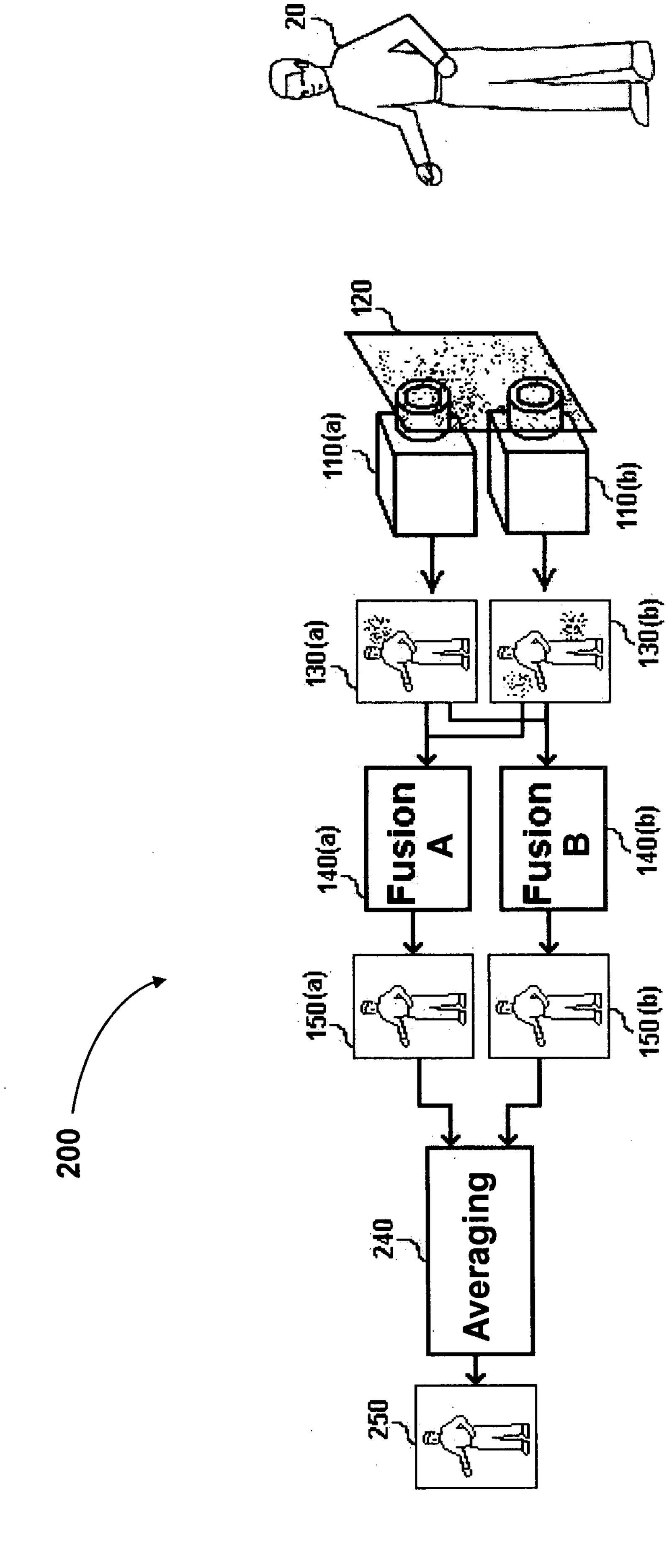
20
120
110(a)
110(b)
130(a)
130(b)
Fusion A
Fusion B
140(a)
140(b)
150(a)
150(b)
200
240
Averaging
250

Fig 2

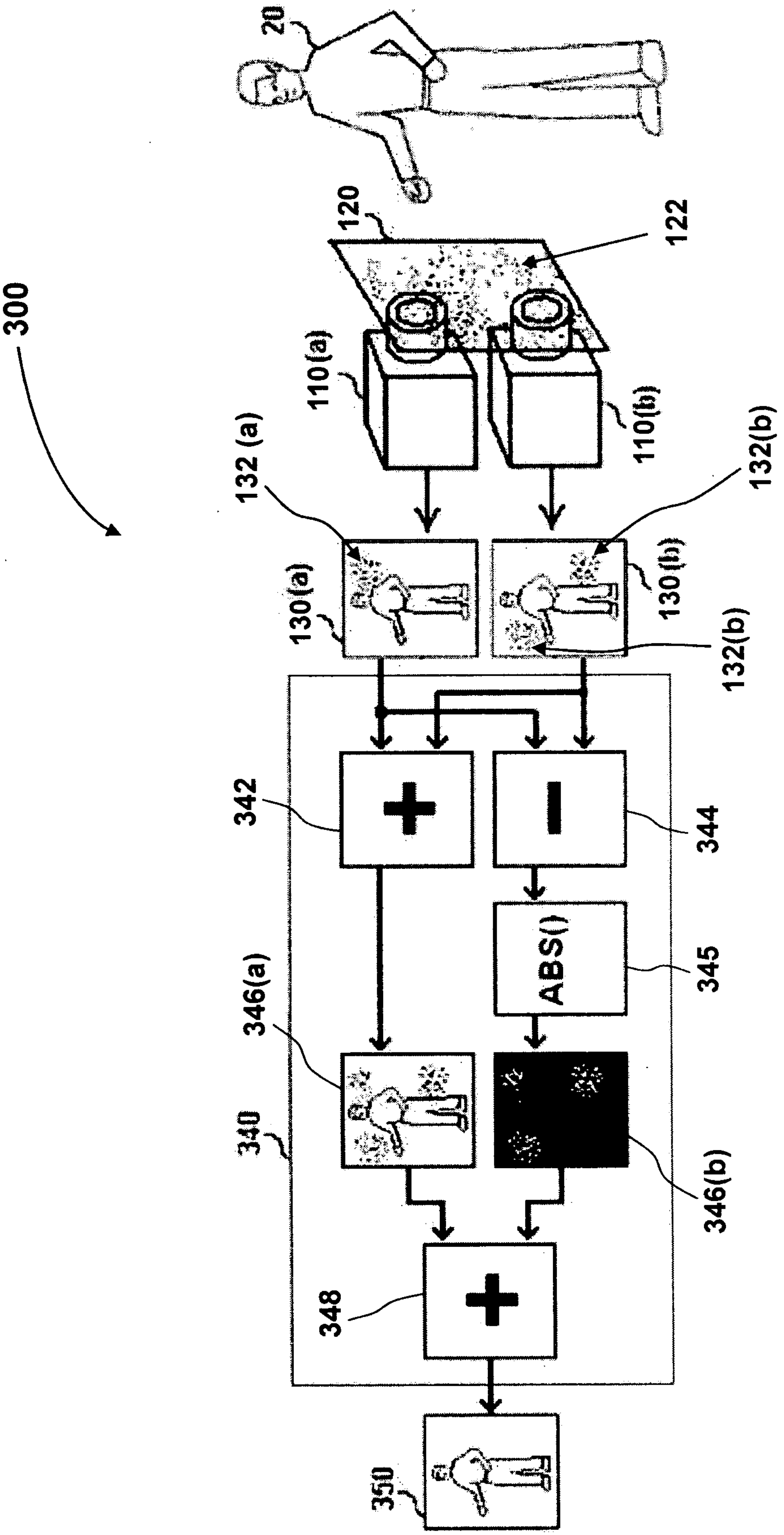
300
20
120
122
110(a)
110(b)
132 (a)
132(b)
130(a)
130(b)
132(b)
342
344
ABS()
345
346(a)
346(b)
340
348
350

Fig 3

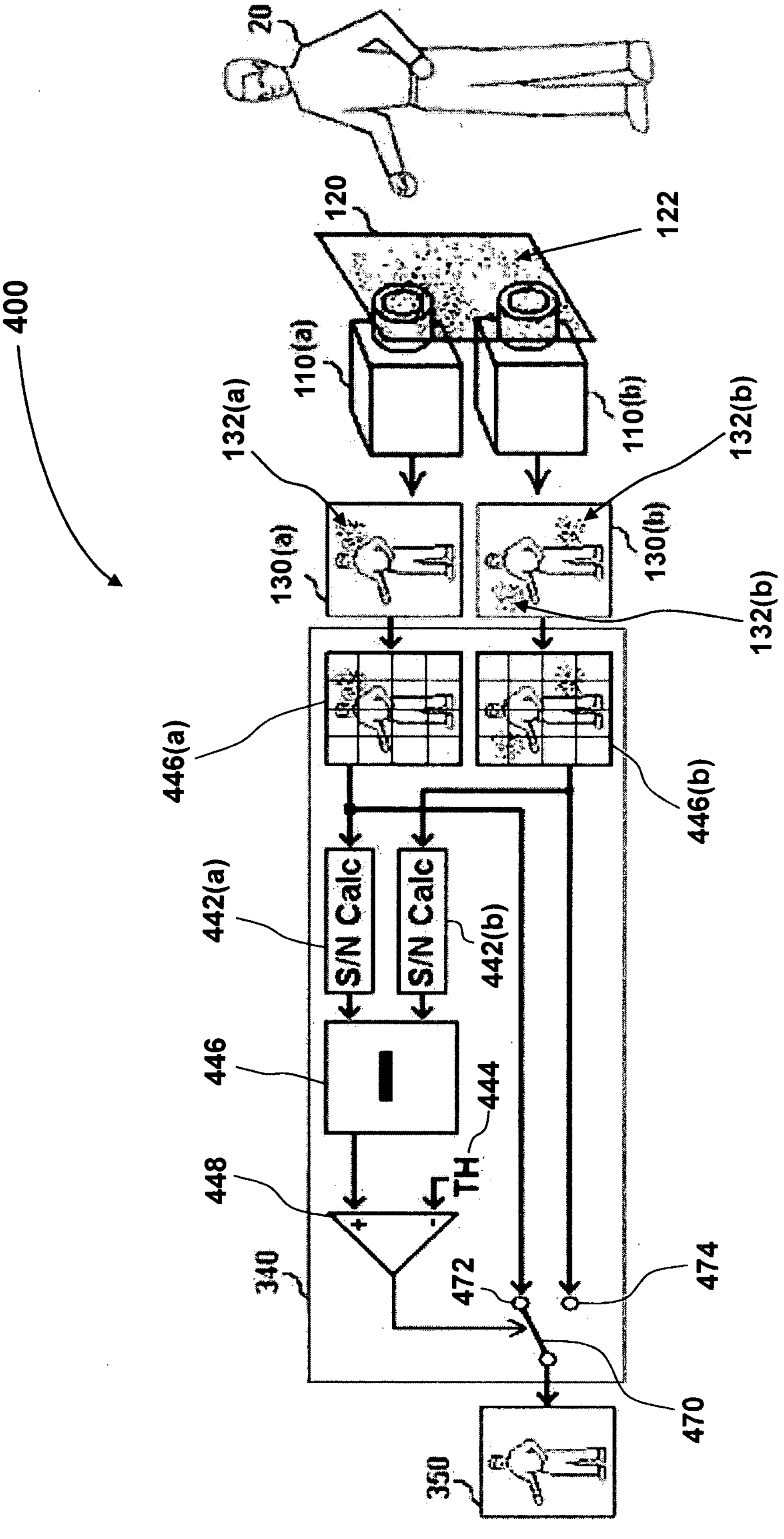
400
20
120
122
110(a)
110(b)
132(a)
132(b)
130(a)
130(b)
132(b)
446(a)
446(b)
S/N Calc
S/N Calc
442(a)
442(b)
446
444
TH
448
+
-
340
472
474
470
350

Fig 4

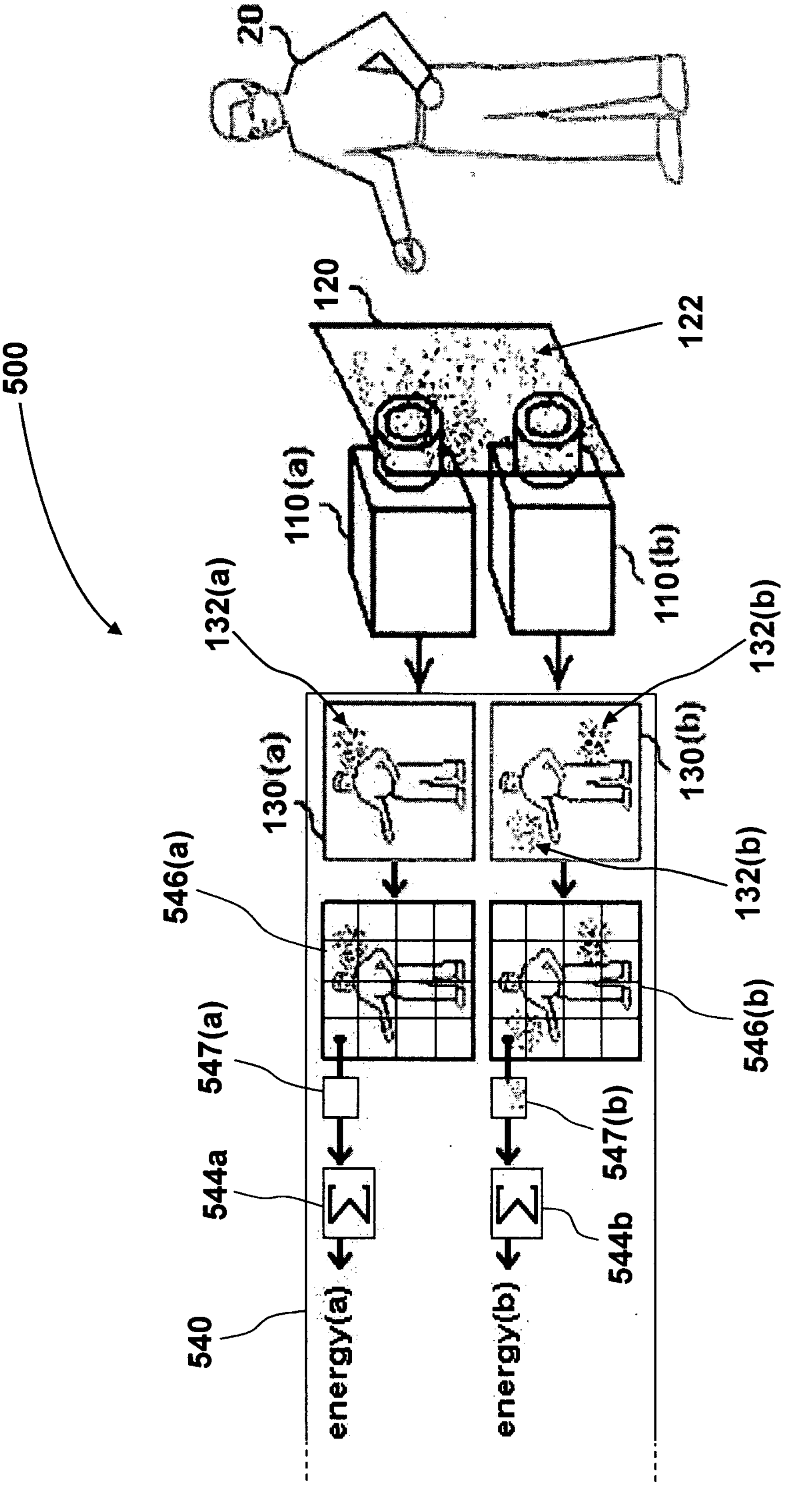
500
20
120
122
110(a)
110(b)
132(a)
132(b)
130(a)
130(b)
132(b)
546(a)
546(b)
547(a)
547(b)
544a
544b
540
energy(a)
energy(b)

Fig 5

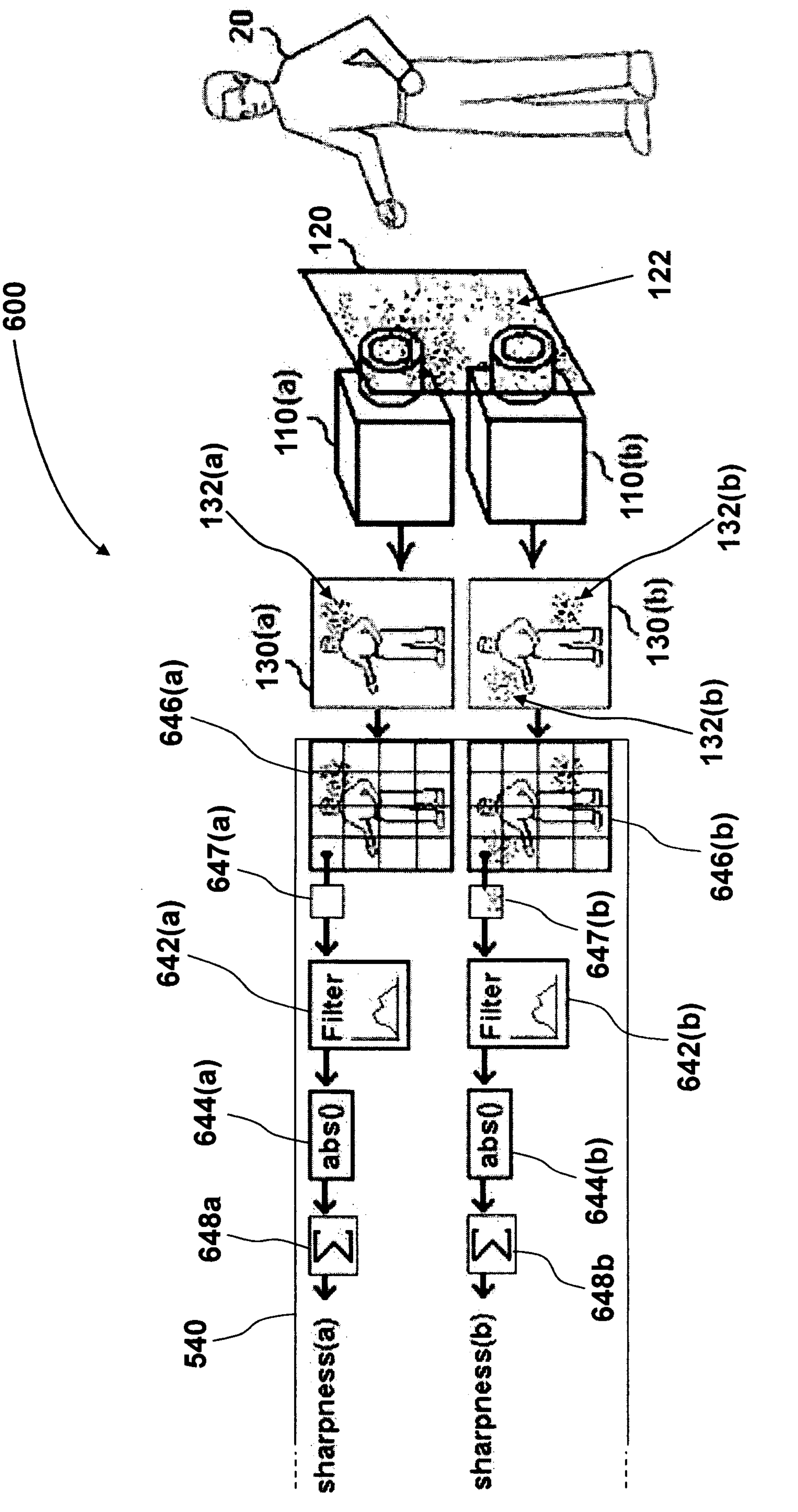
600
20
120
122
110(a)
110(b)
132(a)
132(b)
130(a)
130(b)
646(a)
646(b)
647(a)
647(b)
642(a)
642(b)
Filter
Filter
644(a)
644(b)
abs()
abs()
648a
648b
540
sharpness(a)
sharpness(b)

Fig 6

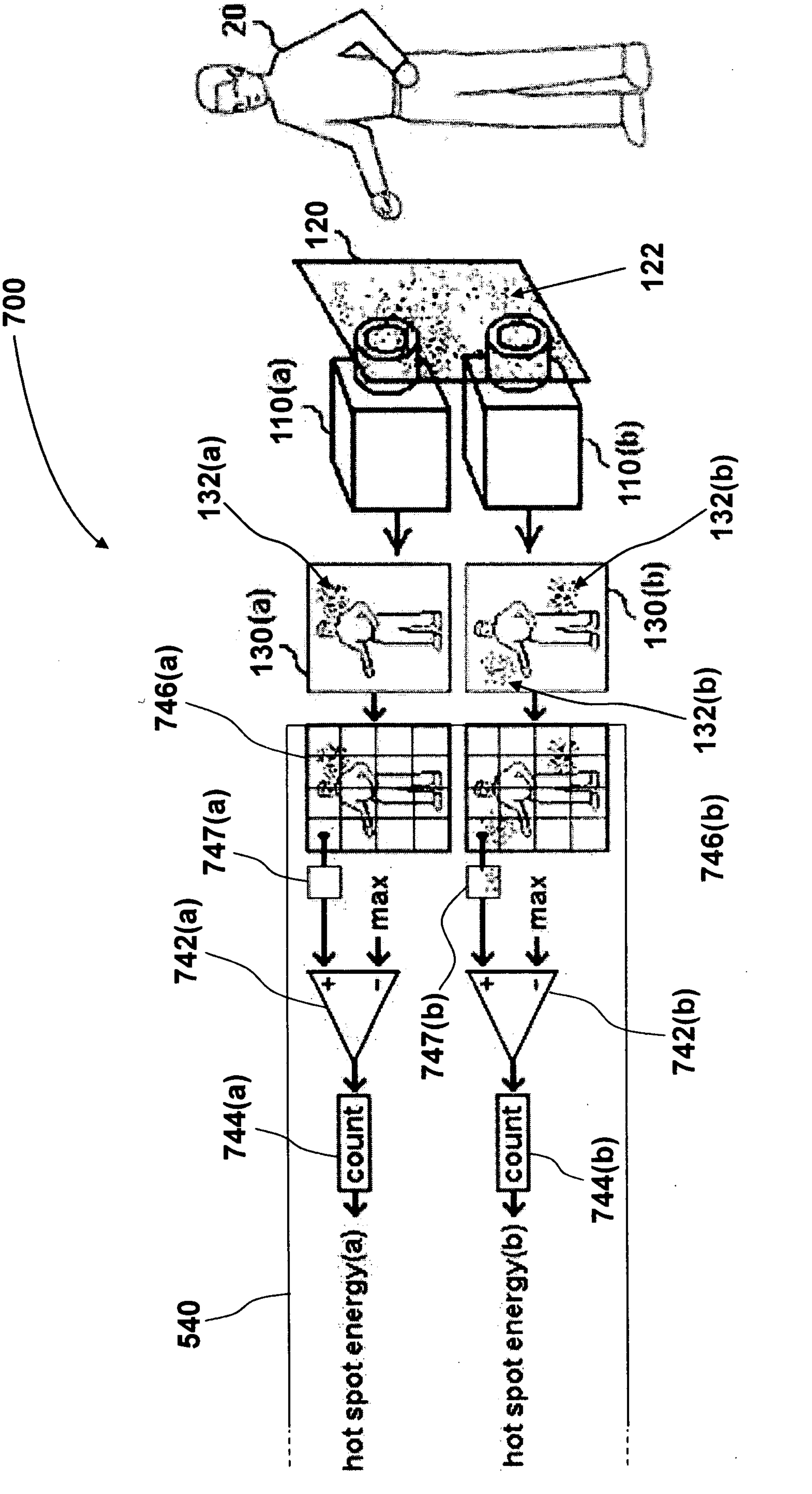
700
20
120
122
110(a)
110(b)
132(a)
132(b)
130(a)
130(b)
132(b)
746(a)
746(b)
747(a)
747(b)
max
max
742(a)
742(b)
744(a)
744(b)
count
count
hot spot energy(a)
hot spot energy(b)
540

Fig 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 10/00282

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - H04N 5/00 (2010.01)
USPC - 348/607
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 348/607

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 348/E3.043, 571, 607 (text search)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWest (PGPB, USPT, EPAB, JPAB), Google,
Search terms used: camera, image, acquisition, field, view, fuse, fusing, imag, reduc, noise , pixel, distor, video, noise, integrat, absolute, value, frame, dimension, frame, primary, signal, noise, secondary, weigh, average, offset, alignment

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US 2003/0053658 A1 (Pavlidis) 20 March 2003 (20.03.2003), para [0012]-[0014], [0054], [0070], [0095], [0110]-[0127], [0146]-[0147]	1, 2, 4-10, 21, 22, 24 --- 3
Y	US 2006/0082675 A1 (McGarvey et al.) 20 April 2006 (20.04.2006), para [0053]	3
A	US 2007/0035630 A1 (Lindenstruth et al.) 15 February 2007 (15.02.2007), entire document	1-10, 21, 22, 24

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 August 2010 (04.08.2010)	17 AUG 2010

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 10/00282

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 11-20 and 23
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.