US 20170277961A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2017/0277961 A1**

Kuehnle (43) **Pub. Date: Sep. 28, 2017**

(54) **AUTOMATIC SURROUND VIEW HOMOGRAPHY MATRIX ADJUSTMENT, AND SYSTEM AND METHOD FOR CALIBRATION THEREOF**

(71) Applicant: **Bendix Commercial Vehicle Systems LLC**, Elyria, OH (US)

(72) Inventor: **Andreas U. Kuehnle**, Villa Park, CA (US)

(21) Appl. No.: **15/081,019**

(22) Filed: **Mar. 25, 2016**

Publication Classification

(51) **Int. Cl.**

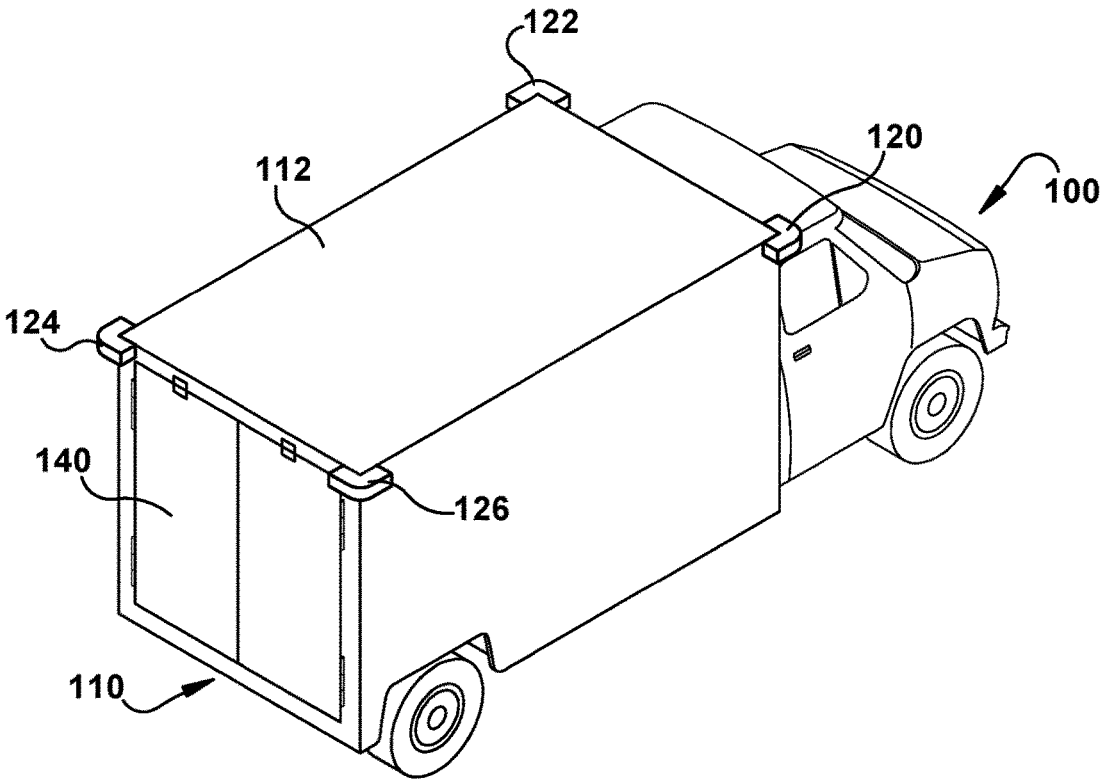
G06K 9/00	(2006.01)
G06T 7/00	(2006.01)
H04N 5/232	(2006.01)
H04N 5/247	(2006.01)
H04N 17/00	(2006.01)

(52) **U.S. Cl.**

CPC ***G06K 9/00805*** (2013.01); ***H04N 5/247*** (2013.01); ***H04N 17/002*** (2013.01); ***H04N 5/23229*** (2013.01); ***G06T 7/0042*** (2013.01); *G06T 2207/10004* (2013.01); *G06T 2207/30261* (2013.01)

(57) **ABSTRACT**

An imaging system adjusts a display of images obtained of an area to compensate for one or more relationships of cameras on a vehicle relative to a peripheral area. The system comprises a processor, an image obtaining unit, a non-transient memory, a situational compensation unit, and a display unit. The image obtaining unit receives first image data representative of a first image, and the memory stores intrinsic image coordinate transformation data representative of an intrinsic mapping between the first image data and first display data representative of an uncompensated bird's eye view image of the peripheral area of the associated vehicle. The situational compensation selectively modifies the intrinsic mapping as an adjusted intrinsic mapping between the first image data and the first display data in accordance with a signal representative of the one or more relationships of the associated vehicle relative to the peripheral area.



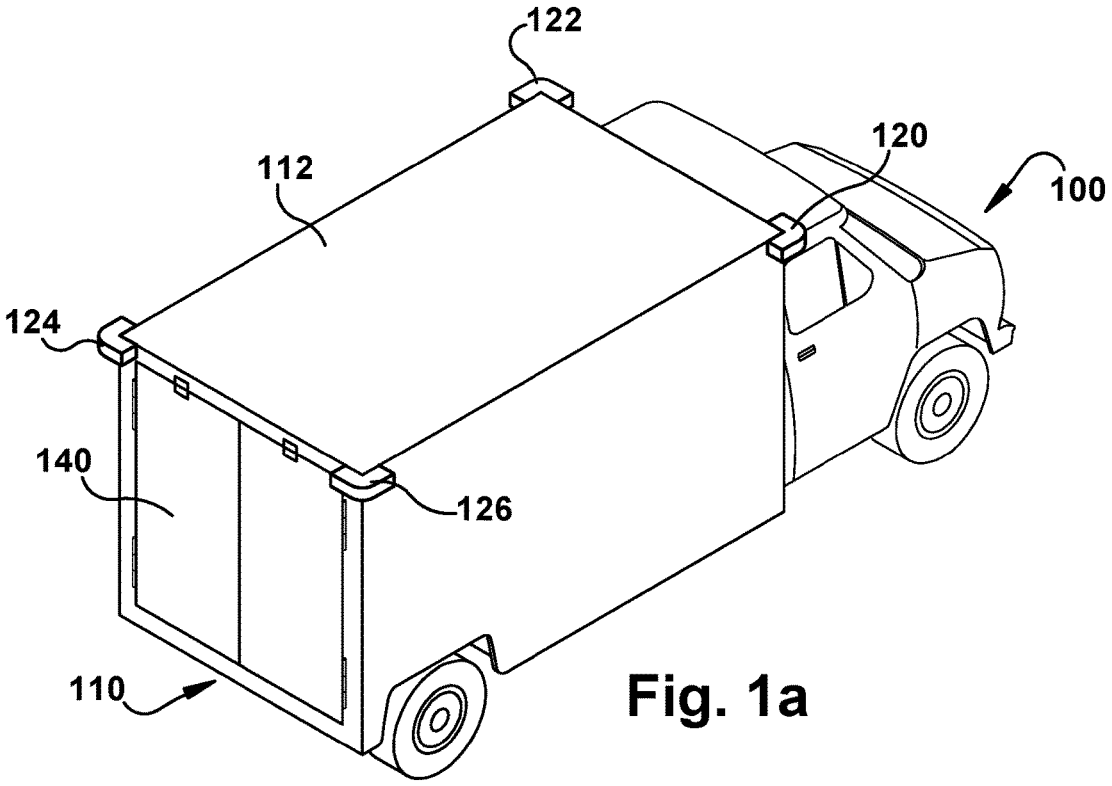


Fig. 1a

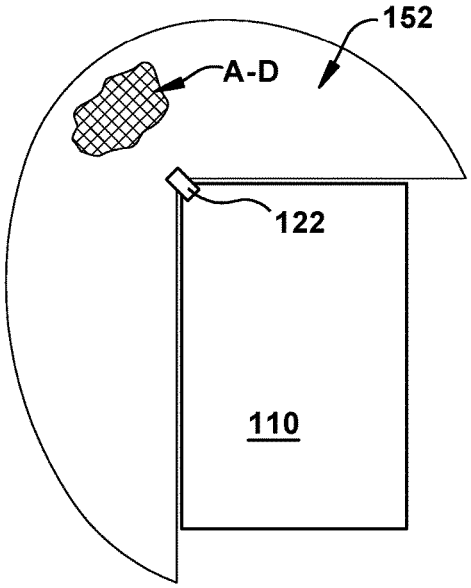


Fig. 1b

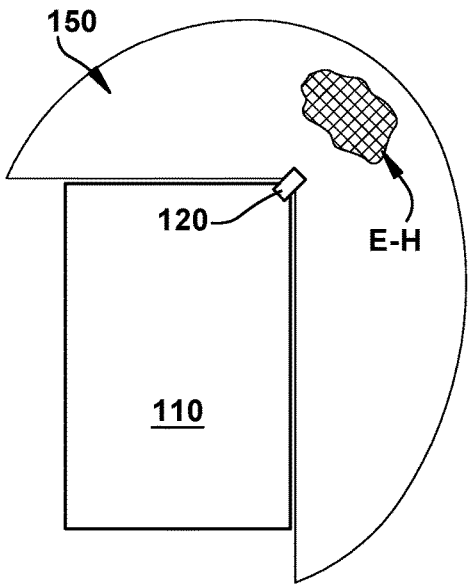


Fig. 1c

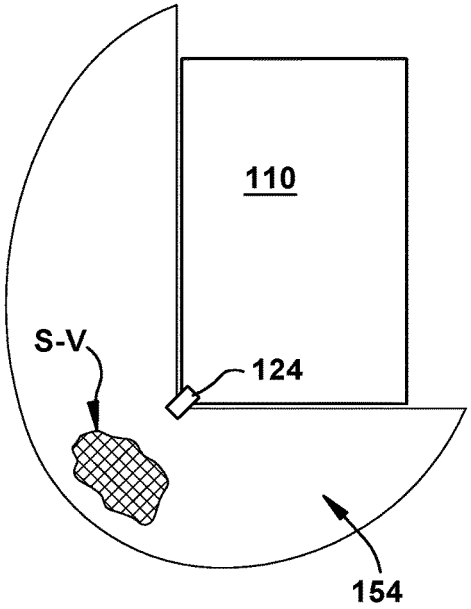


Fig. 1d

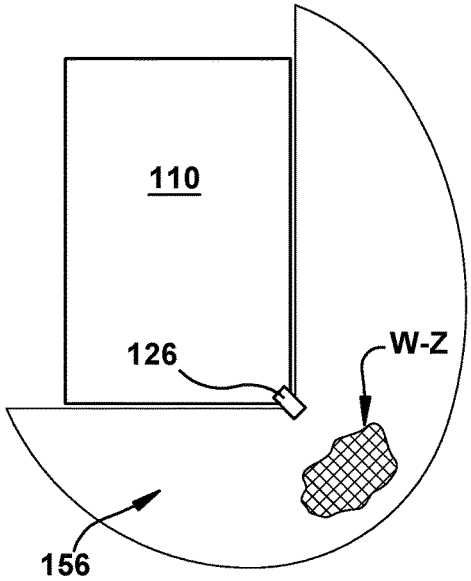


Fig. 1e

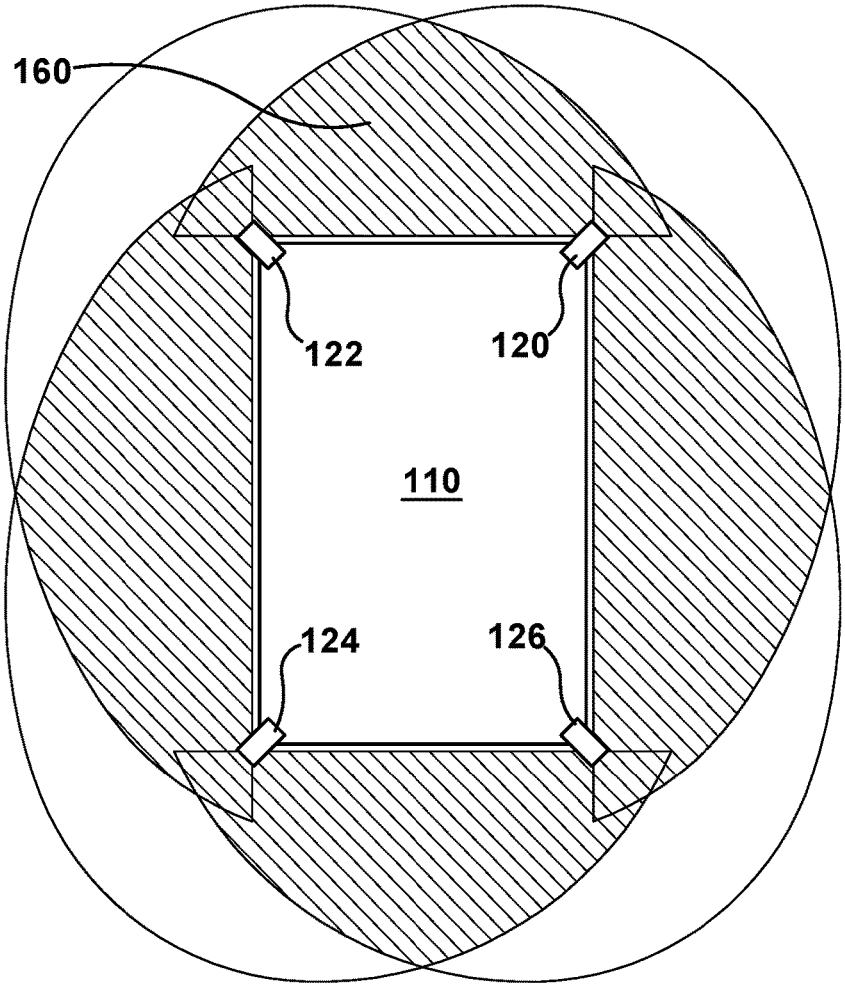


Fig. 1f

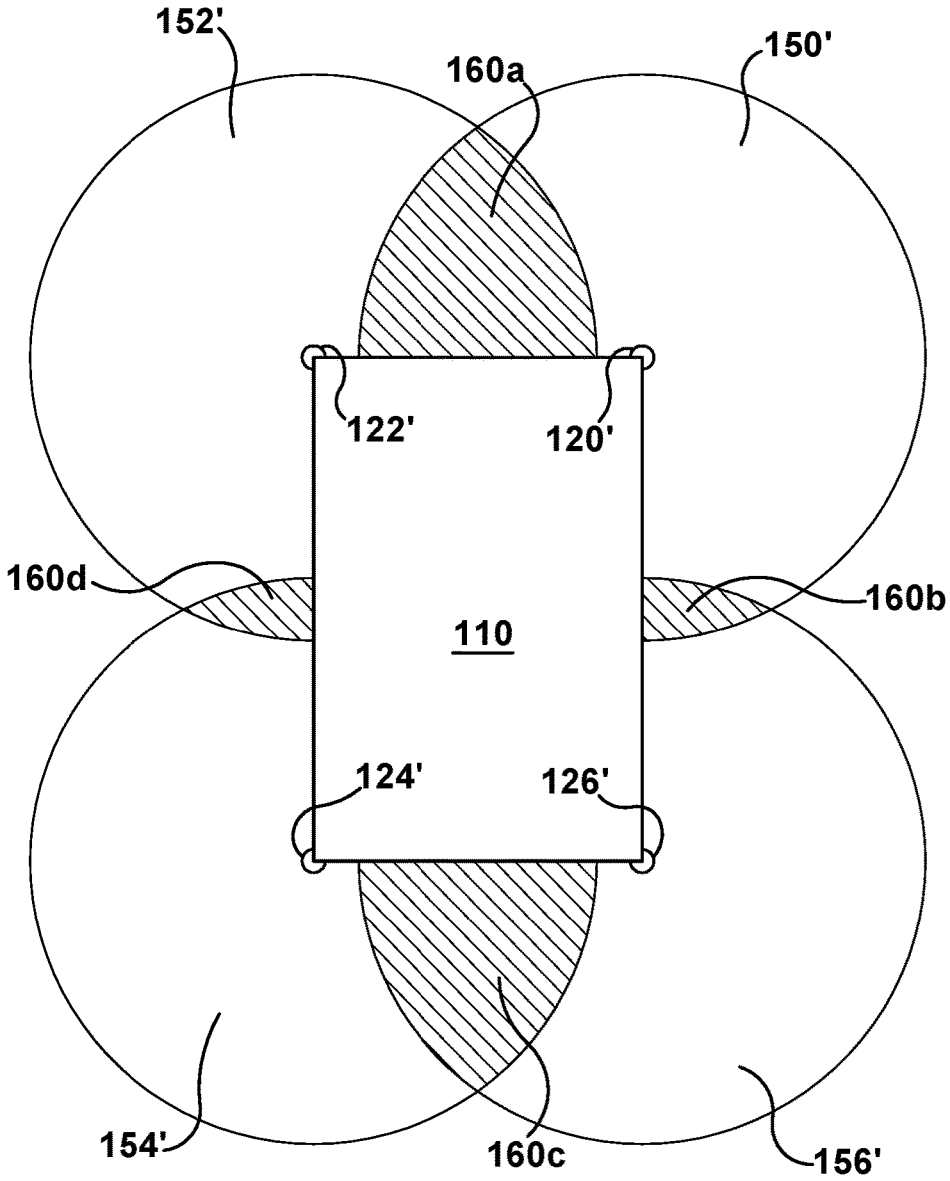


Fig. 1g

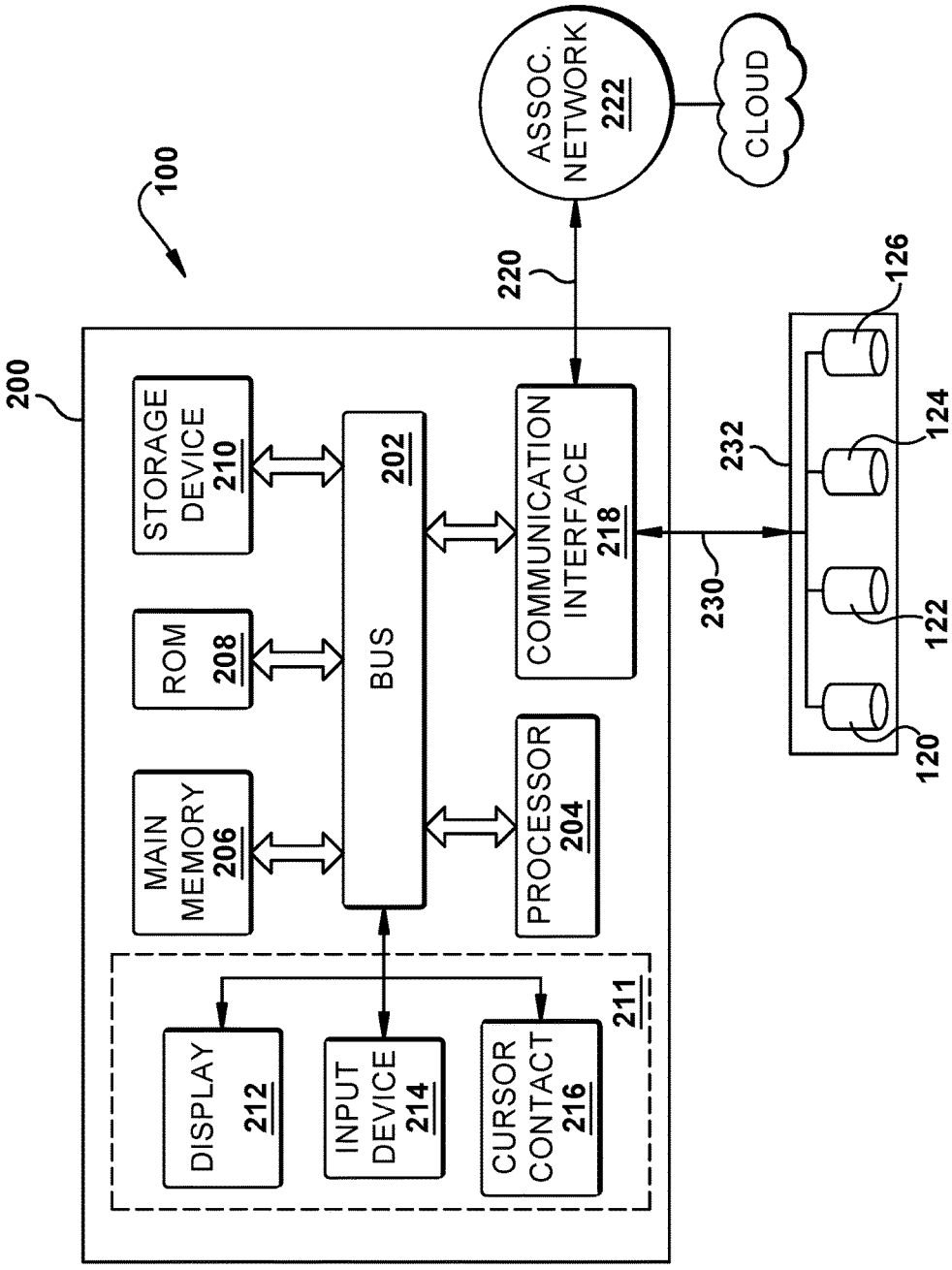

100
200
ASSOC. NETWORK 222
CLOUD
220
126
124
122
120
232
230
STORAGE DEVICE 210
ROM 208
MAIN MEMORY 206
BUS 202
COMMUNICATION INTERFACE 218
PROCESSOR 204
DISPLAY 212
INPUT DEVICE 214
CURSOR CONTACT 216
211

Fig. 2

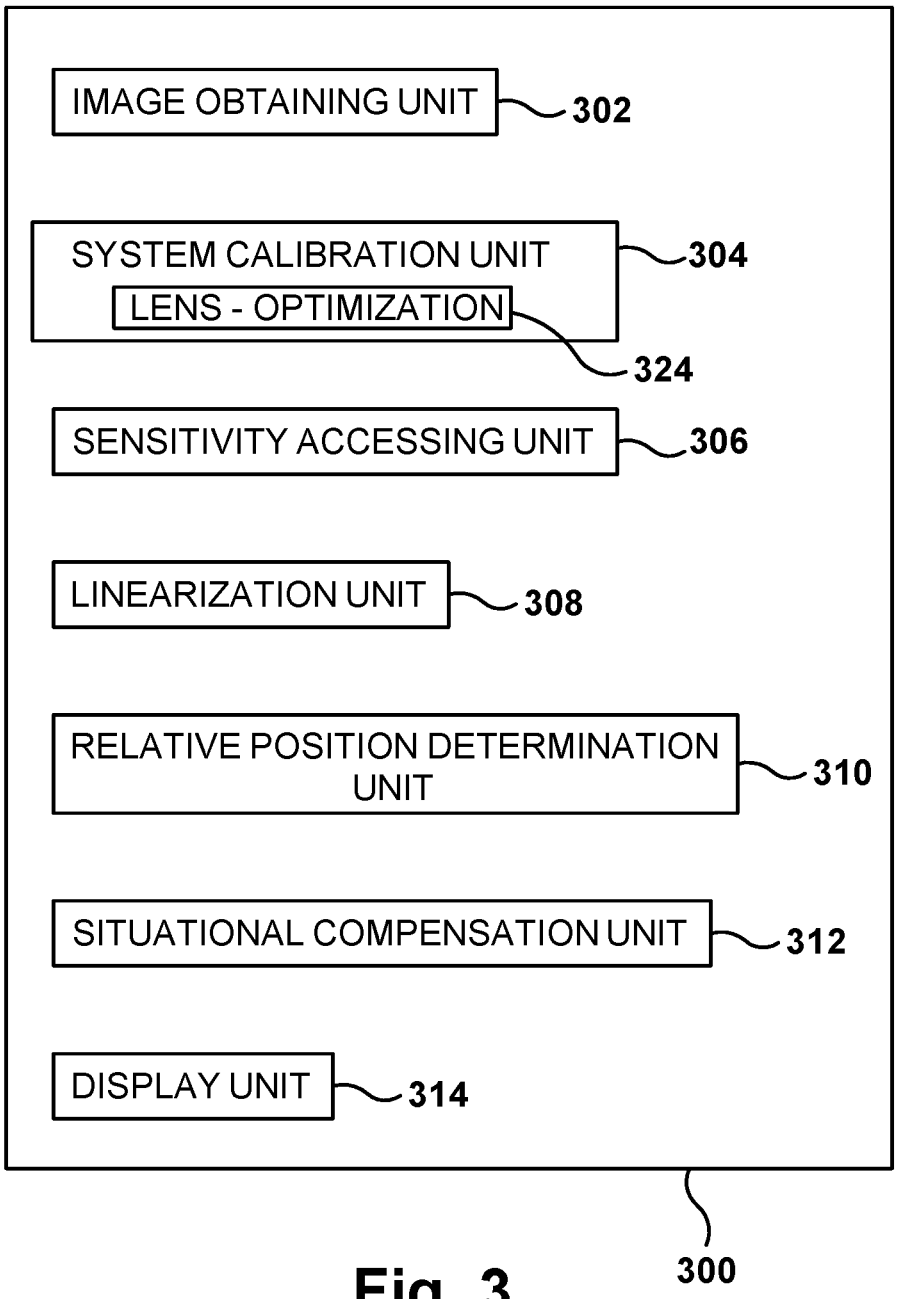


IMAGE OBTAINING UNIT
302
SYSTEM CALIBRATION UNIT
304
LENS - OPTIMIZATION
324
SENSITIVITY ACCESSING UNIT
306
LINEARIZATION UNIT
308
RELATIVE POSITION DETERMINATION UNIT
310
SITUATIONAL COMPENSATION UNIT
312
DISPLAY UNIT
314
300

Fig. 3

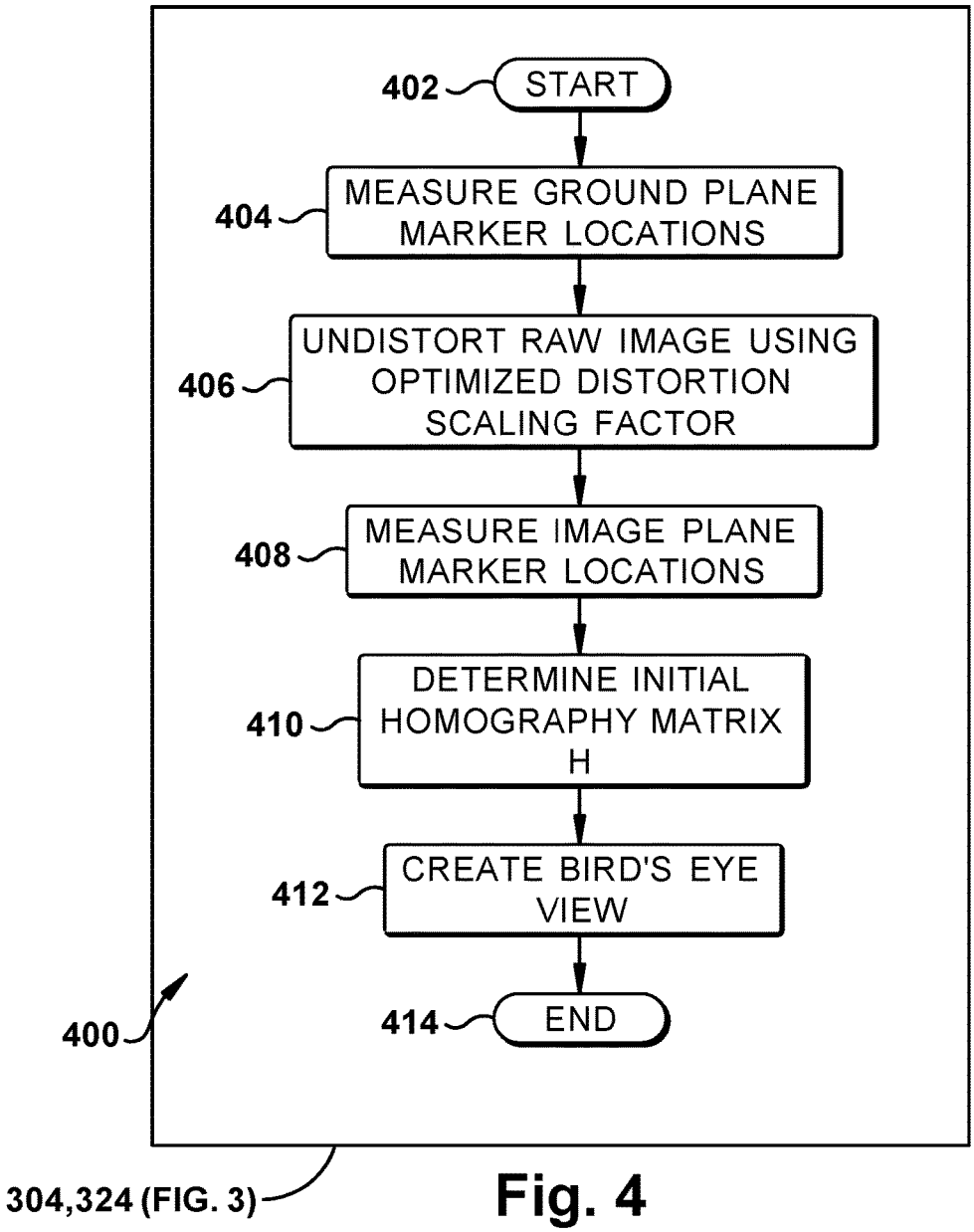

402
START
404
MEASURE GROUND PLANE MARKER LOCATIONS
406
UNDISTORT RAW IMAGE USING OPTIMIZED DISTORTION SCALING FACTOR
408
MEASURE IMAGE PLANE MARKER LOCATIONS
410
DETERMINE INITIAL HOMOGRAPHY MATRIX H
412
CREATE BIRD'S EYE VIEW
414
END
400
304,324 (FIG. 3)

Fig. 4

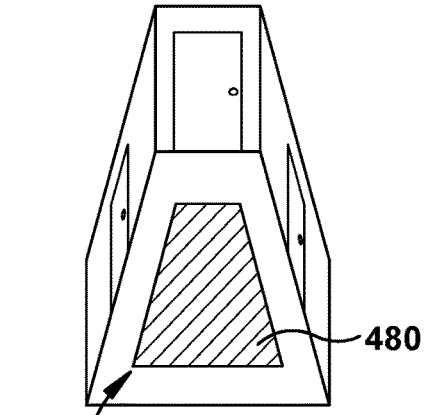


Fig. 4a

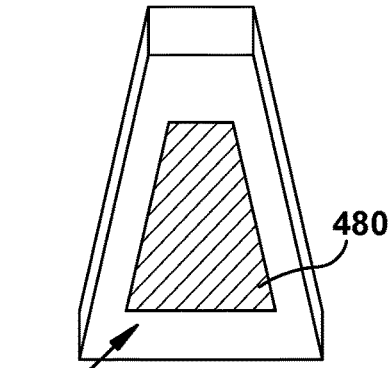


Fig. 4b

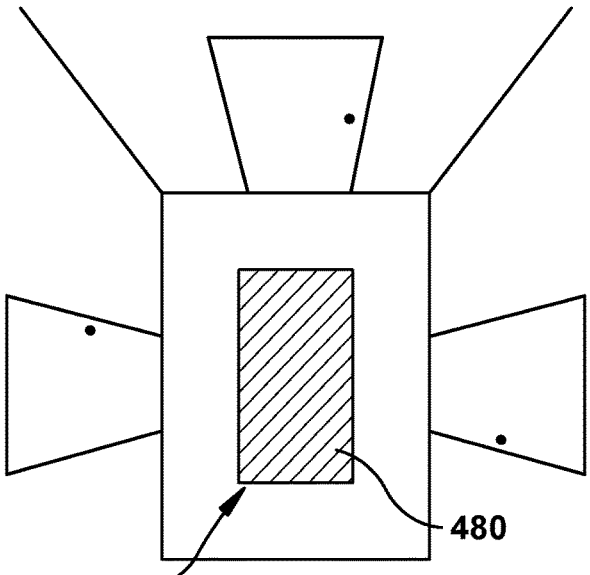


Fig. 4c

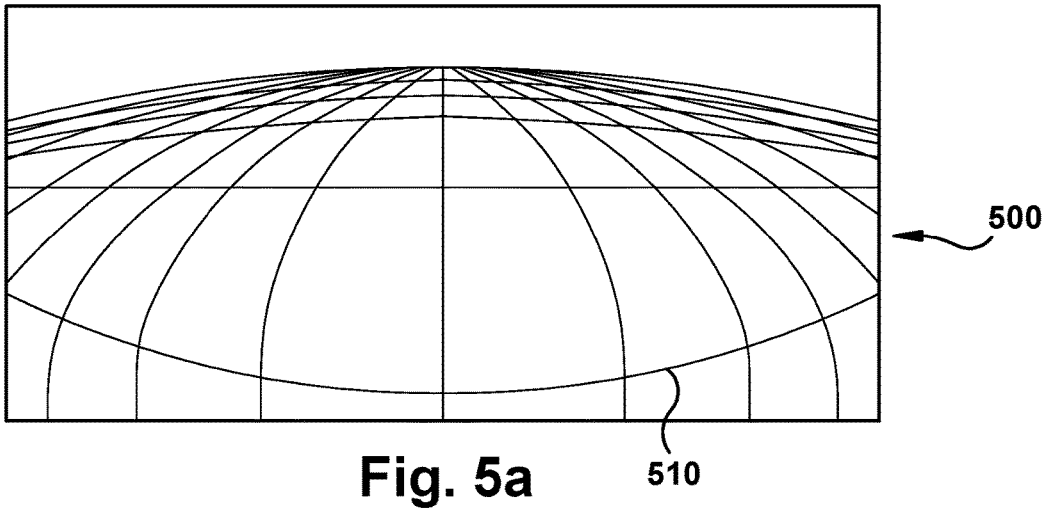


Fig. 5a

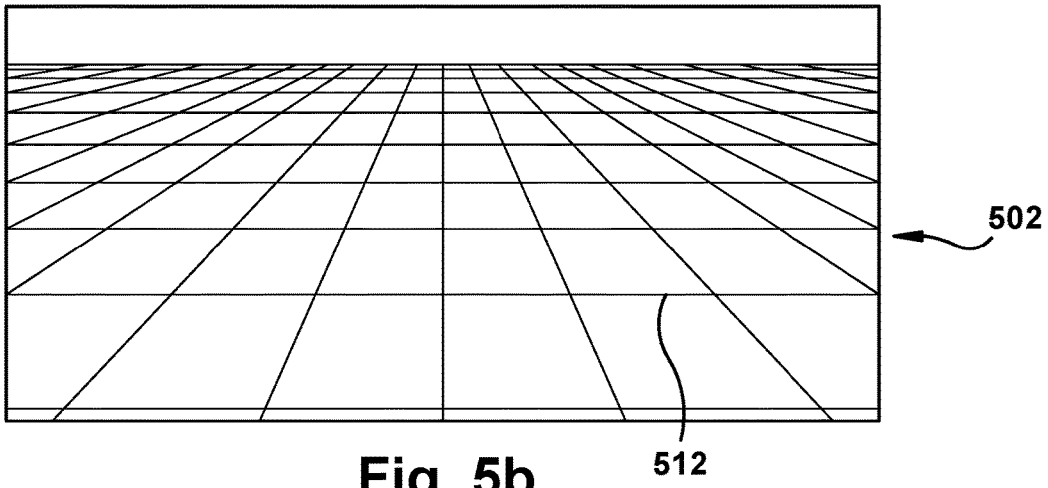


Fig. 5b

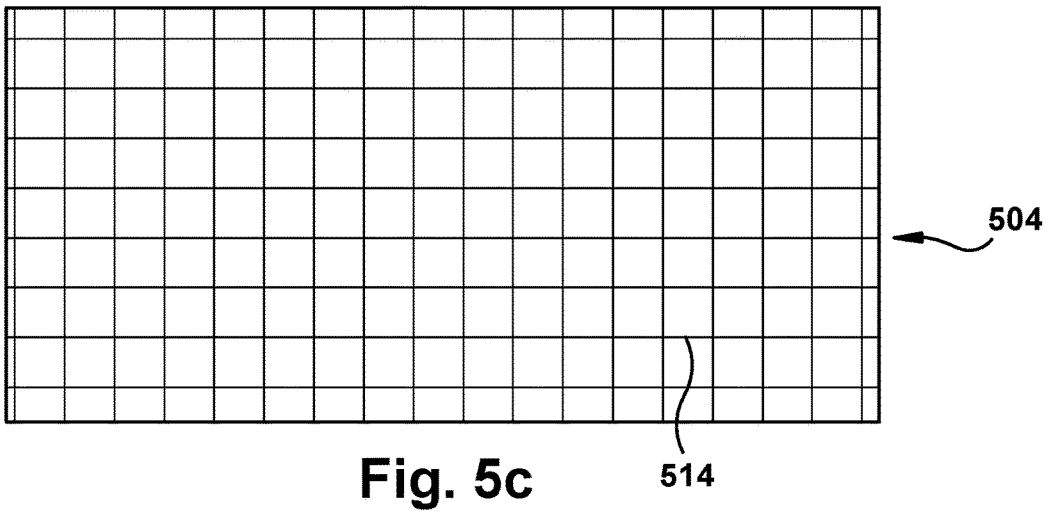


Fig. 5c

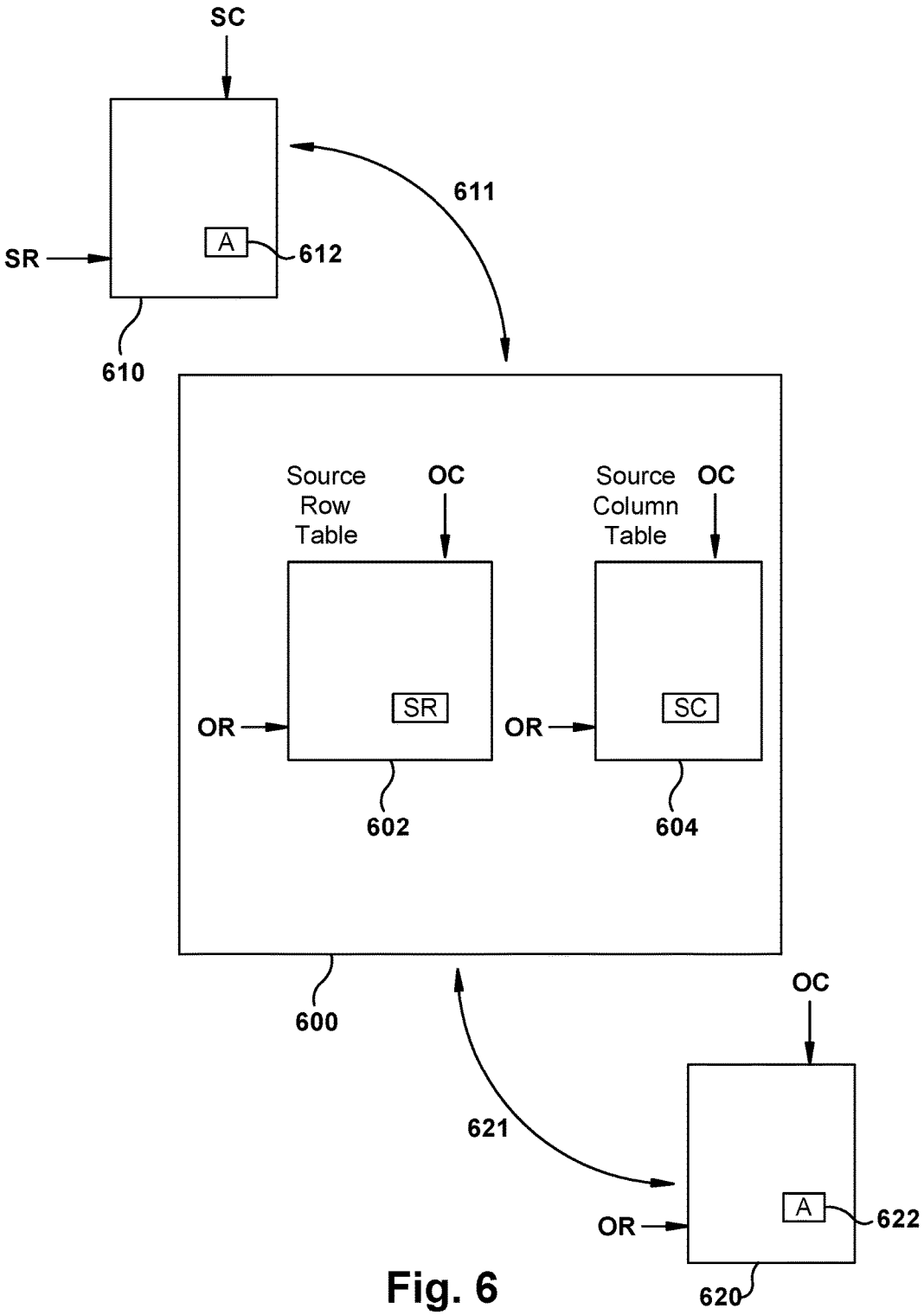

SC
611
SR
A
612
610
Source Row Table
OC
Source Column Table
OC
SR
SC
OR
OR
602
604
600
OC
621
OR
A
622
620

Fig. 6

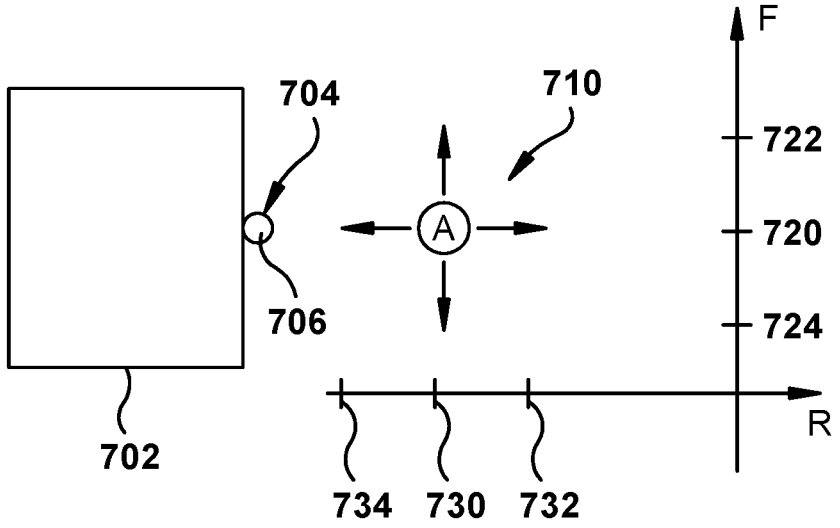


Fig. 7a

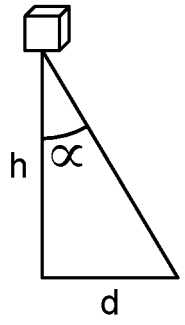


Fig. 7b

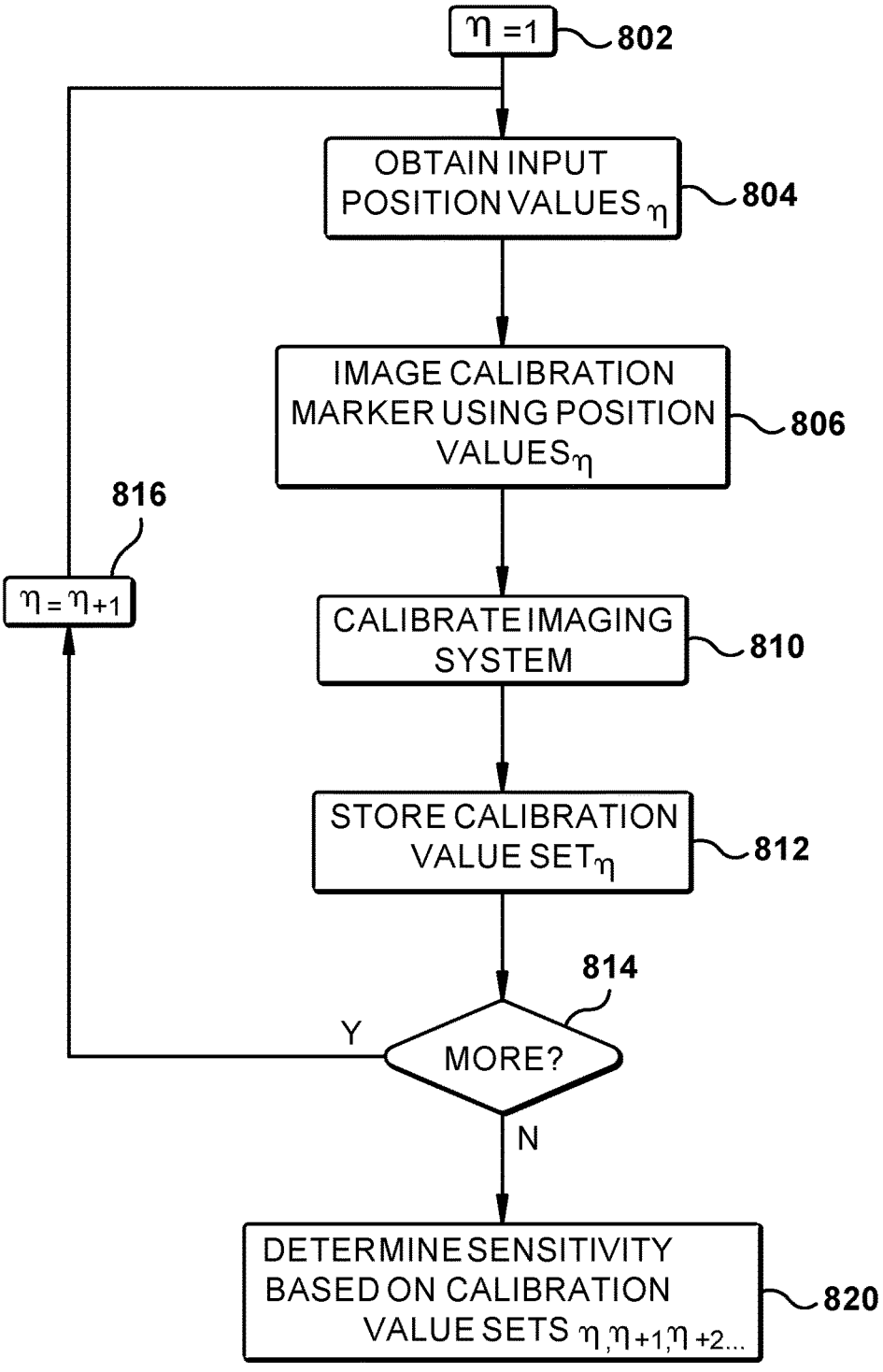

η =1
802
OBTAIN INPUT POSITION VALUES η
804
IMAGE CALIBRATION MARKER USING POSITION VALUES η
806
816
η = η+1
CALIBRATE IMAGING SYSTEM
810
STORE CALIBRATION VALUE SET η
812
814
Y
MORE?
N
DETERMINE SENSITIVITY BASED ON CALIBRATION VALUE SETS η,η+1,η+2...
820

Fig. 8

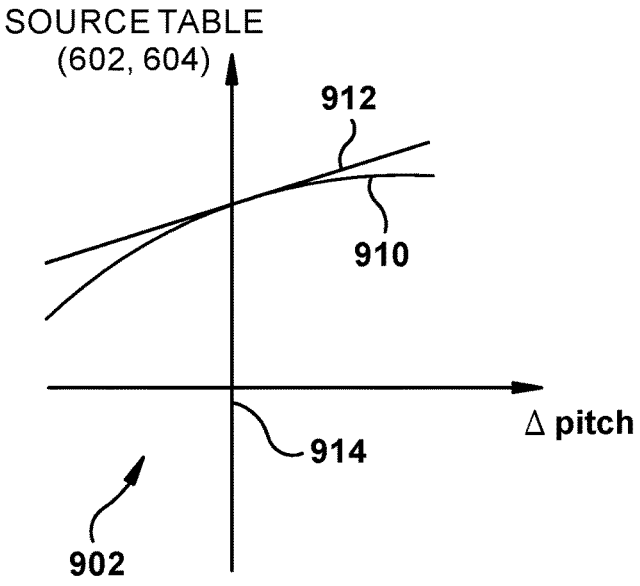

SOURCE TABLE
(602, 604)
912
910
Δ pitch
914
902

Fig. 9a

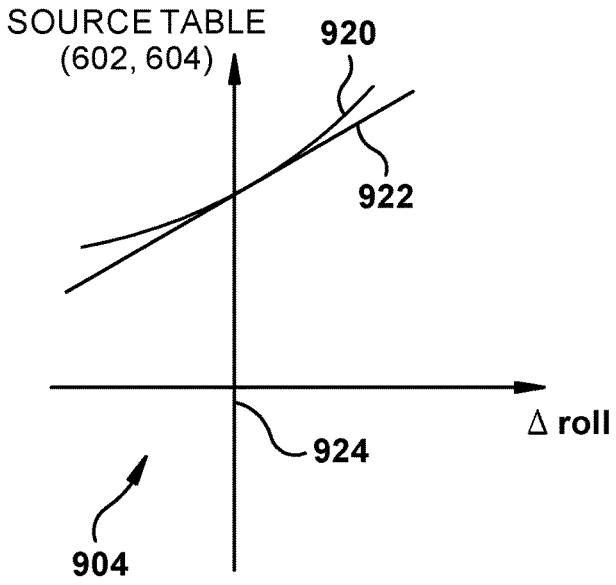

SOURCE TABLE
(602, 604)
920
922
Δ roll
924
904

Fig. 9b

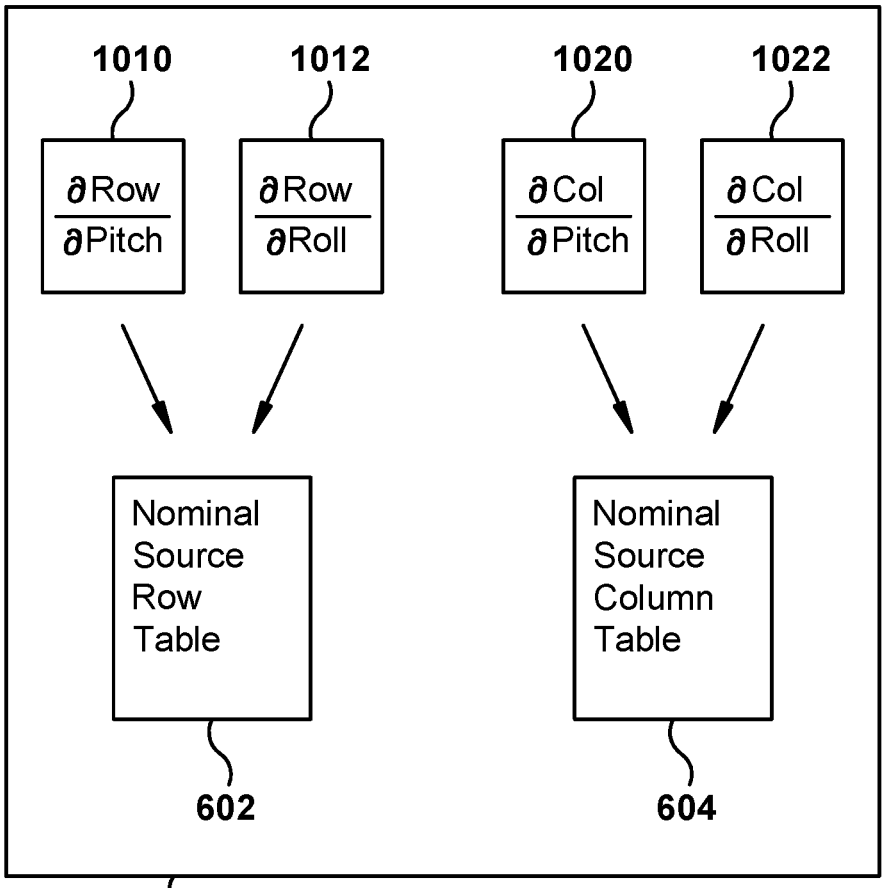

1010
1012
1020
1022
∂Row / ∂Pitch
∂Row / ∂Roll
∂Col / ∂Pitch
∂Col / ∂Roll
Nominal Source Row Table
Nominal Source Column Table
602
604
600'

Fig. 10

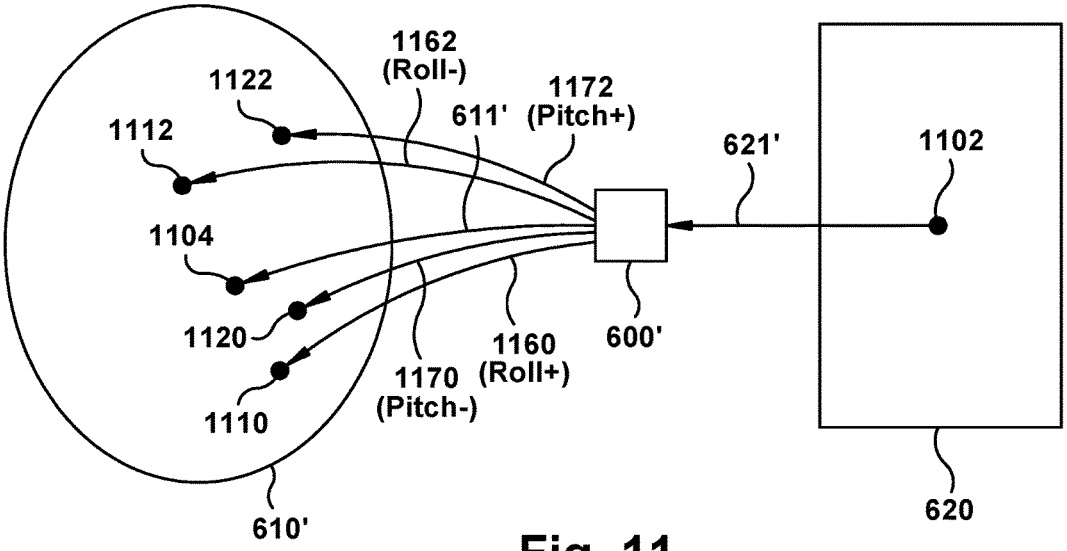


Fig. 11

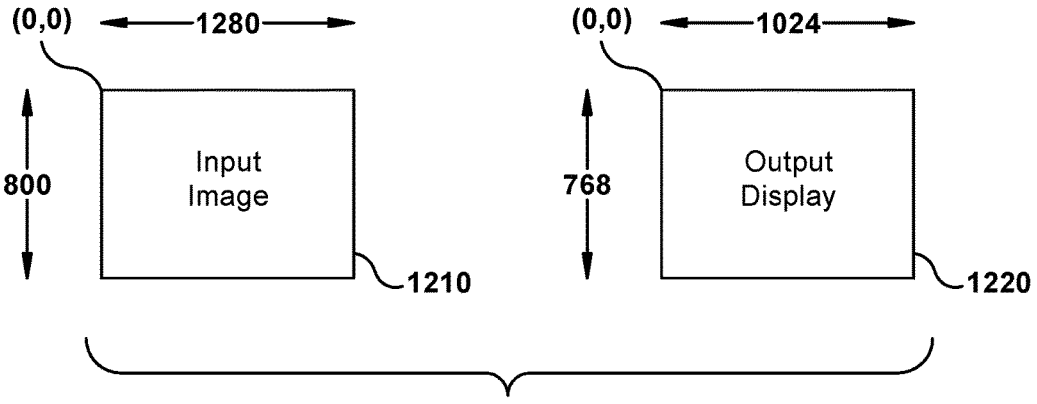


Fig. 12a

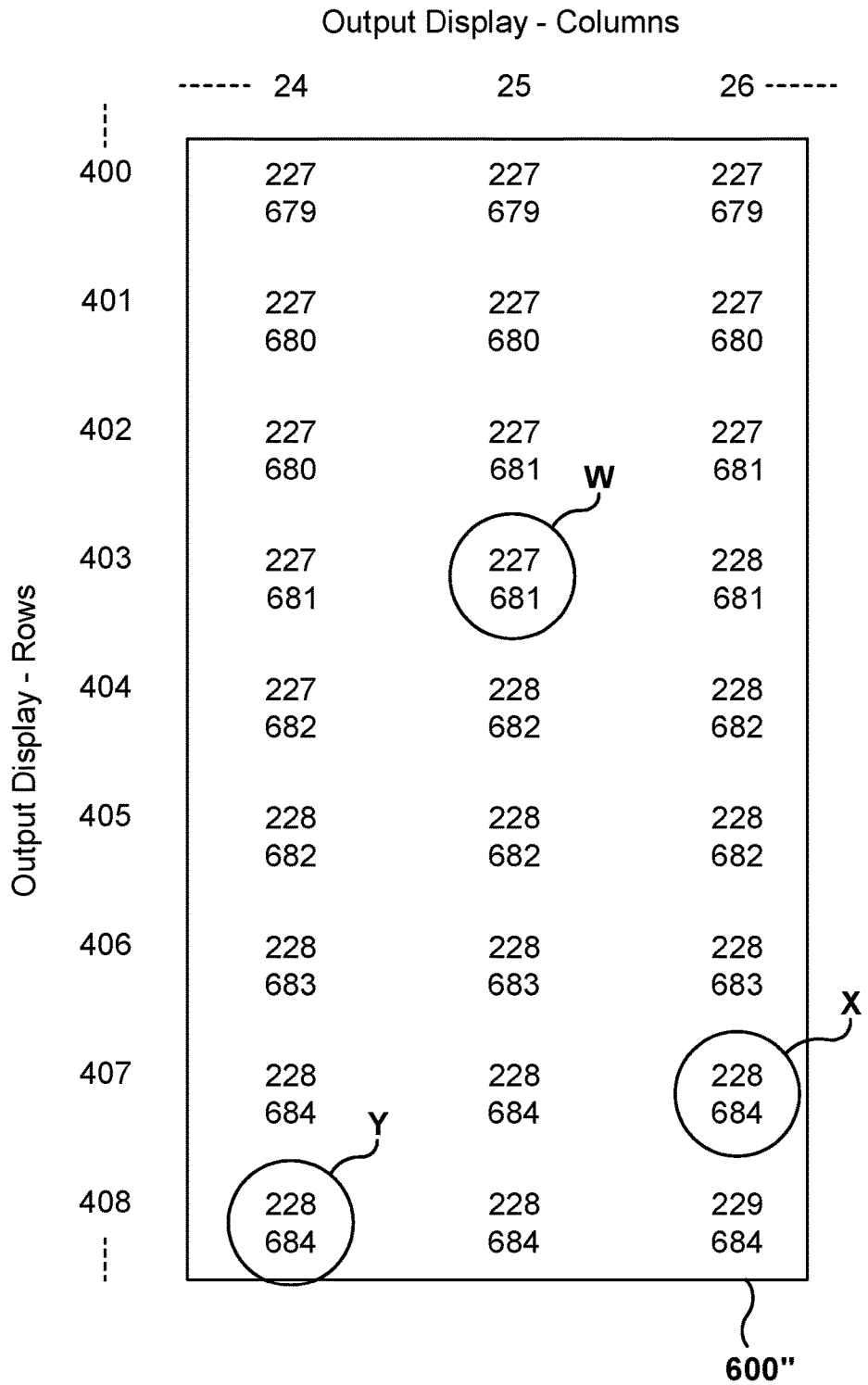

Output Display - Columns
24
25
26
Output Display - Rows
400
401
402
403
404
405
406
407
408
227 679
227 679
227 679
227 680
227 680
227 680
227 680
227 681
227 681
227 681
227 681
227 681
228 681
227 682
228 682
228 682
228 682
228 682
228 682
228 683
228 683
228 683
228 684
228 684
228 684
228 684
228 684
229 684
W
X
Y
600"

Fig. 12b

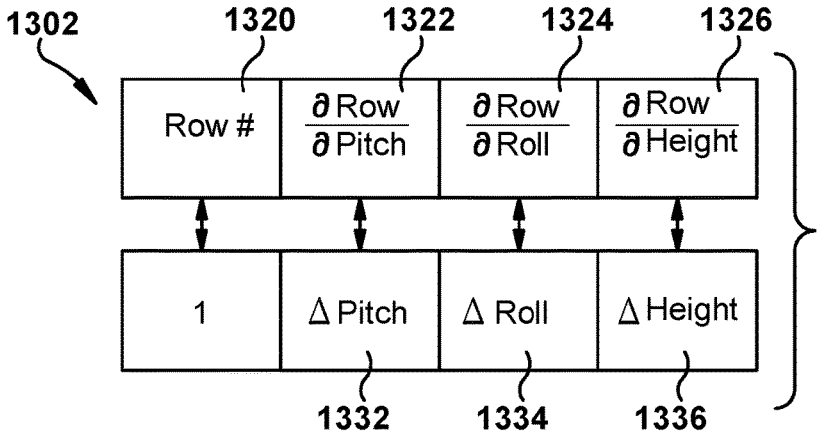


Fig. 13a

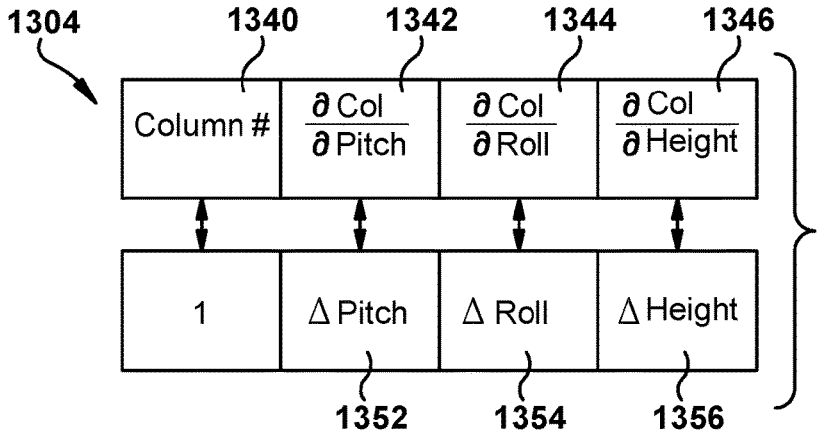


Fig. 13b

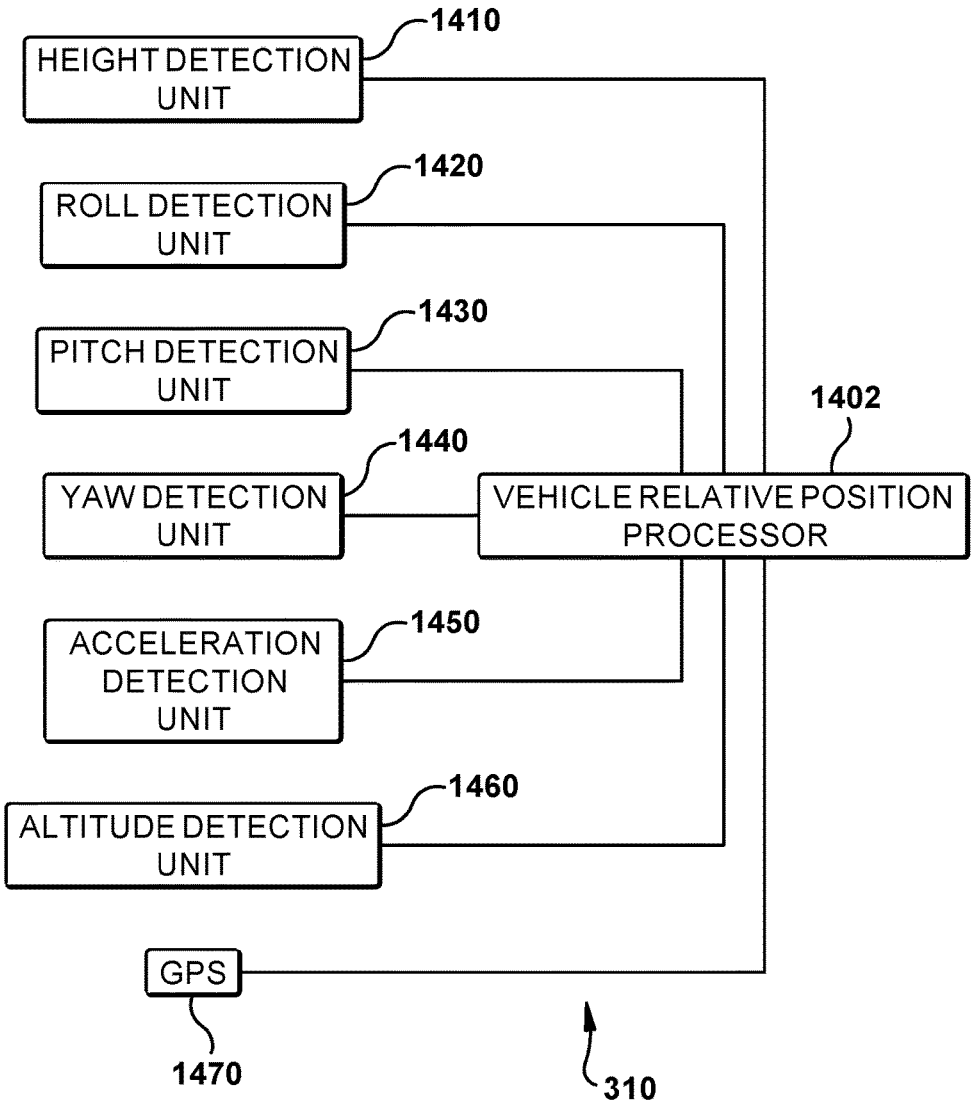

HEIGHT DETECTION UNIT
1410
ROLL DETECTION UNIT
1420
PITCH DETECTION UNIT
1430
YAW DETECTION UNIT
1440
VEHICLE RELATIVE POSITION PROCESSOR
1402
ACCELERATION DETECTION UNIT
1450
ALTITUDE DETECTION UNIT
1460
GPS
1470
310

Fig. 14

AUTOMATIC SURROUND VIEW HOMOGRAPHY MATRIX ADJUSTMENT, AND SYSTEM AND METHOD FOR CALIBRATION THEREOF

TECHNICAL FIELD

[0001] The embodiments herein relate generally to vision/imaging systems and more specifically to vehicle 360° surround view camera systems providing a bird's eye view of a continuous region surrounding a vehicle during use or operation of the vehicle, and to systems and methods for calibrating and using such 360° surround view camera systems. The example embodiments herein will be described in connection with a 360° surround view camera system using a single system of four (4) corner-placed cameras for a non-articulated cargo truck, and to static calibration systems and methods using synthetic vehicle displacement techniques. However, it is to be appreciated that the embodiments are not limited to these applications, but also find use in many other applications including for example surround view camera system dynamic calibration systems and methods, and to vision/imaging systems for multiple articulated cargo trucks and other apparatus using any number of one or more cameras placed anywhere on the vehicle, and to dynamic and/or static calibration systems therefor and methods thereof.

BACKGROUND

[0002] It is common to place cameras on vehicles for purposes of providing one or more images of areas surrounding the vehicle to an operator. This helps to improve the awareness of the operator relative to conditions near the vehicle for avoiding collisions and to assist in maneuvering the vehicle for parking or movement near loading docks or the like. For these reasons and for purposes of attempting to provide a "surround view" of the area around the vehicle, cameras have been located at various positions on the vehicle such as for example at the front end, rear, left side, and right side. These cameras offer the operator various views relative to the vehicle including forward, rear, left and right views. In some applications, the set of individual and separately obtained views are combined by abutting or "stitching" the set of views into a single contiguous or uninterrupted surround view image for visualization on a dashboard display or the like of the vehicle, thereby providing a live panoramic or 360° bird's eye view of the vehicle in its current setting for the convenience of the operator.

[0003] Steps of obtaining the original images, correcting for lens distortion, combining the several views provided by the separate cameras, and converting the overhead camera views by a plane projective transformation with a homography matrix or the like into the bird's eye view suitable for human visualization are complicated and time consuming, even when high speed electronic processing systems are used. For this reason, some systems use one or more dedicated pixel transformation tables such as, for example, a pixel transformation table for carrying out a lens distortion correction, and another pixel transformation table for carrying out a viewpoint change operation. Tables such as these may be stored in a memory in advance as a look up table (LUT) and are useful to generally describe the relationship between addresses or locations of the pixels in the distorted image before a lens distortion correction transformation, and the addresses or locations of the pixels after the lens distortion correction and viewpoint change transformations.

[0004] Although a dedicated precomputed transformation table that is created and stored in advance in a memory of a vision system, for example, might offer computational advantages over brute force matrix math performed on the fly, the inherent inflexibility of this hardwired solution renders the overall results to be somewhat limited relative to the full range of potential operating conditions of the vehicle. For example, vehicle loading, wear, roll, pitch, and other operating conditions introduce complicating factors affecting the processing of the image to be rendered to the vehicle operator beyond the capabilities of current imaging systems including those with dedicated transformation tables.

[0005] It is therefore desirable to provide a vehicle 360° surround view system without these limitations and which provides realistic life-like images to a vehicle operator during operation of the vehicle through the full range of potential operating conditions of the vehicle without introducing any mis-registration artifacts or other confusion into the image. In particular, it is desirable to provide a vehicle surround view system having one or more cameras placed on a vehicle that can quickly accommodate normal vehicle operating parameters including but not limited to vehicle pitch, vehicle roll, vehicle loading, vehicle wear, suspension position, vehicle height relative to the ground, and other operating conditions. It is further desirable to provide systems and methods for easily and efficiently calibrating and using such surround view system.

BRIEF SUMMARY OF EXAMPLE EMBODIMENTS

[0006] In accordance with an example embodiment herein, a vehicle view system includes a camera located at a predetermined position on the vehicle wherein the field of view of the camera provides an area of a field of view adjacent the vehicle carrying the cameras. Further in accordance with the embodiment, a system and method for calibrating the vehicle view system described above are provided determining calibration parameters of the vehicle view system, and selectively adjusting the calibration parameters for motion and other relationships of the vehicle relative to the environment of the vehicle during use thereof.

[0007] In accordance with a further example embodiment herein, a vehicle 360° surround view system includes a set of two (2) or more cameras located at predetermined positions on the vehicle wherein the field of view of each camera overlaps the field of view of at least one other camera of the set of two (2) or more cameras, thereby providing a continuous area of overlapping fields of view completely surrounding the vehicle carrying the cameras. Further in accordance with the embodiments herein, systems and methods for calibrating the vehicle 360° surround view system described above are provided and for adjusting the calibration parameters for motion and other relationships of the vehicle relative to the environment of the vehicle during use thereof.

[0008] In another embodiment, an imaging system adjusts a display of images obtained of a peripheral area adjacent to an associated vehicle to compensate for one or more relationships of the associated vehicle relative to the peripheral area. The system comprises a processor, an image obtaining

unit, a non-transient memory, a situational compensation unit, and a display unit. The image obtaining unit is operatively coupled with the processor and is configured to receive first image data representative of a first image of the peripheral area adjacent to the associated vehicle. The non-transient memory is operatively coupled with the processor, and stores intrinsic image coordinate transformation data representative of an intrinsic mapping between the first image data and first display data representative of an uncompensated bird's eye view image of the peripheral area of the associated vehicle. The intrinsic image coordinate transformation data includes but is not necessarily limited to homography data, lens distortion data, and the like. The situational compensation unit is operatively coupled with the processor and the non-transient memory, and is configured to selectively modify the intrinsic mapping as an adjusted intrinsic mapping between the first image data and the first display data in accordance with a signal representative of the one or more relationships of the associated vehicle relative to the peripheral area. The display unit is configured to display on a human readable output the first display data mapped to the first image data in accordance with the adjusted intrinsic mapping.

[0009] The vision/imaging systems and methods and apparatus for calibrating the vision/imaging systems of the example embodiments are advantageous over traditional devices in many ways including that the embodiments herein minimize the errors in the image displayed to the driver owing to motion or other loading factors of the vehicle to provide a clear and complete composite image, while also providing a wide range of imaging and calibration options and enhancements.

[0010] Additional advantages and features of the embodiments herein will become apparent from the following description and appended claims, taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The foregoing and other features of the embodiments herein will become apparent to those skilled in the art to which the present surround view systems, calibration systems, and calibration methods relate, upon reading the following description with reference to the accompanying drawings, in which:

[0012] FIG. **1***a* is a perspective view of a vehicle in which a 360° surround view camera system according to an example embodiment is applied, showing an installation condition of each camera being located at corners of a nominally rectangular delivery truck vehicle;

[0013] FIGS. **1***b*-**1***e* are schematic top plan views showing a field of view of each camera installed in the vehicle of FIG. **1***a;*

[0014] FIG. **1***f* is a schematic top plan view showing a composite of the fields of view of each camera installed in the nominally rectangular delivery truck vehicle of FIG. **1***a* put together;

[0015] FIG. **1***g* is a schematic top plan view in accordance with a further example embodiment showing a composite of the fields of view of a set of cameras having different characteristics from the cameras of FIGS. **1***a*-**1***f* installed in the nominally rectangular delivery truck vehicle of FIG. **1***a* put together;

[0016] FIG. **2** is a block diagram that illustrates a computer system suitable for supporting and executing the functionality of the example embodiments herein, and upon which the example embodiment may be implemented;

[0017] FIG. **3** is a block diagram of a set of code modules stored in a memory of the computer system of FIG. **2** and executable by a processor of the computer system for optimizing and calibrating the cameras of the 360° surround view system and adjusting the camera images to compensate for motion of the vehicle during use of the vehicle according to the example embodiment;

[0018] FIG. **4** is a flow chart illustrating a method for calibration of individual cameras of the 360° surround view systems of the example embodiments by optimizing homography matrix parameters of the cameras;

[0019] FIGS. **4***a*-**4***c* are schematic perspective views of an image of a square object disposed on the floor of a fictitious hallway graphically illustrating in simple terms a progression of the skew distortion optimization set out in FIG. **4**;

[0020] FIGS. **5***a*-**5***c* are a series of views showing image processing to correct lens distortion in an original photographed image and convert the viewpoint of the image;

[0021] FIG. **6** illustrates use of a look up table (LUT) mapping first image data representative of a first image of the peripheral area adjacent to the associated vehicle to first display data representative of an uncompensated bird's eye view image of the peripheral area of the associated vehicle;

[0022] FIGS. **7***a* and **7***b* illustrate simple examples of a sensitivity adjustment;

[0023] FIG. **8** illustrates a process for determining sensitivity measures;

[0024] FIGS. **9***a* and **9***b* illustrate sensitivity measure linearization;

[0025] FIG. **10** shows an augmented LUT in accordance with an example embodiment;

[0026] FIG. **11** is a conceptual illustration of using the augmented LUT of FIG. **10** to perform mapping adjustments between pixels of a distorted camera image and pixels rendered in an output display in accordance with variations in vehicle roll and pitch parameters;

[0027] FIG. **12***a* is a diagrammatic illustration of an output display and of an input image in accordance with a numerical example embodiment;

[0028] FIG. **12***b* is a diagram of a portion of a LUT in accordance with the numerical example embodiment of FIG. **12***a;*

[0029] FIGS. **13***a* and **13***b* illustrate a storage scheme for locating the augmented LUT of FIG. **10** in a specialized single instruction multiple data architecture processor; and

[0030] FIG. **14** is a diagrammatic illustration of the relative position determination unit of the system in accordance with the example embodiment herein.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

[0031] With reference now to the drawing Figures, wherein the showings are for purposes of describing the embodiments only and not for purposes of limiting same, example embodiments herein relate to a surround view camera system **100** for vehicles having cameras placed at selected positions on the vehicles, and to systems and methods for calibrating the surround view camera systems. The embodiments herein are also applicable to the placement of the cameras at various positions on the vehicles such as, for example, at the corners of the vehicles, and at corners of various one or more substantially rectangular portions of

the vehicles. It is to be appreciated that the embodiments herein are applicable to many different camera placement schemes and to many different cameras having various fields of view, resolution, and other characteristics as may be necessary or desired.

[0032] As representative of the embodiments and with reference in particular first to FIG. **1***a*, the perspective top view shown there illustrates a vehicle **110** in which a 360° surround view camera system **100** according to an embodiment is applied, showing an arrangement of cameras **120**, **122**, **124**, and **126** supported at selected positions on the body **140** of the vehicle **110**. FIGS. **1***b*-**1***e* are schematic top plan views showing a field of view of each camera **120**, **122**, **124**, and **126** installed on the body **140** of the vehicle **110** of FIG. **1***a*, and FIG. **1***f* is a schematic top plan view showing a composite construction of the fields of view of the cameras installed in the vehicle of FIG. **1***a* put together and illustrating overlapping fields of view of the set of cameras of FIG. **1***a*.

[0033] Although a basic delivery panel-type truck **112** is shown as the vehicle **110** in FIGS. **1***a*-**1***f*, the vehicle **110** can be any other vehicle such as a regular passenger automobile or any other type of mobile apparatus having an overall generally rectangular shape. Also, of course the illustrated panel-type truck **112** vehicle **110** illustrated is configured to be located on and move relative to the ground such as a road surface or the like, other vehicles that would be benefited by the surround view camera system **100** of the various embodiments herein include various robotic devices such as automatic guided vehicles (AGVs) configured to be located on and move relative to the floor of a factory or manufacturing facility or the like. In the following explanations, the ground is assumed to be a horizontal plane and the "height" of these cameras indicates a height with respect to the ground.

[0034] As shown in FIG. **1***a*, cameras (image pickup devices) **120**, **122**, **124**, and **126** are mounted at the uppermost parts of the vehicle **110**. The first camera **120** is placed for example at a right uppermost forward part of the vehicle **110**, the second camera **122** is placed for example at the left uppermost forward part of the vehicle **110**, the third camera **124** is placed for example at the left uppermost rearward part of the vehicle **110**, and the fourth camera **126** is placed for example at the right uppermost rearward part of the vehicle **110**. The cameras **120**-**126** may simply be referred to herein and below in this and in the embodiments to be described as "the cameras" or "each camera" without necessarily being distinguished from each other. Although the cameras are arranged as shown, their positions may equivalently be exchanged as may be necessary or desired in accordance with the embodiments into several relative positions such as, for example, by locating the first camera **120** at the left uppermost forward part of the vehicle **110**, and locating the second camera **122** at the right uppermost rearward part of the vehicle **110**.

[0035] It is to be appreciated that the cameras **120**-**126** are arranged on the vehicle **110** such that the optical axes of the cameras are directed obliquely downward at an angle of about 15°-45° relative to an axis perpendicular to the ground plane under the vehicle. To that end, the optical axis of the first camera **120** is directed obliquely downward at an angle of about 15°-45° towards the right forward direction of the vehicle **110**, an optical axis of the second camera **122** is directed obliquely downward at an angle of about 15°-45° towards the left forward direction of the vehicle **110**, an optical axis of the third camera **124** is directed obliquely downward at an angle of about 15°-45° towards the left backward direction of the vehicle **110**, and an optical axis of the fourth camera **126** is directed obliquely downward at an angle of about 15°-45° towards the right backward direction of the vehicle **110**. It is to be further appreciated that the field of view of each camera, i.e. spatial region of which each camera can capture an image, is generally hemispherical in overall shape and is quite large. More particularly, in the example embodiment illustrated, the cameras **120**-**126** each have a field of view of about 360° and are commonly referred to in the industry as "fish eye" lens cameras or imagers. The cameras **120**-**126** may for example be of the type Blue Eagle DC3K-1-LVD available from Silicon Micro Systems, or any similar cameras available from other sources and having the desired characteristics of the embodiments.

[0036] FIGS. **1***b*-**1***e* are schematic top plan views showing a field of view of each camera **120**, **122**, **124**, and **126** installed on the vehicle **110** of FIG. **1***a*. Although a panel-type delivery van **112** having a nominally rectangular overall shape is shown as the vehicle **110** in FIGS. **1***a*-**1***f*, the vehicle **110** can be any other vehicle such as a regular passenger automobile or any other type of mobile apparatus such as for example an AGV having an overall generally rectangular shape and including a set of camera mounts or other similar devices suitable for supporting the cameras **120**, **122**, **124**, and **126** in an elevated position relative to the vehicle **110**. Also, it is to be appreciated that the vehicle **110** is configured to be located on and move relative to the ground such as a road surface or a parking lot adjacent other vehicles, loading docks, or the like. In the following explanations, the ground is assumed to be a horizontal plane and the "height" of these cameras indicates a height with respect to the ground.

[0037] As shown in FIG. **1***a*, cameras (image pickup devices) **120**, **122**, **124**, and **126** are mounted at uppermost parts of the vehicle such as, for example, at the corners of the vehicle **110**. FIG. **1***b* shows the usable field of view **152** of the second camera **122** viewed from above, in other words, the generally hemispherical field of view of the left and forward directed second camera as projected onto the generally planar ground surface at the left front of the vehicle **110**. Similarly, FIG. **1***c* shows the usable field of view **150** of the first camera **120** viewed from above, in other words, the generally hemispherical usable field of view of the right and forward directed first camera as projected onto the ground surface at the right front of the vehicle **110**. FIG. **1***d* shows the usable field of view **154** of the third camera **124** viewed from above, in other words, the generally hemispherical field of view of the left and rearward directed third camera as projected onto the generally planar ground surface at the left rear of the vehicle **110**. Lastly, FIG. **1***e* shows the usable field of view **156** of the fourth camera **126** viewed from above, in other words, the generally hemispherical field of view of the right and rearward directed fourth camera as projected onto the ground surface at the right rear of the vehicle **110**. It is of course to be appreciated that the remaining portions of the generally hemispherical fields of view of the left and forward directed second camera **122**, the right and forward directed first camera **120**, the left and rearward directed third camera **124**, and the right and

rearward directed fourth camera **126** are, in general, partially obstructed by the gross rear shape of the vehicle **110** in that region.

[0038] FIG. **1***f* shows a schematic view in which all of the fields of view as shown in FIGS. **1***b*-**1***e* are put together. It is to be appreciated that, in the illustrated embodiment, the left and forward directed second camera **122** primarily captures an image of a subject or object, including the road surface, located within a predetermined region in front and to the left of the vehicle **110**. Further, the right and forward directed first camera **120** primarily captures an image of a subject or object, including the road surface, located within a predetermined region in front and to the right of the vehicle **110**. Still further, the left and rearward directed third camera **124** primarily captures an image of a subject or object, including the road surface, located within a predetermined region in the rear and to the left of the vehicle **110**. Yet still further, the right and rearward directed fourth camera **126** primarily captures an image of a subject or object, including the road surface, located within a predetermined region in the rear and to the right of the vehicle **110**.

[0039] The fields of view **150**, **152**, **154**, and **156** of the cameras **120**, **122**, **124**, and **126** however, overlap forming a continuous region **160** of overlapping fields of view substantially surrounding the vehicle **110**. This region **160** is often referred to as a common or continuous overlapping field of view. In FIG. **1***f*, the common fields of view are shown as the shaded area. In this embodiment, overall, the fields of view **150**, **152**, **154**, and **156** overlap at a common or overlapping continuous field **160** essentially forming a complete uninterrupted ring around the vehicle from corner to corner including views directed towards the obliquely left-forward of the vehicle **152**; towards the obliquely right-forward of the vehicle **150**; towards the obliquely left-rearward of the vehicle **154**; and towards the obliquely right-rearward of the vehicle **156**.

[0040] FIG. **1***g* is a schematic top plan view in accordance with a further example embodiment showing a composite of the fields of view of a set of cameras having different characteristics from the cameras of FIGS. **1***a*-**1***f* installed in the nominally rectangular delivery truck vehicle of FIG. **1***a* put together. As shown in FIG. **1***g*, cameras (image pickup devices) **120'**, **122'**, **124'**, and **126'** are mounted at uppermost parts of the vehicle such as, for example, at the corners of the vehicle **110**. FIG. **1***g* shows the usable field of view **152'** of the second camera **122'** viewed from above, in other words, the generally hemispherical field of view of the left and forward directed second camera as projected onto the generally planar ground surface at the left front of the vehicle **110**. FIG. **1***g* also shows the usable field of view **150'** of the first camera **120'** viewed from above, in other words, the generally hemispherical usable field of view of the right and forward directed first camera as projected onto the ground surface at the right front of the vehicle **110**. FIG. **1***g* further shows the usable field of view **154'** of the third camera **124'** viewed from above, in other words, the generally hemispherical field of view of the left and rearward directed third camera as projected onto the generally planar ground surface at the left rear of the vehicle **110**. Lastly, FIG. **1***g* shows the usable field of view **156'** of the fourth camera **126'** viewed from above, in other words, the generally hemispherical field of view of the right and rearward directed fourth camera as projected onto the ground surface at the right rear of the vehicle **110**. It is of course to be appreciated that the remaining portions of the generally hemispherical fields of view of the left and forward directed second camera **122'**, the right and forward directed first camera **120'**, the left and rearward directed third camera **124'**, and the right and rearward directed fourth camera **126'** are, in general, partially obstructed by the gross rear shape of the vehicle **110** in that region.

[0041] The fields of view **150'**, **152'**, **154'**, and **156'** of the cameras **120'**, **122'**, **124'**, and **126'** of the embodiment illustrated however, overlap forming a set of discontinuous regions **160***a*, **160***b*, **160***c*, and **160***d* of overlapping fields of view substantially surrounding the vehicle **110**. These regions **160***a*, **160***b*, **160***c*, and **160***d* will be referred to herein, for ease of description, as a common, continuous, or discontinuous overlapping field of view. In FIG. **1***g*, the common fields of view are shown as the shaded areas **160***a*, **160***b*, **160***c*, and **160***d*. In this embodiment, overall, the fields of view **150'**, **152'**, **154'**, and **156'** overlap at common or overlapping discontinuous fields **160***a*, **160***b*, **160***c*, and **160***d* essentially forming an interrupted ring around the vehicle from corner to corner. The fields of view **150'**, **152'**, **154'**, and **156'** include or otherwise define an overlapping view **160***a* directed towards the forward of the vehicle **110**, an overlapping view **160***b* directed towards the right of the vehicle **110**, an overlapping view **160***c* directed towards the rear of the vehicle **110**, and an overlapping view **160***d* directed towards the left of the vehicle **110**.

[0042] FIG. **2** illustrates an example of a computer system **200** upon which an example embodiment may be implemented. Computer system **200** is suitable for implementing the functionality of any embodiment of the surround view camera system **100** described herein including the static calibration using synthetic vehicle movement, and the example embodiment illustrated in FIGS. **1***a*-**1***f*.

[0043] Computer system **200** includes a bus **202** or other communication mechanism for communicating information and a processor **204** coupled with bus **202** for processing information. Computer system **200** also includes a main memory **206**, such as random access memory (RAM) or other dynamic storage device coupled to bus **202** for storing information and instructions to be executed by processor **204**. Main memory **206** also may be used for storing temporary or permanent variables, tables such as LUTs or any other data such as intermediate information created and/or used during execution of instructions to be executed by processor **204**. Computer system **200** further includes a read only memory (ROM) **208** or other static storage device coupled to bus **202** for storing static information and instructions for processor **204**. A storage device **210**, such as a magnetic disk, optical disk, SD memory and/or flash storage, is provided and coupled to bus **202** for storing information and instructions.

[0044] Computer system **200** may be coupled via bus **202** to a user interface **211**. The user interface **211** may comprise a display **212**, such as a cathode ray tube (CRT) or liquid crystal display (LCD), for displaying information to a user of the vehicle **100** described above in connection with the example embodiment. The user interface **211** may further comprise an input device **214**, such as a keyboard including alphanumeric and other keys. The user interface **211** is coupled to bus **202** for communicating information and command selections to the processor **204**. Another type of user input device is cursor control **216**, such as a mouse, a trackball, cursor direction keys, and/or a touchscreen for

communicating direction information and command selections to processor **204** and for controlling cursor movement on display **212**. This input device typically has two degrees of freedom in two axes, a first axis (e.g., x) and a second axis (e.g., y) that allows the device to specify positions in a plane.

[0045] An aspect of the example embodiment is related to the use of computer system **200** to implement the vehicle 360° surround view camera system **100** of the example embodiments herein to provide a bird's eye view of a continuous region surrounding a vehicle such as a cargo truck during use of the vehicle under various conditions, and to provide a system and methods for calibrating such 360° surround view camera system. According to an example embodiment, vehicle 360° surround views and calibration steps are provided by the computer system **200** in response to the processor **204** executing one or more sequences of one or more instructions contained in main memory **206**. Such instructions may be read into main memory **206** from another computer-readable medium, such as storage device **210**. Execution of the sequence of instructions contained in main memory **206** causes processor **204** to perform process steps including the process steps described herein. One or more processors in a multi-processing arrangement may also be employed to execute the sequences of instructions contained in main memory **206**. In alternative embodiments, hard-wired circuitry may be used in place of or in combination with software instructions to implement an example embodiment. Thus, embodiments described herein are not limited to any specific combination of hardware circuitry and software.

[0046] The term "computer-readable medium" as used herein refers to any medium that participates in providing instructions to the processor **204** for execution. Such a medium may take many forms, including but not limited to non-volatile media, and volatile media. Non-volatile media include, for example, optical or magnetic disks, such as storage device **210**. Volatile media include dynamic memory, such as main memory **206**. As used herein, tangible media may include volatile and non-volatile media. Common forms of computer-readable media include, for example, floppy disk, a flexible disk, hard disk, magnetic cards, paper tape, any other physical medium with patterns of holes, a RAM, a PROM, an EPROM, a FLASHPROM, CD, DVD or any other memory chip or cartridge, or any other medium from which a computer can read.

[0047] Various forms of computer-readable media may be involved in carrying one or more sequences of one or more instructions to processor **204** for execution. For example, the instructions may initially be borne on a magnetic disk of a remote computer. The remote computer can load the instructions into its dynamic memory and send the instructions over a telephone line using a modem. A modem local to computer system **200** can receive the data on the telephone line and use an infrared transmitter to convert the data to an infrared signal. An infrared detector coupled to bus **202** can receive the data carried in the infrared signal and place the data on bus **202**. Bus **202** carries the data to main memory **206** from which processor **204** retrieves and executes the instructions. The instructions received by main memory **206** may optionally be stored on storage device **210** either before or after execution by processor **204**.

[0048] Computer system **200** also includes a communication interface **218** coupled to bus **202**. Communication interface **218** provides a two-way data communication coupling computer system **200** to a VPN link **220** that is connected to an Enterprise or other predefined network **222**. In an example embodiment, VPN link **220** is a wireless link. The communication interface **218** also provides a two-way data communication coupling the computer system **200** with a video link **230** that is connected with a camera set **232** including two (2) or more cameras. In the example embodiments herein, the two (2) or more cameras include for example the cameras **120**, **122**, **124**, and **126** of the example embodiment shown in FIGS. **1***a*-**1***f*.

[0049] FIG. **3** is a block diagram of a processing module set **300** comprising plural inter-operative processing modules or units for carrying out the functions of the example embodiment herein. It is to be appreciated that each of the plural processing modules or units forming the processing module set **300** are implemented in hardware, software, or combinations of hardware and software in accordance with the example embodiment. The modules or units forming the processing module set **300** may be conveniently implemented using one or more conventional general purpose or specialized digital computers, computing devices, machines, or microprocessors, including one or more processors, memory and/or computer readable storage media programmed according to the teachings of the present disclosure. Appropriate software coding can readily be prepared by skilled programmers based on the teachings of the present disclosure, as will be apparent to those skilled in the software arts. In some embodiments, the modules or units forming the processing module set **300** may include a computer program product which is a storage medium or computer readable medium (media) having instructions stored thereon/therein which can be used to program a computer to perform any of the processes of the example embodiment. The storage medium can include, but is not limited to, any type of disk including floppy disks, optical discs, DVD, CD-ROMs, microdrive, and magneto-optical disks, ROMs, RAMs, EPROMs, EEPROMs, DRAMs, VRAMs, flash memory devices, magnetic or optical cards, nanosystems (including molecular memory ICs), or any type of media or device suitable for storing instructions and/or data.

[0050] The processing module set of the example embodiment includes, for example, an image obtaining unit **302**, an imaging system calibration unit **304**, an imaging system sensitivity processing module **306**, an imaging system linearization module **308**, a vehicle relative position determination module **310**, an imaging system situational compensation unit **312**, and a display unit module **314**. Each of the modules **302**, **304**, **306**, **308**, **310**, **312**, and **314** is executable alone and/or in combination with others of the modules by the processor **204** described above in connection with FIG. **2**. In accordance with the example embodiment, the processor of the surround view camera system **100** is configured to execute software code and perform a function of obtaining images of areas surrounding the vehicle **110**. In the example embodiment, the image obtaining unit **302** is operatively coupled with the processor **204** and is configured to receive first image data representative of a first image of one or more peripheral areas **150**, **152**, **154**, **156**, **160** adjacent to the vehicle **110**. In accordance with the example embodiment, the situational compensation unit **312** is operatively coupled with the processor **204** (FIG. **2**) and the non-transient memory **206**, **208**, and **210**, and is configured as will be described in greater detail below to selectively modify an

intrinsic mapping as an adjusted intrinsic mapping between obtained image data and display data output on the display **212** in accordance with a signal representative of one or more relationships of the associated vehicle relative to the area peripheral to the vehicle. The display unit module **314** is configured to display on a human readable output **212** first display data mapped to first image data in accordance with the adjusted intrinsic mapping.

[0051] In the example embodiment, the system calibration unit **304** is configured to calibrate each of the cameras **120**, **122**, **124**, and **126** relative to the associated vehicle **110**. The system calibration unit **304** comprises functional modules including a lens distortion scaling optimization module **324** for individually calibrating each of the cameras to correct their respective lens (typically fish-eye) distortion and/or image bowing caused by the inherent physical construction and other intrinsic one or more properties of the fish eye cameras used in the example embodiments. In accordance with the example embodiment, the processor **204** of the surround view camera system **100** executes the lens distortion scaling optimization module **324** for making adjustments to nominal lens distortion parameter values provided by a manufacturer of the fish eye cameras of the embodiments herein.

[0052] FIG. **4** is a flow chart illustrating a method **400** performed by the computer **200** of the surround view camera system **100** in accordance with an embodiment for calibrating homography matrix parameters of the individual cameras **120**, **122**, **124**, and **126** of the example embodiment. In general, the method **400** performs a calibration process for determining a set of homography matrix parameters for each camera, wherein each homography matrix H determined separately for each camera provides the least skew error in the resultant image from that respective camera and, ultimately, the least amount of skew between camera pairs in the composite resultant image to be displayed to the operator on the display device **212** such as will be described in greater detail below. FIGS. **4***a*-**4***c* are schematic perspective views of images **470**, **472**, and **474** of a square object **480** disposed on the fictitious floor of a fictitious hallway graphically illustrating in simple terms a progression of the skew distortion optimization set out in FIG. **4**.

[0053] With continued reference back to FIG. **4**, the method includes an operation at step **402**, of placement of a plurality of sets of physical markers A-D, E-H, S-V, and W-Z on the ground adjacent the vehicle and they are arranged such as shown, for example, in FIGS. **1***b*-**1***e*. In an example embodiment, the sets of markers include a regular repeating checkerboard type grid pattern of square markers, for example. It is advantageous to place the markers at well-separated locations in the image, disposed about the optical axis. The markers may be disposed at positions offset or otherwise spaced away from the major or main optical axis of the cameras by predetermined distances best suited for optimal calibration. At step **404**, the locations of the ground plane markers A-D, E-H, S-V, and W-Z are physically measured relative to the cameras **120**, **122**, **124**, and **126**, and the positions are recorded. At step **406**, the raw image obtained using a first camera is processed to undistort the raw image using one or more optimized distortion characteristic parameters determined by a distortion characteristic optimization method. In the distortion characteristic optimization method of the example embodiment, the cameras of the surround view camera system are individually calibrated in accordance with the embodiment to determine an optimal lens distortion characteristic scaling factor for each camera. In general, the raw or original images obtained by wide-angle or fish-eye lenses are distorted. The distortion can be calculated or characterized from the connection between the undistorted and the distorted field angle. The field angle is the angle formed between a light ray and the optical axis of the lens. The lenses accept incoming light rays from a typically hemispherical area, and strongly bend them inward, toward the optical axis, so as to project the hemisphere onto the imager. The relationship between the incoming light ray field angle and the outgoing light field angle is nonlinear, with large incoming field angles being bent more than small ones. Lens manufacturers typically provide a nominal lens distortion characteristic, as:

Outgoing Field Angle=function(Incoming Field Angle).

[0054] In accordance with the example embodiment herein, a scale factor which compensates for lens variations and adjusts for the lens variations, is added to this equation, as:

Outgoing Field Angle=function(Scale Factor*Incoming Field Angle).

[0055] Accordingly, the new lens characteristic is derived or otherwise calculated or determined in the surround view camera system **100** of the example embodiment by the computer system **200** (FIG. **2**) from the multiplication of the original lens characteristic and the scale factor of the incoming field angle.

[0056] With continued reference to FIG. **4**, the marker size, shape, and locations are measured in the image plane obtained by the first camera obtained at step **408**. It is to be appreciated that at least four (4) marker points are used in the example embodiment to ensure proper calibration although any other number of marker points could be used as necessary or desired achieving commensurate calibration accuracy. In addition, matched filter correlation masks or the like may be used in this process. FIG. **4***a* shows an uncompensated image **470** of an example of a square physical target object **480** disposed on the floor of a hallway of a building. As can be seen, although physically square, the target object **480** has a trapezoidal shape in the uncompensated image **470**.

[0057] Next, at step **410**, the initial or a "default" homography matrix for the active camera being calibrated is obtained. In this step, before describing this calibration processing, the use of the expedient of a homography matrix for converting an original image to a converted image by the planar projective transformation will be considered. In this description, coordinates at each point on the original image are represented by (x, y) and coordinates of each point on the converted image are represented by (X, Y). The relation between the coordinates (x, y) on the original image and the coordinates (X, Y) on the converted image is expressed by the first of the formulas below using a homography matrix H. The homography matrix H is a 3×3 matrix and each of the elements of the matrix is expressed by h_1 to h_9. Moreover, it is convenient to set $h_9=1$ (the matrix is normalized such that $h_9=1$). From the formula, the relation between the coordinates (x, y) and the coordinates (X, Y) also can be expressed by the following formulas.

$$\begin{pmatrix} X \\ Y \\ 1 \end{pmatrix} = H \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

$$= \begin{pmatrix} h_1 & h_2 & h_3 \\ h_4 & h_5 & h_6 \\ h_7 & h_8 & h_9 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

$$= \begin{pmatrix} h_1 & h_2 & h_3 \\ h_4 & h_5 & h_6 \\ h_7 & h_8 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \\ 1 \end{pmatrix}$$

$$X = \frac{h_1 x + h_2 y + h_3}{h_7 x + h_8 y + h_9}$$

$$Y = \frac{h_4 x + h_5 y + h_6}{h_7 x + h_8 y + h_9}$$

[0058] The homography matrix H is uniquely determined if corresponding relations of the coordinates of four or more points between the original image and the converted image are known. Once the homography matrix H is obtained, it becomes possible to convert a given point on the original image to a point on the converted image according to the above formulas. In the example embodiments herein an initial or nominal homography matrix H is received and stored in the memory **210** for later use for improvement of the image displayed to an operator of the vehicle **110**.

[0059] With regard to obtaining the initial homography matrix, error values are obtained or otherwise derived related to the homography related error values. In accordance with an example embodiment, a numerical optimization function is performed to find homography matrix values that make the total registration error smaller. In one embodiment, the numerical optimization step includes a Simplex Method to improve the fidelity between the obtained image and square or rectangular templates. During the calculations, the homography matrix values are adjusted in accordance with the result obtained during the numerical optimization. Next, the raw image data is un-skewed with or using the improved homography matrix values. This image is then in turn once again tested against a known regular square or rectangular grid image to determine improved homography related calibration parameter values.

[0060] Next, at step **412**, an undistorted bird's eye view is generated using the determined homography matrix and optimized lens distortion characteristic parameters.

[0061] FIG. **4***a* shows an uncompensated image **470** of the square physical target object **480**, and FIGS. **4***b*, **4***c* show first and second compensated images **472**, **474** of the square physical object **480** resulting from successive repetition of the compensation processing. It is of course to be appreciated that the calibration and skew compensation optimization method **400** is performed simultaneously for each of the cameras of the system **100**.

[0062] FIG. **5***a* shows an original image **500** of a rectangular region such as, for example, one or more of the calibration grid areas A-D, E-H, S-V, or W-Z (FIGS. **1***b*-**1***c*) photographed by one of the cameras **122**, **120**, **124**, and **126**, respectively. Because the raw or original image **500** is obtained via a wide-angle lens, the image is generally distorted such that the center portion is enlarged and the peripheral portions are reduced as indicated by the grid lines. FIG. **5***b* shows an after-correction image **502**, which is obtained by applying the lens distortion scaling optimization module **324** as described above by the system calibration unit **304**. The distorted image **500** is corrected to the image **502** in accordance with the perspective, such that the perspective view from the viewpoint of the cameras **120**, **122**, **124**, **126** is provided, as indicated by hypothetical vertical-horizontal coordinate **512** on the ground (road surface) as modified from the raw or original hypothetical virtual horizontal coordinate **510** (FIG. **5***a*). The lens distortion correction may be carried out with, for example, a pixel coordinate transformation process using a dedicated pixel transformation table. In accordance with the example embodiment, the transformation table is stored in the memory **206** and describes the relationship between the addresses of the pixels of the image before transformation and the addresses of the pixels after transformation.

[0063] FIG. **5***c* depicts a upper viewpoint image **504**, which is obtained by applying a viewpoint change process on the ground (road surface) image **502** obtained by the lens distortion correction process (FIG. **5***b*). The upper viewpoint image **504** after the viewpoint change process has a viewpoint shifted from the vehicle body to the above-the-vehicle-body, and the hypothetical coordinate **512** of FIG. **5***b* is transformed to a hypothetical rectangular coordinate **514**. The viewpoint change process may be performed by a pixel coordinate transformation process with a second dedicated pixel transformation table, which is stored in the memory **206**.

[0064] In accordance with the example embodiment herein, the lens distortion correction using a first dedicated pixel transformation table and the viewpoint change process (homography) using a second dedicated pixel transformation table are collapsed into a single look up table (LUT) **600** as shown in diagram form in FIG. **6**. In the example embodiment, the LUT comprises a pair of tables including a Source Row Table **602** and a Source Column Table **604** for convenient fast access processing of the LUT **600** by the system **200**. "Source" as used herein may be understood as pertaining to the original, distorted camera image(s). In general, however, it is to be understood that the LUT **600** is indexed **621** relative to an output pixel array **620** for human readable observation on the output display **212** and, further, is also indexed **611** relative to an input pixel array **610** of the original distorted image as obtained by the cameras **120**, **122**, **124**, **126**. The overall system shown in FIG. **6** provides for fast and easy retrieval of pixel information from the input pixel array **610** of the original distorted image directly to the output pixel array **620** for human readable observation on the output display **212** without the requirement of performing time consuming distortion correction and homography processing. Essentially, the LUT inherently includes the distortion correction and homography processing as part of its structure, whereby the time-consuming distortion correction and homography processing normally required by mathematical software or other processing algorithms is simply and advantageously bypassed in accordance with the embodiment via an indexing of the LUT **600** in a manner as will be described below.

[0065] By way of example of using the LUT **600** in accordance with an embodiment herein, in order to determine, for example, a nominal value to be displayed in the output pixel array **620** at output pixel array row OR and output pixel array column OC, both the source row table **602** as well as the source column table **604** are indexed using the

output pixel array row index value OR and the output pixel array column value OC. The index into the source row table **602** using the output pixel array row OR and output pixel array column OC values yields a row pointer of the input pixel array **610**, the pointer having a value SR in the example. Similarly, the index into the source column table **604** using the output pixel array row OR and output pixel array column OC values yields a column pointer of the input pixel array **610**, the pointer having a value SC in the example. The value SR retrieved from the source row table **602** is used to index the input pixel array **610** at the row value indicated by SR. Similarly, the value SC retrieved from the source column **604** is used to index the input pixel array **610** at the column value indicated by SC. In this way, the nominal value A at pixel location (SR, SC) in the input pixel array **610** is directly mapped and therefore may be directly retrieved into the pixel location (OR, OC) in the output pixel array **620** as A, thereby avoiding overhead requirements of real-time distortion correction and homography processing and the like.

[0066] In accordance with the example embodiment, the processor of the surround view camera system **100** is further configured to execute code in the form of the sensitivity processing unit **306** for determining one or more sensitivities of the vehicle and of the surround view system to a corresponding one or more relationships of the vehicle relative to the peripheral area surrounding the vehicle during use therefor. Examples of one or more relationships of the vehicle relative to the peripheral area surrounding the vehicle include vehicle loading, vehicle pitch, vehicle roll, vehicle age, vehicle acceleration, suspension features of the vehicle and others as may be necessary or desired. The sensitivity processing unit **306** is operative to selectively make adjustments in the use of the LUT **600** for making corresponding adjusted use of the calibration and homography matrix parameters using techniques and method steps to be described in greater detail below.

[0067] FIG. **7***a* is a schematic top plan view of a vehicle **702** having an imaging device **704** such as a camera **706** attached to the mid-right side thereof and configured to image a calibration marker **710** disposed on the ground adjacent to the vehicle. In the physical position shown, the marker is at a first forward/aft position **720** relative to the camera and vehicle and a first right/left position **730** relative to the camera and vehicle as shown. In accordance with the example embodiment, the system sensitivity processing unit **306** performs the method shown in FIG. **8** for synthetically (without actual physical movement of the associated vehicle) determining a sensitivity of the surround view camera system **100** (shown in FIG. **7***a* as a simple single camera system for ease of illustration) to vehicle pitch, vehicle roll, and other parameters of the vehicle relative to the areas surrounding the vehicle including, for example, the ground. While for purposes of simplicity of explanation the methodology **800** of FIG. **8** is shown and described as executing serially, it is to be understood and appreciated that the example embodiment is not limited by the illustrated order, as some aspects could occur in different orders and/or concurrently with other aspects from that shown and described herein. Moreover, not all illustrated features may be required to implement the methodology **800** in accordance with the example embodiment.

[0068] The methodology **800** described herein is suitably adapted to be implemented in hardware, software, and/or any one or more combination(s) thereof. For example, the methodology **800** may be implemented by logic and/or by computer system **200** (FIG. **2**) in the surround view camera system **100** described above including the processing module set **300** comprising the plural inter-operative processing modules or units for carrying out the functions of the example embodiment herein. In the example embodiment and as described below, the processor and the situational compensation unit develop sensitivity data for offsetting references to the calibration LUT by a sensitivity of the associated vehicle to relative physical changes between the associated vehicle and the peripheral area adjacent to the associated vehicle using a synthetic displacement of calibration markers imaged by the image obtaining units **232**, **302** using synthetic displacements of calibration markers. It is to be appreciated that "logic," as used in the descriptions herein, includes but is not limited to hardware, firmware, software and/or combinations of each to perform a function (s) or an action(s), and/or to cause a function or action from another component. For example, based on a desired application or need, logic may include a software controlled microprocessor, discrete logic such as an application specific integrated circuit (ASIC), a programmable/programmed logic device, memory device containing instructions, or the like, or combinational logic embodied in hardware. Logic may also be fully embodied as software stored in and/or on a non-transient memory.

[0069] At step **802** a counter parameter n is initialized to 1. At step **804** the system sensitivity processing unit **306** (FIG. **3**) is provided with input position values of the calibration marker **710** such as, for example, the measured actual physical size of the calibration marker **710**, the measured actual physical first forward/aft position **720** of the calibration marker **710** relative to the vehicle and/or relative to the camera **706**, and the measured actual physical first right/left position **730** of the calibration marker **710** relative to the vehicle and/or relative to the camera **706** as shown. The system sensitivity processing unit **306** is also provided with an input position value h (FIG. **7***b*) of the camera **706** relative to the ground under the vehicle **702**. From these values the system sensitivity processing unit **306** images the calibration marker **710** at step **806** and, at step **810**, the system sensitivity processing unit **306** is initially calibrated. The initial calibration parameters are stored in the memory at step **812**. It is to be appreciated that the initial calibration parameters are obtained and/or determined without physical movement of the associated vehicle as well as without synthetic movement of the associated vehicle. After the initial parameters are obtained, however, the example embodiment performs further calibration to dynamic road conditions to establish functional relationships between the raw image obtained and the image displayed by synthetic movement of the vehicle (without physical movement of the vehicle).

[0070] At step **814** it is determined whether the system sensitivity processing unit **306** is to be provided with any additional input position values of the calibration marker **710** and, if so, at step **816** the counter value n is incremented. It is to be appreciated that, in accordance with the example embodiment herein, after being provided with the physical forward/aft, left/right, and height parameters, the system is provided with one or more (preferably many) synthetic forward/aft, left/right, and height parameters for synthetically determining, without physical movement of the asso-

ciated vehicle, a sensitivity of the surround view camera system **100** to vehicle pitch, vehicle roll, and other parameters of the vehicle relative to the areas surrounding the vehicle. More particularly, at step **804** the system sensitivity processing unit **306** is provided with additional input position values of the calibration marker **710** such as, for example, not the measured actual physical first forward/aft position **720** of the calibration marker **710** relative to the vehicle and/or relative to the camera **706**, but instead an "artificial" or synthetic second forward/aft position **722** of the calibration marker **710** relative to the vehicle and/or relative to the camera **706** or third forward/aft position **724** of the calibration marker **710** relative to the vehicle and/or relative to the camera **706** as shown. Similarly at step **804** the system sensitivity processing unit **306** is provided with additional input position values of the calibration marker **710** such as, for example, not the measured actual physical first right/left position **730** of the calibration marker **710** relative to the vehicle and/or relative to the camera **706**, but instead an "artificial" or synthetic second right/left position **732** of the calibration marker **710** relative to the vehicle and/or relative to the camera **706** or third right/left position **734** of the calibration marker **710** relative to the vehicle and/or relative to the camera **706** as shown.

[0071] In general and in accordance with the example embodiment, the direction of the synthetic displacement corresponds to the direction of compensation. For example, pitch sensitivity determination would entail a forward or aft synthetic displacement, and roll sensitivity determination would entail a left or right synthetic displacement. The system sensitivity processing unit **306** is also provided with an input position value h (FIG. **7***b*) of the camera **706** relative to the ground under the vehicle **702**. From these non-physical synthetic values the system sensitivity processing unit **306** images the physical calibration marker **710** at step **806** and, at step **810**, the system sensitivity processing unit **306** determines a sensitivity calibration of the imaging system and of the vehicle relative to changes in virtual marker location. The series of additional sensitivity calibration parameters are stored in the memory at step **812**.

[0072] A conceptual sensitivity calculation is shown in FIG. **7***b* wherein the angle α may be calculated for a given height value h as being a height value of the camera **706** relative to the ground supporting the physical marker **710**, and a given leg length d as being a physical or virtual distance of the marker from the camera in the forward/aft and right/left directions. The angle α may be calculated as the arctangent of (d/h). The amount of displacement from the nominal ground forward/aft and/or left/right positions, used to create the synthetic ground locations, is a function of the marker location, given by the nominal location of the camera during calibration (the vehicle is physically typically within some small tolerance of a nominal position).

[0073] It is to be noted that, in the example embodiment, the synthetic displacement of the ground plane markers produces a new LUT, encoding the new homography matrix and lens distortion characteristics therein. In accordance with the example embodiment, this new LUT is not stored directly, but rather the difference between the new LUT incorporating the synthetic sensitivity parameters relative to the original LUT without or prior to any sensitivity adjustments is stored. This change table, or Δ LUT, is stored as one or more sensitivity values in one or more sensitivity tables, describing how much the source row and column change, at a given display location, per unit of roll, pitch, height change, etc. of the vehicle as determined in the synthetic sensitivity calibration or analysis described above.

[0074] The sets of sensitivity values collected in step **820** using the method **800** described above are used in accordance with the example embodiment to provide offsets to referenced nominal pixel locations to adjust or otherwise compensate for one or more relationships of the vehicle relative to the peripheral area around the vehicle during use thereof. In accordance with a further aspect of the example embodiment, the various one or more sensitivities of the vehicle are linearized by the system linearization unit **308** as will now be described with reference to FIGS. **9***a* and **9***b*. As shown first in FIG. **9***a*, a pitch sensitivity curve **910** is plotted in a graph **902** in a coordinate system comprising changes of vehicle pitch plotted against the LUT **600**; namely, the Source Row Table **602** and Source Column Table **604** values. In the Figure, the pitch sensitivity curve **910** is linearized by the system linearization unit **308** by approximating the pitch sensitivity curve **910** as a straight line **912** tangent to the pitch sensitivity curve **910** at a value **914** of vehicle pitch of the vehicle at rest. Similarly, as shown next in FIG. **9***b*, a roll sensitivity curve **920** is plotted in a graph **904** in a coordinate system comprising changes of vehicle roll plotted against the LUT **600**; namely, the Source Row Table **602** and Source Column Table **604** values. In the Figure, the roll sensitivity curve **920** is linearized by the system linearization unit **308** by approximating the roll sensitivity curve **920** as a straight line **922** tangent to the roll sensitivity curve **920** at a value **924** of vehicle roll of the vehicle at rest.

[0075] FIG. **10** shows an augmented LUT **600'** with the pair of tables described above in connection with FIG. **6** including the Source Row Table **602** and the Source Column Table **604** for convenient fast access processing of the LUT **600** by the system **200**, and further including a set of four (4) motion compensation LUTs **1010**, **1012**, **1020**, and **1022** for compensating the nominal use of the LUT **600** (FIG. **6**) to include the synthetically derived and linearized sensitivity adjustments described above. In particular, the augmented LUT **600'** includes a first redirecting LUT **1010** for offsetting indexes into the Source Row Table **602** in accordance with a linearization such as, for example, the linearized curve **910** of FIG. **9***a*, and a second redirecting LUT **1012** for offsetting indexes into the Source Row Table **602** in accordance with a linearization such as, for example, the linearized curve **920**. Similarly, the augmented LUT **600'** includes a third redirecting LUT **1020** for offsetting indexes into the Source Column Table **604** in accordance with a linearization such as, for example, the linearized curve **910** of FIG. **9***a*, and a fourth redirecting LUT **1022** for offsetting indexes into the Source Column Table **604** in accordance with a linearization such as, for example, the linearized curve **920**.

[0076] In general and in accordance with the example linear embodiment:

$$\text{Adjusted_Value} = \text{Nominal_Source_Value} + [\text{sensitivity}_1 \times (\Delta\text{variable}_1)] + [\text{sensitivity}_1 \times (\Delta\text{variable}_1)] + [\text{sensitivity}_2 \times (\Delta\text{variable}_2)] + \ldots [\text{sensitivity}_n \times (\Delta\text{variable}_n)].$$

[0077] By way of example of using the augmented LUT **600'**, in order to determine, for example, a motion compensated or otherwise adjusted value to be displayed in the output pixel array **620** at output pixel array row OR and output pixel array column OC, indices to both the source

row table **602** as well as the source column table **604** are adjusted by adding values relating to the sensitivity of the vehicle to pitch and to roll in the example described above. The index into the source row table **602** using the output pixel array row OR and the output pixel array column OC values yields a nominal value SR as described above with reference to FIG. **6**. Similarly, the index into the source column table **604** using the output pixel array row OR and the output pixel array column OC values yields a nominal value SC. The value SR retrieved from the source row table **602** is then augmented with values obtained from the first and second sensitivity tables **1010**, **1012** and, thereafter, the augmented value of SR is used to index the input pixel array **610** at the row value indicated by the augmented value of SR. Similarly, the value SC retrieved from the source column **604** is then augmented with values obtained from the third and fourth sensitivity tables **1020**, **1022** and, thereafter, the augmented value of SC is used to index the input pixel array **610** at the column value indicated by the augmented value of SC. In this way, the motion compensated or otherwise adjusted value at pixel location (SR', SC') in the input pixel array **610** is directly mapped and therefore may be directly retrieved into the pixel location (OR, OC) in the output pixel array **620**, thereby avoiding the requirement of the distortion correction and homography processing, while including vehicle motion and other parameter sensitivity compensation.

[0078] In particular then relative to the example linear embodiment described:

$$\text{Adjusted_Output_Row_Value} = \text{Nominal_Source_Row_Value} + [\text{row_sensitivity}_{pitch} \times (\Delta\text{pitch})] + [\text{row_sensitivity}_{roll} \times (\Delta\text{roll})] + \ldots [\text{row_sensitivity}_{variable_n} \times (\Delta\text{variable}_n)].$$

$$\text{Adjusted_Output_Column_Value} = \text{Nominal_Source_Column_Value} + [\text{column_sensitivity}_{pitch} \times (\Delta\text{pitch})] + [\text{column_sensitivity}_{roll} \times (\Delta\text{roll})] + [\text{column_sensitivity}_{variable_n} \times (\Delta\text{variable}_n)].$$

[0079] FIG. **11** is a conceptual illustration of using the augmented LUT **600'** of FIG. **10** to perform mapping adjustments between pixels of a distorted camera image and pixels rendered in an output display in accordance with variations in vehicle roll and pitch parameters. With reference now to that figure, in accordance with the example embodiment herein, the lens distortion correction using the first dedicated pixel transformation table, the viewpoint change process (homography) using the second dedicated pixel transformation table, the several sensitivity measures or tables **1010**, **1012**, **1020**, and **1022** are collapsed into a single augmented look up table (LUT) **600'** as described above and shown in diagram form in FIG. **10**. In the example embodiment, the augmented LUT **600'** is indexed **621'** relative to an output pixel array **620** for human readable observation on the output display **212** of a selected pixel **1102** and, further, is also indexed **611'** relative to an input pixel array **610'** of the original distorted image as obtained by the cameras **120**, **122**, **124**, **126**. The overall system shown in FIG. **11** provides for fast and easy retrieval of the nominal values of the pixel information from the input pixel array **610'** of the original distorted image directly to the output pixel array **620'** for human readable observation on the output display **212** as well as information drawn from other pixel locations based on sensitivity measures or tables as described above without the requirement of performing time consuming distortion correction, homography processing, or sensitivity adjustments. Essentially, the augmented LUT **600'** inherently includes the distortion correction, homography processing, and sensitivity adjustment processing as part of its structure, whereby the distortion correction and homography and sensitivity adjustment processing is simply bypassed via the indexing of the augmented LUT **600'** in a manner as will be described below.

[0080] By way of a further example of using the augmented LUT **600'**, in order to determine, for example, a value to be displayed in the output pixel array **620'** at output pixel **1102**, the augmented LUT **600'** is indexed in accordance with a signal from the vehicle relative position determination unit **310** (FIG. **3**) that the vehicle is experiencing a "−" roll resulting in a − roll sensitivity adjusted index **1162** into the input pixel array **610'** yielding the value at the − roll sensitivity adjusted pixel location **1112**. Similarly, the augmented LUT **600'** is indexed in accordance with a signal from the vehicle relative position determination unit **310** (FIG. **3**) that the vehicle is experiencing a "+" pitch resulting in a + pitch sensitivity adjusted index **1172** into the input pixel array **610'** yielding the value at the + pitch sensitivity adjusted pixel location **1122**. Further, the augmented LUT **600'** is indexed in accordance with a signal from the vehicle relative position determination unit **310** (FIG. **3**) that the vehicle is experiencing a "+" roll resulting in a + roll sensitivity adjusted index **1160** into the input pixel array **610'** yielding the value at the + roll sensitivity adjusted pixel location **1110**. Yet still further, the augmented LUT **600'** is indexed in accordance with a signal from the vehicle relative position determination unit **310** (FIG. **3**) that the vehicle is experiencing a "−" pitch resulting in a − pitch sensitivity adjusted index **1170** into the input pixel array **610'** yielding the value at the − pitch sensitivity adjusted pixel location **1120**. Although the indices **1160**, **1162**, **1170**, and **1172** were described above as operating individually for ease of discussion, it is to be understood that the indices **1160**, **1162**, **1170**, and **1172** may operate simultaneously in the example embodiment and, further, may operate simultaneously in the example in combination with one or more other or additional sensitivity measures.

[0081] Based on the above and in accordance with the example embodiment, overall, one or more blind spot regions in areas peripheral to the vehicle are filled in. First image data representative of a first image of the peripheral area adjacent to the vehicle is received and stored in a memory together with intrinsic image coordinate transformation data comprising homography and lens distortion data representative of an intrinsic mapping between the first image data and display data representative of an uncompensated view of the peripheral area of the vehicle. The situational compensation unit is operable to selectively modify, in accordance with the above description, the intrinsic mapping as an adjusted intrinsic mapping between the first image data and the first display data in accordance with one or more signals representative of the several relationships of the vehicle relative to the peripheral area. An output signal representative of the first display data mapped from the first image data is generated and displayed on the human readable output display of the imaging system.

[0082] In the embodiment, the intrinsic image coordinate transformation data is stored in the LUTs **600**, **600'** mapping first coordinate pairs of the first display data with first coordinate pairs of the image data. The situational compensation unit selectively redirects access to the first image data

as referenced by the LUT by the adjusted intrinsic mapping, wherein the first coordinate pairs of the first display data are mapped from second coordinate pairs of the image data different than the first coordinate pairs of the image data. In particular, in the embodiment, the situational compensation unit selectively redirects access to the first image data as referenced by the calibration LUT by offsetting one or more indexes to the nominal row and column tables in accordance with the one or more relationships of the associated vehicle relative to the peripheral area.

[0083] In addition to the above, it is to be appreciated that the one or more offset relationships for redirecting access to the LUT may be linear, quadratic or of higher order expressed as a set of values representative of one or more operating conditions of the vehicle.

[0084] In the numerical example in FIG. **12***a*, an input image **1210** such as for example as obtained from one or more of the cameras **120**, **122**, **124** or **126** has 1280 columns of pixels and 800 rows of pixels, and an output display **1220** such as for example the display **212** (FIG. **2**) has 1024 columns of pixels and 768 rows of pixels. A LUT **600"** shown in FIG. **12***b* provides a mapping in accordance with the embodiment between the 1280 columns and 800 rows of pixels of the input image **1210** and the 1024 columns and 768 rows of pixels of the output display **1220**. More particularly, in accordance with the embodiment, the LUT **600"** provides a mapping between a single pixel of the input image **1210** and a single pixel of the output display **1220** for providing nominal output display values drawn from the input image. It is to be appreciated that the LUT **600"** of FIG. **12***b* is a representation of the LUT **600'** of FIG. **10** comprising two (2) tables **602**, **1010**, **1012** and **604**, **1020**, **1022** combined into a single but multiple entry LUT **600"** for convenience of reference and description of the example embodiment. The data within the LUT **600"** need not necessarily be stored in the particular arrangement illustrated.

[0085] Using the LUT **600"** of the example embodiment and as shown at W in FIG. **12***b*, the pixel value nominally to be displayed at output display row **404**, column **25** is, according to the LUT **600'**, to be drawn from row **227**, column **681** of the input image pixel array. Similarly, as shown at X, the pixel value nominally to be displayed at output display row **407**, column **26** is, according to the LUT **600'**, to be drawn from row **228**, column **684** of the input image pixel array. For further example and as shown at Y, the pixel value nominally to be displayed at output display row **408**, column **24** is, according to the LUT **600'**, to be drawn from row **228**, column **684** of the input image pixel array. It is to be appreciated that, in the example embodiment, the LUT **600"** has 1024 columns and 768 rows of value pairs, essentially corresponding to the column and row size of the output display **1220** one-to-one.

[0086] The above nominal mapping is then, according to the example embodiment, compensated for vehicle operating parameters including but not limited to vehicle pitch, vehicle roll, vehicle loading, vehicle wear, suspension position, vehicle height relative to the ground, and other operating conditions. The compensation uses the parameters derived from the synthetic displacement compensation described above. As described above, in the general case:

$$\text{Adjusted_Value} = \text{Nominal_Source_Value} + [\text{sensitivity}_1 \times (\Delta\text{variable}_1)] + [\text{sensitivity}_1 \times (\Delta\text{variable}_1)] + [\text{sensitivity}_2 \times (\Delta\text{variable}_2)] + \ldots [\text{sensitivity}_n \times (\Delta\text{variable}_n)].$$

[0087] In particular then, relative to the example embodiment using a LUT having rows and columns of value pairs, wherein the value pairs index into a source image table of nominal values for output display:

$$\text{Adjusted_Output_Row_Value} = \text{Nominal_Source_Row_Value} + [\text{row_sensitivity}_{pitch} \times (\Delta\text{pitch})] + [\text{row_sensitivity}_{roll} \times (\Delta\text{roll})] + [\text{row_sensitivity}_{variable_n} \times (\Delta\text{variable}_n)].$$

and

$$\text{Adjusted_Output_Column_Value} = \text{Nominal_Source_Column_Value} + [\text{column_sensitivity}_{pitch} \times (\Delta\text{pitch})] + [\text{column_sensitivity}_{roll} \times (\Delta\text{roll})] + [\text{column_sensitivity}_{variable_n} \times (\Delta\text{variable}_n)].$$

[0088] Using the above and working towards demonstrating obtaining an output value at row **403**, column **25** of the output display **1220**:

$$\text{Adjusted_Output_Row_403_Value} = \text{Nominal_Source_Row_227_Value} + [\text{row_sensitivity}_{pitch} \times (\Delta\text{pitch})] + [\text{row_sensitivity}_{roll} \times (\Delta\text{roll})] + [\text{row_sensitivity}_{variable_n} \times (\Delta\text{variable}_n)].$$

and

$$\text{Adjusted_Output_Column_25_Value} = \text{Nominal_Source_Column_681_Value} + [\text{column_sensitivity}_{pitch} \times (\Delta\text{pitch})] + [\text{column_sensitivity}_{roll} \times (\Delta\text{roll})] + [\text{column_sensitivity}_{variable_n} \times (\Delta\text{variable}_n)].$$

[0089] Then, if:

[0090] Row Roll Sensitivity=+0.12 pixels/degree of roll

[0091] Row Pitch Sensitivity=−0.024 pixels/degree of pitch

[0092] Column Roll Sensitivity=+0.032 pixels/degree of roll

[0093] Column Pitch Sensitivity=−0.37 pixels/degree of pitch

[0094] Using the above and demonstrating obtaining an output value at row **403**, column **25** of the output display **1220**, wherein the determined row and column values are rounded to the nearest integer value:

$$\text{Adjusted_Output_Row_403_Value} = \text{Nominal_Source_Row_}(227 + [-0.024 \times (\Delta\text{pitch})] + [+0.12 \times (\Delta\text{roll})])$$

and

$$\text{Adjusted_Output_Column_25_Value} = \text{Nominal_Source_Column_}(681 + [-0.37 \times (\Delta\text{pitch})] + [+0.032 \times (\Delta\text{roll})])$$

[0095] In accordance with another aspect of the example embodiment, in order to further increase the speed of the system for rendering images of the areas adjacent to the vehicle on the **112** compensated for changes in one or more relationships of the vehicle relative to the associated peripheral area, parameters described above in connection with the sensitivity adjustment and with physical vehicle monitoring are stored in a wide read memory scheme permitting simultaneous plural parallel read and multiply operations. In this regard, FIG. **13***a* shows a LUT row parameter storage scheme **1302** and FIG. **13***b* shows a LUT column parameter storage scheme **1304**. In the LUT row parameter storage

scheme **1302**, the measure **1322** of system row sensitivity to pitch is stored adjacent (by memory address) to the measure **1324** of system row sensitivity to roll, which is stored adjacent (by memory address) to the measure **1326** of system row sensitivity to height. Similarly, a measure **1332** of a physical change in pitch of the vehicle as may be determined, for example, by the system relative position determination unit **310**, is stored adjacent (by memory address) to a measure **1334** of a physical change in roll of the vehicle as determined by the system relative position determination unit **310**, and to the measure **1336** of a physical change in height of the vehicle as determined by the system relative position determination unit **310**. Similarly, in the LUT column parameter storage scheme **1304** of FIG. **13***b*, the measure **1342** of system column sensitivity to pitch is stored adjacent (by memory address) to a measure **1344** of system column sensitivity to roll is stored adjacent (by memory address) to a measure **1346** of system column sensitivity to height.

[0096] The measure **1352** of a physical change in pitch of the vehicle as may be determined, for example, by the system relative position determination unit **310**, is stored adjacent (by memory address) to a measure **1354** of a physical change in roll of the vehicle as determined by the system relative position determination unit **310**, and to the measure **1356** of a physical change in height of the vehicle as determined by the system relative position determination unit **310**.

[0097] In the example embodiment, the LUT is stored in an ARM NEON single instruction multiple data architecture processor available from ARM Limited. The NEON architecture performs parallel multiplication and addition, enabling quick calculation of the above compensation equations. In this regard, the values **1320**, **1322**, **1324**, and **1326** are read in a single "wide" read, and the values "1," **1332**, **1334**, and **1336** are read in a single "wide" read. Thereafter, the values of the first row set **1320**, **1322**, **1324**, **1326** are multiplied with the values of the vehicle situational data set **1**, **1332**, **1334**, **1336** in a single processor instruction. Similarly, the values of the first column set **1340**, **1342**, **1344**, **1346** are read in a single "wide" read and, thereafter, the values of the first column set **1340**, **1342**, **1344**, **1346** are multiplied with the values of the vehicle situational data set in a single processor instruction.

[0098] FIG. **14** is a diagrammatic illustration of the relative position determination unit **310** of the system in accordance with the example embodiment herein. As shown there, the relative position determination unit **310** of the system includes a vehicle relative position processor **1402** operatively coupled with a set of sensor hardware and/or software modules. In particular, the vehicle relative position processor **1402** is operatively coupled with a vehicle height detection unit **1410**, a vehicle roll detection unit **1420**, a pitch detection unit **1430**, a yaw detection unit **1440**, an acceleration detection unit **1450**, and altitude detection unit **1460**, and with a Global position sensor (GPS) unit **1470**. The vehicle relative position processor unit **310** senses real world conditions of the vehicle and provides real world signals representative of the real world conditions to the vehicle situational compensation unit **312** (FIG. **3**) to reference the augmented LUT using the detected vehicle values and the corresponding sensitivities for rendering the compensated and adjusted image on the vehicle display.

[0099] Described above are example embodiments. It is, of course, not possible to describe every conceivable combination of components or methodologies, but one of ordinary skill in the art will recognize that many further combinations and permutations of the example embodiments are possible. Accordingly, this application is intended to embrace all such alterations, modifications and variations that fall within the spirit and scope of the appended claims interpreted in accordance with the breadth to which they are fairly, legally and equitably entitled.

1. An imaging system adjusting a representation of images obtained of a peripheral area adjacent to an associated vehicle to compensate for one or more relationships of the associated vehicle relative to the peripheral area, the system comprising:

a processor;

an image obtaining unit operatively coupled with the processor and being configured to receive first image data representative of a first image of the peripheral area adjacent to the associated vehicle;

a non-transient memory operatively coupled with the processor, the non-transient memory storing intrinsic image coordinate transformation data comprising homography and lens distortion data representative of an intrinsic mapping between the first image data and first display data representative of an uncompensated view of the peripheral area of the associated vehicle; and

a situational compensation unit operatively coupled with the processor, the image obtaining unit, and the non-transient memory, the situational compensation unit being configured to selectively modify the intrinsic mapping as an adjusted intrinsic mapping between the first image data and the first display data in accordance with a signal representative of the one or more relationships of the associated vehicle relative to the peripheral area.

2. The imaging system according to claim **1**, further comprising:

an interface configured to generate an output signal representative of the first display data mapped from the first image data in accordance with the adjusted intrinsic mapping.

3. The imaging system according to claim **2**, wherein the interface comprises:

a display unit configured to display, on a human readable output, the output signal representative of the first display data mapped from the first image data in accordance with the adjusted intrinsic mapping.

4. The imaging system according to claim **1**, wherein:

the non-transient memory is operative to store the intrinsic image coordinate transformation data in a calibration look up table (LUT) mapping first coordinate pairs of the first display data with first coordinate pairs of the image data; and

the situational compensation unit is configured to selectively redirect access to the first image data as referenced by the calibration LUT by the adjusted intrinsic mapping, wherein the first coordinate pairs of the first display data are mapped from second coordinate pairs of the image data different than the first coordinate pairs of the image data.

5. The imaging system according to claim 4, wherein:
the image obtaining unit comprises at least one camera configured to capture the first image data representative of the first image of the peripheral area adjacent to the associated vehicle as a sequence of image data frame sets, each image data frame set comprising rows and columns of first image data; and
the non-transient memory is operative to store the calibration LUT as nominal row and column tables, the nominal row table relating rows and columns of the first display data with rows and columns of the first image data and the nominal column table relating rows and columns of the first display data with rows and columns of the first image data.

6. The imaging system according to claim 5, wherein:
the situational compensation unit is configured to selectively redirect access to the first image data as referenced by the calibration LUT by offsetting one or more indexes to the nominal row and column tables in accordance with the one or more relationships of the associated vehicle relative to the peripheral area.

7. The imaging system according to claim 6, wherein the situational compensation unit is configured to selectively redirect the access to the first image data as references by the calibration LUT by one or more offset relationships, wherein the one or more offset relationships may be linear, quadratic, or of higher order expressed as a set values representative of one or more operating conditions of the associated vehicle.

8. The imaging system according to claim 6, wherein:
the non-transient memory comprises a plurality of logically adjacent memory locations configured to store selected ones of one or more relationships of the associated vehicle relative to the peripheral area logically adjacent to selected ones of the intrinsic image coordinate transformation data; and
the processor is configured to selectively execute parallel multiplication and addition operations on data stored in the logically adjacent memory locations.

9. The imaging system according to claim 5, wherein the processor and situational compensation unit are configured to develop sensitivity data for offsetting references to the calibration LUT by sensitivity of the associated vehicle to relative physical changes between the associated vehicle and the peripheral area adjacent to the associated vehicle using synthetic displacement of calibration markers imaged by the image obtaining unit.

10. A method of adjusting a representation of images obtained by an associated imaging system of a peripheral area adjacent to an associated vehicle to compensate for one or more relationships of the associated vehicle relative to the peripheral area, the method comprising:
receiving, by an image obtaining unit operatively coupled with a processor, first image data representative of a first image of the peripheral area adjacent to the associated vehicle;
storing, in a non-transient memory operatively coupled with the processor, intrinsic image coordinate transformation data comprising homography and lens distortion data representative of an intrinsic mapping between the first image data and first display data representative of an uncompensated view of the peripheral area of the associated vehicle; and
selectively modifying, by a situational compensation unit operatively coupled with the processor and the non-transient memory, the intrinsic mapping as an adjusted intrinsic mapping between the first image data and the first display data in accordance with a signal representative of the one or more relationships of the associated vehicle relative to the peripheral area.

11. The method according to claim 10, further comprising:
generating at an interface of the associated imaging system an output signal representative of the first display data mapped from the first image data in accordance with the adjusted intrinsic mapping.

12. The method according to claim 11 further comprising:
displaying the output signal on a human readable output of the associated imaging system.

13. The method according to claim 10, further comprising:
storing, in the non-transient memory, the intrinsic image coordinate transformation data in a calibration look up table (LUT) mapping first coordinate pairs of the first display data with first coordinate pairs of the image data;
selectively redirecting, by the situational compensation unit, access to the first image data as referenced by the calibration LUT by the adjusted intrinsic mapping, wherein the first coordinate pairs of the first display data are mapped from second coordinate pairs of the image data different than the first coordinate pairs of the image data.

14. The method according to claim 13, further comprising:
capturing, by at least one camera of the image obtaining unit, the first image data representative of the first image of the peripheral area adjacent to the associated vehicle as a sequence of image data frame sets, each image data frame set comprising rows and columns of first image data; and
storing, in the non-transient memory, the calibration LUT as nominal row and column tables, the nominal row table relating rows and columns of the first display data with rows and columns of the first image data and the nominal column table relating rows and columns of the first display data with rows and columns of the first image data.

15. The method according to claim 14, further comprising:
selectively redirecting, by the situational compensation unit, access to the first image data as referenced by the calibration LUT by offsetting one or more indexes to the nominal row and column tables in accordance with the one or more relationships of the associated vehicle relative to the peripheral area.

16. The method according to claim 15, further comprising selectively redirecting, by the situational compensation unit, the access to the first image data as referenced by the LUT by one or more offset relationships, wherein the one or more offset relationships may be linear, quadratic or of higher order expressed as a set of values representative of one or more operating conditions of the associated vehicle.

17. The method according to claim 15, further comprising:
storing, in a plurality of logically adjacent memory locations of the non-transient memory, selected ones of one or more relationships of the associated vehicle relative

to the peripheral area logically adjacent to selected ones of the intrinsic image coordinate transformation data; and

selectively executing, by the processor, parallel multiplication and addition operations on data stored in the logically adjacent memory locations.

18. The method according to claim **14**, further comprising:

developing, by the processor and the situational compensation unit, sensitivity data for offsetting references to the calibration LUT by sensitivity of the associated vehicle to relative physical changes between the associated vehicle and the peripheral area adjacent to the associated vehicle using a synthetic displacement of calibration markers imaged by the image obtaining unit using synthetic displacements of calibration markers.

19. A non-transitory computer readable storage medium storing one or more sequences of instructions for filling in a blind spot region in a peripheral area of an associated vehicle, wherein said instructions, when executed by one or more processors, cause the one or more processors to execute steps comprising:

receiving, by an image obtaining unit operatively coupled with a processor, first image data representative of a first image of the peripheral area adjacent to the associated vehicle;

storing, in a non-transient memory operatively coupled with the processor, intrinsic image coordinate transformation data comprising homography and lens distortion data representative of an intrinsic mapping between the first image data and first display data representative of an uncompensated view of the peripheral area of the associated vehicle; and

selectively modifying, by a situational compensation unit operatively coupled with the processor and the non-transient memory, the intrinsic mapping as an adjusted intrinsic mapping between the first image data and the first display data in accordance with a signal representative of the one or more relationships of the associated vehicle relative to the peripheral area.

20. The non-transitory computer readable storage medium according to claim **19**, further comprising:

generating at an interface of the associated imaging system an output signal representative of the first display data mapped from the first image data in accordance with the adjusted intrinsic mapping.

21. The non-transitory computer readable storage medium according to claim **20** further comprising:

displaying the output signal on a human readable output of the associated imaging system.

22. The non-transitory computer readable storage medium according to claim **19**, further comprising:

storing, in the non-transient memory, the intrinsic image coordinate transformation data in a calibration look up table (LUT) mapping first coordinate pairs of the first display data with first coordinate pairs of the image data;

selectively redirecting, by the situational compensation unit, access to the first image data as referenced by the calibration LUT by the adjusted intrinsic mapping, wherein the first coordinate pairs of the first display data are mapped from second coordinate pairs of the image data different than the first coordinate pairs of the image data.

23. The non-transitory computer readable storage medium according to claim **22**, further comprising:

capturing, by at least one camera of the image obtaining unit, the first image data representative of the first image of the peripheral area adjacent to the associated vehicle as a sequence of image data frame sets, each image data frame set comprising rows and columns of first image data; and

storing, in the non-transient memory, the calibration LUT as nominal row and column tables, the nominal row table relating rows and columns of the first display data with rows and columns of the first image data and the nominal column table relating rows and columns of the first display data with rows and columns of the first image data.

24. The non-transitory computer readable storage medium according to claim **23**, further comprising:

selectively redirecting, by the situational compensation unit, access to the first image data as referenced by the calibration LUT by offsetting one or more indexes to the nominal row and column tables in accordance with the one or more relationships of the associated vehicle relative to the peripheral area.

25. The non-transitory computer readable storage medium according to claim **24**, further comprising selectively redirecting, by the situational compensation unit, the access to the first image data as referenced by the LUT by one or more offset relationships, wherein the one or more offset relationships may be linear, quadratic or of higher order expressed as a set of values representative of one or more operating conditions of the associated vehicle.

26. The non-transitory computer readable storage medium according to claim **24**, further comprising:

storing, in a plurality of logically adjacent memory locations of the non-transient memory, selected ones of one or more relationships of the associated vehicle relative to the peripheral area logically adjacent to selected ones of the intrinsic image coordinate transformation data; and

selectively executing, by the processor, parallel multiplication and addition operations on data stored in the logically adjacent memory locations.

27. The non-transitory computer readable storage medium according to claim **23**, further comprising:

developing, by the processor and the situational compensation unit, sensitivity data for offsetting references to the calibration LUT by sensitivity of the associated vehicle to relative physical changes between the associated vehicle and the peripheral area adjacent to the associated vehicle using a synthetic displacement of calibration markers imaged by the image obtaining unit using synthetic displacements of calibration markers.

* * * * *