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[Continued on next page]

(54) Title: IMAGING SYSTEM FOR VEHICLE

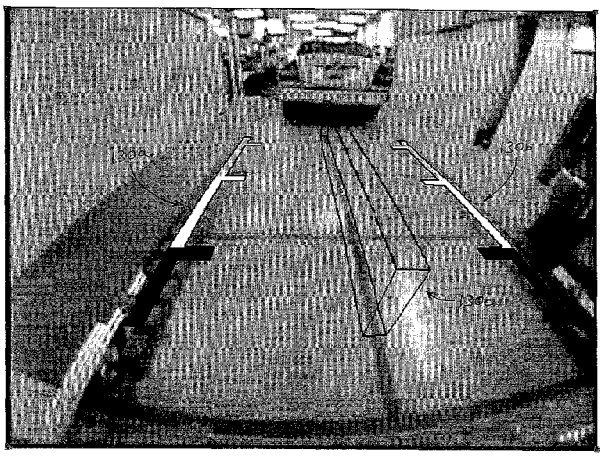

FIG. 5

(57) Abstract: An imaging system for a vehicle includes an imaging sensor (12) and a display device (15) for displaying images representative of image data captured by the imaging sensor. The imaging sensor (12) has a rearward field of view when mounted at the vehicle. The imaging system generates a plurality of graphic overlays (130a, 130b, 130c) on the displayed images to enhance the driver's cognitive awareness of an object rearward of the vehicle. The graphic overlays comprises a plurality of graphic overlay segments. The graphic overlay segments convey three dimensional information to a person viewing the displayed images and the graphic overlays. The imaging system may adjust at least one of a color, an intensity and a rate of flashing of at least one of the plurality of graphic overlay segments in response to an object being detected rearward of the vehicle and within a distance threshold.

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IMAGING SYSTEM FOR VEHICLE

FIELD OF THE INVENTION

The present invention relates generally to imaging or vision systems, particularly for vehicles which provide a vehicle operator with wide angle scenic information of an area immediately around the vehicle, such as rearward of the vehicle.

BACKGROUND OF THE INVENTION

A long felt need in the art of vehicle vision systems, such as rear-view systems, has been to provide an operator of a vehicle with wide angle scenic information of an area around the vehicle, such as directly rearward of the vehicle, when the vehicle is traveling in reverse. Neither interior rear-view mirrors nor side exterior mirrors allow for visibility of the area immediately rearward of the vehicle's bumper, which is the information most critical to the vehicle operator when backing up. Therefore, various camera-based rear view vision systems have been proposed to provide visibility of this blind spot.

It is also known to provide a graphic overlay on the displayed image of the rearward scene to enhance the driver's perception of the rearward field of view. Examples of such graphic overlays are described in U.S. Pat. Nos. 5,670,935; 5,949,331; 6,222,447; and 6,611,202, which are hereby incorporated herein by reference in their entireties.

Various camera-based rear vision systems for vehicles backing up have been proposed. In one form of these systems, a camera with a conventional, standard lens is located on the rearward portion of the vehicle to provide a view of the area behind the vehicle. However, standard lenses fail to capture a wide angle view of the area, thus failing to provide the vehicle operator with an image of the entire critical area directly rearward of the vehicle. In order to provide a wider angle view of the rearward area, a wide angle lens system may be used with the camera to capture the critical area. Examples of such systems are described in U.S. Pat. Nos. 6,922,292; 6,757,109; 6,717,610; 6,590,719; and 6,201,642, which are hereby incorporated herein by reference in their entireties.

SUMMARY OF THE INVENTION

The present invention is directed toward enhancing exterior visibility to the driver of a vehicle by providing an imaging system that provides a wide angle field of view of the area directly exteriorly of a vehicle, and that provides a graphic overlay superimposed on a displayed image to enhance the driver's viewing and understanding or cognitive awareness of the displayed image of the scene rearward of the vehicle and any object or objects detected therein. The

present invention is directed towards enhancing the interpretation of visual information in a rearview vision system by presenting information in a manner which does not require significant concentration of the driver or present distractions to the driver.

The rearview vision system of the present invention has an image capture device or image sensor or camera positioned on the vehicle and directed rearwardly with respect to the direction of travel of the vehicle, and a display for displaying images captured by the image capture device. Image enhancement means may be provided for enhancing the displayed image, such as in the form of graphic overlays superimposed on the displayed image. Such graphic overlays may include indicia of the anticipated path of travel of the vehicle which is useful in assisting the driver in guiding the vehicle in reverse directions, including trailering maneuvers. The graphic overlays may be flashed or intermittently activated and/or displayed in different colors depending on a distance to a detected object rearward of the vehicle so as to provide a spectral cue and a spatial cue to the driver as the driver maneuvers the vehicle in a rearward direction. The graphic overlays may comprise graphic overlay segments extending upward and inward along the sides of the image so as to be indicative of segments extending rearward from the sides of the vehicle. The graphic overlay segments may convey three dimensional information to a person viewing the displayed images and the graphic overlays. The graphic overlay segments may be viewed by the driver as having a virtual height dimension to enhance the driver's cognitive awareness of the graphic overlays. The graphic overlay segments may be displayed as three dimensional graphic overlay segments having a virtual height and a virtual thickness.

Optionally, for rearward facing cameras, the image may be displayed as a mirrored image or reverse image on the display so that the driver of the vehicle, when looking forward toward the image display, views the displayed image as if it is a reflected image in a rear view mirror, in order to assist the driver with guiding the vehicle during a reversing maneuver without having to turn his or her head around to look rearward. Optionally, the image processor or the display may process or adjust the image data to achieve the desired reverse image display. Optionally, any perspective and optical distortion in the captured images may be accounted for or generally matched in the generated graphic overlays so as to provide enhanced or more accurate spatial cues to the driver. Optionally, the graphic overlays may be adjusted in response to an object detection system so as to not display the graphic overlays at areas in the displayed image that are representative of a detected object.

The camera or image sensor of the imaging system may include or utilize a wide angle lens that is compact, durable and inexpensive to manufacture. The image sensor and lens

assembly of the present invention thus may comprise a wide angle lens or lens assembly, such as a multi-element lens assembly having multiple optics to provide a wide angle field of view with reduced distortion. Optionally, the lens may include multiple optics, such as four to seven optic elements, with an outer element (the element at the rearwardmost end of the lens and exposed at the rear exterior of the vehicle) comprising a glass element and with at least one other element comprising a plastic aspheric element.

These and other objects, advantages, purposes, and features of this invention will become apparent upon review of the following specification in conjunction with drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an imaging device comprising an image sensor and lens in accordance with the present invention;

FIG. 2 is an image as displayed to a driver of the vehicle in accordance with the present invention;

FIG. 3 is another image as displayed to a driver of the vehicle and having a graphic overlay of the vehicle's projected rearward trajectory superimposed thereon in accordance with the present invention;

FIG. 4 is another image as displayed to a driver of the vehicle and having a graphic overlay of the vehicle's projected rearward trajectory superimposed thereon and including relative distance markers in accordance with the present invention;

FIG. 4A is a side perspective view of a vehicle and virtual overlay segments of the present invention as they would appear if actually present rearward of the vehicle;

FIG. 5 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon and including relative distance markers in accordance with the present invention;

FIG. 5A is a side perspective view of the graphic overlays of FIG. 5 as they would appear if actually present rearward of the vehicle;

FIG. 6 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon similar to FIG. 5, with the trailer hitch alignment overlay shown as a solid virtual object;

FIG. 6A is a side perspective view of the graphic overlays of FIG. 6 as they would appear if actually present rearward of the vehicle;

FIG. 7 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon, with the trailer hitch alignment overlay shown as a two dimensional overlay;

FIG. 8 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon similar to FIG. 7, with the trailer hitch alignment overlay shown as a solid two dimensional overlay;

FIG. 9 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon similar to FIG. 6, with the trailer hitch alignment overlay shown as a virtual solid wedge-shaped object;

FIG. 10 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon, with the relative distance markers and the trailer hitch alignment overlay shown as virtual solid objects;

FIG. 10A is a side perspective view of the graphic overlays of FIG. 10 as they would appear if actually present rearward of the vehicle;

FIG. 11 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon, with the relative distance markers and the trailer hitch alignment overlay shown as virtual semi-transparent objects;

FIG. 11A is a side perspective view of the graphic overlays of FIG. 11 as they would appear if actually present rearward of the vehicle;

FIG. 12 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon, with the relative distance markers and the trailer hitch alignment overlay shown as virtual semi-transparent objects, and with a lower surface of the virtual distance markers being shown as a solid surface;

FIG. 13 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon similar to FIG. 12, with the lower and upper surfaces of the virtual distance markers being shown as solid surfaces; and

FIG. 14 is another image as displayed to a driver of a vehicle and having a trailer hitch alignment graphic overlay of the vehicle's projected rearward trajectory superimposed thereon, with the relative distance markers shown as vertically spaced apart two dimensional surfaces.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and the illustrative embodiments depicted therein, a wide angle imaging system provides an operator of a vehicle with scenic information of an area immediately exteriorly, such as rearwardly, of the vehicle, which may be an automobile, a light truck, a van, a large truck, a sport utility vehicle or the like. The imaging system includes an image capture device 12 (FIG. 1) having an imaging sensor and a lens or lens assembly 14 that functions to focus a rearward field of view at an imaging plane of the imaging sensor or camera. Images 16 (FIG. 2) are displayed on a display device or screen with reduced distortion to enhance the driver's viewing and understanding of the displayed images. The rearview imaging system includes an image processor for receiving data signals from the image capture device and superimposing the graphic overlay on the displayed image, as discussed below.

The imaging sensor for the vehicle vision system of the present invention may comprise any suitable sensor, and may utilize various imaging sensors or imaging array sensors or cameras or the like, such as a CMOS imaging array sensor, a CCD sensor or other sensors or the like, such as the types described in U.S. Pat. Nos. 5,550,677; 5,670,935; 5,760,962; 5,715,093; 5,877,897; 6,922,292; 6,757,109; 6,717,610; 6,590,719; 6,201,642; 6,498,620; 5,796,094; 6,097,023; 6,320,176; 6,559,435; 6,831,261; 6,806,452; 6,396,397; 6,822,563; 6,946,978; 7,038,577; and 7,004,606; and/or U.S. patent applications, Ser. No. 11/315,675, filed Dec. 22, 2005 and published Aug. 17, 2006 as U.S. Patent Publication No. US-2006-0184297A1; and/or Ser. No. 10/534,632, filed May 11, 2005 and published Aug. 3, 2006 as U.S. Patent Publication No. US-2006-0171704A1; and/or U.S. provisional applications, Ser. No. 60/845,381, filed Sep. 18, 2007; and Ser. No. 60/837,408, filed Aug. 11, 2006, and/or PCT Application No. PCT/US2003/036177 filed Nov. 14, 2003, and published Jun. 3, 2004 as PCT Publication No. WO 2004/047421, which are all hereby incorporated herein by reference in their entireties. The control may include a lens element or optic between the image sensor and the forward scene to substantially focus the scene at an image plane of the image sensor. Optionally, the optic may comprise a wide angle lens that provides a proportionally distributed central portion of the imaged scene while providing classical optical distortion on the periphery of the imaged scene. Optionally, the optic may comprise a non-flat field curvature, which may focus a generally central portion of the imaged scene onto the image sensor, while providing reduced but acceptable focus on the periphery of the imaged scene. The imaging device may comprise an image sensing module or the like, and may utilize aspects described in U.S. patent application Serial No. 10/534,632, filed May 11, 2005; and/or PCT Application No. PCT/US2006/041709, filed Oct. 27, 2006 and published May 10, 2007 as International Publication No. WO

07/053404; and/or PCT Application No. PCT/US2003/036177 filed Nov. 14, 2003 and published Jun. 3, 2004 as PCT Publication No. WO 2004/047421, which are hereby incorporated herein by reference in their entireties.

Such imaging sensors or cameras are pixelated imaging array sensors having a photosensing array of a plurality of photon accumulating or photosensing light sensors or pixels, which are arranged in a two-dimensional array of rows and columns on a semiconductor substrate. The camera established on the substrate or circuit board includes circuitry that is operable to individually access each photosensor pixel or element of the array of photosensor pixels and to provide an output or image data set associated with the individual signals to the control, such as via an analog to digital converter. As the camera receives light from objects and/or light sources in the target scene, the control may then be operable to process the signal from at least some of the pixels to analyze the image data of the captured image, as discussed below.

Optionally, the imaging sensor may be suitable for use in connection with other vehicle imaging systems, such as, for example, an object detection system or blind spot detection system, where a blind spot indicator may be operable to provide an indication to the driver of the host vehicle that an object or other vehicle has been detected in the lane or area adjacent to the side of the host vehicle. In such a blind spot detector/indicator system, the blind spot detection system may include an imaging sensor or sensors, or ultrasonic sensor or sensors, or sonar sensor, or radar, or LIDAR or sensors or the like. For example, the detection system may utilize aspects of the detection and/or imaging systems described in U.S. Pat. Nos. 7,038,577; 6,882,287; 6,198,409; 5,929,786; and/or 5,786,772, and/or U.S. pat. applications, Ser. No. 11/315,675, filed Dec. 22, 2005; and/or Ser. No. 11/239,980, filed Sep. 30, 2005, and/or U.S. provisional applications, Ser. No. 60/696,953, filed Jul. 6, 2006; Ser. No. 60/628,709, filed Nov. 17, 2004; Ser. No. 60/614,644, filed Sep. 30, 2004; and/or Ser. No. 60/618,686, filed Oct. 14, 2004, and/or of reverse or backup aid systems, such as the rearwardly directed vehicle vision systems described in U.S. Pat. Nos. 5,550,677; 5,760,962; 5,670,935; 6,922,292; 6,590,719; 6,201,642; 6,396,397; 6,498,620; 6,717,610; 6,757,109; and/or 7,005,974, and/or of the rain sensors described in U.S. Pat. Nos. 6,250,148 and 6,341,523, and/or of other imaging systems, such as the types described in U.S. Pat. Nos. 7,123,168; 6,353,392; and/or 6,313,454, with all of the above referenced U.S. patents, patent applications and provisional applications and PCT applications being commonly assigned and being hereby incorporated herein by reference in their entireties.

In order to enhance the driver's understanding of what is occurring in the area surrounding the vehicle, the rearview vision system includes a display device or display element having image enhancements (FIG. 3). The display device may comprise any suitable display device or element, such as a video display screen, such as a video display screen utilizing aspects of the display devices described in U.S. Pat. Nos. 5,530,240; 6,329,925; 7;370,983; 7,274,501; 7,255,451; 7,195,381; 7,184,190; 6,690,268; 5,668,663 and/or 5,724,187, and/or in U.S. pat. applications, Ser. No. 10/538,724, filed Jun. 13, 2005; Ser. No. 11/226,628, filed Sep. 14, 2005; Ser. No. 10/993,302, filed Nov. 19, 2004; and/or Ser. No. 11/520,193, filed Sep. 13, 2006; and/or PCT Application No. PCT/US03/29776, filed Sep. 9, 2003; and/or PCT Application No. PCT/US03/35381, filed Nov. 5, 2003; and/or PCT Application No. PCT/US2006/018567, filed May 15, 2006; and/or PCT Application No. PCT/US2006/042718, filed Oct. 31, 2005, and published May 10, 2007 as International PCT Publication No. WO 2007/053710A1; and/or PCT Application No. PCT/US03/40611, filed Dec. 19, 2003, which are all hereby incorporated herein by reference in their entireties. Optionally, the display device or video display screen may be located at or in or near the interior rearview mirror assembly of the vehicle. Optionally, the display screen may be located within the mirror assembly and behind the mirror reflective element so that the display is transmitted through the reflective element for viewing by an occupant of the vehicle, or the display screen may be covertly located behind the reflective element to provide a DOD (Display-on-Demand) display through the transflective reflective element, such that the presence of the video screen is only noticeable or discernible when the video screen is activated, such as by utilizing aspects described in U.S. Pat. Nos. 7,370,983; 7,274,501; 7,184,190; 6,690,268; 5,668,663 and/or 5,724,187, and/or in U.S. pat. applications, Ser. No. 10/538,724, filed Jun. 13, 2005; and/or Ser. No. 11/226,628, filed Sep. 14, 2005, which are all hereby incorporated herein by reference in their entireties.

Optionally, for such rearward facing camera applications, the captured images may be displayed as a mirrored image or reverse image on the display so that the driver of the vehicle, when looking forward toward the image display, views the displayed image as if it is a reflected image in a rearview mirror, in order to assist the driver with guiding the vehicle during a reversing maneuver without having to turn his or her head around to look rearward. Optionally, the image processor or the display may process or adjust the image data to achieve the desired reverse image display, such as by utilizing aspects of the systems described in U.S. Pat. Nos. 5,550,677; 5,670,935; 5,949,331; 6,222,447; 5,760,962; 5,715,093; 5,877,897; 6,922,292; 6,757,109; 6,717,610; 6,590,719; 6,201,642; 6,498,620; 5,796,094; 6,097,023; 6,320,176;

6,559,435; 6,831,261; 6,806,452; 6,396,397; 6,822,563; 6,946,978; 7,038,577; and/or 7,004,606, which are hereby incorporated herein by reference in their entireties.

In the illustrated embodiment, the image enhancements of the imaging system and/or display device include graphic overlays 20a, 20b which are lines or segments intended to illustrate to the driver the anticipated path of rearward movement of the vehicle based on the present trajectory of the vehicle. In the illustrated embodiment of FIG. 3, the graphic overlays 20a, 20b indicate the anticipated vehicle motion as a function of the vehicle direction of travel as well as the rate of turn of the vehicle. Optionally, the displayed image may have a textual message 20c alerting the driver of a detected object or otherwise instructing the driver during the rearward maneuver.

The forward or rearward direction of vehicle travel is determined in response to the operator placing the gear selection device (not shown) in the reverse gear position. The degree of turn of the vehicle may be determined by monitoring the movement of the vehicle steering system, monitoring the output of an electronic compass, or monitoring the vehicle differential drive system or the like. Optionally, and desirably, if the vehicle is not in reverse gear position, the graphic overlays are not presented. The imaging system and graphic overlays may utilize aspects of the systems described in U.S. Pat. Nos. 5,670,935; 5,949,331; 6,222,447; and 6,611,202, which are hereby incorporated herein by reference in their entireties. Optionally, the graphic overlays may be static overlays (in other words, graphic overlays that extend generally rearwardly toward a focal point of expansion rearward of the vehicle and that are not dependent on a steering wheel angle or the like), while remaining within the spirit and scope of the present invention.

Optionally, and as shown in FIGS. 4 and 4A, the graphic overlays 30a, 30b may function to enhance the driver's awareness of an object detected rearward of the vehicle when the vehicle is shifted into a reverse gear. Optionally, the graphic overlays may include a centrally located overlay 30c, such as a dashed line or solid or opaque or semi-transparent or transparent surface or the like, that extends upward toward the focal point of expansion of the displayed image. In the illustrated embodiment, each graphic overlay 30a, 30b may be provided in three different colors, such as a green segment 32, a yellow segment 34 and a red segment 36, with the upper or further out segment 32 being green (or other suitable color or pattern), the middle segment 34 being yellow (or other suitable color or pattern), and the closest or lowest segment 36 being red (or other suitable color or pattern). The individual segments may be activated or overlaid in response to a detection of an object rearward of the vehicle and a detected or determined distance between the rear of the vehicle and the detected object.

For example, the rearward imaging system of the present invention may include an imaging sensor for capturing images in a rearward field of view and a display for displaying the images. The system may include or may operate in conjunction with an object detection system for detecting objects rearward of the vehicle and in the path of the vehicle when the vehicle is traveling in reverse (such as, for example, an ultrasonic sensing system, a lidar sensing system or a radar sensing system or via image processing of the captured images or the like). When the vehicle is reversing and no object is detected by the object detection system (or if an object is detected that is further away from the vehicle than a predetermined threshold distance), the graphic overlay or overlays may not be displayed or may be displayed as non-colored or dark or neutral lines or continuous segment or the like (such as similar to the graphic overlays 20a, 20b shown in FIG. 3). As the vehicle approaches the object so that the object is detected by the object detection system (or when a detected object is within a first threshold distance from the rear of the vehicle but outside of a second threshold distance from the rear of the vehicle), the outer graphic overlay segment 32 may flash or may be displayed as green to alert the driver of the presence of the object, while also notifying the driver that the object is still a safe distance rearward of the vehicle. As the vehicle further approaches the object (for example, when the object is within the second threshold distance from the rear of the vehicle but outside of a third threshold distance from the rear of the vehicle), the middle graphic overlay segment 34 may flash or may be displayed as yellow to alert the driver that the vehicle is approaching the object. As the vehicle further approaches the object (for example, when the object is within the third threshold distance from the rear of the vehicle), the inner graphic overlay segment 36 may flash or may be displayed as red to alert the driver that the vehicle is very near to the object.

Optionally, the system may also provide a tone or audible alert when the vehicle and object are within the third threshold separation distance or when the vehicle and object are less than a fourth threshold distance apart to further alert the driver that the object is very near to the vehicle and that the driver should not back up any further. Optionally, the graphic overlays may also or otherwise vary in shape or pattern or thickness or color to enhance the driver's cognitive awareness of the location of and distance to a detected object rearward of the vehicle. Optionally, as one segment is activated or colored (as the object is detected within the respective range from the rear of the vehicle), the other segment or segments may be deactivated or de-colored, so that the driver can readily discern that the object is detected within the particular range encompassed by the currently activated or colored graphic overlay segments.

Optionally, the graphic overlay may be designed or adjusted or selected to assist colorblind drivers (or others that have different perception of colors than the general population)

to distinguish the color segments of the overlay. A majority of the colorblind population are "red-green colorblind" and have problems in either in the red or green opsin gene. For example, people with a mutant red opsin gene are called "protanopes", while people with a mutant green opsin gene are called "deuteranopes". It is estimated that for males, about 8 percent of Caucasians, about 5 percent of Asians and about 4 percent of Africans are "red-green" colorblind. Color blindness is typically sex-linked, so a reduced number of females are colorblind. Red-green color blind people have difficulty distinguishing colors between red and green with similar intensity or brightness. To address this problem, for example, the graphic overlays of the present invention may replace the red colored segment or segments in the overlay graphics with a reddish purple or vermilion colored segment or segments, and may replace the green colored segment or segments with a blue or bluish green segment or segments. Such colors may be recognized and discerned by a typical red-green colorblind person (the yellow colored segments may remain yellow since typical red-green colorblind people would be able to recognize and discern the yellow colored segments). Optionally, different textural features or patterns (such as different stippling or cross-hatching or different degrees of transparency or translucency of the segments or the like) can be used to assist colorblind drivers to distinguish different segments of the graphic overlay.

Optionally, the different colors or features or patterns of the segments may be selectively provided in response to the user or driver selecting the desired or appropriate graphic overlay display scheme. For example, a software or hardware toggle switch or other suitable user actuatable input (such as a button or a voice recognition system or the like) may be implemented to allow the user or driver of the vehicle to select a suitable overlay color scheme, such as a display displaying normal colored graphic overlays for non-colorblind drivers or a display displaying modified graphic overlays (such as a different color scheme or a different texture or pattern scheme or the like) for colorblind drivers. The switch may offer different choices for the user, such as a color scheme for a red-green colorblind person or a different color scheme for other types of colorblindness (whereby the system adjusts the color scheme of the graphic overlays accordingly).

Optionally, and with reference to FIGS. 5-14, the present invention provides a graphic overlay, such as a generally centrally located alignment overlay, to assist the driver of the vehicle to back up to a trailer hitch or the like. Optionally, and desirably, and as can be seen with reference to FIG. 4A, the camera or image sensor 12 at the rear of the subject vehicle 13 may be offset from the centerline 13a of the vehicle 13 and angled so as to have its field of view be generally rearward and toward the centerline of the vehicle. Such a camera orientation

conveys three dimensional information to the person viewing the display by allowing for a three-dimensional or perspective image of a trailer hitch alignment graphic overlay that may be imaged or displayed on a display device 15 (such as a video display screen or the like, and such as a display screen located at or near the interior rearview mirror of the vehicle) so as to appear to extend rearward from the rear of the vehicle and generally along the centerline of the vehicle. This arrangement allows the diver of a vehicle to identify both the vehicle path center on or along the ground and the trailer hitch path above the ground when a camera or image sensor is offset from the centerline of the subject vehicle. Optionally, the center alignment graphic overlay may be displayed so that a person viewing the displayed image perceives the alignment graphic overlay to be at a different height from the sideward relative distance graphic overlays, in order to convey three dimensional information to the person viewing the display.

For example, and as shown in FIGS. 5 and 5A, a graphic overlay includes a pair of sideward overlays 130a, 130b and a generally centrally located trailer hitch alignment overlay 130c. The side overlays 130a, 130b may be substantially similar to the side overlays 30a, 30b, discussed above, and may have colored segments and the like, such that a detailed discussion of the side overlays need not be included herein. The hitch alignment overlay 130c is generally at or near the center of the displayed image and extends upward toward the focal point of expansion of the displayed image to indicate the predicted path of a trailer hitch. The side overlays 130a, 130b may function as described above, and may be activated or generated or displayed when the vehicle is shifted into reverse, while the hitch alignment overlay 130c may be similarly activated or generated or displayed, or may be activated or generated or displayed in response to a user input, such as a control input or button or the like that is activated by the driver of the vehicle when the driver is about to back up the vehicle to a trailer (or may be automatically activated or generated or displayed in response to the system detecting or identifying a trailer rearward of the vehicle when the vehicle is traveling in reverse), while remaining within the spirit and scope of the present invention.

As can be seen in FIGS. 5 and 5A, the displayed image is captured by an image sensor that is offset from the centerline of the vehicle and is directed rearward and toward the centerline of the vehicle. In the illustrated embodiment, image sensor is disposed about 305 mm offset from the centerline of the vehicle at about 875 mm above the ground and oriented at an angle of about 40 degrees toward the centerline of the vehicle. The hitch alignment overlay 130c is displayed as a three-dimensional shape that extends upward in the image and generally along the centerline of the vehicle and toward the focal point of expansion of the camera. The hitch alignment overlay 130c is generated so as to appear to be a three dimensional object at the rear

of the vehicle (such as an object or alignment element having a height of about 440 mm or thereabouts to approximate a height of a hitch of the vehicle). Thus, the alignment overlay provides two planes, one generally at the ground level and one generally at a typical trailer hitch height.

Other mounting locations and angles for the camera and/or other dimensions of the graphic overlays may be implemented without affecting the scope of the present invention. Because the camera is preferably disposed at a height greater than the virtual height of the alignment element/overlay, the displayed image provides a perspective view rearward and downward toward the three dimensional alignment overlay so that the driver can readily discern and understand the alignment overlay to assist the driver in reversing the vehicle toward a trailer hitch of a trailer or the like. The alignment overlay and the offset camera thus provide a scaled and distorted three dimensional image to provide the driver improved depth perception for driving the vehicle toward the trailer or other targeted object.

In the illustrated embodiment of FIGS. 5 and 5A, alignment overlay 130c is a wire frame or line drawing or representation of a perspective view of a three dimensional rectangular form or virtual three dimensional object or overlay. However, other shapes or forms may be utilized to provide the desired perspective or view to the driver to assist the driver in reversing the vehicle toward a trailer hitch or other object. For example, and as shown in FIGS. 6 and 6A, the side overlays 130a', 130b' may be similar to side overlays 130a, 130b, discussed above, while the alignment overlay 130c' may be a solid or colored three dimensional rectangular form or virtual three dimensional object or overlay to further enhance the viewability and discernability of the alignment overlay to the driver of the vehicle. Optionally, for example, and as shown in FIG. 7, the side overlays 230a, 230b may be similar to side overlays 130a, 130b, discussed above, while the alignment overlay 230c may be a generally planar, two dimensional rectangular form (such as only the upper portion or surface of the three dimensional rectangular form of alignment overlay 130c, discussed above), which may be a wire form representation (as shown in FIG. 7), or the alignment overlay 230c' may be a solid or colored representation (as shown in FIG. 8), depending on the particular application and desired appearance of the alignment overlay in the displayed image. In the illustrated embodiments of FIGS. 7 and 8, the two dimensional alignment overlay 230c is displayed so that, when a person is viewing the displayed image and graphic overlays, the person perceives the alignment overlay 230c to be at a different height (such as higher) than the two dimensional side overlays 230a, 230b (which appear to extend along the ground or road surface rearward of the vehicle) to convey three dimensional information to the person viewing the display. Optionally, and as shown in FIG. 9, the side

overlays 330a, 330b may be similar to side overlays 130a, 130b, discussed above, while the alignment overlay 330c may be a prism or wedge shaped form having an upper surface (such as a surface or portion similar to the upper region of the alignment overlay 130c, discussed above) and a shape that tapers or narrows downward to generally a pointed or narrowed lowered portion, to further enhance the perspective view of the alignment overlay. The alignment overlay 330c may be colored or shaded or solid (as shown in FIG. 9), or may be a wire form representation or the like, without affecting the scope of the present invention.

Optionally, the side overlays may also be represented or generated or displayed three dimensionally to further assist the driver of the vehicle during the rearward maneuver. For example, and as shown in FIGS. 10 and 10A, the side overlays 430a, 430b may appear as three dimensional colored or shaded or solid "walls" extending rearward from the vehicle to assist the driver in guiding or driving the vehicle toward the trailer or targeted object. The side overlays 430a, 430b may be otherwise similar to side overlays 30a, 30b, and may have colored segments 432, 434, 436 or the like, such as discussed above (optionally, the alignment overlay 430c may be similarly colored or patterned if desired). Optionally, and as shown in FIGS. 11 and 11A, the side overlays 430a', 430b' and alignment overlay 430c' may be displayed as wire frame representations and/or as partially transparent colored representations or virtual three dimensional objects or overlays so as to provide the desired color and enhanced viewability and discernability while limiting or reducing any potential interference with the driver's view of other objects in the displayed image. Optionally, and as shown in FIG. 12, the side overlays 430a", 430b" and alignment overlay 430c" may be displayed as wire frame representations and/or as partially transparent colored representations, while the side overlays 430a", 430b" may include a lower portion that is substantially similar to side overlays 30a, 30b to further enhance the viewability and discernability of the side overlays while limiting or reducing any potential interference with the driver's view of other objects in the displayed image. Optionally, and as shown in FIG. 13, the side overlays 430a'", 430b'" and alignment overlay 430c'" may be displayed as wire frame representations and/or as partially transparent colored representations, while the side overlays 430a'", 430b'" may include a lower portion that is substantially similar to side overlays 30a, 30b and an upper portion that is also colored or shaded to generally correspond with the lower portion of the side overlays, in order to provide enhanced viewability and discernability of the side overlays while further limiting or reducing any potential interference with the driver's view of other objects in the displayed image. Optionally, and as shown in FIG. 14, the side overlays 530a, 530b may have an upper portion 531a and a lower portion 531b similar to side overlays 430'", 430'", but may not have the wire form or shaded

region therebetween. The upper and/or lower portions 531a, 531b of side overlays 530a, 530b may have colored segments to assist in indicating a distance to the targeted object. Optionally, and as also shown in FIG. 14, the hitch alignment overlay 530c may comprise a two dimensional rectangular form (either shaded or colored or wire form), such as described above. In the illustrated embodiment of FIG. 14, the alignment overlay 530c is displayed so that, when a person is viewing the displayed image and graphic overlays, the person perceives the alignment overlay 530c to be at a different height (such as higher) than the side overlays 530a, 530b (which appear to extend along the ground or road surface rearward of the vehicle) and generally at or near the perceived height of the upper side overlays 531a, 531b to convey three dimensional information to the person viewing the display. Although several optional configurations and combinations of side overlays and center hitch alignment overlays are shown in FIGS. 4-14, clearly other combinations and configurations may be implemented while remaining within the spirit and scope of the present invention.

The side overlays and the alignment overlay may be static overlays or may be adjusted or curved or reconfigured (such as in response to a steering wheel angle of the vehicle or the like) to provide a dynamic overlay when the vehicle is being driven in reverse toward the trailer or targeted object. The side overlays and the centrally located alignment overlay may be activated or generated or displayed in response to a user input, such as a button or other control input that is activated by the driver of the vehicle when it is desired to back up the vehicle toward a targeted object or trailer hitch. Optionally, for example, the displayed image may be activated in response to the vehicle being shifted into reverse and may include side overlays 30a, 30b (discussed above), and may provide the three dimensional side overlays and the centrally located hitch alignment overlay in response to the user input. The side overlays and/or the centrally located hitch alignment overlays may be displayed in different colors or different intensities or may be intermittently displayed or the like based on a distance between the vehicle and the trailer hitch or targeted object, such as discussed above with respect to side overlays 30a, 30b, while remaining within the spirit and scope of the present invention. The overlays (including the side overlays and the alignment overlay or overlays) are arranged or displayed so that, when a person is viewing the displayed image and graphic overlays, the overlays convey three dimensional information to the person viewing the display (such as by providing an alignment overlay at a different perceived height than at least a portion of the side overlays or by providing an alignment overlay and/or side overlays that are perceived as three dimensional objects, such as solid or transparent or partially transparent objects, or by providing any other suitable

arrangement of overlays to convey three dimensional information or depth to the person viewing the displayed images).

Thus, the imaging system and graphic overlays of the present invention provide enhanced cognitive awareness by the driver of any objects detected rearward of the vehicle when the vehicle is shifted into a reverse gear and as the driver drives the vehicle in a reverse direction. The change in color or change in intensity or intermittent actuation of the graphic overlays on a segment-by-segment basis provides both a spatial cue to the driver of the presence of and proximity of an object rearward of the vehicle and a spectral cue to the driver of the presence of and proximity of an object rearward of the vehicle, so that the driver is readily aware of an object that is detected rearward of the vehicle and is readily aware of the proximity of the detected object to the rear of the vehicle. The centrally located hitch alignment overlay further enhances the discernability of the location of trailer hitch or targeted object to further assist the driver in maneuvering the vehicle in a rearward direction toward the trailer hitch or targeted object.

Optionally, and desirably, the perspective and optical distortion may be accounted for in the generated graphic overlays to provide more accurate spatial cues to the driver. For example, the orientation and arrangement and shape of the overlays as displayed on the display device or video screen may be calculated or displayed based on the distortion of the lens and the angle of the camera on the vehicle. For example, the overlays may be curved as displayed to generally match the curvature or distortion of the image as captured by the camera and wide angle lens at the rear of the vehicle, and/or curved to generally match or account for the perspective of how the camera is mounted on the vehicle. Thus, the arrangement or shape of the graphic overlays in the displayed image is tailored specifically to the particular lens (such as a wide angle lens) used on the camera and to the vehicle mount (such as height and angle) of the camera at the rear of the vehicle.

Optionally, the graphic overlays may be adjustably displayed depending on objects or other vehicles detected rearward of the vehicle. For example, if an object is detected rearward of the vehicle, the graphic overlays may extend rearward from the subject vehicle toward the detected object in the displayed image and may be 'cropped' so that the graphic overlays are not shown at the detected object. Thus, the vehicle path (static) overlays and/or vehicle path trajectory (dynamic - curve or adjust in response to turning of vehicle such as shown in FIG. 3) overlays may appear to "disappear" under the detected object or vehicle. Optionally, the graphic overlays may be adjusted in response to an object detection system, such as an ultrasonic sensing system or the imaging system with image processing of captured images to detect

objects in the captured images or other object detecting devices or systems, whereby, in response to a detection of an object or vehicle in the path of the subject vehicle, such that the vehicle path may no longer be valid or safe, the graphic overlays may be truncated or cropped or shortened so as to end at a location generally at the detected object in the displayed image.

For example, if the system is coupled with an object detection system, such as ultrasonic sensors or other ranging device or the like, and if an object (such as a bumper of another vehicle) is detected at a distance rearward of the subject vehicle (such as about 1 meter rearward of the subject vehicle), the graphic overlays may be cropped so that they "disappear" under the detected object or vehicle (or, in other words, the graphic overlays are shown in the displayed image from the rear of the subject vehicle toward the detected object or vehicle, and are not shown in the displayed image from the detected distance of the detected object or vehicle and rearward from that detected distance or location). Such a graphic overlay adjustment provides the driver of the subject vehicle, when viewing the displayed image with graphic overlays established thereon, an impression that the overlays have gone under the detected object or vehicle that is detected by the ranging device so as to enhance the cognitive awareness of the objects rearward of the subject vehicle during a rearward maneuvering process.

Optionally, and preferably, the image sensor includes or utilizes a wide angle lens that focuses a wide angle rearward field of view (such as a wide angle horizontal field of view of preferably greater than 120 degrees wide and more preferably greater than 135 degrees wide and more preferably at least about 145 degrees wide) onto an image plane of the image sensor. The wide angle lens preferably comprises a multi-element lens having multiple lens optics or elements, such as seven optics arranged along an optic path to focus the rearward wide angle field of view at the imaging plane while reducing distortion of the focused image. Optionally, for example, the wide angle lens may include seven optic elements, with some of the elements being glass elements (such as an outer wide angle element being a glass element) and some of the elements being plastic elements. Optionally, for example, the wide angle lens may include five optic elements, with three of the elements being glass elements (including the outer most element being curved glass and the inner most element being a flat glass coated with infrared cutoff filter and anti-reflection filter), and with two of the elements being plastic elements. Preferably, at least one of the optic elements comprises a plastic aspheric element, and more preferably, two of the optic elements comprise plastic aspheric elements and five of the optic elements comprise glass spherical elements. Such a lens assembly may utilize aspects of the lenses described in U.S. Pat. Nos. 6,922,292; 6,757,109; 6,590,719; and 6,201,642, which are hereby incorporated herein by reference in their entireties.

The lens of the present invention thus may have at least one plastic element, which may provide a cost savings and a reduction in overall lens length. The refractive or diffractive lens element or elements may be made by injection molding or other low cost means. The plastic lens elements may comprise a polycarbonate material or acrylic material or any other suitable plastic or polymeric material. The lens includes non-spherical, refractive or diffractive optic elements, and may have a stop or aperture within the lens to correct distortion in the focused image.

For example, a lens assembly may be provided that is approximately 25 to 26 mm in overall length (from the image plane to the outer end of the lens assembly. The lens elements may be provided in a housing or barrel (such as an aluminum barrel) that may be threaded onto the circuit board that has the image sensor established thereon or threaded onto a housing or mounting portion of an image sensor module. The lens may have a cap diameter of about 12 mm to about 23 mm, with about a 1.0 to 2.5 mm radius on the outer most edge of the lens cap. The lens may provide a wide angle field of view of about 130 degrees in the horizontal and about 105 degrees vertical when the image sensor and lens are mounted at the vehicle, and may have an active sensor area having about a 3.584 mm horizontal dimension and about a 2.688 mm vertical dimension and about a 4.480 diagonal dimension.

The image sensor may comprise a pixelated image sensor (such as a CMOS sensor or the like) having a 640 x 480 array (or other size array depending on the particular application) of pixels that are about 5.6 μm x 5.6 μm. The lens may provide an "F-stop" of about 2.0 (or lower) +/- 5 percent, and may have a relative illumination at greater than 50 percent at full field. Preferably, the lens provides a reduced or lowered optical distortion (geometrical), preferably better than about -45 percent. The lens may have a modulation transfer function (a measurement of lens resolution quality) of greater than about 0.6 at 45 lp/mm on lens axis (zero degrees) and greater than about 0.25 at 45 lp/mm off-axis (between zero degrees and 60 degrees).

The lens preferably includes an integrated infrared (IR) cutoff coating or filter that provides about 85 percent or greater transmission of light therethrough over the visible spectrum (about 400 nm to about 700 nm) of light, and about 50 percent or lower transmission of light therethrough for light having wavelengths greater than about 700 nm and less than about 400 nm. The IR cutoff coating may be applied to one surface of one of the optical elements of the lens. Optionally, the IR cutoff filter may be also applied to a separate glass element, which may be flat and thin and may be located as the last element of the lens assembly. The lens may provide a wide angle field of view and may be able to focus on an object within about 30 cm or thereabouts from the outer end of the lens. The lens preferably has an anti-reflective (AR)

coating on at least some of the surfaces of the optic elements and preferably on all of the surfaces of the optic elements. The lens may have a variation of effective focal length of less than +/- 5 percent. The lens preferably has an image circle diameter of greater than about 4.8 mm and the angle between the lens' optical axis and a barrel reference diameter axis is preferably less than about 1.5 degrees.

The lens is robust and capable of withstanding the extreme climate and environmental conditions that it may encounter at the exterior portion of a vehicle. For example, the lens may be operational at up to about 85 degrees Celsius, and may be able to withstand exposure up to 125 degrees Celsius. The lens is capable of withstanding high temperature and high humidity endurance tests and can withstand exposure at 95 degree Celsius and 85 percent relative humidity for 1200 hours or more. The lens is also capable of withstanding mechanical shock tests (such as 6 shock pulses with 100g and 10 ms half-sine pulses, one in each opposite direction of three perpendicular axes) and vibration tests (such as a vibration test of an RMS acceleration value of about 27.8 m/s^2 for about 27 hours in the x-axis, about 27 hours in the y-axis and about 81 hours in the z-axis. Because the outer optic element is exposed to harsh conditions at the rear of the vehicle, the lens comprises a sealed lens and is capable of passing the required OEM testing, such as a car wash spray test and a heavy splash shower test and a mist test and a salt mist test and a dust test and the like. The lens can also withstand a dunk or soak test where the lens is soaked in 95 degrees Celsius water for at least 1 hour and then the upper body of the lens is dunked or soaked in icy water at a depth of 15 cm for at least 30 minutes. The lens is also capable of withstanding exposure to various chemicals. For example, the outer glass surface of the lens and the outer exterior body of the lens may be resistant to automatic transmission fluid, hypoid lubricant, hydraulic fluid, power steering fluid, differential lubricant, central hydraulic fluid, engine oil, engine wax protective, engine coolant / Ethylene Glycol, gasoline, diesel fuel, kerosene, bio-diesel / Methanol based fuel, brake fluid, windshield washer fluid, window glass cleaner, car wash cleaner/soap solution, car wax and silicone protectants, leather wax, battery acid – dilute sulfuric acid, and calcium chloride, and/or other chemicals the lens may encounter at the vehicle assembly plant and/or during its life on the vehicle.

Because the outer glass optic of the lens assembly is positioned toward an exterior of the vehicle such that an outer surface of the outer glass optic may be exposed to the elements outside of the vehicle, the outer surface may be coated with a protective coating to protect the outer optic from deterioration or damage due to exposure to the elements. Such a protective coating may comprise an organic haricot, an inorganic haricot, or an organic/inorganic

compound or the like. Additionally, the protective coating may include ultraviolet absorbers or stabilizers to protect the outer optic from UV radiation degradation. Such a coating or other additional coating or coatings substantially reduces the susceptibility of the outer optic to abrasion and/or ultraviolet degradation, thereby providing a substantially clear and durable glass-like appearance to the outer optic. Optionally, the hard coating or protective coating may be of the type described in EPC Application No. 98650039.5 for VEHICULAR COMPONENT ASSEMBLY WITH HARD COATED ELEMENT, published on Jan. 20, 1999 under Publication No. EP 0892209, the disclosure of which is hereby incorporated herein by reference in its entirety.

Optionally, the outer optic may be heatable to defog or defrost its surfaces. For example, the outer optic may be formed by a glass material and coated with a transparent conductive coating (such as an indium tin oxide (ITO) transparent conductor or a doped tin oxide or the like), or may include a wire mesh or a conductive coating mesh or the like, whereby heat is generated by energizing the conductive coating or mesh via a power source. Optionally, the outer surface of the outer optic may be coated with an anti-soiling or anti-wetting coating, such as a silicone material, which may provide either a hydrophobic or hydrophilic property to the exposed outer surface of the outer optic.

Optionally, the lens body (barrel and optic elements) may be heated electrically to limit or substantially preclude moisture from being trapped inside the lens from condensation. When the lens is assembled in an environment that humidity/moisture level is not tightly controlled below a certain level, the air packet between optic elements inside the lens typically has water molecules in the form of moisture. When the lens is exposed to a temperature that is lower than the dew point temperature of the moisture density level, moisture condensation occurs within the lens, and a small cluster of water droplets may form on the surfaces of the optic elements inside the lens. The condensation or water droplets may blocks or attenuate light passing through the lens and thus may degrade the lens and furthermore may reduce or impair the camera performance. In some situations, the condensation water may drop onto the camera circuitry or circuit board or PCB and may cause an electrical malfunction or electrical shortage. Optionally, a means for measuring the temperature of the lens, such as a temperature sensor, such as a thermal couple or the like, may be used to determine the temperature at or within the lens, while a control means may be responsive to the temperature signal and may activate a heating current or voltage at or in the lens to heat the lens or lens elements above a threshold level in response to a detection or determination that the temperature at or in or of the lens is dropping below the dew point level. Thus, the lens or lens elements may be heated to remain above the dew point

temperature so as to limit or substantially avoid moisture condensation from occurring within the lens.

Optionally, a lens body may be filled with a gas that is without water moisture. For example, a dry air, nitrogen gas or helium gas (or other suitable non-moisture gas or air) can be filled inside the lens body. The lens is then sealed to keep the moisture from getting inside lens from outside. The lens can be assembled in an enclosed environment that is filled with the gas without water moisture, such as a dry air, nitrogen or helium gas or the like. Optionally, another means for addressing the moisture issue may provide breathing paths within the lens. For example, the lens body can be designed to have one or more breathing paths by which air and water molecules can travel from all of the inside cavities of the lens to the outside of the lens, such as through the lens bottom or other body wall or housing wall. Optionally, by providing some moisture absorbing material inside the camera cavity, the water molecules that may originally exist inside the lens body can be absorbed by the moisture absorbing material.

Optionally, the lens of the present invention may have a lens barrel and a lens cap made of plastic material or one made of a plastic material and one made of a metal material. Optionally, the plastic lens barrel and lens cap can be made in injection molding process, and thus may provide a lower cost of the lens. Optionally, the plastic parts can be made via injection molding, and thus can be made at a lower cost and in a higher volume.

An automotive camera is typically exposed to a wide temperature range (for example, from about -40 degrees C to about 85 degrees C) and is typically required by the automobile manufacturer to maintain sufficient or good lens focus throughout the expected temperature ranges to which the vehicle may be exposed. Because using an injection molded plastic material may reduce the overall cost of the camera, plastic materials may be selected for use in the lens barrel and the camera body, including the lens holder. Optionally, a metallic material, such as aluminum and/or copper and/or the like, may be selected for use in the lens barrel or camera body. The material selection for the lens and/or camera mechanical design may be selected to achieve good or sufficient lens focus over the entire temperature range to which the camera may be subjected.

The use of a plastic material in the camera body and lens barrel may pose a challenge in maintaining the focus of the camera because of the larger or enhanced thermal expansion (as compared to metallic material), which can potentially cause the lens to become less focused. In order to reduce the temperature effects on the lens focus, the type of material (plastic or metal) may be selected to match the camera lens holder material type (plastic or metal). The lens is mounted to the camera lens holder at the top or outer part of the lens, or at the part that is closer

to the lens outer surface. When the camera is subjected to a substantial change in temperature, the expansion or contraction of the plastic lens barrel or camera lens holder may move the lens focal plane away from the imager sensing plane, and thus may cause de-focusing or blurriness in the captured images. To counter this potential problem, the material for the lens barrel and/or the camera lens holder may be selected to have the same or similar thermal expansion. For example, a same or similar plastic material having the same or similar thermal expansion performance characteristics or properties may be selected for both components.

Thus, when the camera is exposed to temperature changes, such as to an extreme hot (or cold) temperature, the expansion (or contraction) of the lens barrel happens generally simultaneously with the expansion (or contraction) of the camera lens holder, but the expansions (or contractions) expand/contract in the opposite directions of one another. The net result is a cancellation or reduction or offsetting of the thermal expansion of the components and, thus, enhanced focusing for the combined system over a broad range of temperatures. In other words, the result may be an elimination or reduction or offset of the movement of lens focal plane. Optionally, a metal lens barrel with metal camera lens holder may be selected to provide a similar benefit of maintaining focus under a wide temperature range, because of their similar thermal expansion characteristics.

The above design and material selection thus may maintain good or sufficient focus over a wide temperature range, which is very important to automotive camera applications. However, when combining a metal lens barrel with the plastic camera lens holder, or vise versa, because of the substantial differences in thermal expansion characteristics between the plastic and metal materials, there may be a reduced or no cancellation or reduction or offset of the movement of lens focal plane. The camera thus may become out of focus or less focused at extreme temperature conditions. Thus, the matching of the lens barrel material and the camera lens holder material, such as matching plastic with plastic or metal with metal, is a desirable selection for enhanced performance of the camera throughout a wide temperature range.

The wide angle lens includes corrective refractive and diffractive elements positioned along the optic path between the wide angle outer optic and the image sensor. Additional corrective elements may also be included to further correct color or distortion within the refracted image. Diffractive elements are preferably included to correct the color focusing within the refracted image. The diffractive element or elements may further include an aspheric refractive optic element attached thereto or on an opposite surface of a respective optic element to further correct for distortions and aberrations within the focused image. Optionally, these refractive optic elements may be transparent plastic optic elements, having a varying width and

surface curvature, such that the image passing through the refractive lens is refracted in varying degrees, corresponding to the magnitude of distortion in the image received by the refractive optics. Therefore, either by themselves, or in conjunction with the image sensor and/or image processing of the captured images, the refractive and/or diffractive optic elements of the lens function as a means for correcting distortions within the image.

The image system may further reduce image distortion via other distortion reducing means, such as by utilizing non-uniformly distributed pixels at the image array sensor (as discussed below), or such as via an on-imager processing unit (such as a system on chip or the like), such as an FPGA, CPLD, DSP, microprocessor or the like, and associated software, or such as via display means where the distortion correction is done in the displayed image via a non-uniformly distributed pixelated array of the display or via image processing hardware or software of the display device or module.

It is further envisioned that the wide angle imaging system may include electronic image processing or distortion correction to further correct the image displayed on the display. The distortion correction process may be performed by an image processing algorithm or by pixel distribution variation on image capture device and/or an associated display. Preferably, the system may display a vehicle reference, such as a rear bumper of the vehicle, as is seen outside the vehicle, so as to provide a sense of correctness to the image displayed to the driver. For example, an image processing algorithm may be provided which ensures that straight horizontal and/or vertical lines in the scenic information exteriorly of the vehicle are displayed as straight horizontal and/or vertical lines in the image displayed on the display. Such processing allows the imaging system to implement the wide angle lens and still provide a substantially realistic display image to the driver.

Optionally, the image sensor and/or image processing of the captured images may be capable of reducing distortion of the captured image. Such distortion reduction may be accomplished by a non-uniform array of photosensing pixels of the image sensor, such as described in U.S. Pat. No. 5,796,094, which is hereby incorporated herein by reference in its entirety. The non-uniform array may have a coarse distribution of pixels in a center region, with a finer distribution of pixels along the perimeter regions of the captured image. Such non-uniform pixelation of the imaging array receives the focused image and varies correspondingly with the magnitude of distortion in the image refracted through the lens.

Optionally, the image system of the present invention may provide correction of image perspective distortion. Image distortion from the camera with a wide angle lens includes not only lens geometrical distortion (such as pincushion and barrel distortions), but also perspective

distortion, which is caused not by lens distortion, but rather is a perspective distortion or view change whereby an object appears in different sizes when it is located at different distances from the camera. This type of distortion may also be corrected via one or more refractive and/or diffractive optic elements of the lens so as to function as lens-based means for correcting distortion. Optionally, the perspective distortion may also or otherwise be corrected via an imager-based means, image processing means and/or display means for correcting distortion, such as those described above.

Optionally, the graphic overlays may be superimposed or projected onto the displayed image based on the image distortion. For example, the system may change or adjust the graphic overlay projection (such as the angle, curvature, thickness, length and/or other characteristics of the lines or overlays) of an overlay pattern in accordance with the position of the overlay pixel at the displayed image. The graphic overlay projection can be designed based on the lens distortion curve. When an image processing distortion correction is applied to the camera, the camera system level distortion curve can be known by design or measurement, and the graphic overlay projection can be designed based on the camera system level distortion curve.

Thus, the wide angle rearward image system of the present invention provides a wide angle rearward field of view with reduced distortion to the driver of the vehicle so that the images displayed to the driver are readily recognized by the driver when the driver is reversing the vehicle. The image system preferably provides graphic overlays to further enhance the driver's cognitive awareness of detected objects rearward of the vehicle. Although described as a rearward facing imaging system, aspects of the present invention are equally suited for other imaging systems of vehicles, such as side object detection systems or blind spot detection systems or forward facing imaging systems, such as lane departure warning systems and/or the like.

Changes and modifications in the specifically described embodiments can be carried out without departing from the principles of the invention, which is intended to be limited only by the scope of the appended claims, as interpreted according to the principles of patent law including the doctrine of equivalents.

CLAIMS:

1. An imaging system for a vehicle, said imaging system comprising:

an imaging sensor, wherein said imaging sensor comprises a two-dimensional array of light sensing photosensor elements, and wherein said imaging sensor has a rearward field of view when mounted at the vehicle;

a display device for displaying images representative of image data captured by said imaging sensor; and

wherein said imaging system generates a plurality of graphic overlays on said displayed images to enhance the driver's cognitive awareness of an object rearward of the vehicle, said graphic overlays comprising a plurality of graphic overlay segments, said graphic overlay segments conveying three dimensional information to a person viewing said displayed images and said graphic overlays.

2. The imaging system of claim 1, wherein said imaging system adjusts at least one of a color, an intensity and a rate of flashing of at least one of said plurality of graphic overlay segments in response to an object being detected rearward of the vehicle and within a distance threshold

3. The imaging system of claim 1, wherein said each of said overlays comprises at least two segments, and wherein said imaging system is operable to adjust at least one of a color, an intensity and a rate of flashing of a first graphic overlay segment in response to an object being detected rearward of the vehicle and within a first distance threshold, and wherein said imaging system is operable to adjust at least one of a color, an intensity and a rate of flashing of a second graphic overlay segment in response to an object being detected rearward of the vehicle and within a second distance threshold.

4. The imaging system of claim 1, wherein said graphic overlays are displayed so as to generally correspond to the distortion in said displayed images.

5. The imaging system of claim 1, wherein said graphic overlays are adjusted in response to an object detection system so as to not be displayed at areas of said displayed image that are representative of a detected object.

6. The imaging system of claim 1, wherein said imaging system generates an alignment graphic overlay on said displayed images to assist the driver of the vehicle to align the vehicle with a targeted object.

7. The imaging system of claim 6, wherein said alignment graphic overlay comprises a centrally located overlay extending rearward from a centerline of the vehicle.

8. The imaging system of claim 7, wherein said imaging sensor is offset from the centerline of the vehicle, said alignment graphic overlay being displayed as a sideward perspective view of a virtual alignment graphic overlay to enhance the driver's cognitive awareness of the alignment graphic overlay.

9. The imaging system of claim 7, wherein said graphic overlay segments comprise a side graphic overlay segment extending upward and inward along each side of the image so as to be indicative of segments extending rearward from the sides of the vehicle, and wherein said alignment graphic overlay is viewed by the driver as having a different virtual height dimension than said side graphic overlay segments to enhance the driver's cognitive awareness of said graphic overlays.

10. The imaging system of claim 1, wherein said graphic overlay segments comprise a graphic overlay segment extending upward and inward along each side of the image so as to be indicative of segments extending rearward from the sides of the vehicle, and wherein said graphic overlay segments are viewed by the driver as having a virtual height dimension to enhance the driver's cognitive awareness of said graphic overlays.

11. The imaging system of claim 10, wherein said graphic overlay segments are displayed as three dimensional graphic overlay segments having a virtual height and a virtual thickness.

12. The imaging system of claim 11, wherein said imaging system generates an alignment graphic overlay on said displayed images to assist the driver of the vehicle to align the vehicle with a targeted object, and wherein said alignment graphic overlay comprises a centrally located overlay extending rearward from generally a centerline of the vehicle.

13. The imaging system of claim 11, wherein said three dimensional graphic overlay segments comprise first and second segments, said first segment comprising a different color segment than said second segment.

14. The imaging system of claim 13, wherein a color scheme of said first and second segments is selectively adjustable by the driver of the vehicle to configure said graphic overlays for the vision characteristics of the driver of the vehicle.

15. The imaging system of claim 11, wherein said three dimensional graphic overlay segments are displayed such that images of the rearward scene rearward of and toward either side of the vehicle are viewable through said three dimensional graphic overlay segments.

16. The imaging system of claim 1, wherein said imaging sensor has a lens for focusing a field of view onto an image plane of said imaging sensor, and wherein said lens comprises a multi-element wide angle lens, and wherein said multi-element wide angle lens comprises at least one plastic aspheric element and wherein an outer element comprises a wide angle glass element, and wherein one of (a) said multi-element wide angle lens comprises a seven element lens, said seven element lens comprising two plastic elements and five glass elements, and (b) said multi-element wide angle lens comprises a five element lens, said five element lens comprising two plastic elements and three glass elements.

17. The imaging system of claim 1, wherein said imaging sensor has a lens for focusing a field of view onto an image plane of said imaging sensor, and wherein a material of a lens barrel and a material of a lens holder are selected to have substantially similar thermal expansion characteristics to substantially offset thermal expansion of said lens barrel and said lens holder to generally maintain the focus of said imaging sensor.

18. An imaging system for a vehicle, said imaging system comprising:

an imaging sensor, wherein said imaging sensor comprises a two-dimensional array of light sensing photosensor elements, and wherein said imaging sensor has a rearward field of view when mounted at the vehicle;

a display device for displaying images representative of image data captured by said imaging sensor;

wherein said imaging system generates a plurality of graphic overlays on said displayed images to enhance the driver's cognitive awareness of an object rearward of the vehicle, said graphic overlays comprising a plurality of graphic overlay segments;

wherein said graphic overlay segments comprise a side graphic overlay segment extending upward and inward along each side of the image so as to be indicative of segments extending rearward from the sides of the vehicle and wherein said graphic overlay segments comprise an alignment graphic overlay segment to assist the driver of the vehicle to align the vehicle with a targeted object; and

wherein at least one of said graphic overlay segments is viewed by the driver as having a virtual height dimension to enhance the driver's cognitive awareness of said graphic overlays, and wherein said at least one of said graphic overlay segments is displayed as a three dimensional graphic overlay segment having a virtual height and a virtual thickness.

19. The imaging system of claim 18, wherein at least one of said graphic overlay segments comprises at least two segment portions, and wherein said imaging system is operable to adjust at least one of a color, an intensity and a rate of flashing of a first segment portion in response to an object being detected rearward of the vehicle and within a first distance threshold, and wherein said imaging system is operable to adjust at least one of a color, an intensity and a rate of flashing of a second segment portion in response to an object being detected rearward of the vehicle and within a second distance threshold.

20. The imaging system of claim 18, wherein said alignment graphic overlay comprises a centrally located overlay extending rearward from a centerline of the vehicle.

21. The imaging system of claim 20, wherein said alignment graphic overlay is displayed as a three dimensional graphic overlay segment, and wherein said imaging sensor is offset from the centerline of the vehicle, said alignment graphic overlay being displayed as a sideward perspective view of a virtual alignment graphic overlay to enhance the driver's cognitive awareness of said alignment graphic overlay.

22. The imaging system of claim 18, wherein said graphic overlays are adjusted in response to an object detection system so as to not be displayed at areas of said displayed image that are representative of a detected object.

23. The imaging system of claim 18, wherein said side graphic overlay segments include laterally extending horizontal linear marks to assist the driver in judging distances rearward of the vehicle.

24. The imaging system of claim 18, wherein at least one of said graphic overlay segments comprises first and second segment portions, said first segment portion comprising a different color segment than said second segment portion.

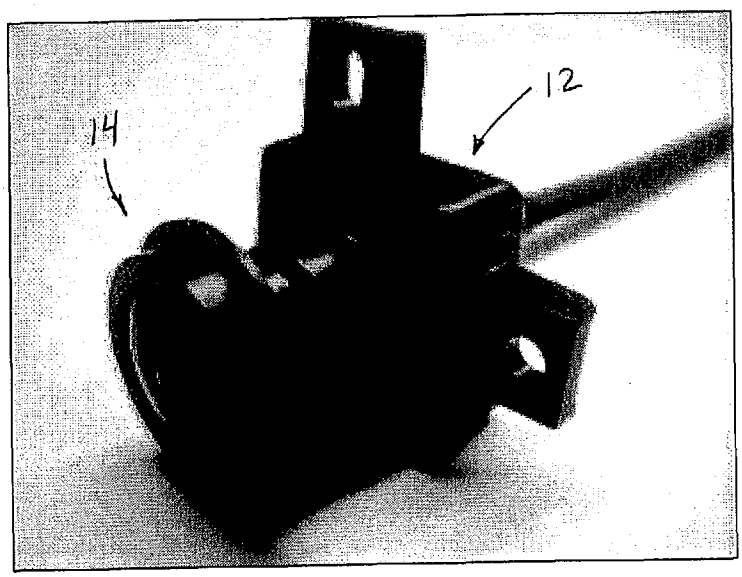
25. The imaging system of claim 18, wherein said at least one three dimensional graphic overlay segment is displayed such that images of the rearward scene rearward of and toward either side of the vehicle are viewable through said at least one three dimensional graphic overlay segment.

26. The imaging system of claim 25, wherein said imaging system adjusts at least one of a color, an intensity and a rate of flashing of at least one of said at least one three dimensional graphic overlay segment in response to an object being detected rearward of the vehicle and within a distance threshold.

27. The imaging system of claim 18, wherein a color scheme of said graphic overlay segments is selectively adjustable by the driver of the vehicle to configure said graphic overlay segments for the vision characteristics of the driver of the vehicle.

FIG. 2

FIG. 1



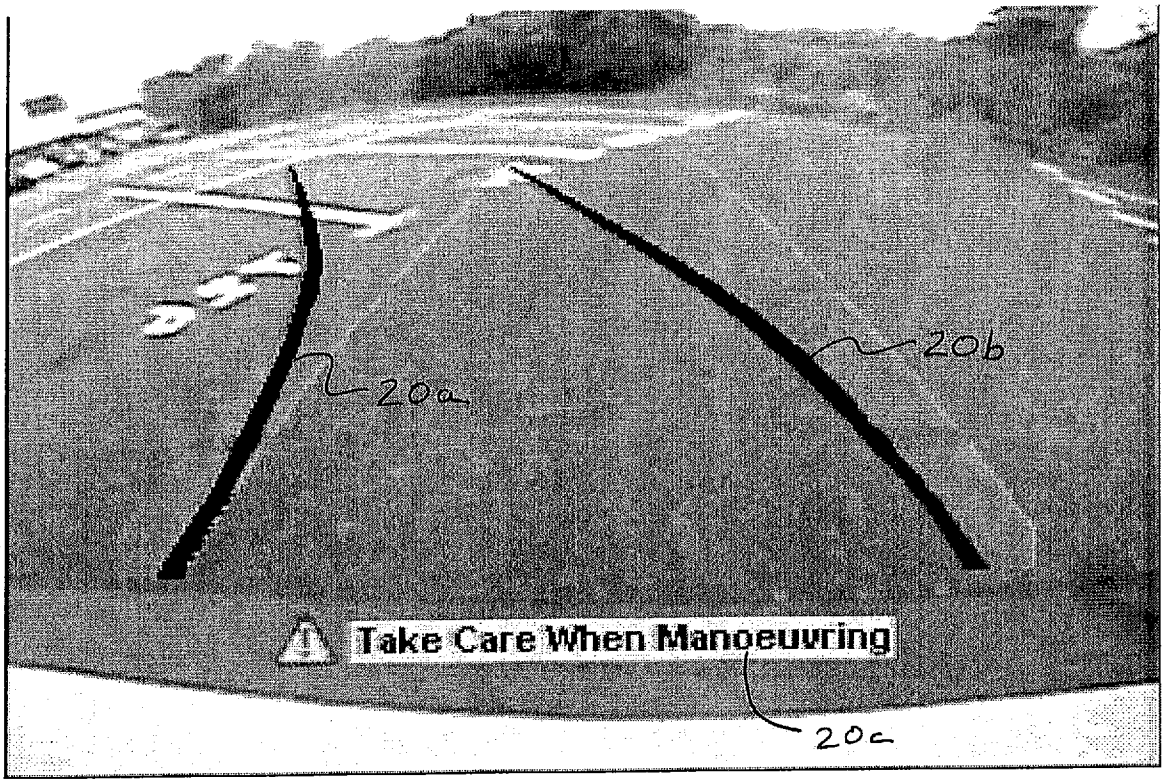

20a
20b
Take Care When Manoeuvring
20c

FIG. 3

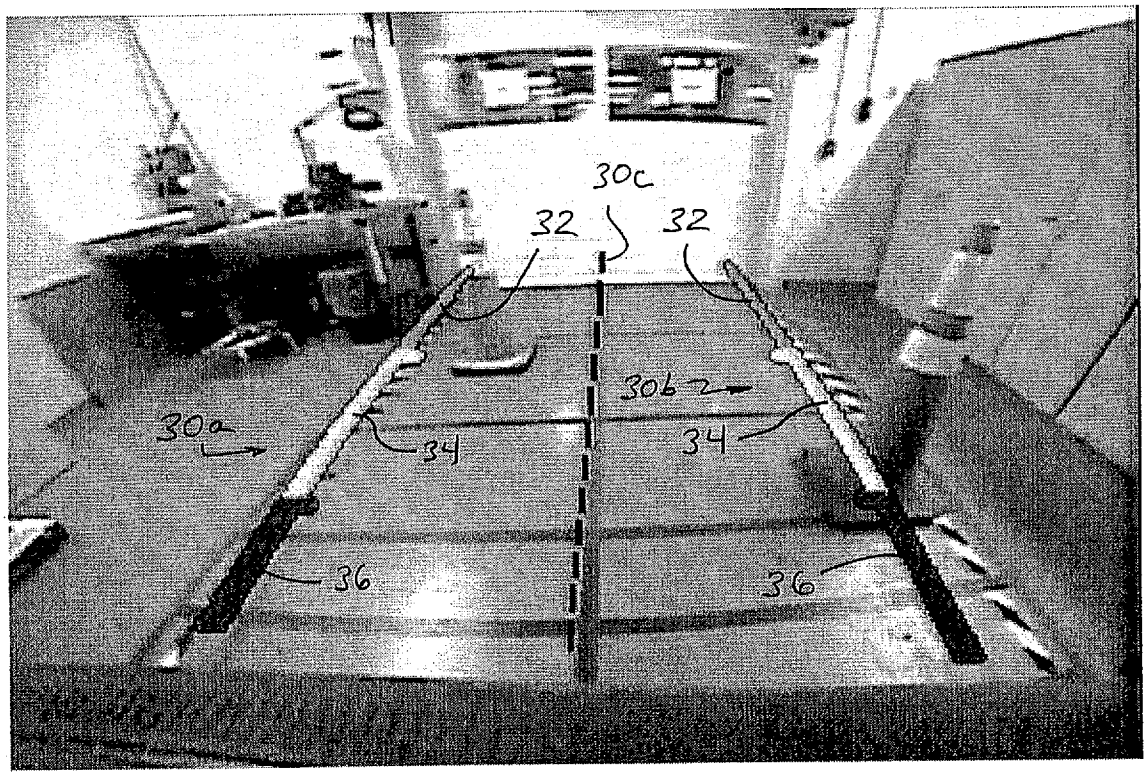

30c
32
32
30b
30a
34
34
36
36

FIG. 4

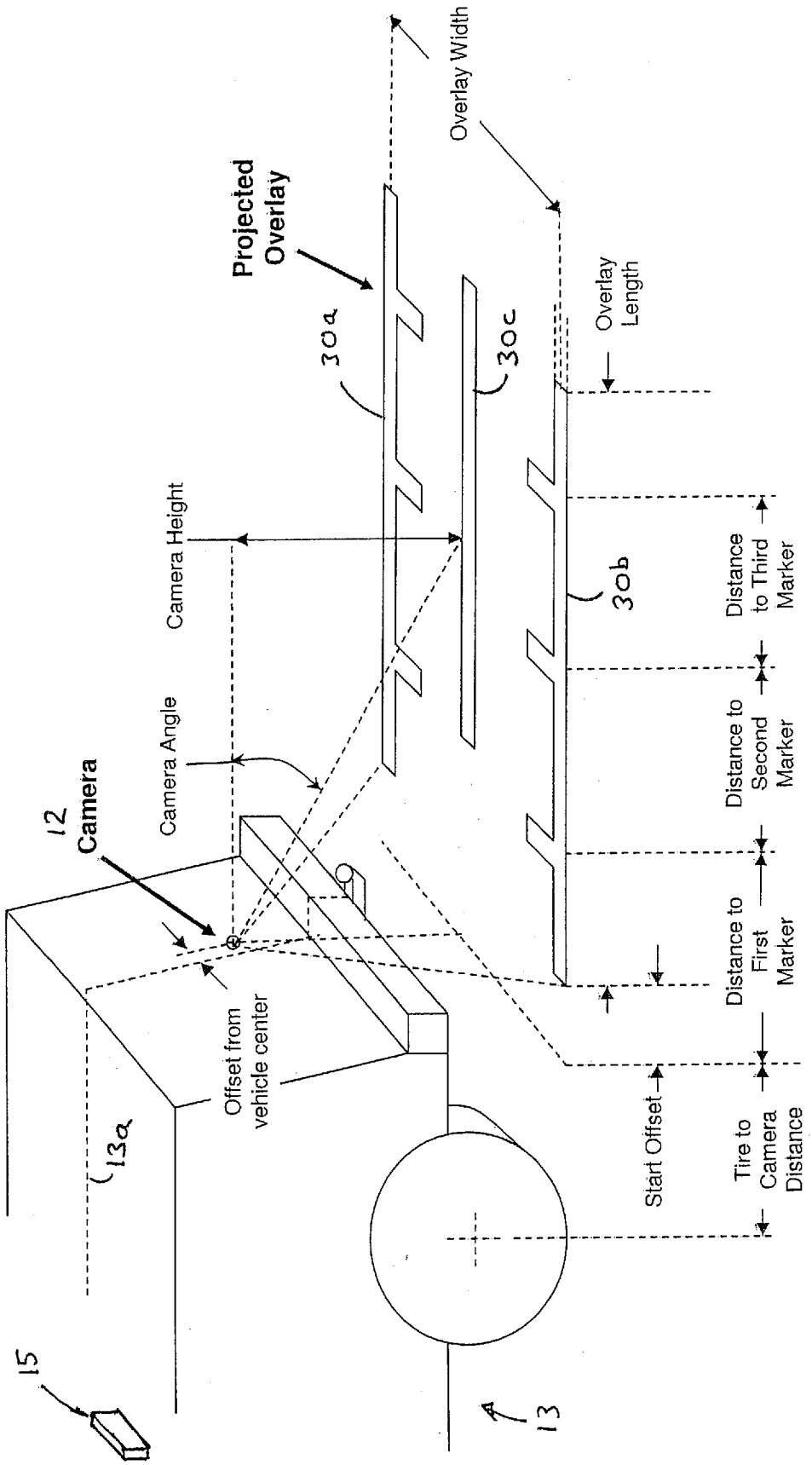

Projected Overlay
Overlay Width
Overlay Length
30a
30c
30b
Camera Height
Camera Angle
12 Camera
Offset from vehicle center
13a
15
13
Start Offset
Tire to Camera Distance
Distance to First Marker
Distance to Second Marker
Distance to Third Marker

FIG. 4A

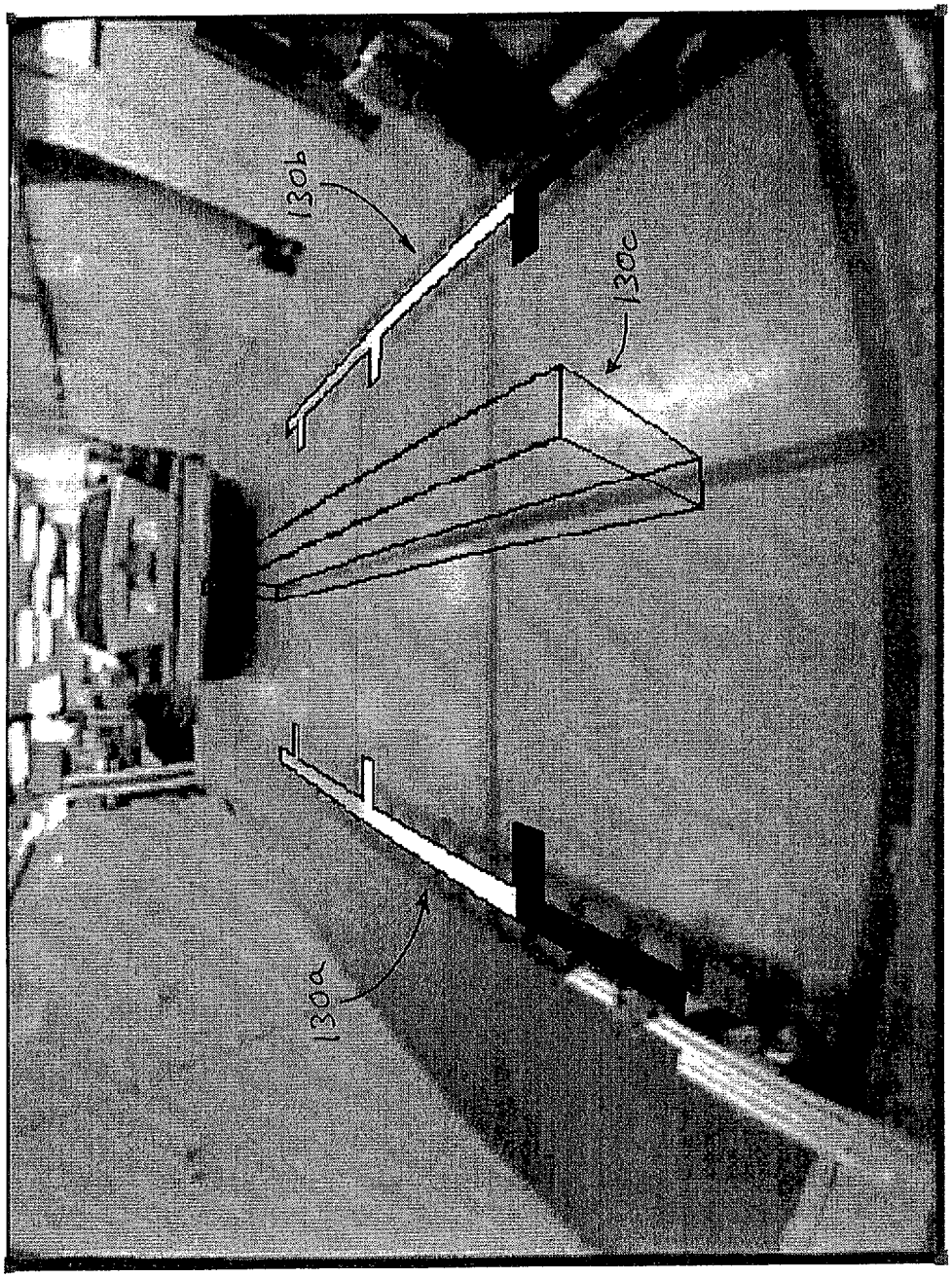
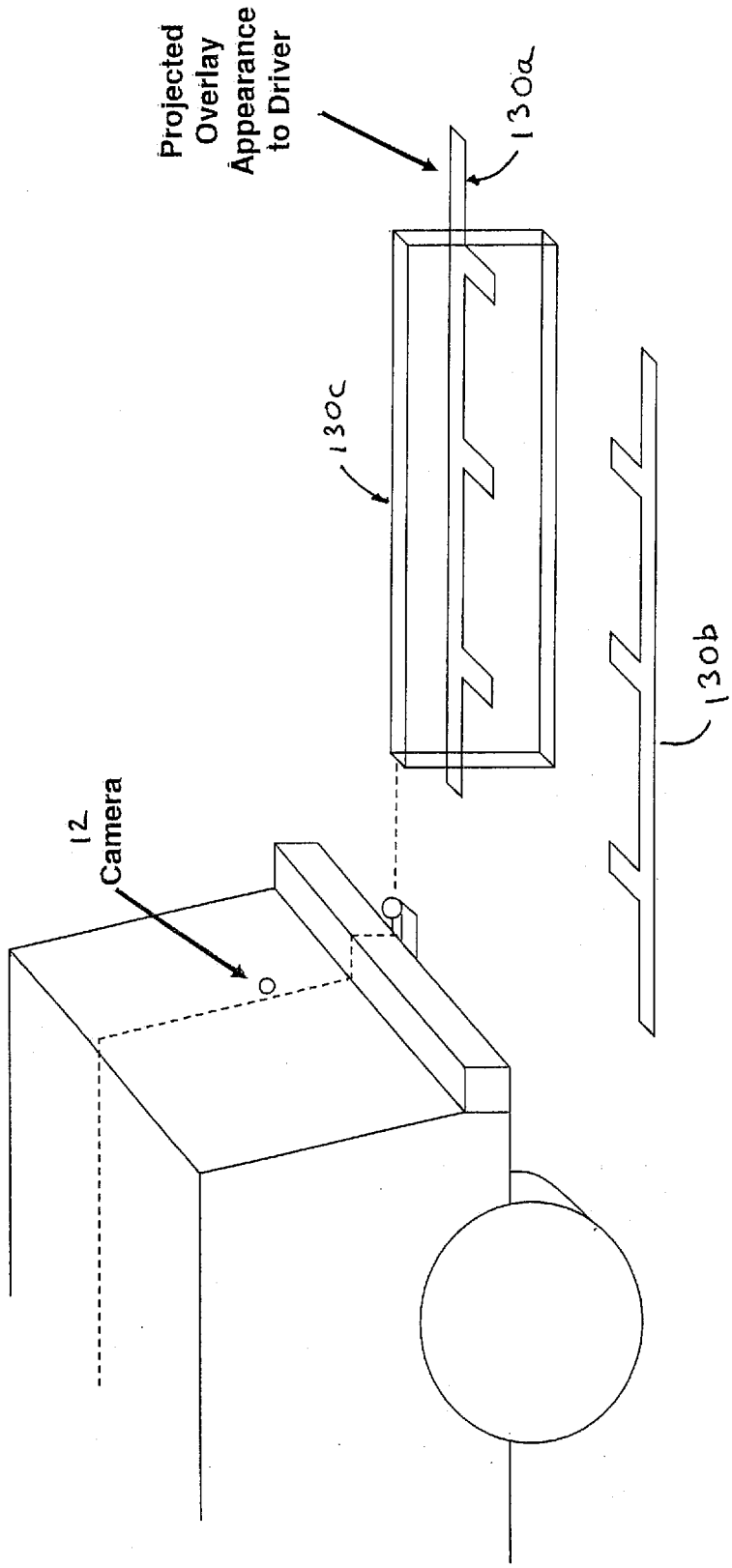


FIG. 5


Projected
Overlay
Appearance
to Driver
130a
130c
130b
12
Camera

FIG, 5A

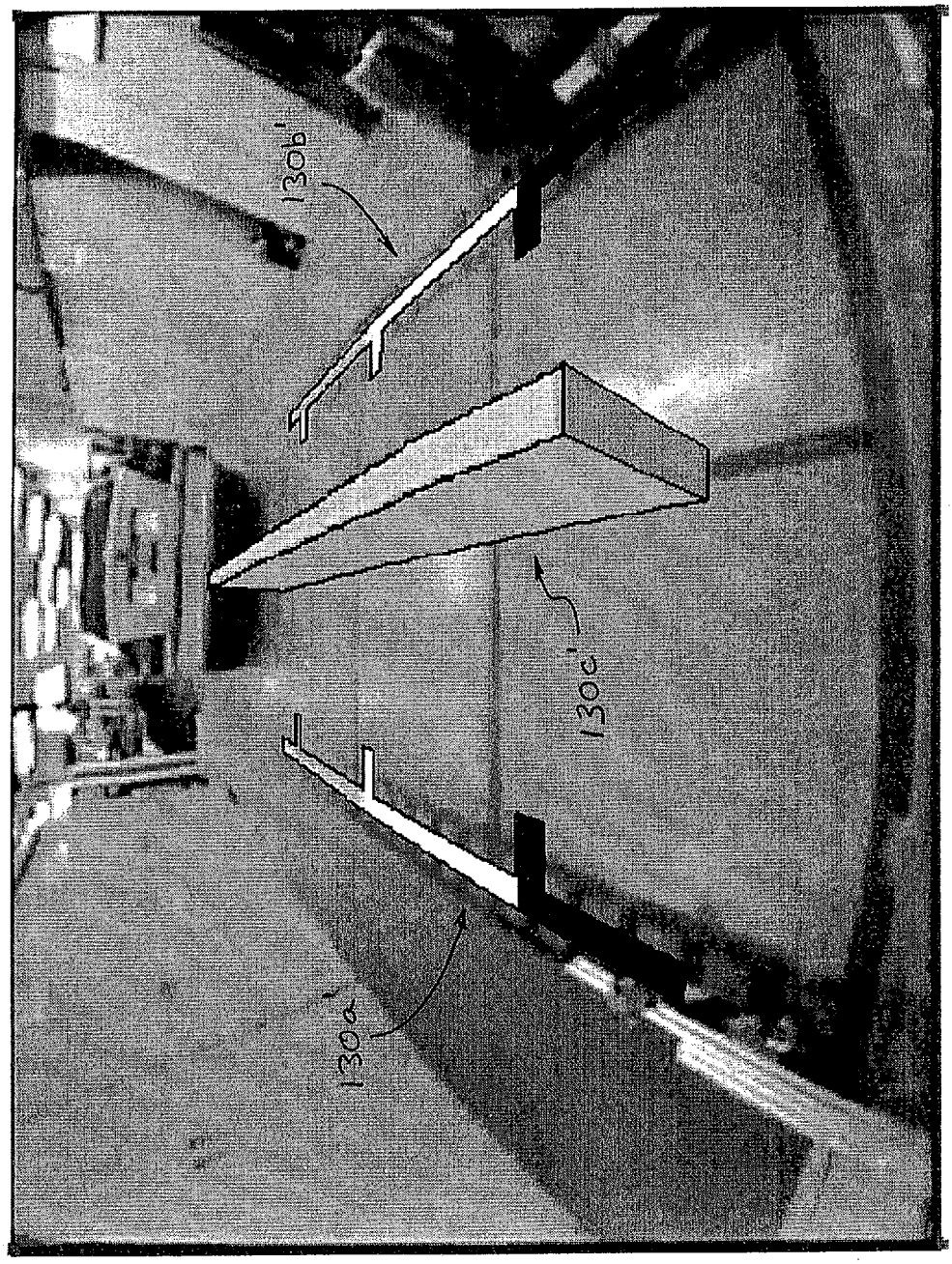


FIG. 6

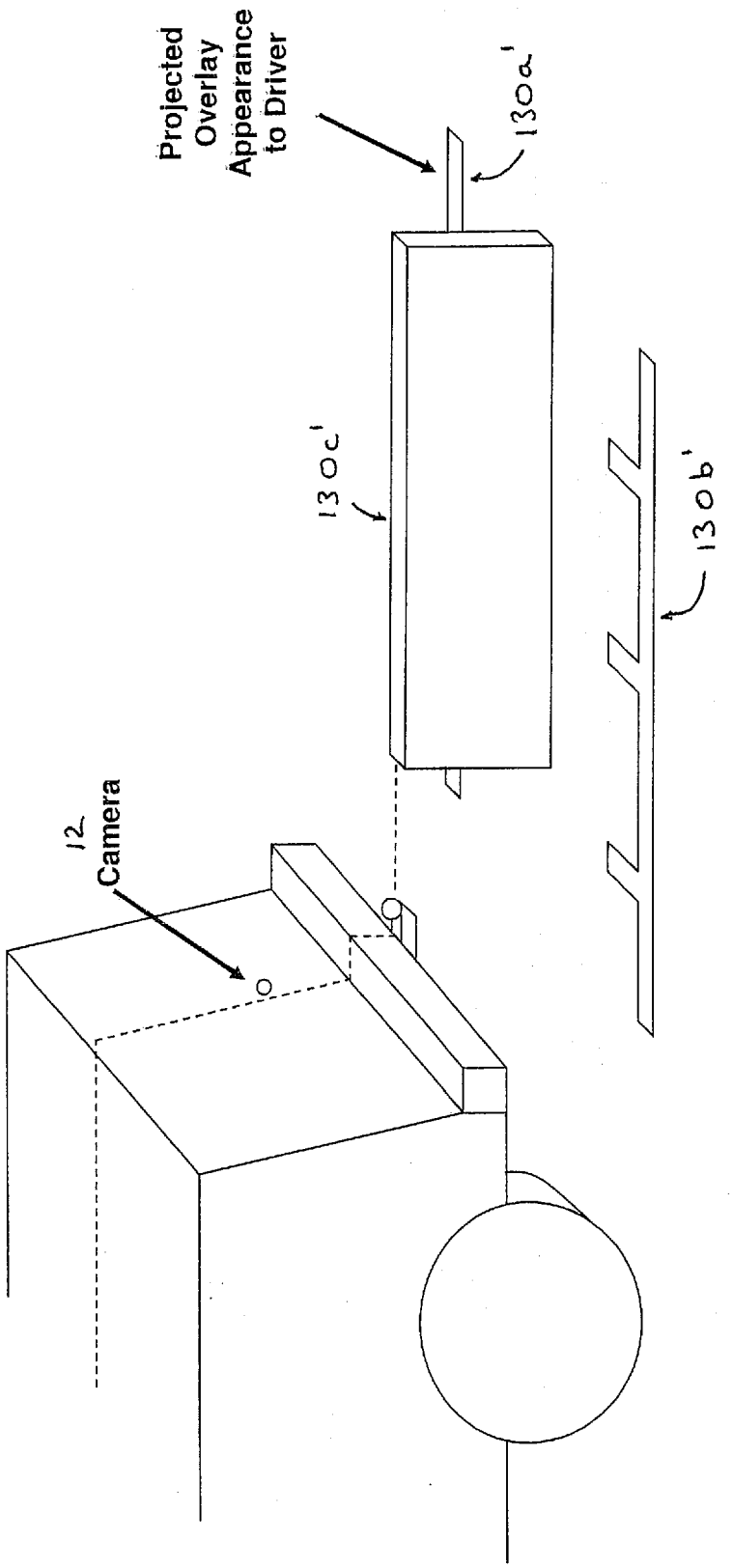

Projected Overlay Appearance to Driver
130a'
130c'
130b'
12 Camera

FIG. 6A

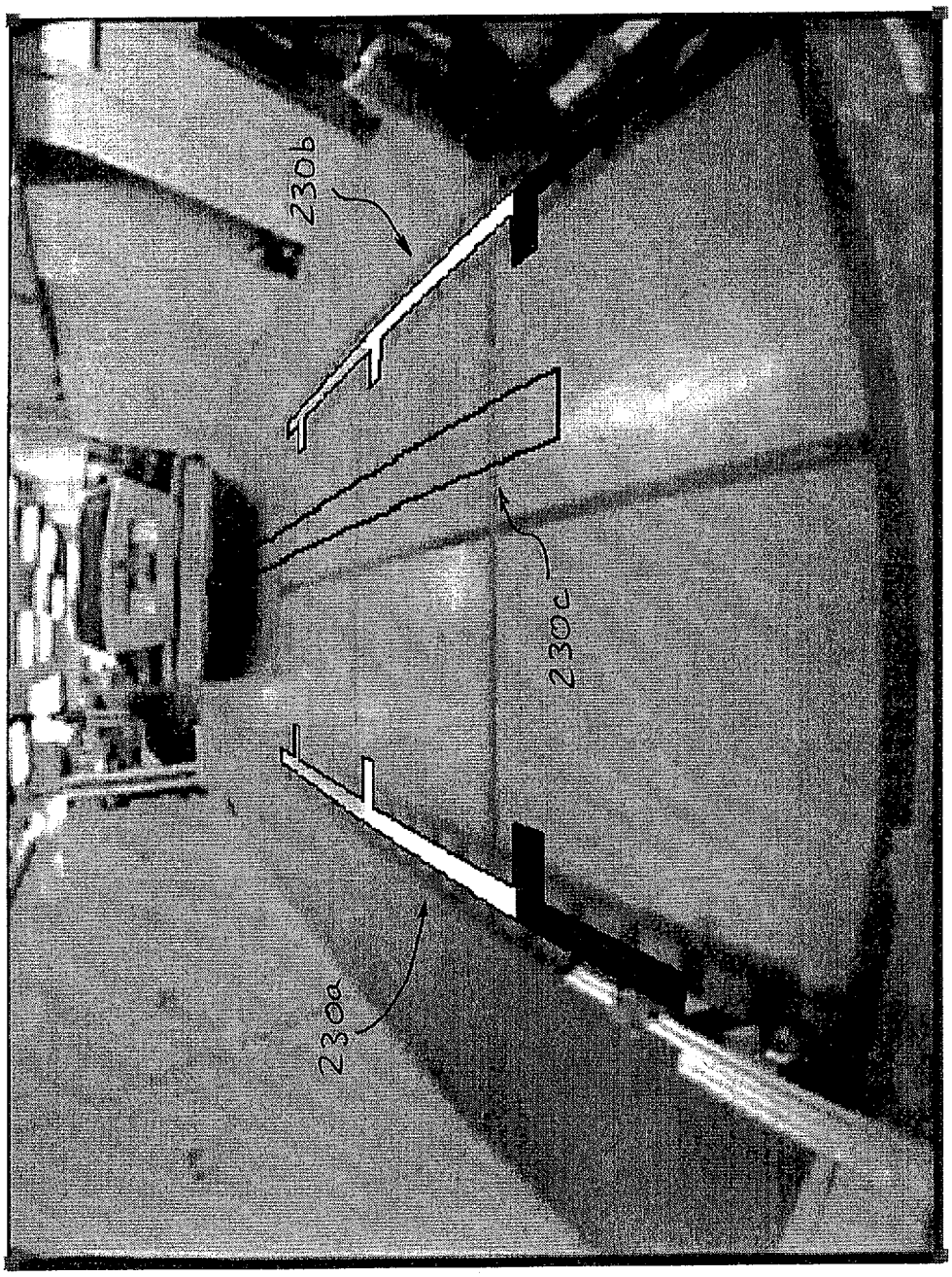


FIG. 7

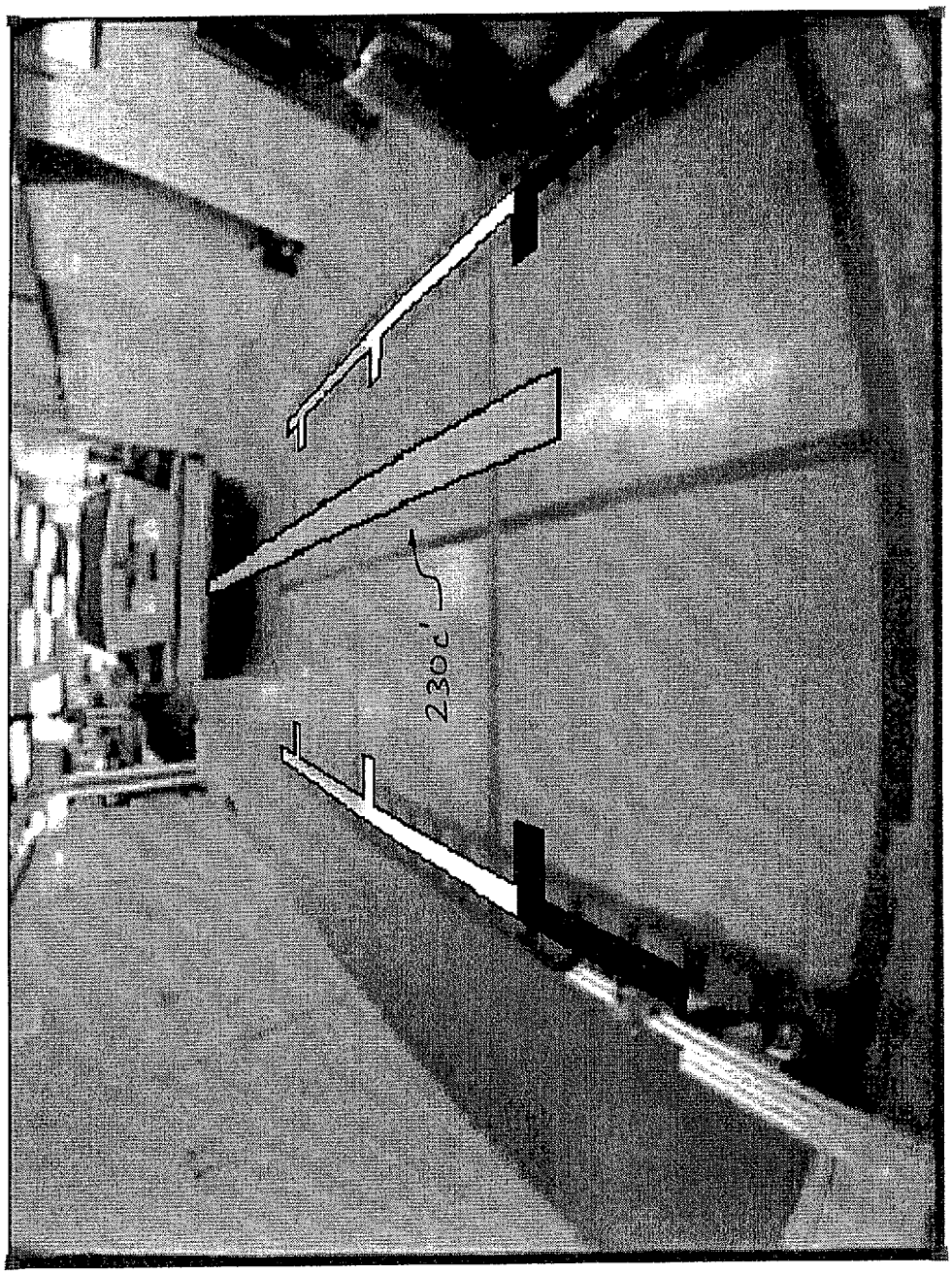


FIG. 8

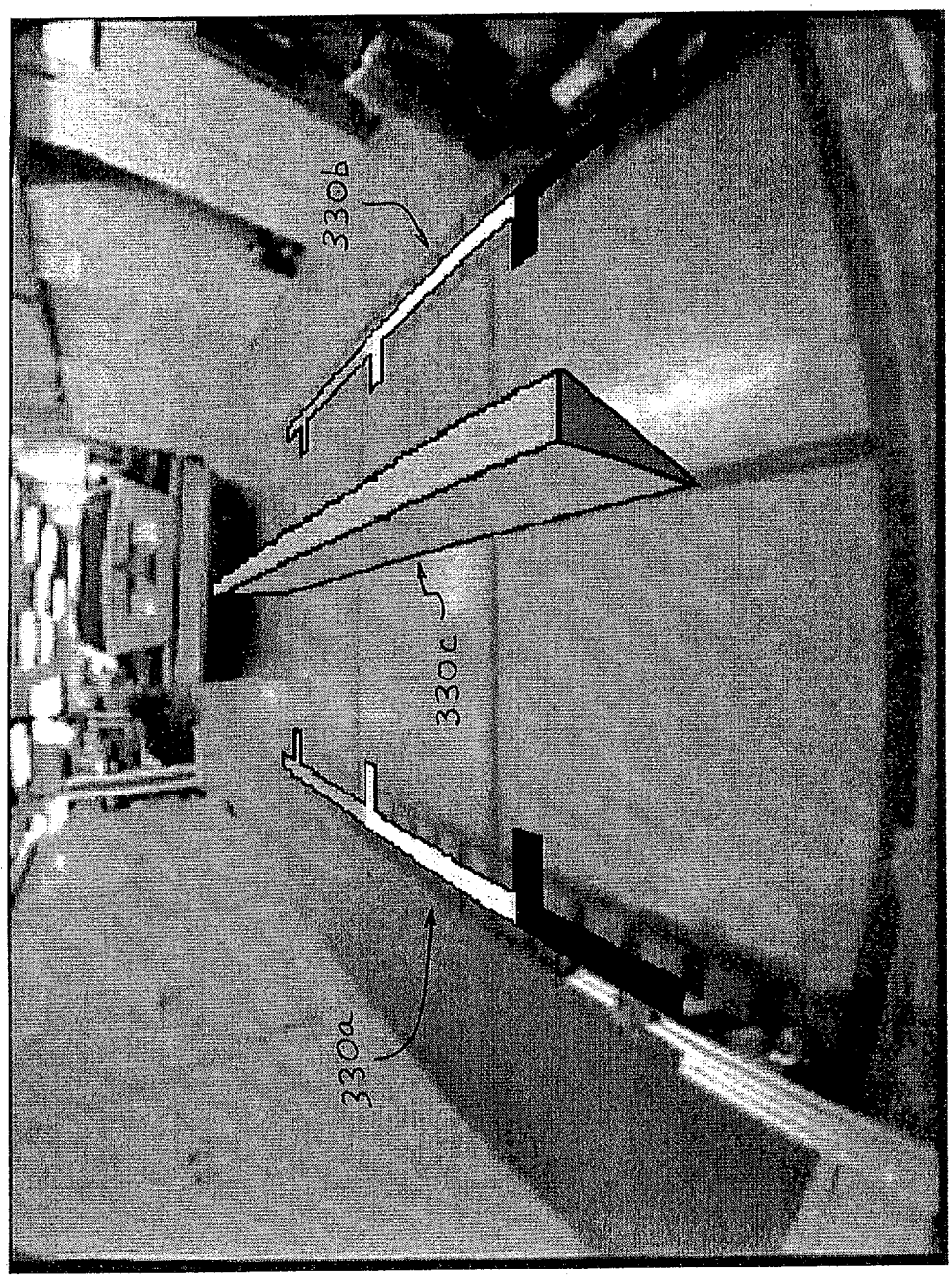


FIG. 9

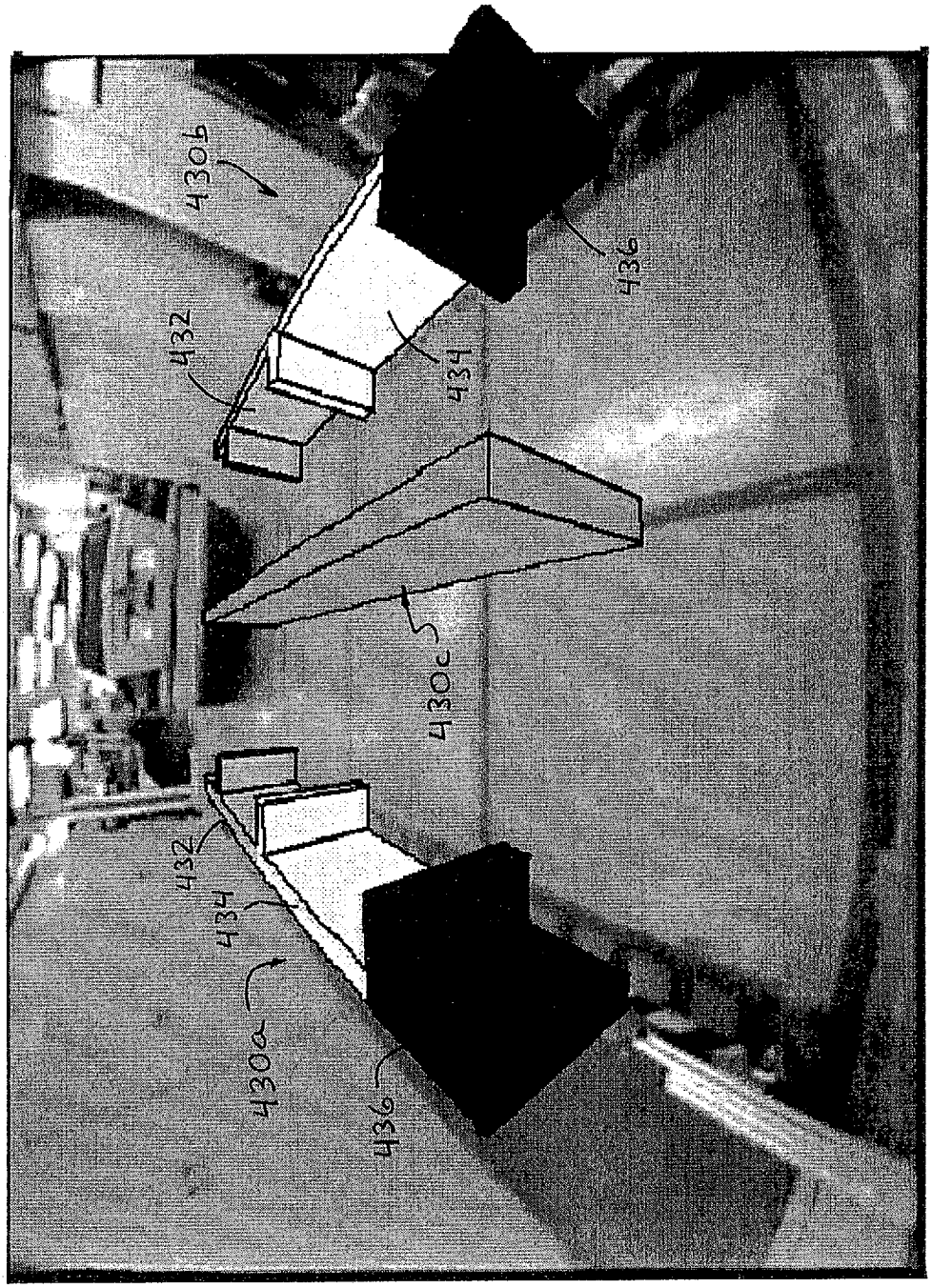


FIG. 10

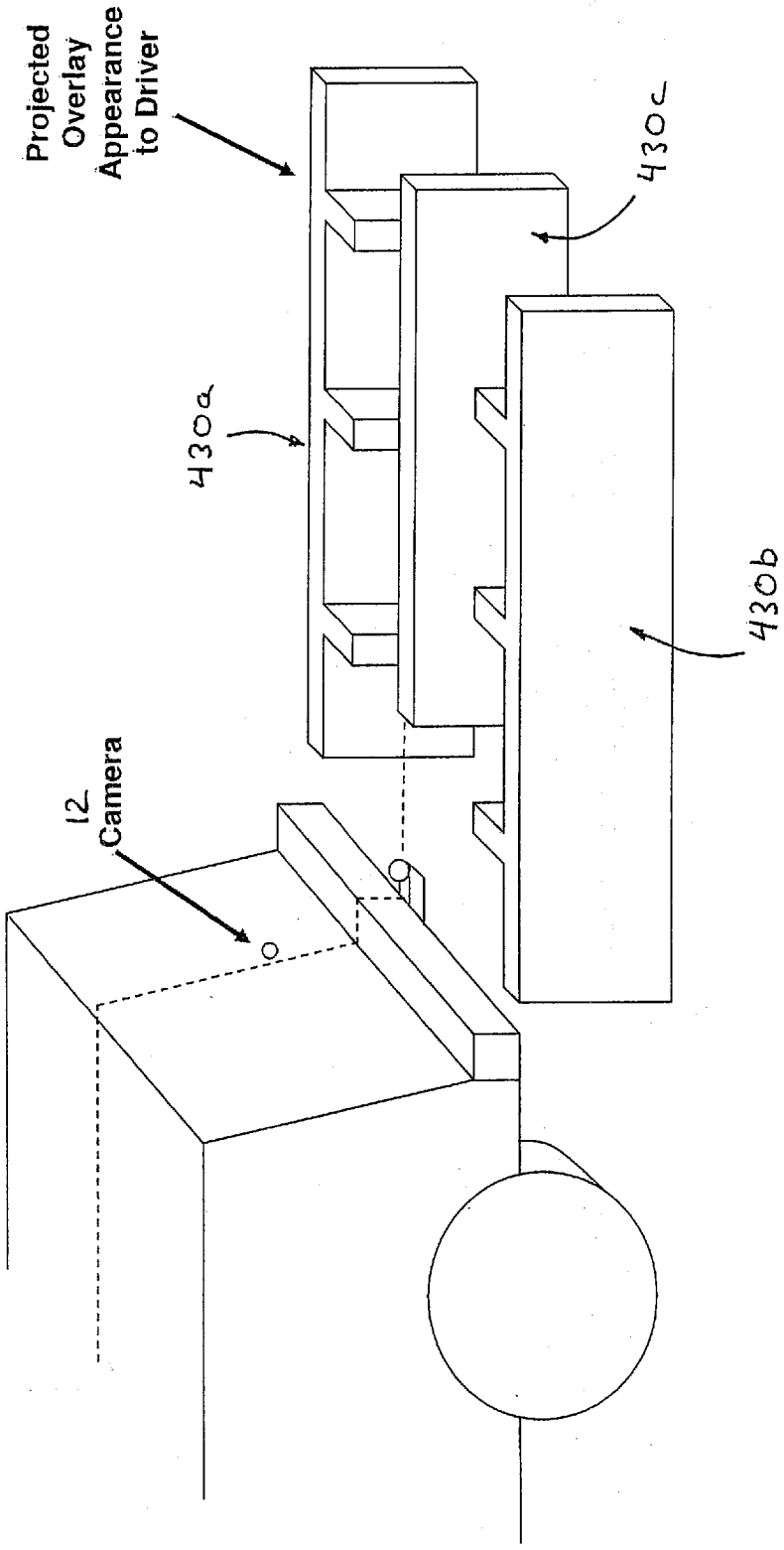

Projected Overlay Appearance to Driver
430c
430a
430b
12 Camera

FIG. 10A

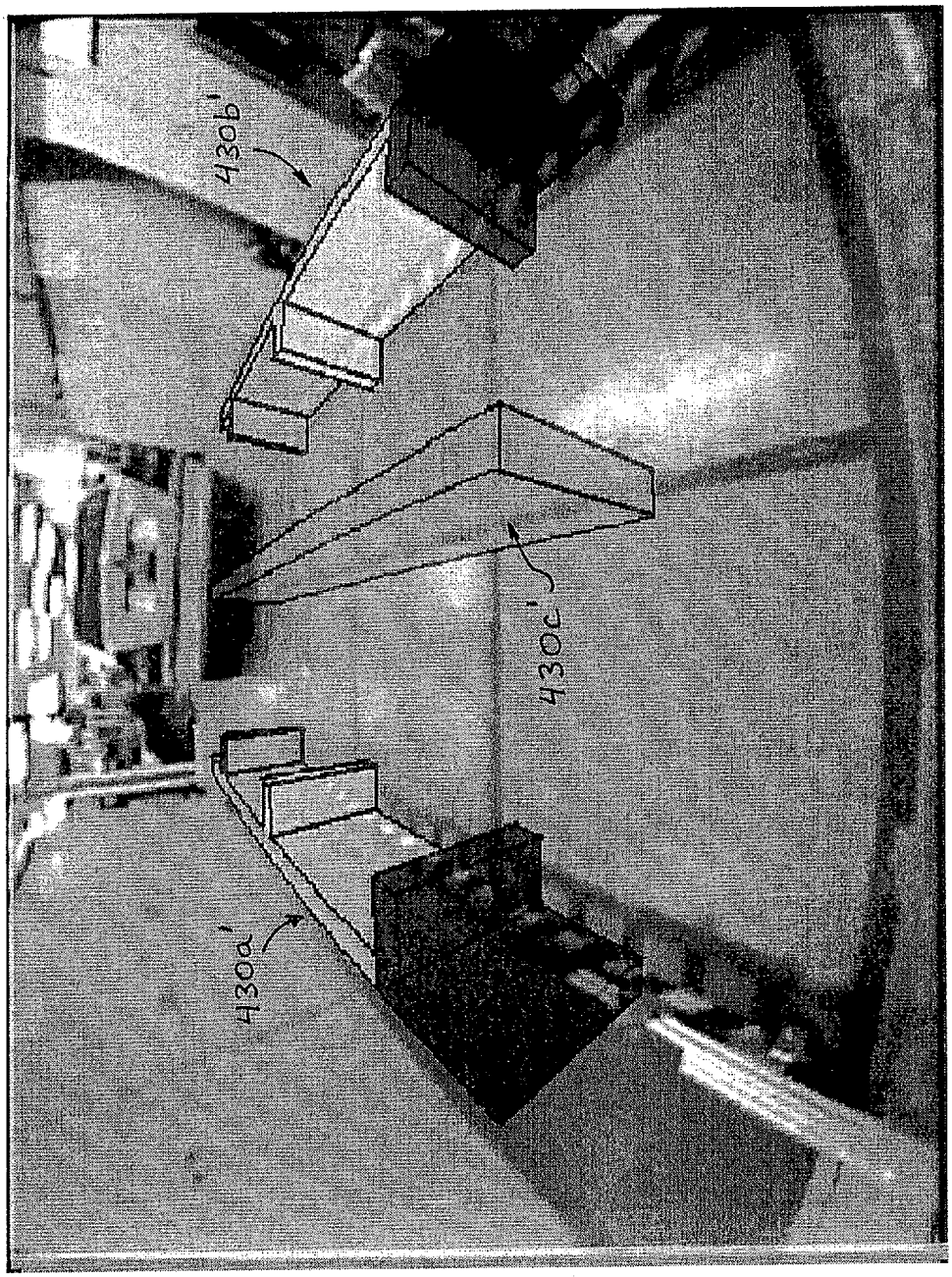


FIG. 11

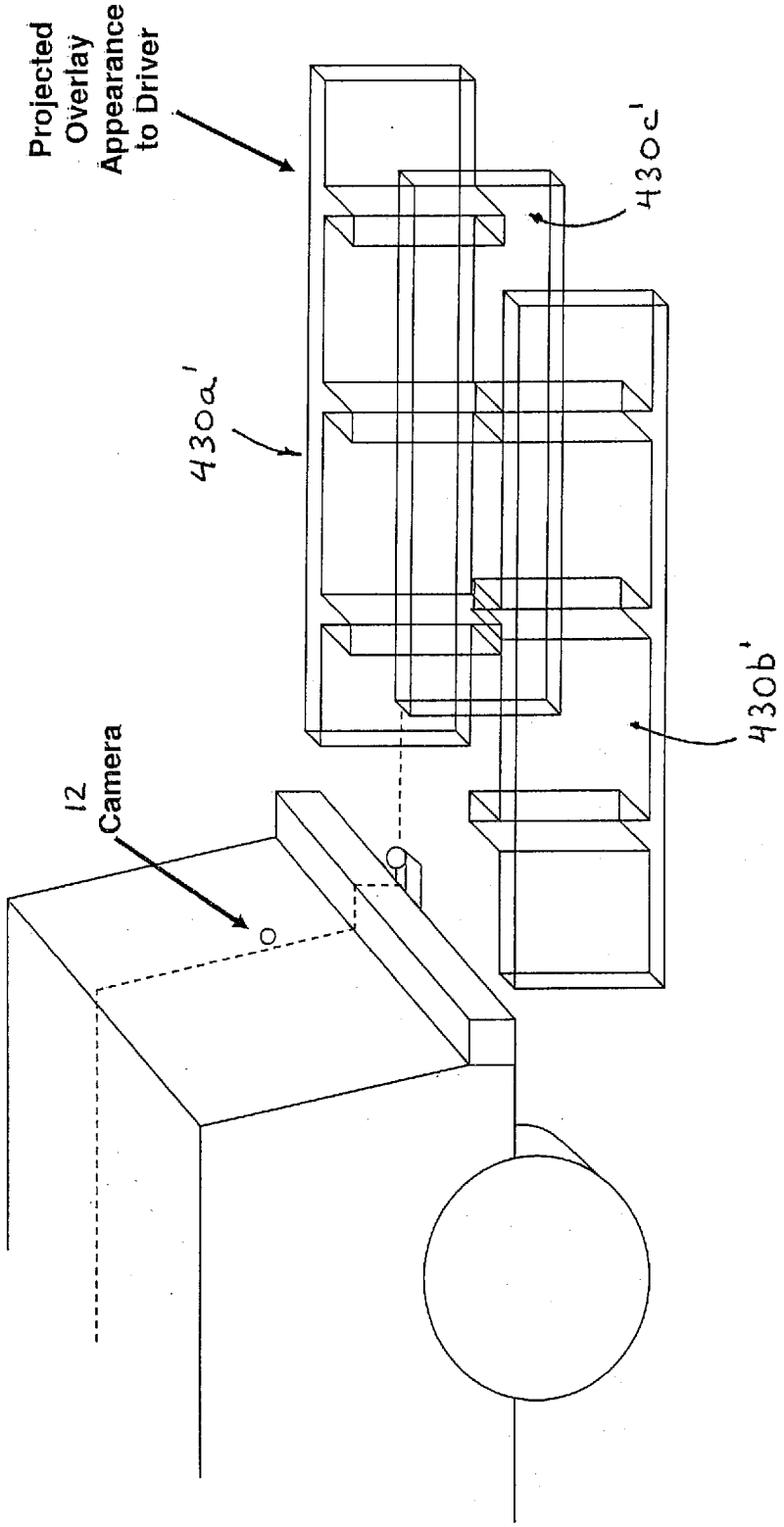

Projected Overlay Appearance to Driver
430c'
430a'
430b'
12 Camera

FIG. 11A

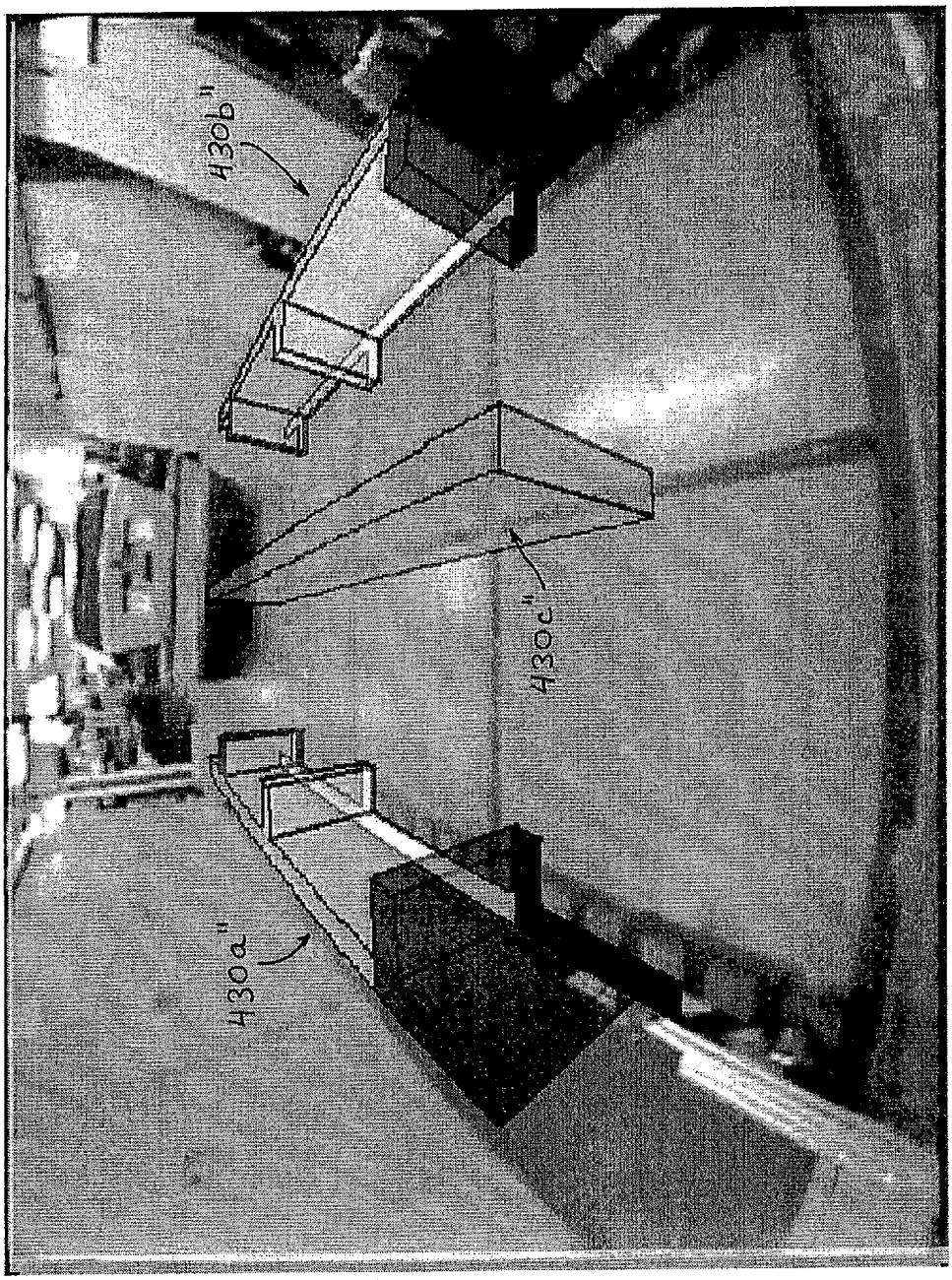


FIG. 12

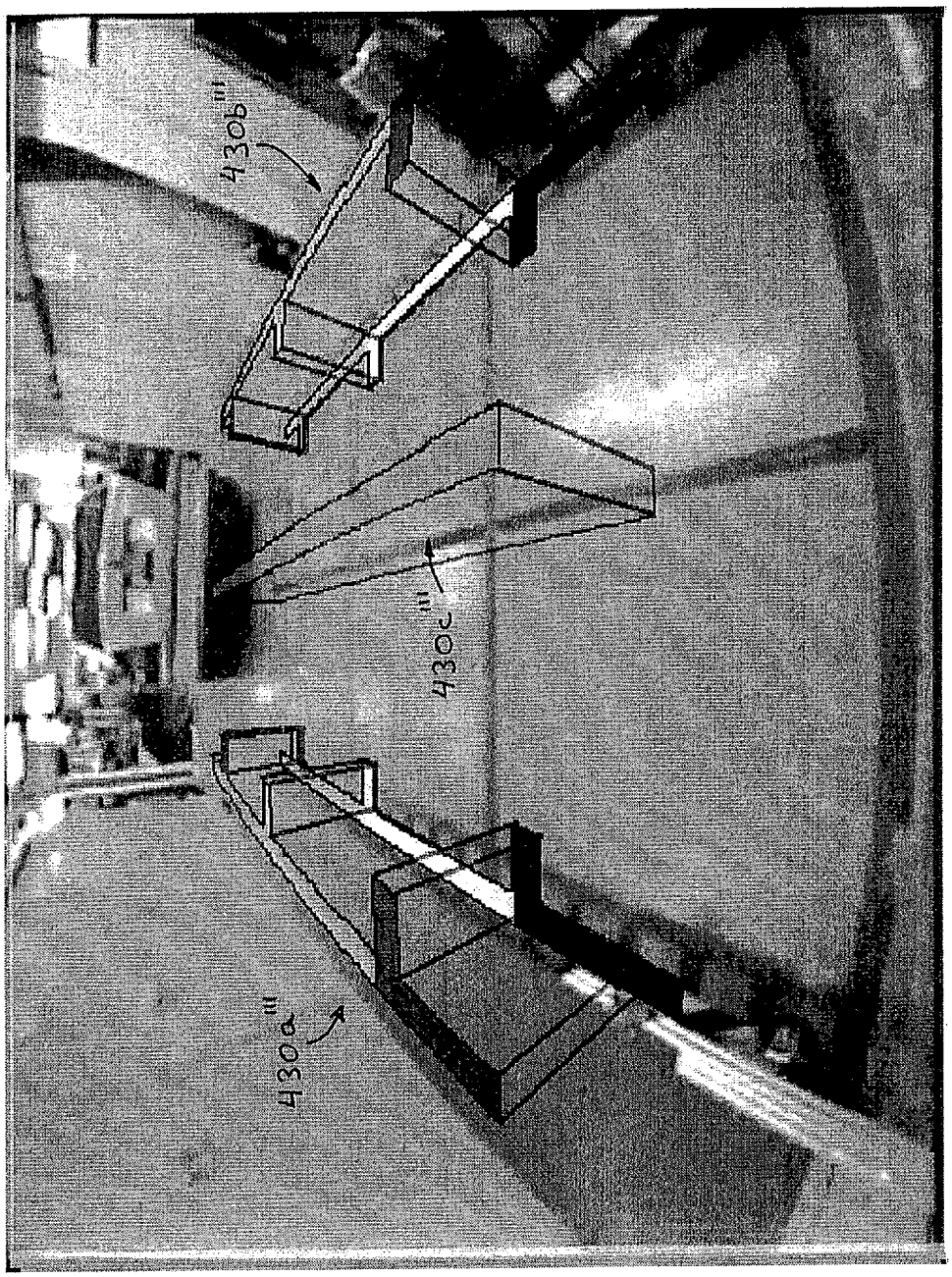


FIG. 13

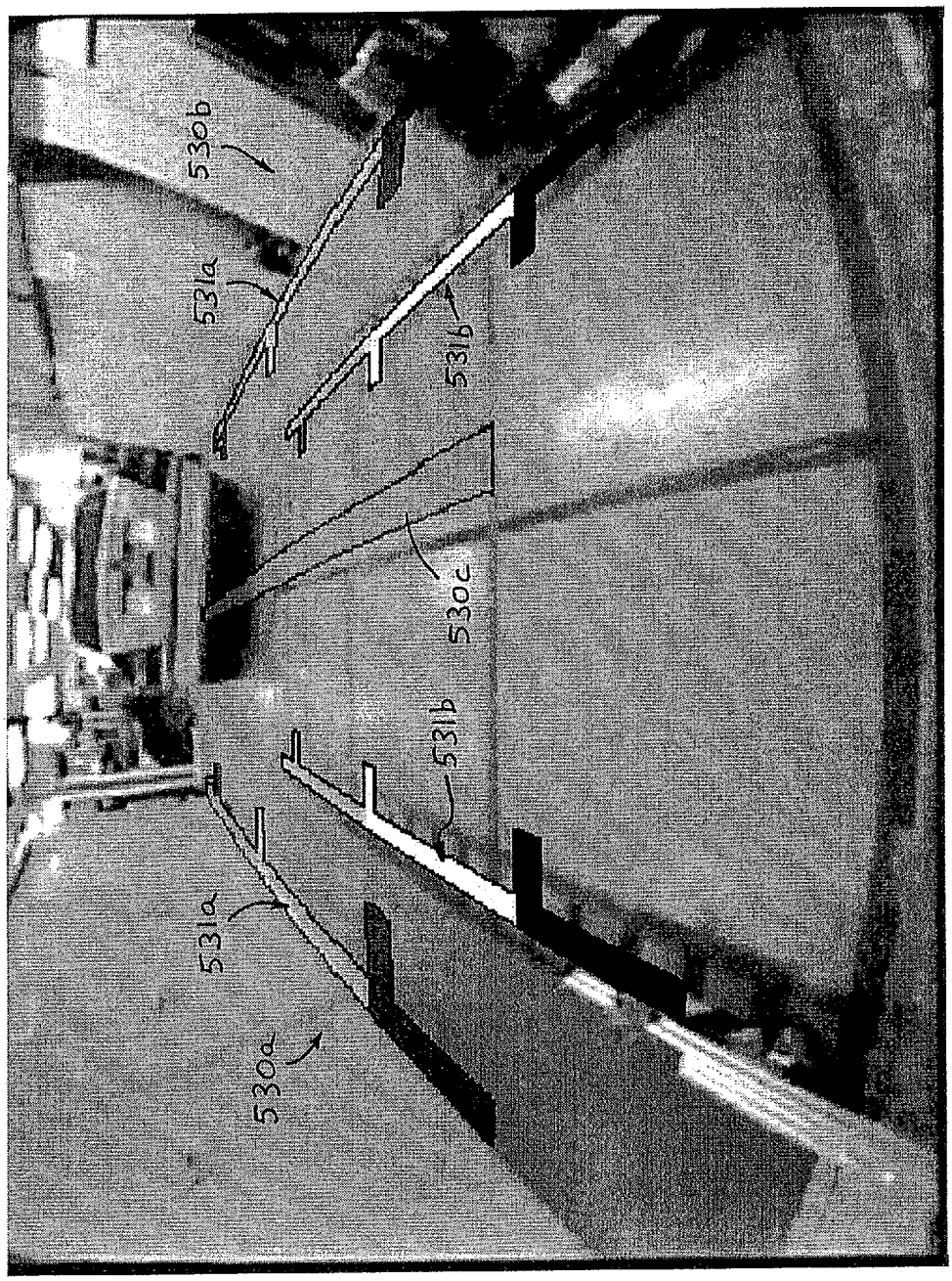


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 08/76022

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G09F 9/00 (2008.04)
USPC - 340/461
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 340/461

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 340/425.5, 461; 348/148

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (PGPB,USPT,EPAB,JPAB); Google; Google Scholar
Search Terms Used: imaging, vehicle, automobile, car, truck, sensor, light, display, photo, graphic, overlay, 3-D, three dimensional, color

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007/0120657 A1 (SCHOFIELD et al.) 31 May 2007 (31.05.2007), abstract, para [0008], [0019], [0024], [0026], [0046], [0047], [0049], [0053], [0054], Fig. 6	1-27
Y	US 7,167,779 B2 (KASHIWADA et al.) 23 January 2007 (23.01.2007), col 1, ln 56-60, and Fig. 3	1-27
Y	US 2006/0245653 A1 (CAMUS et al.) 02 November 2006 (02.11.2006), para [0005], Fig. 5 and Fig. 6	9-15, 18-27
Y	US 6,498,620 B2 (SCHOFIELD et al.) 24 December 2002 (24.12.2002), col 22, ln 10-15	13-15, 24, 27
Y	US 6,631,994 B2 (SUZUKI et al.) 14 October 2003 (14.10.2003), col 80, ln 63-col 81, ln 6	17

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
02 November 2008 (02.11.2008)	24 NOV 2008
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (April 2007)