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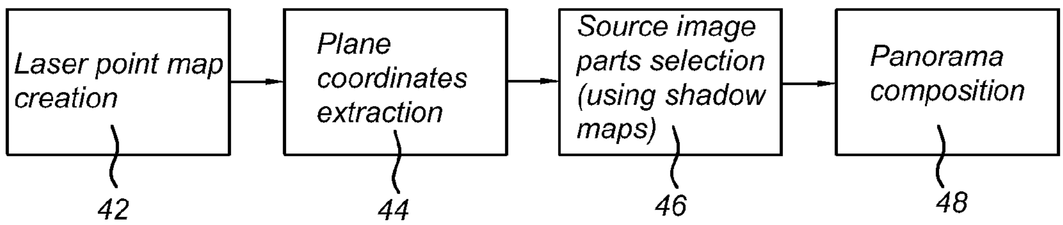
(54) **Title:** METHOD OF AND APPARATUS FOR PRODUCING A MULTI-VIEWPOINT PANORAMA

Fig 4



(57) **Abstract:** A method of producing multi-viewpoint panorama of a roadside is disclosed. The method comprises: - acquiring a set of laser scan samples obtained by at least one terrestrial based laser scanner mounted on a moving vehicle, wherein each sample is associated with location data and orientation data; - acquiring at least one image sequence, wherein each image sequence is obtained by means of a terrestrial based camera mounted on the moving vehicle, wherein each image of the at least one image sequences is associated with location and orientation data; - extracting a surface from the set of laser scan samples and determining the location of said surface in dependence of the location data associated with the laser scan samples; - producing a multi-viewpoint panorama for said surface from the at least one image sequence in dependence of the location of the surface and the location and orientation data associated with each of the images.

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Method of and apparatus for producing a multi-viewpoint panorama

Field of the invention

The present invention relates to a method of producing a multi-viewpoint panorama. The present invention further relates to a method of producing a roadside panorama from multi viewpoint panoramas. The invention further relates to an apparatus for a multi-viewpoint panorama, a computer program product and a processor readable medium carrying said computer program product. The invention further relates to a computer-implemented system using said roadside panoramas.

Prior art

Nowadays, people use navigation devices to navigate themselves along roads or use map displays on the internet. Navigations devices show in their display a planar perspective, angle perspective (bird view) or variable scale “2D” map of location. Only information about the roads or some simple attribute information about areas, such as lakes and parks are shown in the display. This kind of information is really an abstract representation of the location and does not show what can be seen by a human or by a camera positioned at the location (in reality or virtually) shown in the display. Some internet applications show top looking down pictures taken from satellite or airplane and still fewer show a limited set of photographs taken from the road, perhaps near the location (real or virtual) of the user and facing in generally the same direction as the user intends to look.

There is a need for more accurate and realistic roadside views in future navigation devices and internet applications. The roadside views enables a user to see what can be seen at a particular location and to verify very easily whether the navigation device uses the right location when driving or verify that the place of interested queried on the internet is really the place they want or just viewing the area in greater detail for pleasure or business reasons. In the display the user can than see immediately whether the buildings seen on the display correspond to the building he can see at the roadside or envision from memory or other descriptions. A panorama image produced from images that are captured from different viewpoints is considered to be multi-viewpoint or multi-perspective. Another type of panorama image is a slit-scan panorama. In their simplest form, a strip panorama exhibits orthographic projection along the horizontal axis, and perspective projection along the vertical axis.

A system for producing multi-viewpoint panoramas is known from Photographing long scenes with multi-viewpoint panoramas, Aseem Agarwala, et al, ACM Transactions on Graphics (Proceedings of SIGGRAPH 2006), 2006. A system for producing multi-viewpoint panoramas of long, roughly planar scenes, such as facades of buildings along a city street, produces from a relatively sparse set of photographs captured with a handheld still camera. A user has to identify the dominant plane of the photographed scene. Then, the system computes a panorama automatically using Markov Random Field optimization.

Another technique for depicting realistic images of what is around is to develop a full 3D model of the area and then apply realistic textures to the outer dimensions of each building. The application, such as that in the navigation unit or on the internet, can then use 3D rendering software to construct a realistic picture of the surrounding objects.

Summary of the invention

The present invention seeks to provide an alternative method of producing multi-viewpoint panoramas and an alternative way of providing a high quality easy to interpret set of images representing a virtual surface with near photo quality which are easy to manipulate to obtain pseudo realistic perspective view images without the added cost and complexity of developing a full 3D model.

According to the present invention, the method comprises:

- acquiring a set of laser scan samples obtained by a laser scanner mounted on a moving vehicle, wherein each sample is associated with location data;
- acquiring at least one image sequence, wherein each image sequence has been obtained by means of a terrestrial based camera mounted on the moving vehicle, wherein each image of the at least one image sequences is associated with location and orientation data;
- extracting a surface from the set of laser scan samples and determining the location of said surface in dependence of the location data associated with the laser scan samples;

- producing a multi-viewpoint panorama for said polygon from the at least one image sequence in dependence of the location of the surface and the location and orientation data associated with each of the images.

The invention is based on the recognition that a mobile mapping vehicle which drives on the surface of the earth, records surface collected geo-position image sequences with terrestrial based cameras. Furthermore, the mobile mapping vehicle records laser scan samples which enables software to generate a 3D representation of the environment of the mobile mapping vehicle from the distance information from the laser scanner samples. The position and orientation of the vehicle is determined by means of a GPS receiver and an inertial measuring device, such as one or more gyroscopes and/or accelerometers. Moreover, the position and orientation of the camera with respect to the vehicle and thus with respect to the 3D representation of the environment is known. To be able to generate a visually attractive multi viewpoint panorama, the distance between the camera and the surface of the panorama has to be known. The panorama can represent a view of the roadside varying from a building surface up to a roadside panorama of a street. This can be done with existing image processing techniques. However, this needs a lot of computer processing power. According to the invention, the surface is determined by processing the laser scanner data. This needs much less processing power to determine the position of a surface than using only image processing techniques. Subsequently, the multi viewpoint panorama can be generated by projecting the images or segments of images recorded onto the determined surface.

The geo-positions of the cameras and laser scanners are accurately known by means of an onboard positioning system (e.g. a GPS receiver) and other additional position and orientation determination equipment (e.g. Inertial Navigation System – INS).

A further improvement of the invention is the ability to provide imagery that shows some of the realism of a 3D image, without the processing time necessary to compute the 3D model nor the processing time necessary to render a full 3D model. A 3D model comprises a plurality of polygons or surface. Rendering a full 3D model requires to evaluate for each of the polygons whether they could be seen when the 3D model is viewed from a particular side. If a polygon can be seen, the polygon will be projected on the imagery. The multi viewpoint panorama according to the invention is only one surface for a whole frontage.

Further embodiments of the invention have been defined in the dependent claims.

In an embodiment of the invention producing comprises:

- detecting one or more obstacles obstructing in all images of the at least one image sequences to view a part of the surface;
- projecting a view of one of the one or more obstacles to the multi-viewpoint panorama. The laser scanner samples enables us to detect for each image which obstacles are in front of the camera and before the position of the plane of the multi viewpoint panorama to be generated. These features enable us to detect which parts of the plane are not visible in any of the images and should be filled with an obstacle. This allows us to minimize the number of obstacles visible in the panorama in front of facades and consequently to exclude from the multi viewpoint panorama as much as possible obstacles not obstructing in all of the images to view a part of the surface. This enables us to provide a multi viewpoint panorama of a frontage with a good visual quality.

In a further embodiment of the invention producing further comprises:

- determining for each of the detected obstacle whether it is completely visible in any of the images;
- if a detected obstacle is completely visible in at least one image, projecting a view of said detected object from one of said at least one image to the multi-viewpoint panorama. These features allows us to reduce the number of obstacles which will be visualized partially in the panorama. This improves the attractiveness of the multi viewpoint panorama.

In an embodiment of the invention the multi viewpoint panorama is preferably generated from parts of images having an associated looking angle which is most perpendicular to the polygon. This feature enables us to generate from the images the best quality multi viewpoint panorama.

In an embodiment of the invention a roadside panorama is generated by combining multi viewpoint panoramas. A common surface is determined for a roadside panorama parallel to but a distance from a line, e.g. centerline of a road. The multi viewpoint panoramas having a position different from the common surface are projected on the common surface to represent each of the multi viewpoint panoramas as it was seen at a distance equivalent to the distance between the surface and the line. Accordingly, a panorama is generated which visualized the objects in the multi viewpoint panoramas having a position different from the common surface, now as seen from the same distance. As much as possible obstacles have been removed from the multi viewpoint panoramas to obtain the best visual quality, a roadside panorama is generated wherein many of the obstacles along the road will not be visualized.

The roadside panorama according to the invention provides the ability to provide imagery that shows some of the realism of a 3D view of a street, without the processing time necessary to render a full 3D model of the buildings along said street. Using a 3D model of said street to provide the 3D view of the street would require to determine for each building, or part of each building, along the street whether it is seen and subsequently to render each 3D model of the buildings, or parts thereof, into the 3D view. Imagery that shows some of the realism of a 3D view of a street can easily be provided with the roadside panoramas according to the invention. The roadside panorama represents the buildings along the street when projected onto a common surface. Said surface can easily be transformed into a pseudo-perspective view image by projecting sequentially the columns of pixels of the roadside panorama on the 3D view, starting with the column of pixels with the farthest position from the viewing position up to the column of pixels with nearest position from the viewing point. In this way a realistic perspective view image can be generated for the surfaces of the left and right roadside panorama, resulting in a pseudo realistic view of a street. Only two images representing two surfaces are needed instead of a multitude of polygons when using 3D models of the buildings along the street.

The present invention can be implemented using software, hardware, or a combination of software and hardware. When all or portions of the present invention are implemented in software, that software can reside on a processor readable storage medium. Examples of appropriate processor readable storage medium include a floppy disk, hard disk, CD ROM, DVD, memory IC, etc. When the system includes hardware, the hardware may include an output device (e. g. a monitor, speaker or printer), an input device (e.g. a keyboard, pointing device and/or a microphone), and a processor in communication with the output device and processor readable storage medium in communication with the processor. The processor readable storage medium stores code capable of programming the processor to perform the actions to implement the present invention. The process of the present invention can also be implemented on a server that can be accessed over telephone lines or other network or internet connection.

Short description of drawings

The present invention will be discussed in more detail below, using a number of exemplary embodiments, with reference to the attached drawings that are intended to illustrate the invention but not to limit its scope which is defined by the annexed claims and its equivalent embodiment, in which

Figure 1 shows a MMS system with a camera and a laser scanner;

Figure 2 shows a diagram of location and orientation parameters;

Figure 3 shows a block diagram of a computer arrangement with which the invention can be performed;

Figure 4 is a flow diagram of an exemplar implementation of the process for producing road information according to the invention;

Figure 5 shows a histogram based on laser scan samples;

Figure 6 shows a exemplar result of polygon detection;

Figure 7 shows a perspective view of the projection of a source image on a virtual plane;

Figure 8 show a top view of the projection of a source image on a virtual plane;

Figure 9 show a side view of the projection of a source image on a virtual plane;

Figure 10 shows a top view of two cameras on different positions recording the same plane;

Figure 11 shows the perspective view images from the situation shown in figure 10;

Figure 12 illustrates the process of composing a panorama from two images;

Figure 13 shows a top view of two cameras on different positions recording the same plane;

Figure 14 shows the perspective view images from the situation shown in figure 13;

Figure 15a-d show an application of the panorama,

Figure 16a-e illustrates a second embodiment of finding areas in source images from generating a multi viewpoint panorama,

Figure 17 shows a flowchart of an algorithm to assign the parts of the source images to be selected; and

Figure 18 shows another example of a roadside panorama.

Detailed description of exemplary embodiments

Figure 1 shows a MMS system that takes the form of a car 1. The car 1 is provided with one or more cameras 9(i), i = 1, 2, 3, … I, and one or more laser scanners 3(j), j = 1, 2, 3, … J. The looking angle or the one or more cameras 9(i) can be in any direction with respect to the driving direction of the car 1 and can thus be a front looking camera, a side looking camera or rear looking camera, etc. Preferably, the angle between the driving direction of the car 1 and the looking angle of a camera is within the range of 45 degree – 135 degree on either side. The car 1 can be driven by a driver along roads of interest. In an exemplar embodiment two side looking cameras are mounted on the car 1, wherein the distance between the two cameras is 2 meters and the looking angle of the cameras is perpendicular to the driving direction of the car 1 and parallel to the earth surface. In another exemplar embodiment two cameras have been mounted on the car 1, the cameras having a horizontal looking angle to one side of the car and a forward looking angle of about 45° and 135° respectively. Additionally, a third side looking camera having an upward looking angle of 45°, may be mounted on the car. This third camera is used to capture the upper part of buildings at the roadside.

The car 1 is provided with a plurality of wheels 2. Moreover, the car 1 is provided with a high accuracy position determination device. As shown in figure 1, the position determination device comprises the following components:

- a GPS (global positioning system) unit connected to an antenna 8 and arranged to communicate with a plurality of satellites SLi (i = 1, 2, 3, …) and to calculate a position signal from signals received from the satellites SLi. The GPS unit is connected to a microprocessor μP. Based on the signals received from the GPS unit, the microprocessor μP may determine suitable display signals to be displayed on a monitor 4 in the car 1, informing the driver where the car is located and possibly in what direction it is traveling. Instead of a GPS unit a differential GPS unit could be used. Differential Global Positioning System (DGPS) is an enhancement to Global Positioning System (GPS) that uses a network of fixed ground based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. These stations broadcast the difference between the measured satellite pseudoranges and actual (internally computed) pseudoranges, and receiver stations may correct their pseudoranges by the same amount.

- a DMI (Distance Measurement Instrument). This instrument is an odometer that measures a distance traveled by the car 1 by sensing the number of rotations of one or more of the wheels 2. The DMI is also connected to the microprocessor μP to allow the microprocessor μP to take the distance as measured by the DMI into account while calculating the display signal from the output signal from the GPS unit.
- an IMU (Inertial Measurement Unit). Such an IMU can be implemented as 3 gyro units arranged to measure rotational accelerations and translational accelerations along 3 orthogonal directions. The IMU is also connected to the microprocessor μP to allow the microprocessor μP to take the measurements by the DMI into account while calculating the display signal from the output signal from the GPS unit. The IMU could also comprise dead reckoning sensors.

It will be noted that one skilled in the art can find many combinations of Global Navigation Satellite systems and on-board inertial and dead reckoning systems to provide an accurate location and orientation of the vehicle and hence the equipment (which are mounted with know positions and orientations with references to the vehicle).

The system as shown in figure 1 is a so-called “mobile mapping system” which collects geographic data, for instance by taking pictures with one or more camera(s) 9(i) mounted on the car 1. The camera(s) are connected to the microprocessor μP. The camera(s) 9(i) in front of the car could be a stereoscopic camera. The camera(s) could be arranged to generate an image sequence wherein the images have been captured with a predefined frame rate. In an exemplary embodiment one or more of the camera(s) are still picture cameras arranged to capture a picture every predefined displacement of the car 1 or every interval of time. The predefined displacement is chosen such that a location at a predefined distance perpendicular to the driving direction is captured be at least two subsequent pictures of a side looking camera. For example a picture could be captured after each 4 meters of travel, resulting in an overlap in each image of a plane parallel to the driving direction at 5 meters distance.

The laser scanner(s) 3(j) take laser samples while the car 1 is driving along buildings at the roadside. They are also connected to the microprocessor μP and send these laser samples to the microprocessor μP.

It is a general desire to provide as accurate as possible location and orientation measurement from the 3 measurement units: GPS, IMU and DMI. These location and orientation data are measured while the camera(s) 9(i) take pictures and the laser scanner(s) 3(j) take laser samples . The pictures and laser samples are stored for later use in a suitable memory of the μP in association with corresponding location and orientation data of the car 1, collected at the same time these pictures were taken. The pictures include information as to road information, such as center of road, road surface edges and road width. As the location and orientation data associated with the laser samples and pictures is obtained from the same position determination device, an exact match can be made between the pictures and laser samples.

Figure 2 shows which position signals can be obtained from the three measurement units GPS, DMI and IMU shown in figure 1. Figure 2 shows that the microprocessor μP is arranged to calculate 6 different parameters, i.e., 3 distance parameters x, y, z relative to an origin in a predetermined coordinate system and 3 angle parameters ω_x, ω_y, and ω_z, respectively, which denote a rotation about the x-axis, y-axis and z-axis respectively. The z-direction coincides with the direction of the gravity vector. The global UTM coordinate system could be used as predetermined coordinate system.

It is a general desire to provide as accurate as possible location and orientation measurement from the 3 measurement units: GPS, IMU and DMI. These location and orientation data are measured while the camera(s) 9(i) take images and the laser scanner(s) 3(j) take laser samples. Both the images and the laser samples are stored for later use in a suitable memory of the microprocessor in association with the corresponding location and orientation data of the car 1 at the instant in time these pictures and laser samples were taken and the position and orientation of the cameras and the laser scanners relative to the car 1.

The pictures and laser samples include information as to objects at the roadside, such as building block facades. In an embodiment, the laser scanner(s) 3(j) are arranged to produce an output with minimal 50 Hz and 1deg resolution in order to produce a dense enough output for the method. A laser scanner such as MODEL LMS291-S05 produced by SICK is capable of producing such an output.

The microprocessor in the car 1 and memory 9 may be implemented as a computer arrangement. An example of such a computer arrangement is shown in figure 3.

In figure 3, an overview is given of a computer arrangement 300 comprising a processor 311 for carrying out arithmetic operations. In the embodiment shown in figure 1, the processor would be the microprocessor µP.

The processor 311 is connected to a plurality of memory components, including a hard disk 312, Read Only Memory (ROM) 313, Electrical Erasable Programmable Read Only Memory (EEPROM) 314, and Random Access Memory (RAM) 315. Not all of these memory types need necessarily be provided. Moreover, these memory components need not be located physically close to the processor 311 but may be located remote from the processor 311.

The processor 311 is also connected to means for inputting instructions, data etc. by a user, like a keyboard 316, and a mouse 317. Other input means, such as a touch screen, a track ball and/or a voice converter, known to persons skilled in the art may be provided too.

A reading unit 319 connected to the processor 311 is provided. The reading unit 319 is arranged to read data from and possibly write data on a removable data carrier or removable storage medium, like a floppy disk 320 or a CDROM 321. Other removable data carriers may be tapes, DVD, CD-R, DVD-R, memory sticks etc. as is known to persons skilled in the art.

The processor 311 may be connected to a printer 323 for printing output data on paper, as well as to a display 318, for instance, a monitor or LCD (liquid Crystal Display) screen, or any other type of display known to persons skilled in the art.

The processor 311 may be connected to a loudspeaker 329.

Furthermore, the processor 311 may be connected to a communication network 327, for instance, the Public Switched Telephone Network (PSTN), a Local Area Network (LAN), a Wide Area Network (WAN), the Internet etc by means of I/O means 325. The processor 311 may be arranged to communicate with other communication arrangements through the network 327. The I/O means 325 are further suitable to connect the position determining device (DMI, GPS, IMU), camera(s) 9(i) and laser scanner(s) 3(j) to the computer arrangement 300.

The data carrier 320, 321 may comprise a computer program product in the form of data and instructions arranged to provide the processor with the capacity to perform a method in accordance to the invention. However, such computer program product may, alternatively, be downloaded via the telecommunication network 327.

The processor 311 may be implemented as a stand alone system, or as a plurality of parallel operating processors each arranged to carry out subtasks of a larger computer program, or as one or more main processors with several sub-processors. Parts of the functionality of the invention may even be carried out by remote processors communicating with processor 311 through the telecommunication network 327.

The components contained in the computer system of Figure 3 are those typically found in general purpose computer systems, and are intended to represent a broad category of such computer components that are well known in the art.

Thus, the computer system of Figure 3 can be a personal computer, workstation, minicomputer, mainframe computer, etc. The computer can also include different bus configurations, networked platforms, multi-processor platforms, etc. Various operating systems can be used including UNIX, Solaris, Linux, Windows, Macintosh OS, and other suitable operating systems.

For post-processing the images and scans as taken by the camera(s) 9(i) and the laser scanner(s) 3(j) and position/orientation data; a similar arrangement as the one in figure 3 will be used, be it that that one will not be located in the car 1 but may conveniently be located in a building for off-line post-processing. The images and scans as taken by camera(s) 9(i) and scanner(s) 3(j) and associated position/orientation data are stored in one or more memories 312-315. That can be done via storing them first on a DVD, memory stick or the like, or transmitting them, possibly wirelessly, from the memory 9. The associated position and orientation data, which defines the track of the car 1 could be stored as raw data including time stamps. Furthermore, each image and laser scanner sample has a time stamp. The time stamps enables us to determine accurately the position and orientation of the camera(s) 9(i) and laser scanner(s) 3(j) at the instant of capturing an image and laser scanner sample, respectively. In this way the time stamps define the spatial relation between views shown in the images and laser scanner samples. The associated position and orientation data could also be stored as data which is linked by the used database architecture to the respective images and laser scanner samples.

In the present invention, multi viewpoint panoramas are produced by using both the images taken by the camera(s) 9(i) and the scans taken by the laser scanner(s) 3(j). The method uses a unique combination of techniques from both the field of image processing and laser scanning technology. The invention can be used to generate a multi viewpoint panorama varying from a frontage of a building to a whole roadside view of a street.

Figure 4 shows a flow diagram of an exemplar implementation of the process for producing roadside information according to the invention. Figure 4 shows the following actions:

A. action 42: laser point map creation

B. action 44: plane coordinates extraction of object from the laser point map

C. action 46: source image parts selection (using shadow maps)

D. action 48: panorama composition from the selected source image parts.

These actions will be explained in detail below.

A. action 42: laser point map creation

A good method for finding plane points is to use a histogram analysis. The histogram comprises a number of laser scan samples as taken by the laser scanner(s) 3(j) at a certain distance as seen in a direction perpendicular to a trajectory traveled by an MMS system and summed along a certain distance traveled by the car 1. The laser scanner(s) scan in an angular direction over, for instance, 180° in a surface perpendicular to the earth surface. E.g., the laser scanner(s) may take 180 samples each deviating by 1° from its adjacent samples. Furthermore, a slice of laser scan samples is made at least every 20 cm. With a laser scanner which rotates 75 time a second, the car should not drive faster then 54 km/h. Most of the time, the MMS system will follow a route along a line that is directed along a certain road (only when changing lanes for some reason or turning a corner the traveled path will show deviation from this).

The laser scanner(s) 3(j) are, in an embodiment 2D laser scanner(s). A 2D laser scanner 3(j) provides a triplet of data, so called a laser sample, comprising time of measurement, angle of measurement, and distance to nearest solid object that is visible at this angle from the laser scanner 3(j). By combining the car 1 position and orientation, which is captured by the position determination devices in the car, the relative position and orientation of the laser scanner with respect to the car 1 and the laser sample, a laser point map as shown in figure 5 is created. The laser point map shown in figure 5 is obtained by a laser scanner which scans in a direction perpendicular to the driving direction of the car. If more than one laser scanner is used to generate the laser point map, the laser scanners may for example have an angle of 45°, 90° and/or 135°. If using only one laser scanner, a laser scanner scanning perpendicular to the driving direction provides the best resolution in the laser point map space for finding vertical planes parallel to the driving direction.

In figure 5, there are shown two histograms:

1. distance histogram 61 - this histogram 61 shows the number of laser scan samples as a function of distance to the car 1 as summed over a certain travel distance, e.g. 2 meter, including samples close to the car 1. When every 20 cm a laser scan slice is made, the laser scan samples of 10 slices will be taken into account. There is a peak shown close to the car 1 indicating a laser “echo” close to the car 1. This peak relates to many echo’s being present close to the car 1 because of the angular sweep made by the laser scanning. Moreover, there is a second peak present at a greater distance which relates to a vertical surface of an object identified at that greater distance from the car 1.
2. distance histogram 63 showing only the second peak at a certain distance from the car 1 indicating only one object. This histogram is achieved by eliminating the higher density of laser scan samples in the direct neighbourhood of the car 1 due to the angular distribution of the laser scanning. The effect of this elimination is that one will better see objects at a certain distance away from the car 1, i.e. the façade of a building 65. The elimination has further the effect that in the histogram the influence of obstacles is reduced. Which reduces the chance that an obstacle erroneously will be recognized as a vertical plane.

The peak on histogram 63 indicates the presence of a flat solid surface parallel to the car heading. The approximate distance between the car 1 and the façade 65 can be determined by any available method. For instance, the method as explained in a copending patent application PCT/NL2006/050264, which is hereby incorporated by reference, can be used for that purpose. Alternatively, GPS (or other) data indicating the trajectory travelled by the car 1 and data showing locations of footprints of buildings can be compared and, thus, render such approximate distance data between the car 1 and the façade 65. By analysing the histogram data within a certain area about this approximate distance, the local maximal peak within this area is identified as being the base of a façade 65. All laser scan samples that are within a perpendicular distance of, for instance, 0.5 m before this local maximal peak are considered as architectural detail of the façade 65 and marked as "plane points". The laser scan samples that have a perpendicular distance larger than the maximal peek are discarded or could be marked as "plane points". All other samples, are the laser scan samples having a position between the position of the local maximum peak and the position of the car 1, are considered as "ghost points" and are marked so. It is observed that the distance of 0.5 m is only given as an example. Other distances may be used, if required.

Along the track of the car 1, a histogram analysis is performed every 2 meters. In this way the laser point map is divided in slices of 2 meters. In every slice the histogram determines whether a laser scan sample is marked "plane point" or "ghost point".

B. action 44: plane coordinates extraction of object from the laser point map

The laser samples marked as "plane points" are used to extract plane coordinates from the laser point map. The present invention operates on a surface in a 3D space, representing a frontage (typically building facade). The present invention is elucidated by examples wherein the surface is a polygon being a vertical rectangle representing a building facade. It should be noted that the method can be applied to any 'vertical' surface. Therefore the term "polygon" in the description below, should not be limited to a closed plane figure bounded by straight sides, but could in principle be any 'vertical' surface. 'Vertical' surface means any common constructed surface that can be seen by the camera(s).

The polygons are extracted from the laser scanners data marked as "plane points". Many prior art techniques are available, including methods based on the RANSAC (Random Sample Consensus) algorithm, to find planes or surfaces.

The straightforward RANSAC algorithm is used directly on the 3D points marked as “plane points”. For only vertical planes a simplified embodiment of the invention first all non-ground points are projected on some horizontal plane by discarding the height value of a 3D point. Then lines are detected using RANSAC or Hugh transform on the 2D points of said horizontal plane. These lines are used to derive the lower and upper position of the plane along the lines.

The algorithms described above require additional processing for finding plane limiting polygons. There are known prior art methods for finding the plane limiting polygons. In an example, all laser points that are below a given threshold from the plane are projected on a plane. This plane is similar to an 2D image on which clustering techniques and image segmentation algorithms can be applied to obtain the polygon representing the boundary of for example a building façade. Figure 6 shows a exemplar result of polygon detection. The laser scanner map shown is figure 6 is obtained by combining the laser scanner samples from two laser scanners. One having an angle of 45° with the driving direction of the car 1 and the other having an angle of 135° with the driving direction of the car 1. Therefore, it is possible to extract next to the polygon of the plane of the front façade 600 of a building, the two polygons of the plane of the side facades 602, 604. For each detected plane, the polygon is described by plane coordinates which are the 3D positions of the corners of the plane in the predetermined coordinate system.

It should be noted that also geo-referenced 3D positions about buildings, which could be obtained from commercial databases, could be used to retrieve the polygons of planes and to determine whether a laser scanner sample from the laser scanner map is a “plane point” or a “ghost point”.

It should be noted that when a multi viewpoint panorama is generated for a frontage of only one building the orientation of the base of the frontage may not necessarily be parallel to the driving direction.

The multi viewpoint panoramas of frontages can be used to generate a roadside multi view point panorama. A roadside panorama is a composition of a plurality of multi viewpoint panoramas of buildings. Characteristics of a roadside panorama according to the invention are:

- the panorama represents a virtual common constructed vertical surface;

- each column of pixels of the panorama represents the vertical surface at a predefined perpendicular distance from the track of the car, center line of the street or any other representation of a line along the street, and

- each pixel of the panorama represents an area of the surface, wherein the area has a fixed height.

In case a roadside panorama of a street is generated, the surface of the panorama is generally regarded to be parallel to the driving direction, centerline or any other feature of a road extending along the road. Accordingly, the surface of a roadside panorama of a curved street will follow the curvature of the street. Each point of the panorama is regarded to be seen as perpendicular to the orientation of the surface. Therefore, for a roadside panorama of a street, the distance up to the most common surface is searched for in the laser scanner map or has been given a predefined value. This distance defines the resolution of the pixels of the panorama in horizontal and vertical directions. The vertical resolution depends on the distance, whereas the horizontal resolution depends on a combination of the distance and the curvature of the line along the street. However, the perpendicular distance between the driving direction of the car and the base of the vertical surface found by the histogram analysis may comprise discontinuities. This could happen when two neighboring buildings do not have the same building line (i.e. do not line up on the same plane). To obtain a roadside panorama defined above, the multi viewpoint panorama of each building surface will be transformed to a multi viewpoint panorama as if the building surface has been seen from the distance up to the most common surface. In this way, every pixel will represent an area having equivalent height.

In the known panoramas, two objects having the same size but at different distances will be shown in the panorama with different sizes. According to an embodiment of the invention, a roadside panorama will be generated wherein two similar objects having different perpendicular distances with respect to the driving direction will have the same size in the multi viewpoint panorama. Therefore, when generating the roadside panorama, the panorama of each facade will be scaled such that each pixel of the roadside panorama will have the same resolution. Consequently, in a roadside panorama generated by the method described above, a building having a real height of 10 meters at 5 meter distance will have the same height in the roadside panorama as a building having a real height of 10 meters at 10 meter distance.

A roadside panorama with the characteristics described above, shows the facades of buildings along the street, as buildings having the same building line, whereas in reality they will not have the same building line. The important visual objects of the panorama are in the same plane. This enables us to transform without annoying visual deformation the front view panorama into a perspective view. This has the advantage that the panorama can be used in applications running on a system as shown in figure 3 or any kind of mobile device, such as a navigation device, with minimal image processing power. By means of the panorama, wherein the facades of buildings parallel to the direction of a street are scaled to have the same building line, a near-realistic view of the panorama can be presented from any viewing angle. A near-realistic view is an easy to interpretative view that could represent the reality but that does not correspond to the reality.

C. action 46: source image parts selection (using shadow maps)

A multi-viewpoint panorama obtained by the present invention is composed from a set of images from image sequence(s) obtained by camera(s) 9(i). Each image has associated position and orientation data. The method described in unpublished patent application PCT/NL2006/050252 is used to determine which source images have viewing windows which include at least a part of a surface determined in action 44. First, from at least one source image sequence produced by the cameras, the source images having a viewing window which includes at least a part of the surface for which a panorama has to be generated, are selected. This could be done as each source image has associated position and orientation of the camera capturing said source image.

In the present invention, a surface corresponds to mainly vertical planes. By knowing the position and orientation of the camera together with the viewing angle and viewing window, the projection of the viewing window on the surface can be determined. A person skilled in the art knowing the math of goniometry is able to rewrite the orthorectification method described in the unpublished application PCT/NL2006/050252, into a method for projecting a viewing window having an arbitrary viewing angle on an arbitrary surface. The projection of a polygon or surface area on a viewing window of a camera with both an arbitrary position and orientation is performed by three operations: rotation over focal point of camera, scaling and translation.

Figure 7 shows a perspective view of the projection of a source image 700, which is equivalent to the viewing window of a camera on a virtual surface 702. The virtual surface 702 corresponds to a polygon and has the coordinates (xt1, yt1, zt1), (xt2, yt2, zt2), (xt3, yt3, zt3) and (xt4, yt4, zt4). Reference 706 indicates the focal point of the camera. The focal point 706 of the camera has the coordinates (xf, yf, zf). The border of the source image 700 defines the viewing window of the camera. The crossings of a straight line through the focal point 706 of the camera through both the viewing window and the virtual surface 702 define the projection from a pixel of the virtual surface 702 on a pixel of the source image 700. Furthermore, the crossing with the virtual surface 702 of a straight line through the focal point 706 of the camera and a laser scanner sample marked as “ghost points” defines a point of the virtual plane that cannot be seen in the viewing window. In this way, a shadow 708 of an obstacle 704 can be projected on the virtual surface 702. A shadow of an obstacle is a contiguous set of pixels in front the virtual surface, e.g. a façade. As the position of the virtual surface corresponds to the position of a frontage, the shadow can be projected on the virtual surface accurately. It should be noted that balconies which extend up to 0.5 meter from the frontage are regarded to be part of the common constructed surface. Consequently, details of the perspective view of said balconies in the source image will be projected on the multi viewpoint panorama. Details of the perspective view are sides of the balconies perpendicular to the frontage, which will not be visualized in a pure front view image of a building.

The above projection method is used to selects source images viewing at least a part of the surface. After selection of a source image viewing at least a part of the surface, in the laser scanner map the laser scanner samples having a position between the position of the focal point of the camera and the position of the surface are selected. These are the laser scanner samples which are marked as “ghost point” samples. The selected laser scan samples represent obstacles that hinder the camera to record the object represented by the virtual surface 702. The selected laser scanner samples are clustered by known algorithms to form one or more solid obstacles. Then a shadow of said obstacles is generated on the virtual surface 702. This is done by extending a straight line through the focal point 706 and the solid obstacle up to the position of the virtual surface 702. The position where a line along the boundary of the obstacle hits the virtual surface 702 corresponds to a boundary point of the shadow of the obstacle.

From figure 7 it can be seen that an object 704, i.e. a tree, in front of the surface 702 is seen in the image. If the position of the object 704 with respect the virtual surface 702 and focal point 706 of the camera is known, the shadow 708 of the object 704 on the virtual surface 702 can easily be determined.

According to the invention the surface retrieved from the laser scanner map or 3D information about building façades from commercial databases, are used to create geo-positioned multi-viewpoint panoramas of said surface. The method according to the invention combines the 3D information of the camera 9(i) position and orientation, the focal length and resolution (= pixel size) of an image, the 3D information of a detected plane and 3D positions of the ghost point samples of the laser scanner map. The combination of position and orientation information of the camera and the laser scanner map enables the method to determine for each individual image:

1) whether a source image captured by the camera includes at least a part of the surface; and

2) which object is hindering the camera to visualize the image information that would be at said part of the surface.

The result of the combination enables the method to determine on which parts of the images a façade represented by the virtual plane is visible. Thus which images could be used to generate the multi viewpoint panorama. An image having a viewing window that could have captured at least a part of the virtual surface but could not capture any part of the virtual surface due to an huge obstacle in front of the camera, will be discarded. The “ghost points” between the location of the surface and the camera position are projected on the source image. This enables the method to find surfaces or areas (shadow zones) where the obstacle is visible on the source image(s) and hence the final multi-viewpoint panorama.

It should be noted that examples to elucidate the invention uses a polygon as virtual surface. Simple examples have been used to reduce the complexity of the examples. However, a person skilled in the art would immediately recognize that the invention is not limited to flat surfaces but could be used for any smooth surface, for example a vertical curved surface.

Figure 8 and 9 show a top view and side view, respectively, of projecting an obstacle 806 on a source image 800 and a virtual surface 804. The position of the obstacle 806 is obtained from the laser scanner map. Thus according to the invention the position of objects is not obtained by complex image processing algorithms which uses image segmentation and triangulation algorithms on more than one image to detect and determine positions of planes and obstacles in images, but by using the 3D information from the laser scanner map in combination with the position and orientation data of the camera. Using the laser scanner map in combination with the position and orientation data of a camera provides a simple and accurate method to determine in an image the position of obstacles which hinder the camera to visualize the area of a surface of an object behind said obstacle. Goniometry is used to determine the position of the shadow 802 of the obstacle 806 on the source image 800 as well as the shadow 808 of the obstacle 806 on the virtual surface 804 which describes the position and orientation of the frontage of an object, i.e. a building facade. A shadow 808 on the virtual surface will be called shadow zone in the following description of the invention.

A multi viewpoint panorama is composed by finding the areas of the source images which visualize in the best way the surface that has been found in the laser scanner map and projecting said areas on the multi viewpoint panorama. The areas of the source images that do not visualize obstacles or visualize an obstacle with the smallest shadow (= area) on the multi viewpoint panorama should be selected and combined to obtain the multi viewpoint panorama.

Two possible implementations will be disclosed for finding the parts of the source images to generate the multi viewpoint panorama.

First embodiment for finding the areas.

The above objective has been achieved in the first embodiment by generating a shadow map for each source image that visualizes a part of the surface. A shadow map is a binary image, wherein the size of the image corresponds to the area of the source image that visualizes the plane when projected on the plane and wherein for each pixel is indicated whether it visualizes in the source image the surface or an obstacle. Subsequently, all shadow maps are superposed on a master shadow map corresponding to the surface. In this way one master shadow map is made for the surface and thus for the multi viewpoint panorama to be generated.

In an embodiment, a master shadow map is generated wherein a shadow zone in this master shadow map indicates that at least one of the selected source images visualizes an obstacle when the area of the at least one selected source image corresponding to the shadow zone is projected on the multi viewpoint panorama. In other words, this master shadow map identifies which areas of a façade are not obstructed by any obstacle in the images. It should be noted that the size and resolution of the master shadow map is similar to the size and resolution of the multi viewpoint panorama to be produced.

The master shadow map is used to split the multi view point panorama into segments. The segments are obtained by finding the best "sawing paths" to cut the master shadow map into said segments, wherein the paths on the master shadow map are not dividing a shadow zone in two parts. The segmentation defines how the panorama has to be composed. It should be noted that a sawing path is always across an area of the master shadow map that has been obtained by superposition of the shadow maps of at least two images. Having the paths between the shadow zones ensures that the seams between the segments in the panorama are in the visual parts of a façade and not possibly in an area of an obstacle that will be projected on the façade. This enables the method to select the best image for projecting an area corresponding to a segment on the panorama. The best image could be the image having no shadow zones in the area corresponding to the segment or the image having the smallest shadow zone area. An additional criterion to determine the best position of the "sawing path" may be the looking angles of the at least two images with respect to the orientation of the plane of the panorama to be generated. As the at least two images have different positions, the looking angle with respect to the façade will differ. It has been found that the most perpendicular image will provide the best visual quality in the panorama.

Each segment can be defined as a polygon, wherein the edges of a polygon are defined by a 3D position in the predefined coordinate system. As the "sawing paths" are across pixels which visualize in all of the at least two source images the surface corresponding to the plane, this allows the method to create a smoothing zone between two segments. The smoothing reduces visual disturbances in the multi viewpoint panorama. This aspect of the invention will be elucidated later on. The width of the smoothing zone could be used as a further criterion for finding the best "sawing paths".

The width of the smoothing zone could be used to define the minimal distance between a sawing path and a shadow zone. If the nearest distance between the borderline of the two shadow zones is smaller than a predefined distance, a segment will be created with two shadow zones. Furthermore, the pixels of the source images for the smoothing zone should not represent obstacles. The pixels for the smoothing zone are a border of pixels around the shadows. Therefore the width of the smoothing zone defines the minimal distance between the borderlines of a shadow zone and the polygon defining the segment which encompasses said shadow zone. It should be noted that the distance between the borderline of a shadow zone and the polygon defining the segment could be zero if the obstacle causing the shadow zone is partially visible in an image.

A multi viewpoint panorama is generated by combining the parts of the source images associated with the segments. To obtain the best visualization of a multi viewpoint panorama, for each segment, one has to select the source image which visualizes in the most appropriate way said segment of the object for which a multi viewpoint panorama has to be generated.

Which area of a source image that has to be used to produce the corresponding segment of the panorama is determined in the following way:

1. select the source images having an area which visualize the whole area of a segment;

2. select from the source images in the previous action the source image that comprises the least number of pixels marked as shadow in the associated segment in the shadow map associated with said source image.

The first action ensures that the pixels of source images corresponding to a segment are taken from only one source image. This reduces the number of visible disturbances such as visualizing partially an obstacle. For example, a car parked in front of an area of a building corresponding to a segment that can be seen in three images, one visualizing the front end, one visualizing the back end and one visualizing the whole car, in that case the segment from the image visualizing the whole car will be taken. It should be noted, that choosing other images could result in a panorama visualizing more details of the object to be represented by the panorama that are hidden behind the car in the selected image. It has been found that a human finds an image which completely visualizes an obstacle more attractive than an image which visualized an said obstacle partially. It should further be noted that there could be an image that visualizes the whole area without a car, however with a less favorable viewing angle than the other three images. In that case this image will be chosen as it comprises the least number (zero) of pixels marked as shadow in the associated segment in the shadow map associated with said image.

Furthermore, when there are two ore images which visualize the whole area without any object (= zero pixels marked as shadow), the image that has the nearest perpendicular viewing angle will be chosen for visualizing the area in the multi viewpoint panorama.

The second action after the first action ensures that the source image is selected which visualizes the most of the object represented by the panorama. Thus for each segment the source image is selected which visualizes the smallest shadow zone area in the area corresponding to said segment.

If there isn't any image visualizing the whole area corresponding to a segment, the segment has to be sawed in sub-segments. In that case the image boundaries can be used as sawing paths. The previous steps will be repeated on the sub-segments to select the image having the most favorable area for visualizing the area in the multi viewpoint panorama. Parameters to determine the most favorable area are the number of pixels marked as shadow and the viewing angle.

In other words source images for the multi viewpoint panorama are combined in the following way:

1. When the shadow zones in the master shadow map are disjoint, the splice is performed in the part of the multi viewpoint panorama laying between shadow zones defined by the master shadow map;

2. When shadow zones of the obstacles visible in the selected source images projected on the multi viewpoint panorama are overlapping or not disjoint, the area of the multi viewpoint panorama is split into parts with the following rules:

a) the source image containing the full shadow zone is selected to put into the multi view point panorama. When there is more than one source image containing the full shadow zone, the source image visualizing the segment with the nearest looking angle to a vector perpendicular is selected. In other words, front view source images visualizing a segment are preferred above angle viewed source images;

b) when there isn't any image covering full shadow zone, the segment is taken from the most perpendicular parts of the source images visualizing the segment.

Second embodiment for finding the areas.

The second embodiment will be elucidated by the figures 16a-f. Figure 16a shows a top view of two camera positions 1600, 1602 and a surface 1604. Between the two camera positions 1600, 1602 and the surface 1604 are located a first obstacle 1606 and a second obstacle 1608. The first obstacle 1606 can be seen in the viewing window of both camera positions and the second obstacle 1608 can only be seen by the first camera position 1600. Three (shadow) zone can be derived by projecting a shadow of the obstacles on the surface 1604. Zone 1610 is obtained by projecting a shadow of the second obstacle on the surface from the first camera position 1600. Zone 1612 and zone 1614 have been obtained by projecting a shadow of the first obstacle on the surface from the second and first camera position respectively. Shadow maps will be generated for the source images captured from the first and second camera position 1600, 1602 respectively. For each part of a source image visualizing a part of the surface 1604, a shadow map will be generated. This shadow maps, which are referenced in the same coordinate system as the multi viewpoint panorama of the surface 1604 to be generated, indicate for each pixel, whether the pixel visualizes the surface 1604 or could not visualize the surface due to an obstacle.

Figure 16b shows the left shadow map 1620 corresponding to the source image captured from the first camera position 1600 and the right shadow map 1622 corresponding to the source image captured from the second camera position 1602. The left shadow map shows which areas of the surface 1604 visualized in the source image does not comprise visual information of the surface 1604. Area 1624 is a shadow corresponding to the second obstacle 1608 and area 1626 is a shadow corresponding to the first obstacle 1606. It can be seen that the first obstacle 1606 is taller then the second obstacle 1608. The right shadow map 1622 shows only one area 1628, which does not comprise visual information of the surface 1604. Area 1628 corresponds to a shadow of the first obstacle 1606.

The shadow maps are combined to generate a master shadow map. A master shadow map is a map associated with the surface for which a multi viewpoint panorama has to be generated. However, according to the second embodiment, for each pixel in the master shadow map is determined whether or not it can be visualized by at least one source image. The purpose of the master shadow map is to find the areas of the panorama that could not visualize the surface but will visualize an obstacle in front of the surface.

Figure 16c shows a master shadow map 1630 that have been obtained by combining the shadow maps 1620 and 1622. This combination can be accurately made because the position and orientation of each camera is accurately recorded. Area 1640 is an area of the surface 1604 that cannot be visualized by either the source image captured from the first camera position 1600 or the second camera position 1602. The pixels of this area 1640 are critical as they will always show an obstacle and never the surface 1604. The pixels in area 1640 obtain a corresponding value, e.g. “critical”. Area 1640 will show in the multi viewpoint panorama of the surface 1604 a part of the first obstacle 1606 or a part of the second obstacle 1608. Each of the other pixels will obtain a value indicating that a value of the associated pixel of the multi viewpoint panorama can be obtained from at least one source image to visualize the surface. In figure 16c, the areas 1634, 1636 and 1638 indicate the areas corresponding to the areas 1624, 1626 and 1628 in the shadow maps of the respective source images. Said areas 1634, 1636 and 1638 obtain a value indicating that a value of the associated pixel of the multi viewpoint panorama can be obtained from at least one source image to visualize the surface.

The master shadow map 1630 is subsequently used to generate for each source image a usage map. A usage map has a size equivalent to the shadow map of said source image. The usage map indicates for each pixel:

1) whether the value of the corresponding pixel(s) in the source image **should be used** to generate the multi viewpoint panorama,

2) whether the value of the corresponding pixel(s) in the source image **should not be used** to generate the multi viewpoint panorama, and

3) whether the value of the corresponding pixels(s) in the source image **could be used** to generate the multi viewpoint panorama.

This map can be generated by verifying for each shadow zone in the shadow map of a source image whether the corresponding area in the master shadow map comprises at least one pixel indicating that the pixel can not visualize by any of the source image the surface 1604 in the multi viewpoint panorama. If so, the area corresponding to the whole shadow zone will be marked “should be used”. If not, the area corresponding to the whole shadow will be marked “should not be used”. The remaining pixels will be marked “could be used”. Figure 16d shows the left usage map 1650 that has been obtained by combining the information in the shadow map 1620 and the master shadow map 1630. Area 1652 corresponds to the shadow of the second obstacle 1608. This area 1652 has obtained the value “should be used” as the area 1624 in the shadow map 1620 has one or more corresponding pixels in the master shadow map marked “critical”. This means that if one pixel of the area 1652 has to be used to generate the multi viewpoint panorama, all the other pixels of said area have to be used. Area 1654 corresponds to the shadow of the first obstacle 1606. Said area 1654 has obtained the value “should not be used” as the area 1626 in the corresponding shadow map 1620 does not have any pixel in the corresponding area 1636 in the master shadow map marked “critical”, this means that the first obstacle 1606 can be removed from the multi viewpoint panorama by choosing the corresponding area in the source image captured by the second camera 1602. Therefore, the area in the source image corresponding to area 1654 should not be used to generate the multi viewpoint panorama of surface 1604. The right usage map 1656 of figure 16d has been obtained by combining the information in the shadow map 1622 and the master shadow map 1630. Area 1658 corresponds to the shadow of the second obstacle 1606. This area 1658 has obtained the value “should be used” as the area 1628 in the shadow map 1622 has one or more corresponding pixels in the master shadow map marked “critical”. This means that if one pixel of the area 1658 has to be used to generate the multi viewpoint panorama, all the other pixels of said area have to be used.

The maps 1650 and 1656 are used to select which parts of the source images have to be used to generate the multi viewpoint panorama. One embodiment of an algorithm to assign the parts of the source images to be selected will be given. It should be clear to the skilled person that may other possible algorithms can be used. A flow chart of the algorithm is shown in figure 17. The algorithm starts with retrieving an empty selection map indicating for each pixel of the multi viewpoint panorama which source image should be used to generate the multi viewpoint panorama of the surface 1604 and the usage maps 1650, 1656 associated with each source image.

Subsequently a pixel of the selection map is selected 1704 to which no source image has been assigned. In action 1706, a source image is searched which has in its associated usage map a corresponding pixel marked as “should be used” or “could be used”. Preferably, if the corresponding pixel in all usage maps is marked as “could be used”, the source image having the most perpendicular viewing angle with respect to the pixel is selected. Furthermore, to optimize the visibility of the surface 1604 in the panorama, in the case the corresponding pixel in one of the usage maps is marked “must be used”, by means of the master shadow map, preferably, the source image having the smallest area in the usage map marked “must be used” which covers the area marked “critical” in the master shadow map is selected.

After selecting the source image, in action 1708 the usage map of the selected image is used to determine which area of the source around the selected pixel should be used to generated the panorama. This can be done by a growing algorithm. For example, by selecting all neighboring pixels in the usage map marked “should be used” and could be used, and wherein no source image has been assigned to the corresponding pixel in the selection map.

Next action 1710 determines whether to all pixels a source image has been assigned. If not, again action 1704 is performed by selecting a pixel to which no source image has been assigned and the subsequent actions will be repeated until to each pixel a source image will be assigned.

Figure 16e shows two images identifying which parts of the source images are selected for generating a multi viewpoint panorama for surface 1604. The combination of the parts is shown in figure 16f, which corresponds to the selection map 1670 of the multi viewpoint panorama for surface 1604. The left image 1660 of figure 16e corresponds to the source image captured by the first camera 1600 and the right image 1662 corresponds to the source image captured by the second camera 1602. The pixels in the left segment 1672 of the selection map 1670 are assigned to the corresponding area in the source image captured from the first camera position 1600, this area corresponds to area 1664 in the left image 1660 of figure 16e. The pixels in the right segment 1674 of the selection map 1670 are assigned to the corresponding area in the source image captured from the second camera position 1602. This area corresponds to area 1666 in the right image 1662 of figure 16e.

When applying the algorithm described above, a pixel was selected at the left part of the selection map, e.g. upper left pixel. Said pixel is only present in one source image. In action 1708, the neighboring area could grow till it was bounded by the border of the selection map and the pixels marked “not to be used”. In this way area 1664 is selected and in the selection map 1670, to the pixels of segment 1672, the first source image is assigned. Subsequently, a new pixel to which no source image has been assigned, is selected. This pixel is positioned in area 1666. Subsequently, the neighboring area of said pixel is selected. The borders of the area 1666 are defined by the source image borders and the already assigned pixels in the selection map 1670 to other source images, i.e. assigned to the image captured by the first camera.

The selection of pixels from the source images corresponding to the segments 1672 and 1674 would result in a multi viewpoint panorama wherein the first obstacle 1606 is not visible and the second obstacle is fully visible.

In the right image of figure 16e, area 1668 identifies an area which corresponding pixels could be used to generated the multi viewpoint panorama of surface 1604. This area could be obtained by extending action 1708 with the criterion that the growing process stops when the width of an overlapping border with other source images exceeds a predefined threshold value, e.g. 7 pixels, or at pixels marked as “should use” or “should not use” in the usage map. Area 1668 is such an overlapping border. This is illustrated in figure 16e by area 1676. This area can be used as smoothing zone. This enables the method to mask irregularities between two neighboring source images, e.g. difference in color between images. In this way the color can change smoothly from a background color of the first image to a background color of the second color. This reduces the number of abrupt color changes in area that normally should have the same color.

The two embodiments for selecting source image parts describe above generate a map for the multi viewpoint panorama wherein each pixel is assigned to a source image. This means that all information visible in the multi viewpoint panorama will be obtained by projecting corresponding source image parts on the multi viewpoint panorama. Both embodiment try to eliminate as much as possible obstacles, by choosing the parts of the source images which visualize the surface instead of the obstacle. Some parts of the surface are not visualized in any source image and thus an obstacle or part of an obstacle will be visualized if only a projection of pixels of source image parts on the panorama is applied. However, the two embodiments can be adapted to derive first a feature of the areas of the surface which cannot be seen from any of the source images. These areas correspond to the shadows in the master shadow map of the second embodiment. Some features that could be derived are height, width, shape, size. If the feature of an area matches a predefined criterion, the pixels in the multi viewpoint panorama corresponding to said area could be derived from the pixels in the multi viewpoint panorama surrounding the area. For example, if the width of the area does not exceed a predetermined number of pixels in the multi viewpoint panorama, e.g. the shadow of a lamppost, the pixel values can be obtained by assigning the average value of neighboring pixels or interpolation. It should be clear that other threshold functions may be applied.

Furthermore, an algorithm could be applied which decides whether the resulting obstacle is significant enough to be reproduced with some fidelity. For example, a tree blocking the façade is shown in two images, in one image only a small part is seen at the border of the image and in the other image the whole tree is seen. The algorithm could be arranged to determine whether including the small part in the panorama would not look stupid. If so, the small part is shown, resulting in a panorama visualizing the greatest part of the façade and a small visual irregularity due to the tree. If not, the whole tree will be included, resulting in a panorama which discloses a smaller part of the façade, but no visual irregularity with respect to the tree. In these ways, the number of visible obstacles and corresponding size in the multi viewpoint panorama can be further reduced. This enables the method to provide a panorama with the best visual effect. The functions can be performed on the respective shadow maps.

D. action 48: panorama composition from the selected source image parts.

After generating a segmented map corresponding to the multi viewpoint panorama and selecting for each segment the source image that should be used to project the area corresponding to said segment in the source image, the areas in the source images associated with the segments are projected on the panorama. This process is comparable to the orthorectification method described in unpublished patent application PCT/NL2006/050252, which can be described as performing three operations on the areas of the source images, namely rotation over focal point of camera, scaling and translation, all commonly known algorithms in image processing. All the segments form together a mosaic which is a multi viewpoint panorama as images are used having different positions (= viewpoints).

Visual irregularities at the crossings from one segment to another segment can be reduced or eliminate by defining a smoothing zone along the boundary of two segments.

In an embodiment, the values of the pixels of the smoothing zone are obtained by averaging the values of the corresponding pixels in the first and second source image. In another embodiment the pixel value is obtained by the formula:

$$value_{pan} = \alpha \times value_{image1} + (1-\alpha) \times value_{image2}$$

wherein, $value_{pan}$, $value_{image1}$ and $value_{image2}$ are the pixel values in the multi viewpoint panorama, the first image and second image respectively and α is a value in the range 0 to 1, wherein $\alpha = 1$ where the smoothing zone touches the first image and $\alpha = 0$ where the smoothing zone touches the second image. α could change linearly from one side of the smoothing zone to the other side. In that case $value_{pan}$ is the average of the values of the first and second image in the middle of the smoothing zone, which is normally the place of splicing. It should be noted that parameter α may have any other suitable course when varying from 0 to 1.

In the technical field of image processing many other algorithms are known to obtain a smooth crossing from one segment to another segment.

The method described above will be elucidated by some simple examples.

Figure 10 shows a top view of two cameras 1000, 1002 on different positions A, B and recording the same plane 1004. The two cameras 1000, 1002 are mounted on a moving vehicle (not shown) and the vehicle is moved from position A to position B. Arrow 1014 indicates the driving direction. In the given example, the sequences of source images include only two source images that visualize plane 1004. One source image is obtained from the first camera 1000, at the instant the vehicle is at position A. The other source image is obtained from the second camera 1002, at the instant the vehicle is at position B. Figure 11 shows the perspective view images from the situation shown in figure 10. The left and right perspective view images correspond to the source images captured by the first 1000 and second camera 1002, respectively. Both cameras have a different looking angle with respect to the driving direction of the vehicle. Figure 10 shows an obstacle 1006, for example a column, positioned between the position A and B and the plane 1004. Thus a part 1008 of the plane 1004 is not visible in the source image captured by the first camera 1000 and a part 1010 of the plane 1004 is not visible in the source image captured by the source image captured by the second camera 1002.

The shadow map associated with the source image captured with camera 1000 has a shadow at the right half and the shadow map associated with the source image captured with camera 1000 has a shadow at the left half. Figure 10 shows a top view of the master shadow map of the plane 1004. The shadow map comprises two disjoint shadows 1008 and 1010. According to the invention the place 1012 of splicing the master shadow map is between the two shadows 1008 and 1010. In figure 11, the polygons 1102 and 1104 represent the two segments in which the plane 1004 is divided.

As described above, the method according the invention analyses for each segment the corresponding area in the shadow map of each source image. The source image visualizing the segment with the smallest shadow area will be selected. In the given example the source image comprising no shadows in the corresponding segment will be selected to represent said segment. Thus, the left part of the plane 1004, indicated by polygon 1102 in figure 11 will be obtained from the image captured by the first camera 1000 and the right part of plane 1004, indicated by polygon 1104 in figure 11 will be obtained from the image captured by the first camera 1002.

Figure 12 illustrates the process of composing a panorama for plane 1004 in figure 10 from the two images shown in figure 11 after selection for each segment the corresponding source image to visualize the corresponding segment. In an embodiment the segments defined by polygons 1102 and 1104 are projected on the multi viewpoint panorama for plane 1004.

The two segments could not be perfectly matched at the place of splicing 1202. Reasons for this could be the difference in resolution, colors, and other visual parameters of the two source images at the place of splicing 1202. A user could notice said irregularities in the panorama when the pixels values of the two segments at both sides of the place of spicing 1202 are directly derived from only one of the respective images. To reduce the visibility of said defects, a smoothing zone 1204 around the place of splicing 1202 can be defined.

Figures 13 and 14 show another simple example similar to the example give above for elucidating the invention. In this example another obstacle obstructs to visualize plane 1304. Figure 13 shows a top view of two cameras 1300, 1302 on different positions C, D and recording the same plane 1304. The two cameras 1300, 1302 are mounted on a moving vehicle (not shown) and the vehicle is moved from position C to position D. Arrow 1314 indicates the driving direction. In the given example, the sequences of source images include only two source images that visualize plane 1304. One source image is obtained from the first camera 1300, at the instant the vehicle is at position C. The other source image is obtained from the second camera 1302, at the instant the vehicle is at position D. Figure 14 shows the perspective view images from the situation shown in figure 13. The left and right perspective view images shown in figure 14 correspond to the source images captured by the first 1300 and second camera 1302, respectively. Both cameras have a different looking angle with respect to the driving direction of the vehicle. Figure 13 shows an obstacle 1306, for example a column, positioned between the position C and D and the plane 1004. Thus a part 1308 of the plane 1304 is not visible in the source image captured by the first camera 1300 and a part 1310 of the plane 1304 is not visible in the source image captured by the source image captured by the second camera 1302.

Figure 13 shows a top view of the master shadow map associated with the plane 1304. The master shadow map shows that shadows 1008 and 1010 have an overlapping area. As there are only two images visualizing plane 1304, the area of the plane associated with the shadow corresponding to the overlap cannot be seen in any of the images. Thus, the area corresponding to the overlap in the panorama of the plane 1304 will visualize the corresponding part of the obstacle 1306. Now, the master shadow map could be divided in three parts, wherein one part comprises the shadow. The borderline of the polygon defining the segment comprising the shadow is preferably spaced at a minimum distance from the borderline of the shadow. This allows us to define a smoothing zone. References 1312 and 1316 indicate the left and right borderline of the segment. As both source images visualize fully the segment, what can easily be seen in figure 14, the segment will be taken from the source image having the most perpendicular looking angle with respect to the plane. In the given example the segment will be taken from the source image taken by the second camera 1302. As the segment comprising the obstacle and the most right part of the plane will be taken from the same source image to project said segments on the panorama, the borderline with reference 1316 can be removed and no smoothing zone has to be defined there. Thus finally two segments remain to compose the panorama of plane 1304. In figure 14, the polygons 1302 and 1304 represent the two segments of the source images which are used to compose the plane 1304. Reference 1312 indicate the borderline where a smoothing zone could be defined.

The method described above is performed automatically. It might happen that the quality of the multi viewpoint panorama is such that the image processing tools and object recognition tools performing the invention need some correction. For example the polygon found in the laser scanner map corresponds to two adjacent buildings whereas for each building façade a panorama has to be generated. In that case the method includes some verification and manual adaptation actions to enable the possibility to confirm or adapt intermediate results. These actions could also be suitable for accepting intermediate results or the final result of the road information generation. Furthermore, the superposition of the polygons representing building surfaces and/or the shadow map on one or more subsequent source images could be used to request a human to perform a verification.

The multi viewpoint panoramas produced by the invention are stored in a database together with associated position and orientation data in a suitable coordinate system. The panoramas could be used to map out pseudo-realistic, easy to interpret and produce views of cities around the world in applications as Google Earth, Google Street View and Microsoft's Virtual Earth or could be conveniently stored or served up on navigation devices.

As described above the multi viewpoint panoramas are used to generated roadside panoramas.

Figure 15a – 15d show an application of roadside panoramas produced by the invention. The application enhances the visual output of current navigation systems and navigation applications on the Internet. A device performing the application does not need dedicated image processing hardware to produce the output. Figure 15a shows a pseudo perspective view of a street that could be produced easily without using complex 3D models of the buildings at the roadside. The pseudo perspective view has been obtained by processing the left and right roadside panorama of said street and a map generated likeness of the road surface (earth surface) between the two multi viewpoint panoramas. The map and two images could have been obtained by processing the images sequences and position/heading data that have been recorded during a mobile mapping session, or could have used the images for the virtual planes and combined it with data derived from a digital map database. Figure 15b shows the roadside panorama of the left side of the street and figure 15c shows the roadside panorama of the right side of the street. Figure 15d shows a segment expanded from a map database or could also be from orthorectified image of the street also collected from the mobile mapping vehicle. It can be seen that by means of a very limited number of planes a pseudo-realistic view of a street can be generated. References 1502 and 1506 indicate the parts of the image that has been obtained by making a pseudo perspective view of the panoramas of figure 15b and 15c respectively. The parts 1502 and 1506 can easily be generated by transforming the panorama of figure 15b and 15c into a perspective view image by projecting sequentially the columns of pixels of the roadside panorama on the pseudo-realistic view, starting with the column of pixels with the farthest position from the viewing position up to the column of pixels with nearest position from the viewing point. Reference 1504 indicates the part of the image that has been obtained by making an expansion of the map database or a perspective view of the orthorectified image of the road surface.

It should be noted that in the pseudo perspective view image, all buildings at a side of the road have the same building line and hence it cannot be a complete perspective view. In reality, each building could have its own building line. In panoramas captured by a slit-scan camera, the buildings will then have different sizes. Using this type of panorama in the present application would result in a strange looking perspective view image. Different perpendicular distances between the buildings and the road will be interpreted as different height and size of the building in the perspective view image. The invention enables the production of a reasonably realistic view image in such a case at a small fraction of the processing power needed for a more complete 3D representation. According to the method according to the invention a roadside panorama for a street is generated in two steps. Firstly, for the building along the street a one or more multi viewpoint panorama will be made. Secondly, a roadside panorama is generated by projecting the one or more multi viewpoint panorama on one common smooth surface. In an embodiment the common smooth surface is parallel to a line along the road, e.g. track line of car, centerline, borderline(s). “Smooth” means that the distance between the surface and line along the road may vary, but not abruptly.

In the first action, a multi viewpoint panorama is generated for each smooth surface along the roadside. A smooth surface can be formed by one or more neighboring building facades having the same building line. Furthermore, in this action as much as possible obstacles in front of the surface will be removed. The removal of obstacles can only be done accurately when the determined position of a surface corresponds to the real position of the façade of the building. The orientation of the surface along the road may vary. Furthermore, the perpendicular distance between the direction of the road and the surface of two neighboring multi viewpoint panoramas along the street may vary.

In the second action, from the generated multi viewpoint panoramas in the first action, a roadside panorama is generated. The multi viewpoint panorama is assumed to be a smooth surface along the road, wherein each pixels is regarded to represent the surface as seen from a defined distance perpendicular to said surface. In a roadside panorama according to the invention the vertical resolution of each pixel of the roadside panorama is similar. For example, a pixel represents a rectangle having a height of 5 cm. The roadside panorama used in the application is a virtual surface, wherein each multi viewpoint panorama of buildings along the roadside is scaled such that it has a similar vertical resolution at the virtual surface. Accordingly, a street with houses having equivalent frontages but differing building line will be visualized in the panorama as houses having the same building line and similar frontages.

To the roadside panorama as described above, depth information can be associated along the horizontal axis of the panorama. This enables applications running on a system having some powerful image processing hardware, to generate a 3D representation from the panorama according to the real positions of the buildings.

In current digital map databases, streets and roads are stored as road segments. The visual output of present applications using a digital map can be improved by associating in the database with each segment, a left and right roadside panorama and optionally an orthorectified image of the road surface of said street. In the digital map the position of the multi viewpoint panorama can be defined with absolute coordinated or coordinates relative to a predefined coordinate of the segment. This enables the system to determine accurately the position of a pseudo perspective view of a panorama in the output with respect to the street.

A street having crossing or junctions, will be represented by several segments. The crossing or junction will be a start or end point of a segment. When for each segment the database comprises associated left and right roadside panorama, a perspective view as shown in figure 15a can be generated easily by making a perspective view of the left and right roadside panoramas associated with the segments of the street visible and at reasonable distance. Figure 15a is a perspective view image generated for the situation that a car has a driving direction parallel to the direction of the street. Arrow 1508 indicates the orientation and position of the car on the road. As a panorama is generated for the most common plane, a panorama will start with the most left building and end with the most right building of the roadside corresponding to a road segment. Consequently, no panorama is present for the space between buildings at a crossing. In one embodiment, these parts of the perspective view image will not be filed with information. In another embodiment, these parts of the perspective view image will be filed with the corresponding part of the panoramas associated with the segments coupled to a crossing or junction and the expanded map data or orthorectified surface data. In this way, two sides of a building at the corner of a crossing will be shown in the perspective view image.

In a navigation system without dedicated image processing hardware, while driving a car, the display can still be frequently refreshed, e.g. every one second in dependence of the traveled distance. In that case, every second a perspective view will be generated and outputted based upon the actual GPS position and orientation of the navigation device.

Furthermore, a multi viewpoint panorama according to the invention is suitable to be used in an application for easily providing pseudo-realistic views of the surrounding of a street, address or any other point of interest. For example, the output present route planning systems can easily enhance by adding geo referenced roadside panorama according to the invention, wherein the facades of the buildings have been scaled to make the resolution of the pixels of the buildings equal. Such a panorama corresponds to a panorama of a street wherein all buildings along the street have the same building line. A user searches for a location. Then the corresponding map is presented in a window on the screen. Subsequently, in another window on the screen (or temporarily on the same window) an image is presented according to the roadside perpendicular to the orientation of the road corresponding to said position (like that of figures 15b or 15c. In another implementation, the direction of the map on the screen could be used to define in which orientation a perspective view of the panorama should be given. All pixels of the roadside panorama are regarded to represent a frontage at the position of the surface of the roadside panorama. The roadside panorama only comprises visual information that is assumed to be on the surface. Therefore, a pseudo-realistic perspective view can easily be made for any arbitrary viewing angle of the roadside panorama. By a rotation function of the system, the map can be rotated on the screen. Simultaneously, the corresponding perspective pseudo-realistic image can be generated corresponding to the rotation made. For example, when the direction of the street is from the left to the right side of the screen representing corresponding part of the digital map, only a part of the panorama as shown in figure 15b will be displayed. The part can be displayed without transforming the image as the display is assumed to represent a roadside view, which is perpendicular to the direction of the street. Furthermore, the part shown corresponds to a predetermined region of the panorama left and right from the location selected by the user. When the direction of the street is from the bottom to the top of the screen, a perspective view like figure 15a will be produced by combining the left and right roadside panorama and optionally the orthorectified image of the road surface.

The system could also comprise a flip function, to rotate the map by one instruction over 180° and to view the other side of the street.

A panning function of the system could be available for walking along the direction of the street on the map and to display simultaneously the corresponding visualization of the street in dependence of the orientation of the map on the screen. Every time a pseudo-realistic image will be presented as the images used, left and right roadside panorama and orthorectified road surface image (if needed) represent rectified images. A rectified image is an image wherein each pixel represents a pure front view of the buildings facades and top view of the road surface.

Figure 15b and 15c show roadside panoramas of a street wherein all houses have the same ground level. However, it is obvious to the person skilled in the art that the method described above normally will generate a road side panorama wherein houses with different ground levels will be shown in the roadside panorama as different heights. Figure 18 shows such a roadside panorama. In the roadside panorama, only the pixels corresponding to the surfaces representing the multi viewpoint panoramas along the road should be shown on a display. Therefore, the pixels in the areas 1802 and 1804 should not be taken into account when reproducing the roadside panorama on a display. Preferably, said areas 1802 and 1804 will be given a value, pattern or texture that enables to detect where borderline of area of the object along the roadside is. For example, the pixels in said areas 1802 and 1804 will obtain a value which normally is not present in images, or in each column of pixels, the value of the pixels starts with a first predefined value and is ended with a pixel having a second predefined value, wherein the first predefined value differs from the second predefined value. It will be noted that buildings on a hill could have frontage wherein the ground level has a slope. This will then also be seen in the multi viewpoint panorama of the frontage and the road side panorama comprising said multi viewpoint panorama.

There are applications which visualize height information of a road when producing on a screen a perspective view image of a digital map. A roadside panorama as shown in figure 18 is very suitable for use in those applications to provide a pseudo-realistic perspective view of a street. The height of the road surface will match in most occasions to the ground level of the frontage. The multi viewpoint panorama of a frontage could have been projected on the surface associated with the roadside panorama. In that case the height of the road surface could not match, with the height of the ground level of the frontage. The application could be provided with an algorithm which detects a difference between the heights of the road surface and the ground level of the frontage in the multi viewpoint panorama. Therefore, the application is arranged to determine in each column of pixels the vertical position of the lowest position of a pixel corresponding to objects represented by the roadside panorama by detecting the position of the top pixel of area 1802. As each pixel represents an area with a predetermined height, the difference in height between road surface and ground level can be determined. This difference along the street is subsequently used to correct the height of the frontage in the panorama and to generate a pseudo perspective view image of the road surface with road sides, wherein the height of the road surface matches the height of the ground level of the frontage.

There are applications which use maps which do not comprise height of the roads. Therefore they are only suitable for producing a perspective view of a horizontal map. Combination of the roadside panorama of figure 18 would result in a perspective view image, wherein the ground level of the buildings is varying along the road. This inconsistency may not look realistic. Two embodiments will be given in which these applications could provide pseudo realistic perspective view image.

In the first embodiment, the application will derive the height information from the roadside panorama and use the height information to enhance the perspective view of the horizontal map. Therefore, the application is arranged to determine in each column of pixels the vertical position of the lowest position of a pixel corresponding to objects represented by the roadside panorama by detecting the position of the top pixel of area 1802. As each pixel represents an area with a predetermined height, the difference in height along the street can be determined. This difference along the street is subsequently used to generate a pseudo perspective view image of the road surface which visualizes the corresponding difference in heights along the street. In this way, the roadside panorama and road surface can be combined wherein in the pseudo-realistic perspective view image the road surface and the surface of roadside view will be contiguous. It is obvious for one skilled in the art, that if a road surface with varying height has to be generated according to the frontage ground levels shown in figure 18, a road surface should be generated that increases/decreases gradually. Preferably, a smoothing function is applied to the ground levels along the street derived from the roadside panorama. The result of this is a smoothly changing height of the road surface, which is a much more realistic view of a road surface.

In the second embodiment, in contrary to the first embodiment, the application will remove the area 1802 from the roadside panorama and use the thus obtained image to be combined with the horizontal map. Removal of the area 1802 will result in an image similar to a road side panorama is shown in figure 15c. By removing the height information from the roadside panorama, a pseudo-realistic perspective view image is generated, representing a horizontal road surface with along the road buildings all having the same ground level. In the event, the ground level of a façade in the roadside panorama has a slope, the slope could be seen in the pseudo-realistic perspective view image by distortion of the visual rectangularity of doors and windows.

The foregoing detailed description of the invention has been presented for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed, and obviously many modifications and variations are possible in light of the above teaching. For example, instead of using the source images of two or more cameras, the image sequence of only one camera could be used to generate a panorama of a building surface. In that case two subsequent images should have enough overlap, for instance >60%, for a façade at a predefined distance perpendicular to the track of the moving vehicle.

The described embodiments were chosen in order to best explain the principles of the invention and its practical application to thereby enable others skilled in the art to best utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the claims appended hereto.

CLAIMS

1. Method of producing a multi-viewpoint panorama of a roadside comprising:
- acquiring a set of laser scan samples obtained by at least one terrestrial based laser scanner mounted on a moving vehicle, wherein each sample is associated with location data and orientation data;
- acquiring at least one image sequence, wherein each image sequence is obtained by means of a terrestrial based camera mounted on the moving vehicle, wherein each image of the at least one image sequences is associated with location and orientation data;
- extracting a surface from the set of laser scan samples and determining the location of said surface in dependence of the location data associated with the laser scan samples;
- producing a multi-viewpoint panorama for said surface from the at least one image sequence in dependence of the location of the surface and the location and orientation data associated with each of the images.

2. Method according to claim 1, wherein producing comprises:
- detecting an obstacle obstructing in a first image of the at least one image sequences to view to a part of the surface;
- selecting an area of a second image which visualizes said part of the surface; and
- using said area of the second image to produce said part of the multi viewpoint panorama.

3. Method according to claim 1, wherein producing comprises:
- detecting one or more obstacles obstructing in all images of the at least one image sequences to view a part of the surface;
- projecting a view of one of the one or more obstacles to the multi-viewpoint panorama.

4. Method according to claim 3, wherein producing further comprises:
- determining for each of the detected obstacles whether it is completely visible in any of the images;

- if a detected obstacle is completely visible in at least one image, projecting a view of said detected object from one of said at least one image to the multi-viewpoint panorama.

5. Method according to any one of the claims 1 - 4, wherein preferably the panorama is generated from parts of images having an associated looking angle which is most perpendicular to the surface.

6. Method according to claim 1, wherein producing comprises:
- generating a master shadow map for the surface;
- producing the multi-viewpoint panorama in dependence of the master shadow map.

7. Method according to claim 6, wherein generating a master shadow map comprises:
- selecting images having a viewing window which includes at least a part of the surface;
- generating a shadow map for each selected image by projecting a shadow of an obstacle in front of the surface which is visualized in the corresponding selected image; and
- combining the shadow maps of the selected images to obtain the master shadow map.

8. Method according to claim 6 or 7, wherein producing further comprises:
- splitting the master shadow map into segments;
- determine for each segment the corresponding image having no obstacle in its associated viewing window; and
- using said corresponding image to project the area associated to said segment on the multi-viewpoint panorama.

9. Method according to claim 8, wherein producing further comprises:
- if no corresponding image for a segment has been found, using an image having the whole obstacle in its associated viewing window.

10. Method according to claim 8 or 9, wherein producing further comprises:

- if no corresponding image for a segment has been found, using the image having an associated looking angle which is most perpendicular to the surface

11. Method according to claim 1, 2 or 3, wherein the surface is extracted by performing a histogram analysis on the set of laser scan samples.

12. Method of producing a roadside panorama comprising:
- retrieving multiple multi viewpoint panoramas that could have been generated by any one of the claims 1 – 10 and associated position information;
- determining the position of a virtual surface for the roadside panorama; and
- projecting the multiple multi viewpoint panoramas on the virtual surface.

13. An apparatus for performing the method according to any one of the claims 1 – 11, the apparatus comprising:
- an input device;
- a processor readable storage medium; and
- a processor in communication with said input device and said processor readable storage medium;
- an output device to enable the connection with a display unit;
said processor readable storage medium storing code to program said processor to perform a method comprising the actions of:
- acquiring a set of laser scan samples obtained by at least one terrestrial based laser scanner mounted on a moving vehicle, wherein each sample is associated with location data and orientation data;
- acquiring at least one image sequence, wherein each image sequence is obtained by means of a terrestrial based camera mounted on the moving vehicle, wherein each image of the at least one image sequences is associated with location and orientation data;
- extracting a surface from the set of laser scan samples and determining the location of said surface in dependence of the location data associated with the laser scan samples;
- producing a multi-viewpoint panorama for said surface from the at least one image sequence in dependence of the location of the surface and the location and orientation data associated with each of the images.

14. A computer program product comprising instructions, which when loaded on a computer arrangement, allow said computer arrangement to perform any one of the methods according to claims 1 – 11.

15. A processor readable medium carrying a computer program product, when loaded on a computer arrangement, allow said computer arrangement to perform any one of the methods according to claims 1 – 11.

16. A processor readable medium carrying a multi viewpoint panorama that has been obtained by performing any one of the methods according to claims 1 – 11.

17. A computer-implemented system that provides simultaneously on a screen a map and a selected location in a street and a pseudo-realistic view from the location, comprising

a map comprising the selected location;

at least one roadside panorama according to claim 11;

a map generating component for displaying with a variable orientation on a screen a display map including the selected location in a street; and

a view generating component for generating a pseudo-realistic view for the selected location from said at least one roadside panorama in dependence of the variable orientation.

18. A computer-implemented system according to claim 17, wherein in the map and the pseudo-realistic view are combined into one pseudo perspective view.

*****

Fig 1

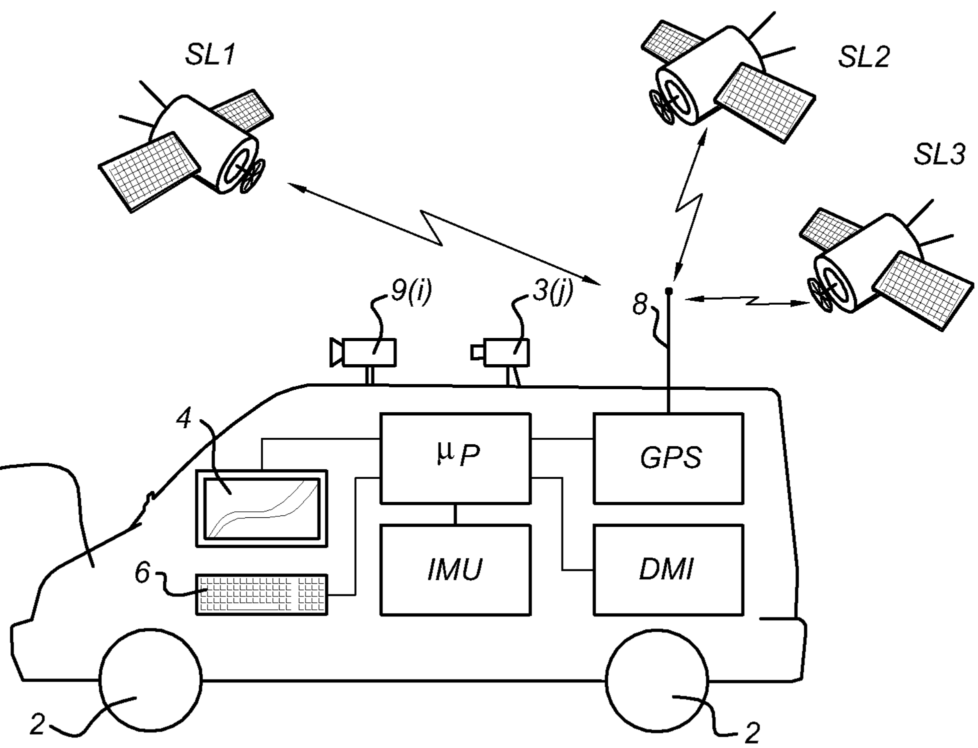
SL1
SL2
SL3
9(i)
3(j)
8
4
1
μP
GPS
IMU
DMI
6
2
2

Fig 2

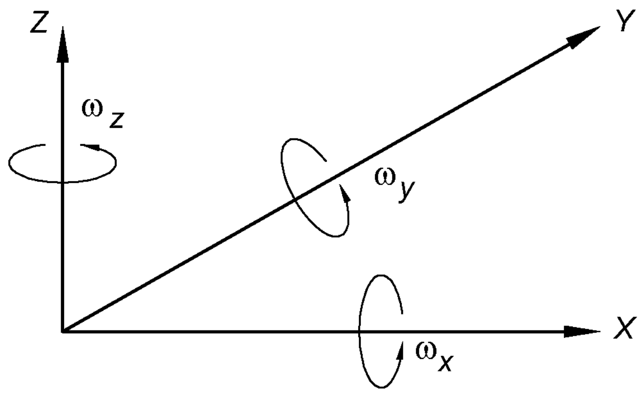
Z
Y
X
ω_z
ω_y
ω_x

Fig 3

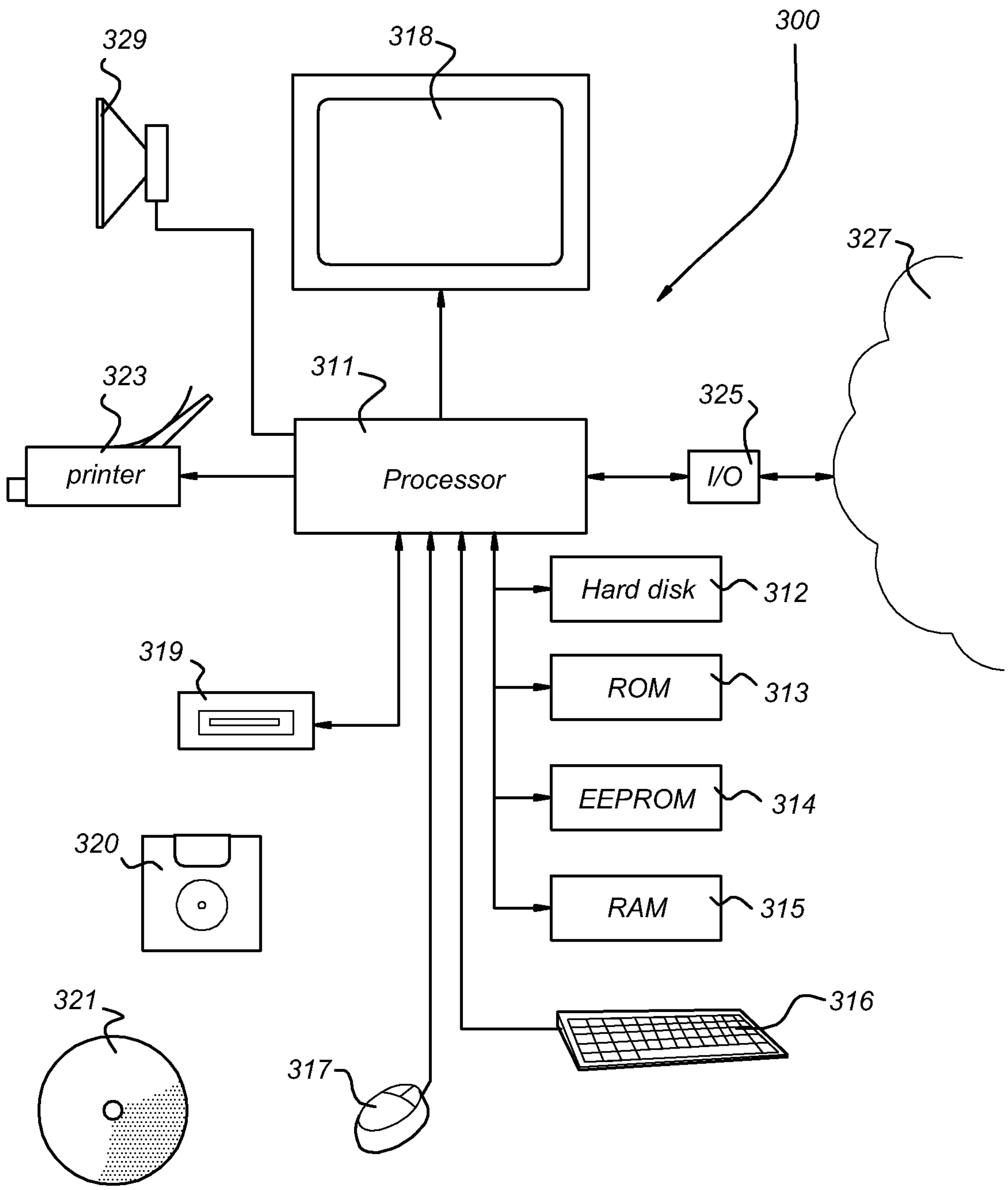
300
329
318
327
323
311
325
printer
Processor
I/O
Hard disk
312
319
ROM
313
320
EEPROM
314
RAM
315
321
316
317

Fig 4

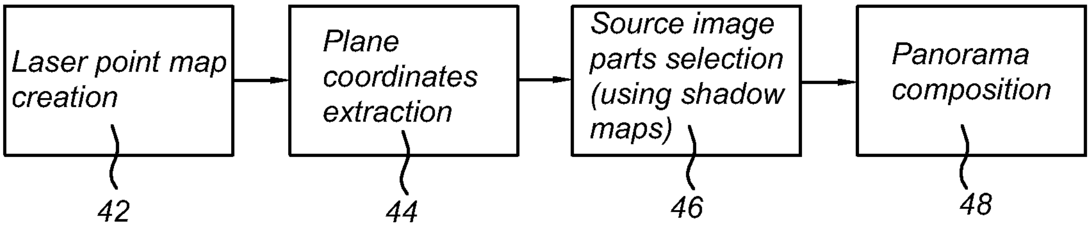
Laser point map creation
Plane coordinates extraction
Source image parts selection (using shadow maps)
Panorama composition
42
44
46
48

Fig 5

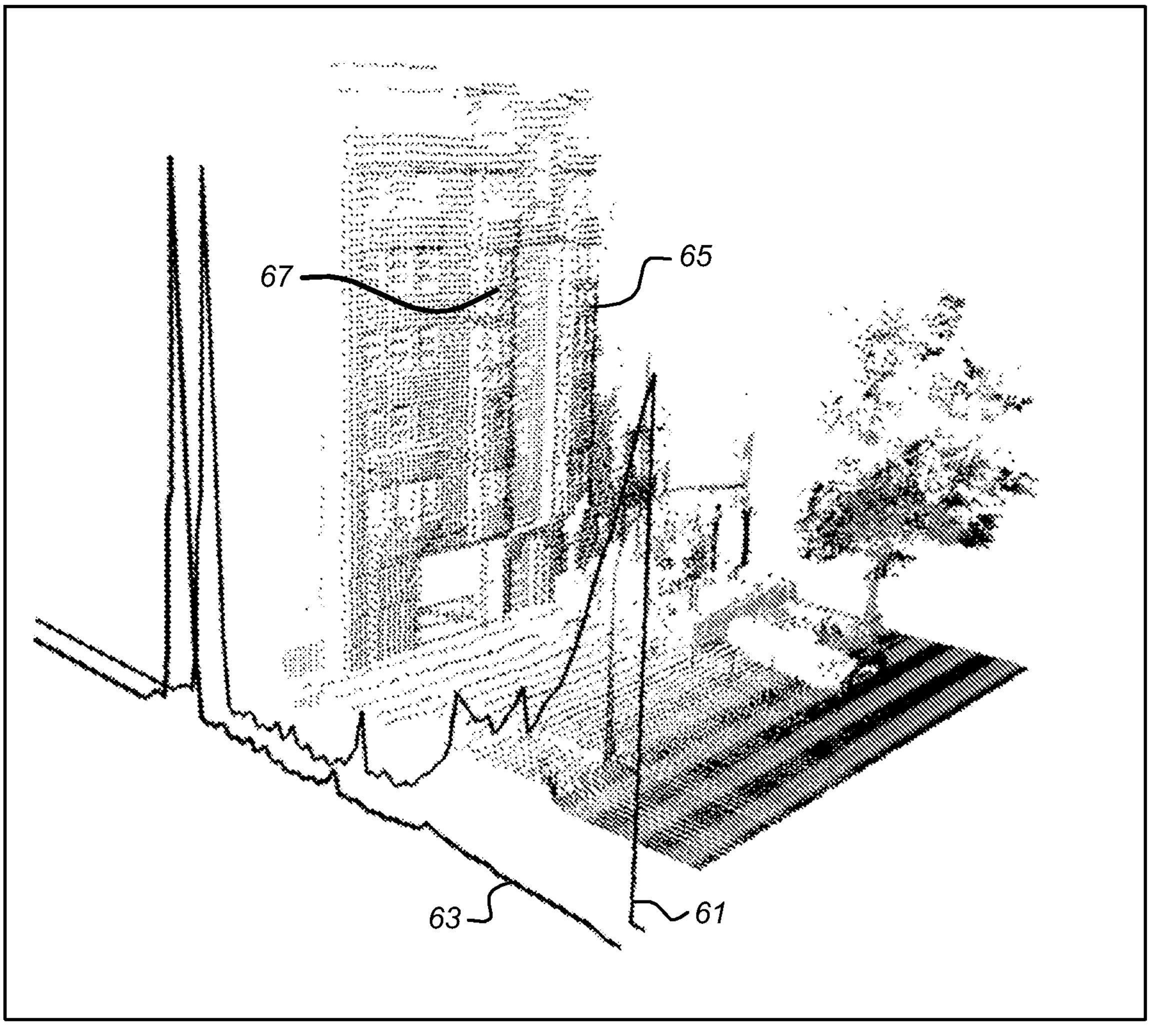
67
65
63
61

Fig 6

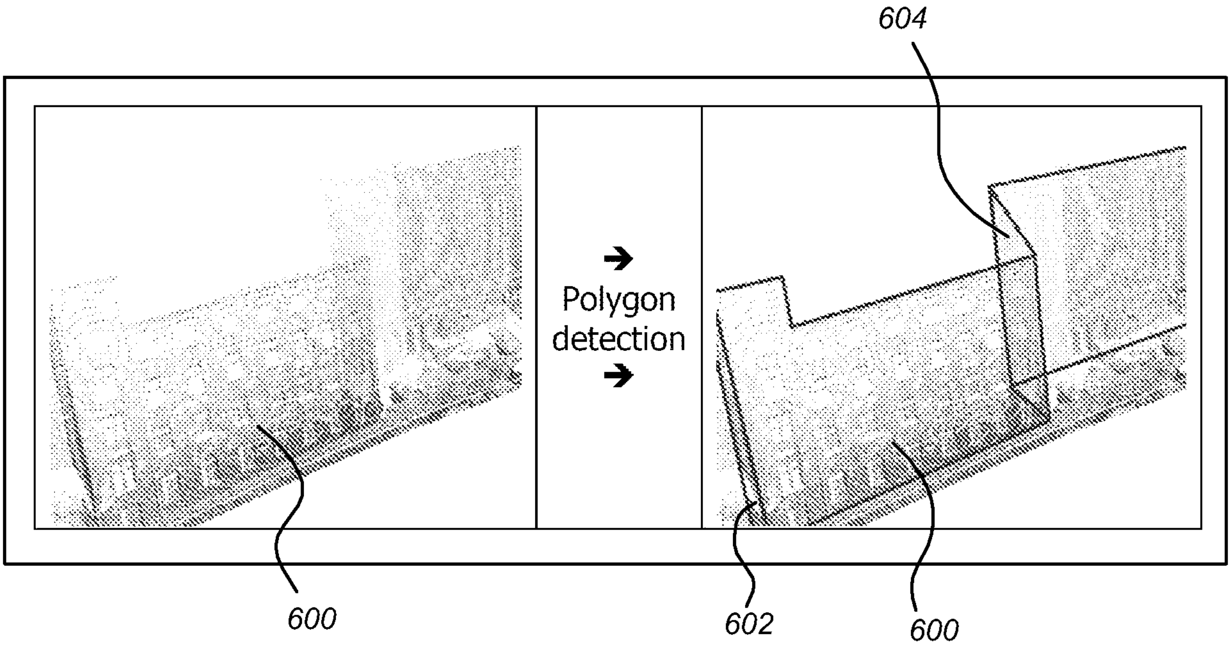
604
Polygon detection
600
602
600

Fig 7

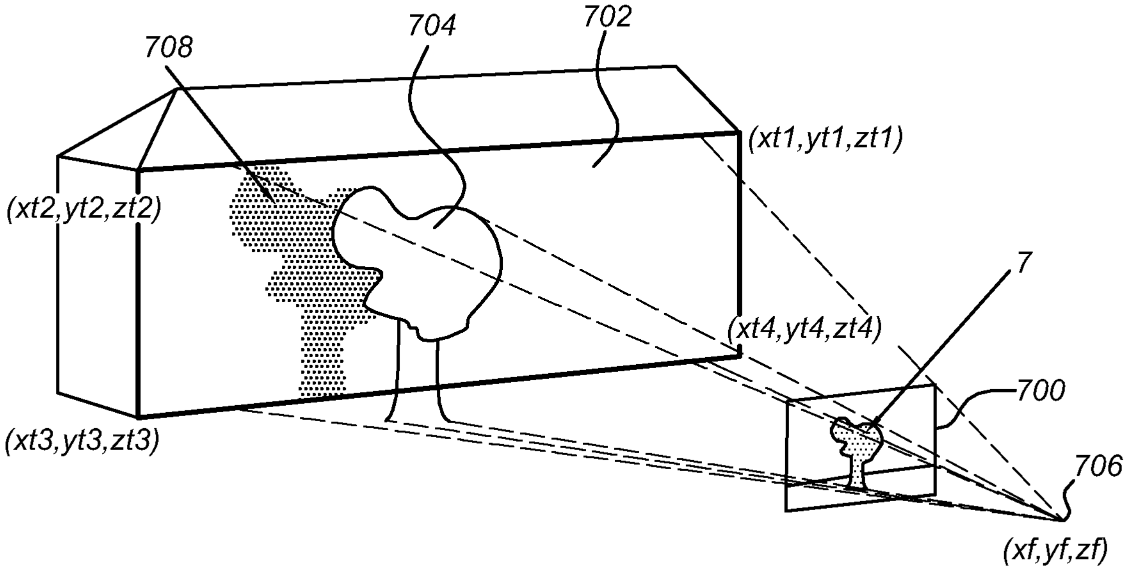
708
704
702
(xt1,yt1,zt1)
(xt2,yt2,zt2)
7
(xt4,yt4,zt4)
700
(xt3,yt3,zt3)
706
(xf,yf,zf)

Fig 8

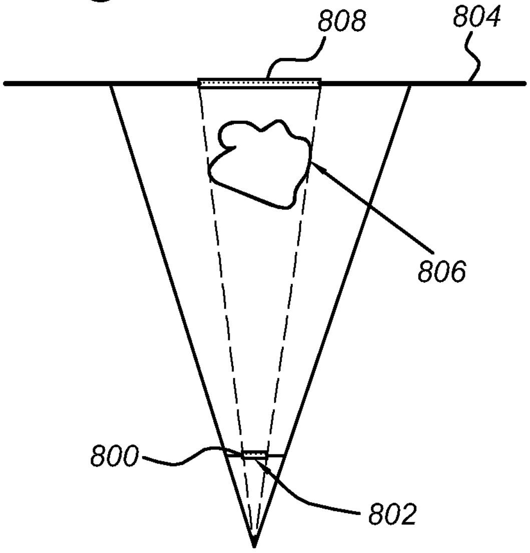

Fig 9

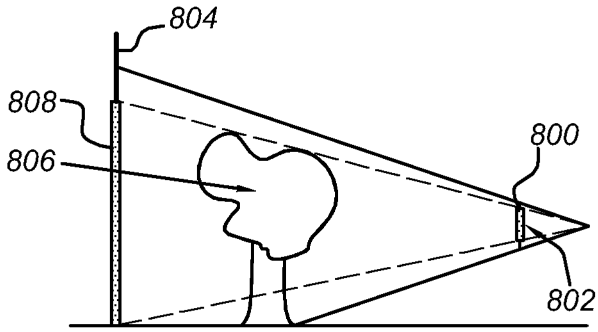

Fig 10

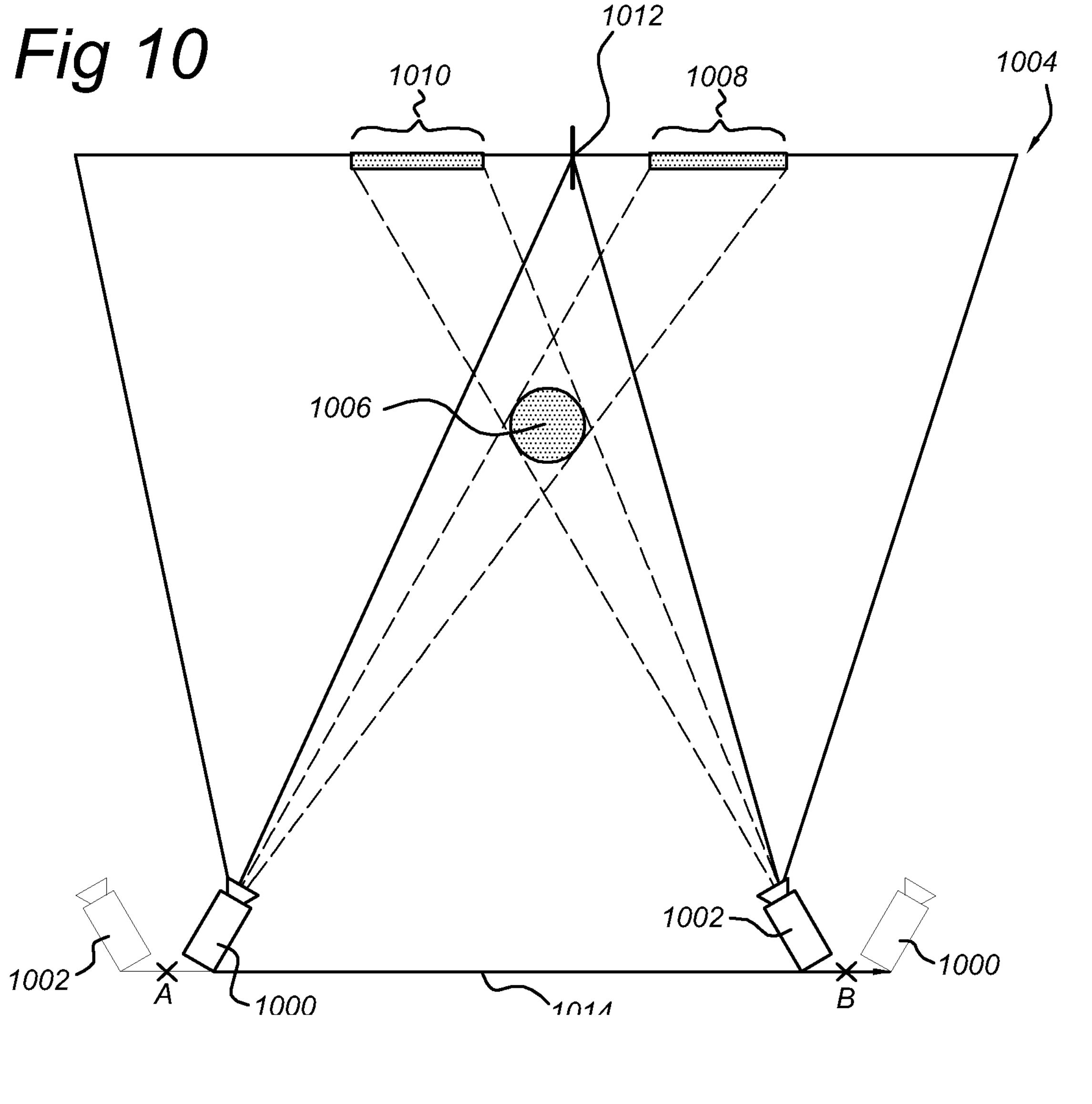

Fig 11

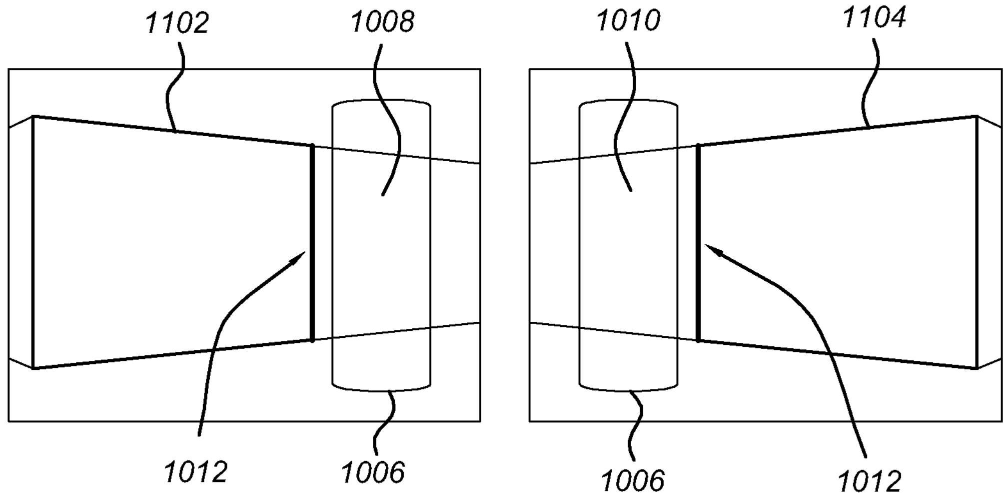
1102
1008
1010
1104
1012
1006
1006
1012

Fig 12

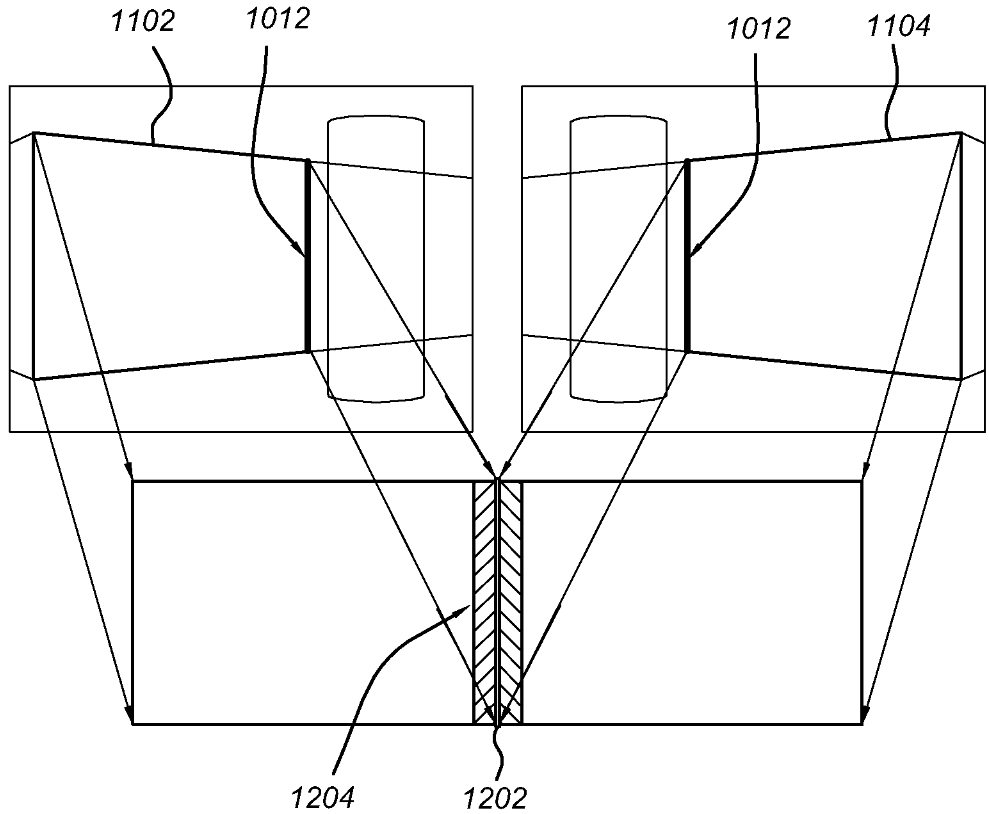
1102
1012
1012
1104
1204
1202

Fig 13

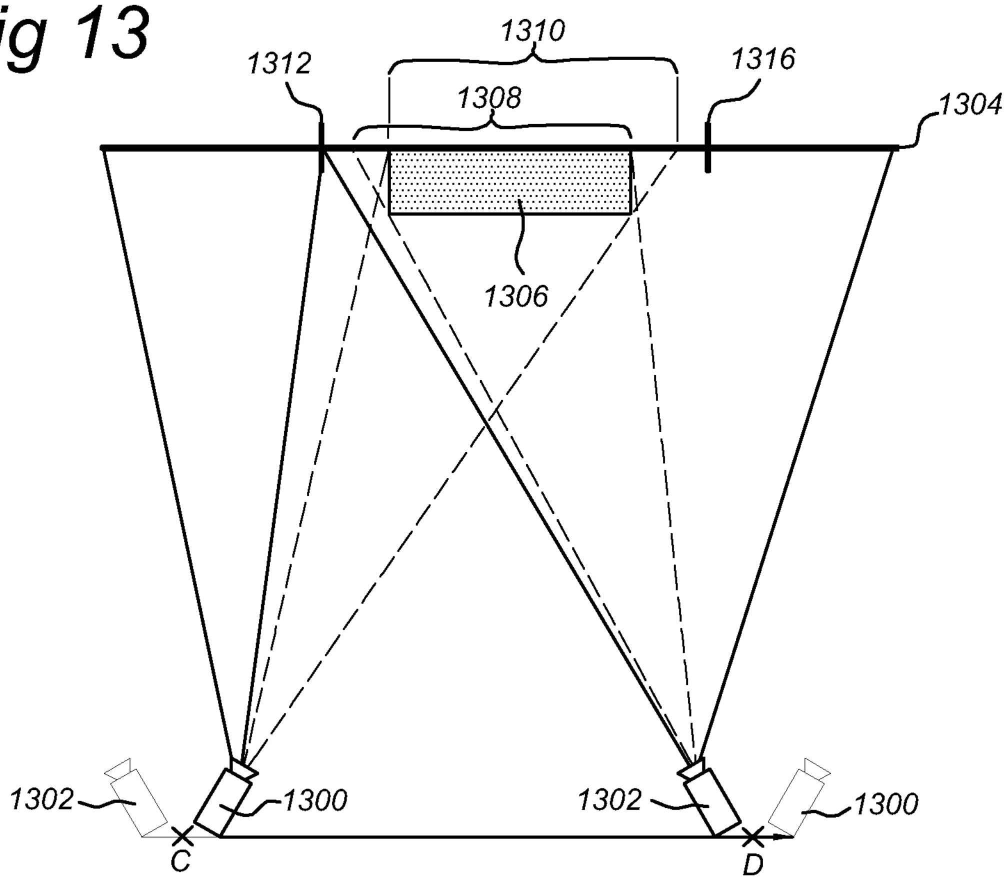
1310
1312
1316
1308
1304
1306
1302
1300
1302
1300
C
D

Fig 14

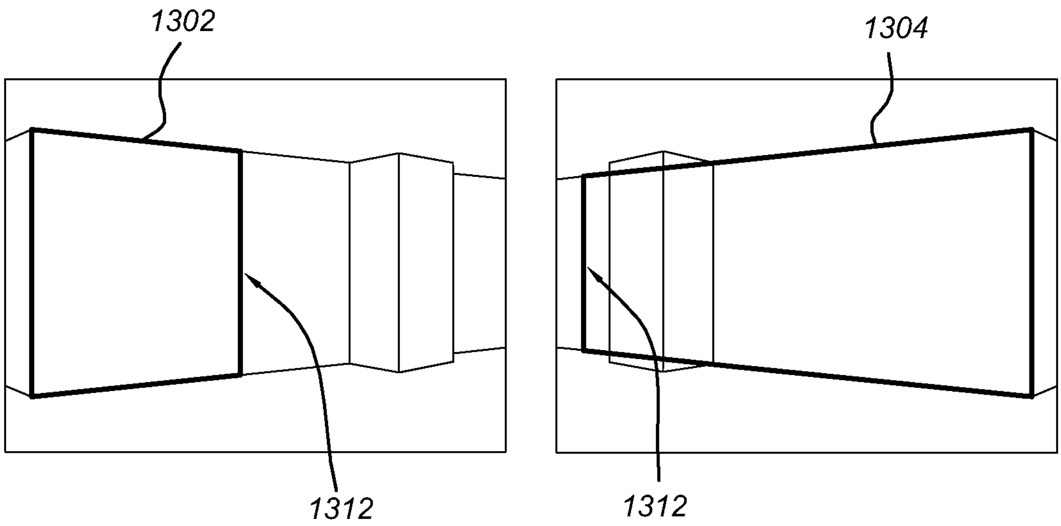
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Fig 15a

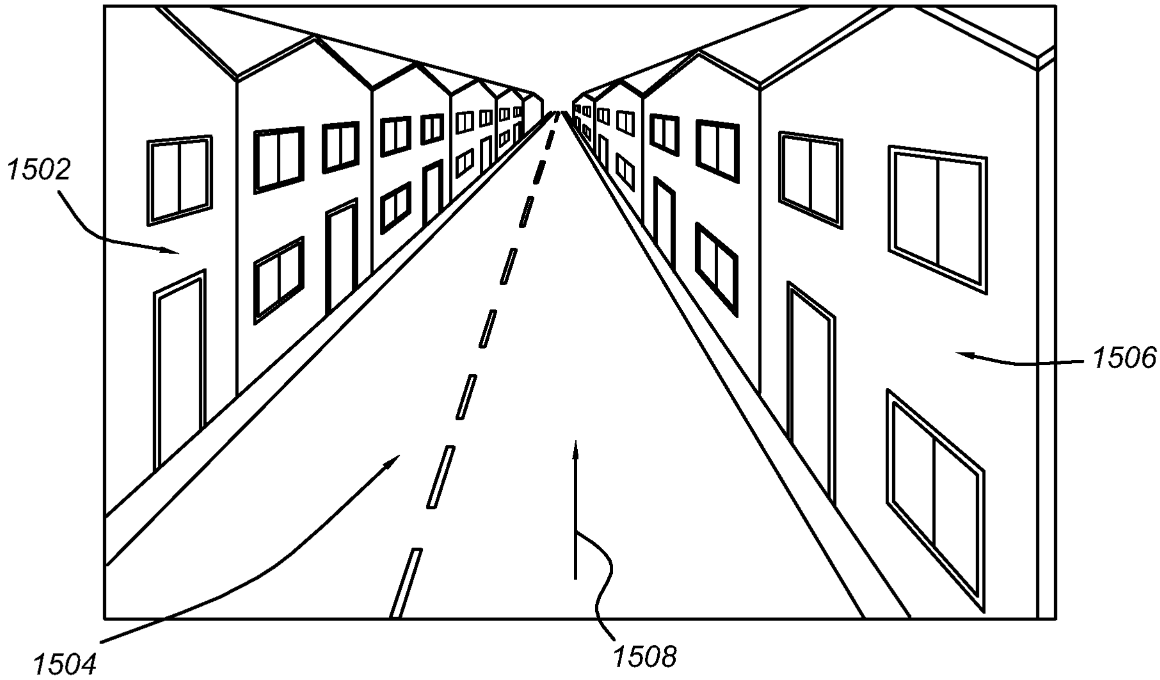


Fig 15b

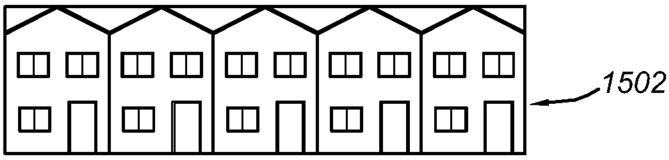


Fig 15d

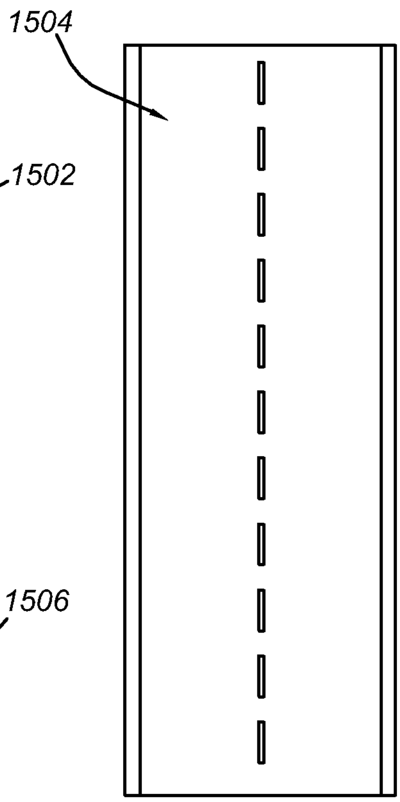


Fig 15c

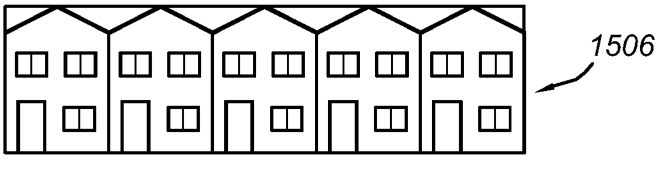


Fig 16a

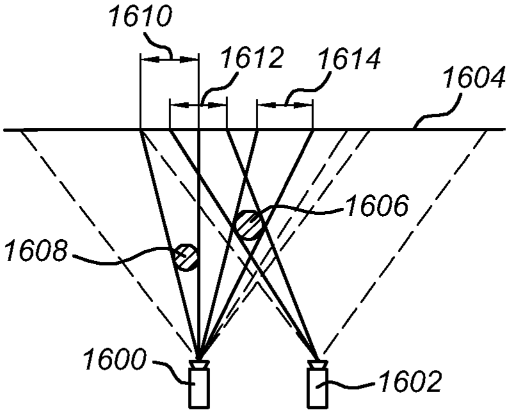


Fig 16b

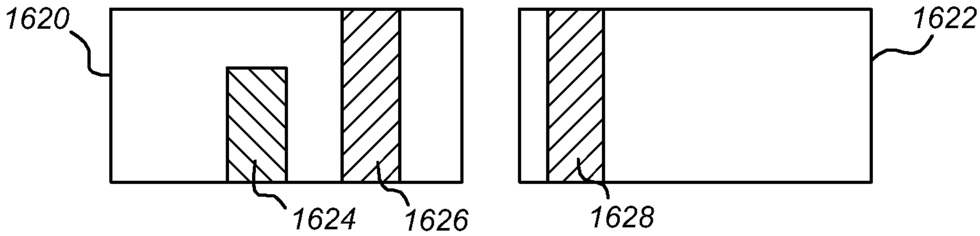


Fig 16c

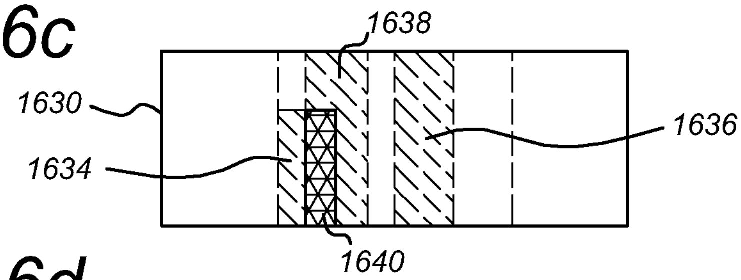


Fig 16d

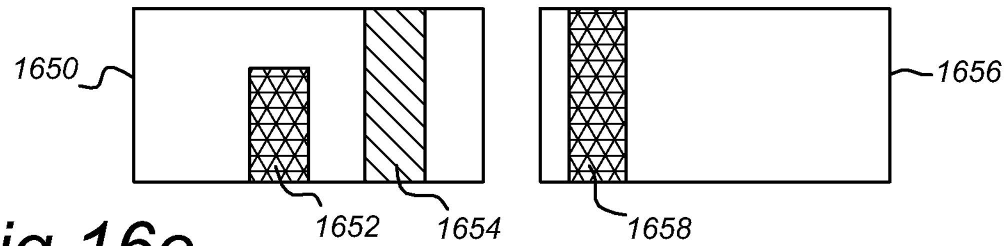


Fig 16e

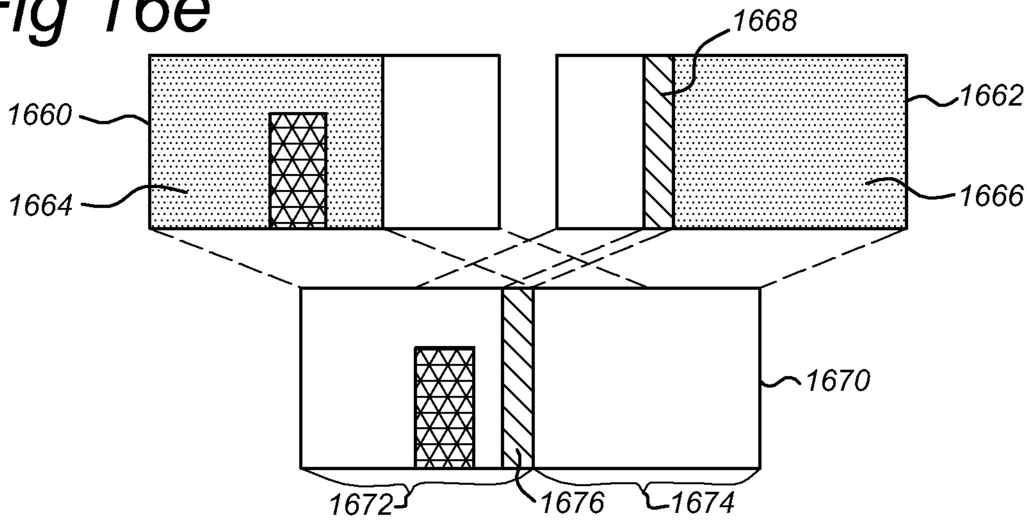


Fig 17

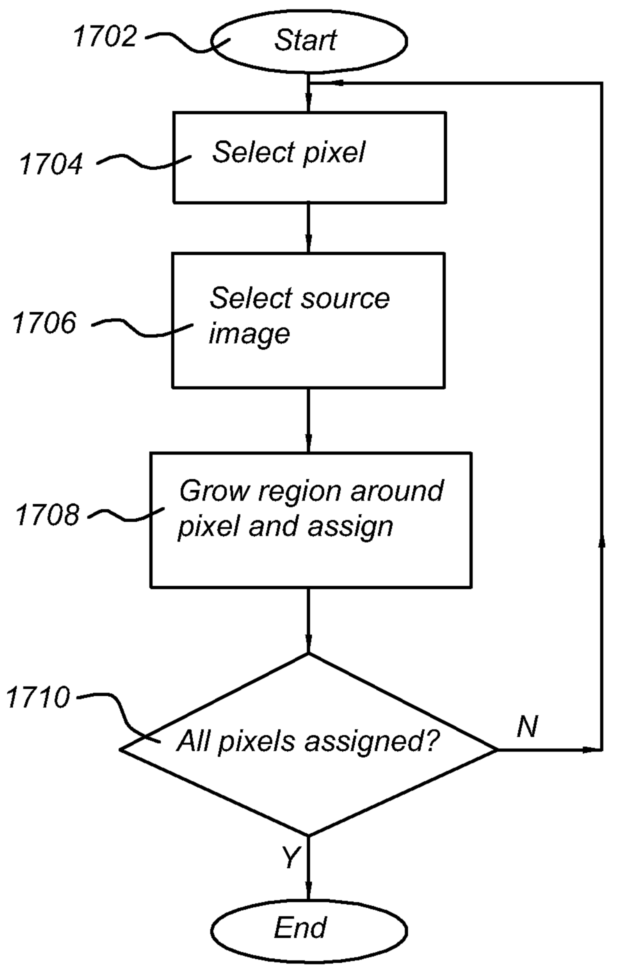
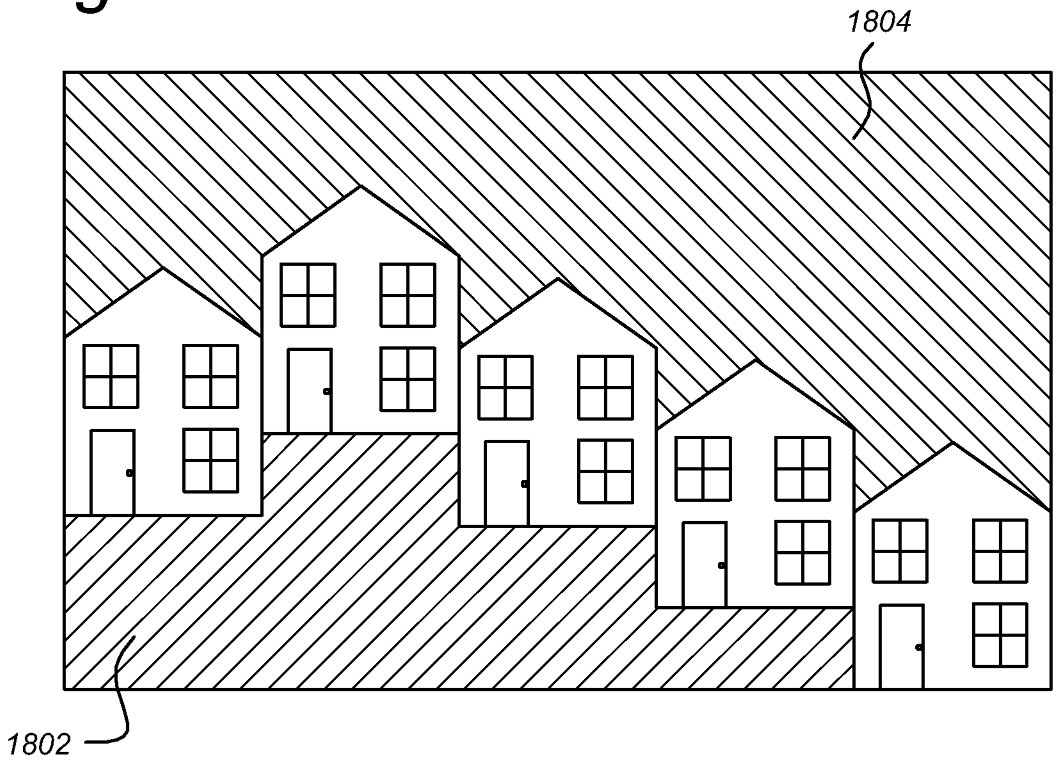

1702
Start
1704
Select pixel
1706
Select source image
1708
Grow region around pixel and assign
1710
All pixels assigned?
N
Y
End

Fig 18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INTERNATIONAL SEARCH REPORT

International application No
PCT/NL2007/050319

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06T15/10 G06T17/50

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)
G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC, COMPENDEX, IBM-TDB

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FRUH C ET AL: "Data processing algorithms for generating textured 3D building facade meshes from laser scans an camera images" 3D DATA PROCESSING VISUALIZATION AND TRANSMISSION, 2002. PROCEEDINGS. FIRST INTERNATIONAL SYMPOSIUM ON JUNE 19-21, 2002, PISCATAWAY, NJ, USA,IEEE, 19 June 2002 (2002-06-19), pages 834-847, XP010596758 ISBN: 0-7695-1521-4 abstract	1-5, 11-18
Y	page 835, paragraph II page 837, paragraph IV page 839, left-hand column, line 1 - page 843, paragraph VIII	6-10
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"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
28 April 2008	21/05/2008

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Zamuner, Umberto

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ROMÁN, AUGUSTO; LENSCH, HENDRIK P. A.: "Automatic Multiperspective Images" RENDERING TECHNIQUES 2006: 17TH EUROGRAPHICS WORKSHOP ON RENDERING, [Online] June 2006 (2006-06), pages 83-92, XP002478441 ISBN: 3-905673-35-5 Retrieved from the Internet: URL:http://graphics.stanford.edu/papers/autoperspective/autoperspective-lowres.pdf> [retrieved on 2008-04-11] abstract page 86, paragraph 3 - page 89, paragraph 6	1,11-17
Y	US 2007/076016 A1 (AGARWALA ASEEM O [US] ET AL) 5 April 2007 (2007-04-05) abstract paragraphs [0004] - [0008], [0011] - [0016], [0034] - [0058], [0067] - [0076]	6-10
A	ZHAO HUIJING ET AL: "UPDATING A DIGITAL GEOGRAPHIC DATABASE USING VEHICLE-BORNE LASER SCANNERS AND LINE CAMERAS" PHOTOGRAMMETRIC ENGINEERING AND REMOTE SENSING, AMERICAN SOCIETY FOR PHOTOGRAMMETRIC AND REMOTE, US, vol. 71, no. 4, April 2005 (2005-04), pages 415-424, XP009085661 ISSN: 0099-1112	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/NL2007/050319

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2007076016 A1	05-04-2007	US 2007078848 A1	05-04-2007
		US 2007076920 A1	05-04-2007
		WO 2007041657 A1	12-04-2007

Form PCT/ISA/210 (patent family annex) (April 2005)

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[87] 国际公布 WO2008/150153 英 2008.12.11
[85] 进入国家阶段日期 2009.12.7
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代理人 刘国伟

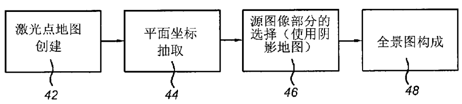
权利要求书 3 页 说明书 24 页 附图 10 页

[54] 发明名称

产生多视点全景图的方法及设备

[57] 摘要

本发明揭示一种产生路边的多视点全景图的方法。所述方法包含：获取通过安装在移动车辆上的至少一个基于陆地的激光扫描仪获得的一组激光扫描样本，其中每一样本与位置数据及定向数据相关联；获取至少一个图像序列，其中借助安装在所述移动车辆上的基于陆地的相机获得每一图像序列，其中所述至少一个图像序列中的每一图像与位置及定向数据相关联；从所述组激光扫描样本中抽取表面且依据与所述激光扫描样本相关联的所述位置数据确定所述表面的位置；依据所述表面的所述位置及与所述图像中的每一者相关联的所述位置及定向数据从所述至少一个图像序列产生所述表面的多视点全景图。



1、一种产生路边的多视点全景图的方法，其包含：

获取通过安装在移动车辆上的至少一个基于陆地的激光扫描仪获得的一组激光扫描样本，其中每一样本与位置数据及定向数据相关联；

获取至少一个图像序列，其中借助安装在所述移动车辆上的基于陆地的相机获得每一图像序列，其中所述至少一个图像序列中的每一图像与位置及定向数据相关联；

从所述组激光扫描样本中抽取表面且依据与所述激光扫描样本相关联的所述位置数据确定所述表面的位置；

依据所述表面的所述位置及与所述图像中的每一者相关联的所述位置及定向数据从所述至少一个图像序列产生所述表面的多视点全景图。

2、根据权利要求1所述的方法，其中产生包含：

检测在所述至少一个图像序列中的第一图像中阻碍观看所述表面的一部分的障碍物；

选择第二图像的显像所述表面的所述部分的区域；及

使用所述第二图像的所述区域产生所述多视点全景图的所述部分。

3、根据权利要求1所述的方法，其中产生包含：

检测在所述至少一个图像序列中的所有图像中阻碍观看所述表面的一部分的一个或一个以上障碍物；

将所述一个或一个以上障碍物中的一者的视图投影到所述多视点全景图。

4、根据权利要求3所述的方法，其中产生进一步包含：

针对所述所检测的障碍物中的每一者确定其是否在所述图像中的任一者中完全可见；

如果所述所检测的障碍物在至少一个图像中完全可见，那么将所述所检测对象的视图从所述至少一个图像中的一者投影到所述多视点全景图。

5、根据权利要求1到4中任一权利要求所述的方法，其中优选地从图像中具有最垂直于所述表面的相关联视角的部分产生所述全景图。

6、根据权利要求1所述的方法，其中产生包含：

产生所述表面的主阴影地图；

依据所述主阴影地图产生所述多视点全景图。

7、根据权利要求6所述的方法，其中产生主阴影地图包含：

选择具有包括所述表面的至少一部分的观看窗口的图像；

通过投影在所述表面前方显像于对应的选定图像中的障碍物的阴影来产生每一选定图像的阴影地图；及

组合所述选定图像的所述阴影地图以获得所述主阴影地图。

8、根据权利要求6或7所述的方法，其中产生进一步包含：

将所述主阴影地图分成若干段；

针对每一段确定在其相关联观看窗口中不具有障碍物的对应图像；及

使用所述对应图像将与所述段相关联的区域投影在所述多视点全景图上。

9、根据权利要求8所述的方法，其中产生进一步包含：

如果尚未找到段的对应图像，那么使用在其相关联观看窗口中具有整个障碍物的图像。

10、根据权利要求8或9所述的方法，其中产生进一步包含：

如果尚未找到段的对应图像，那么使用具有最垂直于所述表面的相关联视角的所述图像。

11、根据权利要求1、2或3所述的方法，其中通过对所述组激光扫描样本执行直方图分析来抽取所述表面。

12、一种产生路边全景图的方法，其包含：

检索可能已通过权利要求1到10中任一权利要求及相关联的位置信息产生的多个多视点全景图；

确定所述路边全景图的虚拟表面的位置；及

将所述多个多视点全景图投影在所述虚拟表面上。

13、一种用于执行根据权利要求1到11中任一权利要求所述的方法的设备，所述设备包含：

输入装置；

处理器可读存储媒体；及

处理器，其与所述输入装置及所述处理器可读存储媒体通信；

输出装置，其用以实现与显示器单元的连接；

所述处理器可读存储媒体存储代码，所述代码用以编程所述处理器以执行包含以下动作的方法：

获取通过安装在移动车辆上的至少一个基于陆地的激光扫描仪获得的一组激光扫描样本，其中每一样本与位置数据及定向数据相关联；

获取至少一个图像序列，其中借助安装在所述移动车辆上的基于陆地的相机获得每一图像序列，其中所述至少一个图像序列中的每一图像与位置及定向数据相关联；

从所述组激光扫描样本中抽取表面且依据与所述激光扫描样本相关联的所述位置数据确定所述表面的位置；

依据所述表面的所述位置及与所述图像中的每一者相关联的所述位置及定向数据从所述至少一个图像序列产生所述表面的多视点全景图。

14、一种包含指令的计算机程序产品，当加载于计算机布置上时所述计算机程序产品允许所述计算机布置执行根据权利要求1到11所述的方法中的任一者。

15、一种携载计算机程序产品的处理器可读媒体，当加载于计算机布置上时所述

计算机程序产品允许所述计算机布置执行根据权利要求 1 到 11 所述的方法中的任一者。

16、一种携载多视点全景图的处理器可读媒体，所述多视点全景图已通过执行根据权利要求 1 到 11 所述的方法中的任一者获得。

17、一种在屏幕上同时提供地图及街道中的选定位置以及来自所述位置的伪现实视图的计算机实施的系统，其包含

包含所述选定位置的地图；

根据权利要求 11 所述的至少一个路边全景图；

用于在屏幕上以可变定向显示包括街道中的所述选定位置的显示地图的地图产生组件；及

用于依据所述可变定向从所述至少一个路边全景图产生所述选定位置的伪现实视图的视图产生组件。

18、根据权利要求 17 所述的计算机实施的系统，其中所述地图与所述伪现实视图组合为一个伪透视图。

产生多视点全景图的方法及设备

技术领域

本发明涉及一种产生多视点全景图的方法。本发明进一步涉及一种从多视点全景图产生路边全景图的方法。本发明进一步涉及一种用于多视点全景图的设备、一种计算机程序产品及一种携载所述计算机程序产品的处理器可读媒体。本发明进一步涉及一种使用所述路边全景图的计算机实施的系统。

背景技术

当今，人们使用导航装置来沿道路对自己进行导航或使用因特网上的地图显示。导航装置在其显示器中显示位置的平面透视、有角透视（鸟瞰图）或可变比例的“2D”地图。所述显示器中仅显示关于道路的信息或一些关于区域（例如，湖泊及公园）的简单属性信息。此种信息实际上是位置的抽象表示且并不显示位于所述显示器中所示（实际地或虚拟地）的位置处的人或相机可看到的事物。一些因特网应用显示从卫星或飞机上拍摄的俯视图片且仍很少地显示从道路拍摄的有限的一组照片，可能在用户的位置（真实的或虚拟的）附近且面向用户打算看向的大致相同的方向。

在未来的导航装置及因特网应用中需要更准确且更现实的路边视图。所述路边视图使得用户能够看到在特定位置可看到的事物且在驾驶时非常容易地检验导航装置是否使用正确的位置或检验在因特网上询问的所关心的地方真正是其想去的地方或仅仅因为娱乐或商业原因而更详细地观看所述区域。在所述显示器中，用户则可立即看到在显示器上看到的建筑物是否对应于其可在路边看到的建筑物或根据记忆或其它描述想象的建筑物。将从自不同的观点捕获的图像产生的全景图像视为多视点或多视角的。另一种类型的全景图像是缝隙扫描全景图。在其最简单的形式中，条带全景图沿水平轴展现正射投影，且沿垂直轴展现透视投影。

从阿什姆 阿加瓦拉（Aseem Agarwala）等人的以多视点全景图拍摄长景物（Photographing long scenes with multi-viewpoint panoramas）（ACM 图形学汇刊（SIGGRAPH 2006 学报），2006 年）知道用于产生多视点全景图的系统。用于产生长、大致平面的景物（例如，沿城市街道的建筑物的正面）的多视点全景图的系统从使用手持式照相机捕获的相对稀疏的一组照片产生。用户必须识别所拍摄的景物的主平面。然后，系统使用马可夫随机场优化自动计算全景图。

用于描绘周围事物的现实图像的另一种技术是开发区域的全 3D 模型且然后将现实纹理应用到每一建筑物的外部尺寸。应用（例如，导航单元中或因特网上的应用）

则可使用 3D 再现软件来构造周围对象的现实图片。

发明内容

本发明试图提供一种产生多视点全景图的替代方法及一种以接近照片的质量提供表示虚拟表面的一组高质量的易于理解的图像的替代方式，所述图像易于操纵以获得伪现实透视图像而不存在开发 3D 模型的增加的成本及复杂性。

根据本发明，所述方法包含：

获取通过安装在移动车辆上的激光扫描仪获得的一组激光扫描样本，其中每一样本与位置数据相关联；

获取至少一个图像序列，其中已借助安装在所述移动车辆上的基于陆地的相机获得每一图像序列，其中所述至少一个图像序列中的每一图像与位置及定向数据相关联；

从所述组激光扫描样本中抽取表面且依据与所述激光扫描样本相关联的所述位置数据确定所述表面的位置；

依据所述表面的所述位置及与所述图像中的每一者相关联的所述位置及定向数据从所述至少一个图像序列产生所述多边形的多视点全景图。

本发明是基于辨识移动测绘车辆，所述移动测绘车辆行驶在地球表面上、用基于陆地的相机记录表面收集的地理位置图像序列。此外，所述移动测绘车辆记录激光扫描样本，所述激光扫描样本使得软件能够根据来自所述激光扫描仪样本的距离信息产生所述移动测绘车辆的环境的 3D 表示。借助 GPS 接收器及惯性测量装置（例如，一个或一个以上回转仪及/或加速计）确定车辆的位置及定向。此外，已知相机相对于车辆且因此相对于环境的 3D 表示的位置及定向。为能够产生视觉上有吸引力的多视点全景图，必须知道相机与全景图的表面之间的距离。所述全景图可表示路边的视图，其从建筑物表面一直变化为街道的路边全景图。此可通过现有图像处理技术完成。然而，此需要大量的计算机处理能力。根据本发明，通过处理激光扫描仪数据来确定所述表面。此比仅使用图像处理技术需要少得多的处理能力来确定表面的位置。随后，可通过将所记录的图像或图像的段投影到所确定的表面上来产生多视点全景图。

借助车载定位系统（例如，GPS 接收器）及其它额外位置与定向确定装备（例如，惯性导航系统-INS）准确地知道相机及激光扫描仪的地理位置。

本发明的另一个改进是在没有计算 3D 模型所必需的处理时间也没有再现全 3D 模型所必需的处理时间的情况下提供显示某种写实性 3D 图像的影像的能力。3D 模型包含多个多边形或表面。再现全 3D 模型需要针对多边形中的每一者评价在从特定侧观看所述 3D 模型时所述多边形是否可被看到。如果可看到多边形，那么所述多边形将投影在所述影像上。根据本发明的多视点全景图仅为整个临街面的一个表面。

本发明的其它实施例已界定于所附权利要求书中。

在本发明的一个实施例中，产生包含：

检测在所述至少一个图像序列中的所有图像中阻碍观看所述表面的一部分的一个或一个以上障碍物；

将所述一个或一个以上障碍物中的一者的视图投影到多视点全景图。激光扫描仪样本使我们能够针对每一图像检测哪些障碍物在相机的前方且在将要产生的多视点全景图的平面的位置之前。这些特征使我们能够检测所述平面的哪些部分在所述图像中的任一者中不可见且应填满障碍物。此允许我们最小化在正面前方在所述全景图中可见的障碍物的数量且从而从多视点全景图中排除尽可能多的障碍物以便在所有所述图像中不阻碍观看所述表面的一部分。此使我们能够提供具有良好的视觉质量的临街面的多视点全景图。

在本发明的另一个实施例中，产生进一步包含：

针对所检测的障碍物中的每一者确定其是否在所述图像中的任一者中完全可见；

如果所检测的障碍物在至少一个图像中完全可见，那么将所述所检测对象的视图从所述至少一个图像中的一者投影到多视点全景图。这些特征允许我们减少将部分地显像于所述全景图中的障碍物的数量。此改善所述多视点全景图的吸引力。

在本发明的一个实施例中，优选地从图像中具有最垂直于多边形的相关联视角的部分图像产生多视点全景图。此特征使我们能够从所述图像产生质量最好的多视点全景图。

在本发明的一个实施例中，通过组合多视点全景图来产生路边全景图。针对路边全景图确定平行于线（例如，道路的中心线）但距所述线一定距离的共用表面。将具有与所述共用表面不同的位置的多视点全景图投影在所述共用表面上以便就像在等于所述表面与所述线之间的距离的距离处看到所述多视点全景图中的每一者那样表示所述多视点全景图中的所述每一者。相应地，产生全景图，所述全景图显像具有与所述共用表面不同的位置的多视点全景图中的对象，现在就像从相同的距离看到那样。已从所述多视点全景图中移除尽可能多的障碍物以获得最好的视觉质量，产生其中将不显像沿道路的许多障碍物的路边全景图。

根据本发明的路边全景图提供显示街道的某种写实性 3D 视图的影像的能力，而不存在再现沿所述街道的建筑物的全 3D 模型所必需的处理时间。使用所述街道的 3D 模型提供所述街道的 3D 视图需要针对沿所述街道的每一建筑物或每一建筑物的部分确定其能否被看到且随后将所述建筑物或其部分的每一 3D 模型再现为 3D 视图。可容易地通过根据本发明的路边全景图提供显示街道的某种写实性 3D 视图的影像。所述路边全景图表示当投影到共用表面上时沿所述街道的建筑物。可容易地通过依序（以具有距离观看位置最远的位置的像素列开始一直到具有距离观看点最近的位置的像素列）将所述路边全景图的像素列投影在所述 3D 视图上将所述表面变换为伪透视图像。以此方式，可针对左及右路边全景图的表面产生现实的透视图像，从而产生街道的伪现实视图。当使用沿街道的建筑物的 3D 模型时，仅需要表示两个表面的两个图像替代多个多边形。

可使用软件、硬件或软件与硬件的组合来实施本发明。当本发明的全部或部分在软件中实施时，所述软件可驻存于处理器可读存储媒体上。适当的处理器可读存储媒体的实例包括软磁盘、硬磁盘、CD ROM、DVD、存储器 IC 等。当系统包括硬件时，所述硬件可包括：输出装置（例如，监视器、扬声器或打印机）；输入装置（例如，键盘、指向装置及/或麦克风）；及处理器，其与所述输出装置通信；以及处理器可读存储媒体，其与所述处理器通信。所述处理器可读存储媒体存储代码，所述代码能够编程所述处理器以执行所述动作从而实施本发明。本发明的过程还可在可经由电话线或其它网络或因特网连接存取的服务器上实施。

附图说明

下文将使用多个实例性实施例参照附图更详细地论述发明，所述附图打算图解说明本发明而非限制其由所附权利要求书及其等效实施例界定的范围，附图中

图 1 显示具有相机及激光扫描仪的 MMS 系统；

图 2 显示位置及定向参数的图示；

图 3 显示本发明可借助其执行的计算机布置的框图；

图 4 是根据本发明用于产生道路信息的过程的实例性实施方案的流程图；

图 5 显示基于激光扫描样本的直方图；

图 6 显示多边形检测的实例性结果；

图 7 显示源图像在虚拟平面上的投影的透视图；

图 8 显示源图像在虚拟平面上的投影的俯视图；

图 9 显示源图像在虚拟平面上的投影的侧视图；

图 10 显示在不同位置的记录同一平面的两个相机的俯视图；

图 11 显示来自图 10 中所示的情形的透视图；

图 12 图解说明从两个图像构成全景图的过程；

图 13 显示在不同位置的记录同一平面的两个相机的俯视图；

图 14 显示来自图 13 中所示的情形的透视图；

图 15a-d 显示全景图的应用，

图 16a-e 图解说明在源图像中找到产生多视点全景图的区域的第二实施例，

图 17 显示用以分派源图像中将要选择的部分源图像的算法的流程图；及

图 18 显示路边全景图的另一个实例。

具体实施方式

图 1 显示采用汽车 1 形式的 MMS 系统。汽车 1 具有一个或一个以上相机 9（i）（i = 1, 2, 3, ... I）及一个或一个以上激光扫描仪 3（j）（j = 1, 2, 3, ... J）。视角或所述一个或一个以上相机 9（i）可在相对于汽车 1 的驾驶方向的任何方向上且因此可以是

前视相机、侧视相机或后视相机等。优选地，汽车 1 的行驶方向与相机的视角之间的角度在任一侧上在 45 度到 135 度的范围内。汽车 1 可由驾驶员驾驶着沿感兴趣的道路行驶。在实例性实施例中，两个侧视相机安装在汽车 1 上，其中所述两个相机之间的距离是 2 米且所述相机的视角垂直于汽车 1 的行驶方向且平行于地球表面。在另一个实例性实施例中，两个相机已安装在汽车 1 上，所述相机具有与所述汽车的一个侧的水平视角及向前视角，其分别为约 45°及 135°。另外，具有 45°的向上视角的第三侧视相机可安装在所述汽车上。此第三相机用于捕获路边的建筑物的上部部分。

汽车 1 具有多个车轮 2。此外，汽车 1 具有高准确性位置确定装置。如图 1 中所示，所述位置确定装置包含以下组件：

- GPS（全球定位系统）单元，其连接到天线 8 且经布置以与多个卫星 SLi（i = 1, 2, 3, ...）通信且根据从卫星 SLi 接收的信号计算位置信号。所述 GPS 单元连接到微处理器 μP。基于从所述 GPS 单元接收的信号，所述微处理器 μP 可确定将显示于汽车 1 中的监视器 4 上的合适的显示信号，从而告知驾驶员汽车的所在位置及所述汽车可能正沿哪个方向行进。替代 GPS 单元，可使用差分 GPS 单元。差分全球定位系统（DGPS）是对全球定位系统（GPS）的增强，其使用固定的基于地面的参考站网络来广播由卫星系统所指示的位置与已知的固定位置之间的差异。这些站广播所测量的卫星伪距与实际（在内部计算的）伪距之间的差异，且接收器站可将其伪距校正相同量。
- DMI（距离测量器具）。此器具是通过感测车轮 2 中的一者或一者以上的旋转次数来测量汽车 1 行进的距离的计程仪。所述 DMI 还连接到微处理器 μP 以允许所述微处理器 μP 考虑由所述 DMI 测量的距离，同时依据来自所述 GPS 单元的输出信号计算显示信号。
- IMU（惯性测量单元）。此种 IMU 可实施为 3 个回转仪单元，其经布置以测量沿 3 个正交方向的旋转加速度及平移加速度。所述 IMU 还连接到微处理器 μP 以允许所述微处理器 μP 考虑所述 DMI 的测量结果，同时依据来自所述 GPS 单元的输出信号计算显示信号。所述 IMU 还可包含航位推算传感器。

应注意，所属领域的技术人员可找到全球卫星导航系统与车载惯性与航位推算系统的许多组合以提供车辆的准确位置及定向且因此提供装备（其以参照所述车辆的已知位置及定向安装）的准确位置及定向。

如图 1 中所示的系统为所谓的“移动测绘系统”，其（举例来说）通过借助安装在汽车 1 上的一个或一个以上相机 9（i）拍摄图片来收集地理数据。所述相机连接到微处理器 μP。所述汽车前方的相机 9（i）可以是立体相机。所述相机可经布置以产生图像序列，其中已以预界定的帧速率捕获了图像。在实例性实施例中，所述相机中的一者或一者以上为照相机，其经布置以在汽车 1 的每个预界定位移或每个时间间隔捕获图片。所述预界定位移经选择以使得在垂直于行驶方向的预界定距离处的位置捕获为侧视相机的至少两个连续图片。举例来说，可在每行进 4 米之后捕获图片，从而在平行于行驶方向的平面的每一图像中在 5 米距离处产生重叠。

当汽车 1 正沿路边的建筑物行驶时，激光扫描仪 3（j）扫描激光样本。其还连接到微处理器 μP 且将这些激光样本发送到微处理器 μP。

通常想要从 3 个测量单元 GPS、IMU 及 DMI 尽可能准确地提供位置及定向测量。当相机 9（i）拍摄图片且激光扫描仪 3（j）扫描激光样本时，测量这些位置及定向数据。存储所述图片及激光样本以供稍后联合在拍摄这些图片的同时收集的汽车 1 的对应的位置及定向数据用于 μP 的合适的存储器中。所述图片包括关于道路信息的信息，例如，道路的中心、路面边缘及道路宽度。由于从同一位置确定装置获得与所述激光样本及图片相关联的位置及定向数据，因此可在所述图片与激光样本之间进行精确的匹配。

图 2 显示哪些位置信号可从图 1 中所示的三个测量单元 GPS、DMI 及 IMU 获得。图 2 显示微处理器 μP 经布置以计算 6 个不同参数，即，相对于预定坐标系统中的原点的 3 个距离参数 x、y、z 及分别是 ω_x、ω_y、ω_z 的 3 个角参数，其分别表示绕 x 轴、y 轴及 z 轴的旋转。z 方向与重力向量的方向一致。总体 UTM 坐标系统可用作预定坐标系统。

通常想要从 3 个测量单元 GPS、IMU 及 DMI 尽可能准确地提供位置及定向测量。当相机 9（i）拍摄图像且激光扫描仪 3（j）扫描激光样本时测量这些位置及定向数据。存储所述图像及所述激光样本两者以供稍后联合在拍摄这些图片及激光样本的时刻汽车 1 的对应的位置及定向数据以及相机及激光扫描仪相对于汽车 1 的位置及定向用于微处理器的合适的存储器中。

所述图片及激光样本包括关于路边的对象（例如，建筑物块正面）的信息。在一个实施例中，激光扫描仪 3（j）经布置以产生具有最小 50 Hz 及 1 度的分辨率的输出以便产生用于所述方法的足够密集的输出。由 SICK 生产的激光扫描仪（例如，MODEL LMS291-S05）能够产生此种输出。

汽车 1 中的微处理器及存储器 9 可实施为计算机布置。图 3 中显示此种计算机布置的实例。

在图 3 中，给出计算机布置 300 的概略图，其包含用于实施算术运算的处理器 311。在图 1 所示的实施例中，所述处理器将是微处理器 μP。

处理器 311 连接到多个存储器组件，包括硬磁盘 312、只读存储器（ROM）313、电可擦除可编程只读存储器（EEPROM）314 及随机存取存储器（RAM）315。未必需要提供所有这些存储器类型。此外，这些存储器组件无需在物理上接近于处理器 311 定位而是可远离处理器 311 定位。

处理器 311 还连接到用户用来输入指令、数据等的构件，如键盘 316 及鼠标 317。也可提供所属领域的技术人员已知的其它输入构件，例如触摸屏、轨迹球及/或声音转换器。

提供连接到处理器 311 的读取单元 319。读取单元 319 经布置以从可移除数据载体或可移除存储媒体（如软磁盘 320 或 CDROM 321）读取数据及可能在其上写入数

据。其它可移除数据载体可以是磁带、DVD、CD-R、DVD-R、存储器棒等，如所属领域的技术人员已知。

处理器 311 可连接到打印机 323 以在纸张上以及向显示器 318 打印输出数据，所述显示器例如监视器或 LCD（液晶显示器）屏幕或所属领域的技术人员已知的任何其它类型的显示器。

处理器 311 可连接到扩音器 329。

此外，处理器 311 可借助 I/O 构件 325 连接到通信网络 327，例如，公共交换电话网络（PSTN）、局域网（LAN）、广域网（WAN）、因特网等。处理器 311 可经布置以通过网络 327 与其它通信布置通信。I/O 构件 325 进一步适于将位置确定装置（DMI、GPS、IMU）、相机 9（i）及激光扫描仪 3（j）连接到计算机布置 300。

数据载体 320、321 可包含数据及指令形式的计算机程序产品，所述计算机程序产品经布置以给处理器提供执行根据本发明的方法的能力。然而，此种计算机程序产品或者可经由电信网络 327 下载。

处理器 311 可实施为独立系统，或实施为多个各自经布置以实施较大计算机程序的子任务的并行操作处理器，或实施为具有若干子处理器的一个或一个以上主处理器。本发明的部分功能性甚至可由通过电信网络 327 与处理器 311 通信的远程处理器实施。

图 3 的计算机系统中所含有的组件为通常在通用计算机系统中找到的那些组件，且打算表示在所属技术中众所周知的这些计算机组件的宽广种类。

因此，图 3 的计算机系统可以是个人计算机、工作站、小型计算机、大型计算机等。所述计算机还可包括不同的总线配置、联网平台、多处理器平台等。可使用各种操作系统，包括 UNIX、Solaris、Linux、Windows、Macintosh OS 及其它合适的操作系统。

为对通过相机 9（i）及激光扫描仪 3（j）拍摄的图像及扫描以及位置/定向数据进行后处理，将使用与图 3 中的布置类似的布置，但此布置将不位于汽车 1 中而是可方便地位于建筑物中用于离线后处理。将通过相机 9（i）及扫描仪 3（j）拍摄的图像及扫描以及相关联的位置/定向数据存储在一个或一个以上存储器 312-315 中。此存储可通过首先将所述图像及扫描以及所述相关联位置/定向数据存储在 DVD、存储器棒或类似物上或从存储器 9 中传输其（可能无线地）完成。可将界定汽车 1 的轨迹的相关联位置及定向数据存储为原始数据，包括时间戳。此外，每一图像及激光扫描仪样本具有时间戳。所述时间戳使我们能够准确地确定相机 9（i）及激光扫描仪 3（j）在分别捕获图像及激光扫描仪样本时的位置及定向。以此方式，所述时间戳界定图像中所示的视图与激光扫描仪样本之间的空间关系。也可将相关联的位置及定向数据存储为由所使用的数据库架构与相应的图像及激光扫描仪样本链接的数据。

在本发明中，通过使用相机 9（i）所拍摄的图像及激光扫描仪 3（j）所扫描的扫描两者来产生多视点全景图。所述方法使用来自图像处理及激光扫描技术两个领域的独特的技术组合。本发明可用于产生从建筑物的临街面变化为街道的整个路边视图的

多视点全景图。

图 4 显示根据本发明用于产生路边信息的过程的实例性实施方案的流程图。图 4 显示以下动作：

A.动作 42：激光点地图创建

B.动作 44：从激光点地图中抽取对象的平面坐标

C.动作 46：源图像部分选择（使用阴影地图）

D.动作 48：从选定的源图像部分构成全景图下文将详细阐释这些动作。

A.动作 42：激光点地图创建

用于找到平面点的好方法是使用直方图分析。直方图包含激光扫描仪 3（j）在某一距离处扫描的如在垂直于 MMS 系统行进的轨道的方向上看到且沿汽车 1 行进的某一距离相加的激光扫描样本的数量。所述激光扫描仪可在垂直于地球表面的表面中在（举例来说）跨越 180°的角方向上扫描。例如，所述激光扫描仪可扫描 180 个样本，每一样本从其邻近样本偏离 1°。此外，至少每 20 cm 制作激光扫描样本片。通过一秒旋转 75 次的激光扫描仪，汽车行驶速度不应快于 54 km/h。在大多数时间，MMS 系统将沿行沿一条线的路线，所述线沿某条道路引导（仅当由于某个原因改变车道或拐弯时，所行进的路径将显示从此路线的偏离。

激光扫描仪 3（j）在一个实施例中是 2D 激光扫描仪。2D 激光扫描仪 3（j）提供一组三个数据（所谓的激光样本），其包含测量时间、测量角度及从激光扫描仪 3（j）到在此角度上可见的最近的固体的距离。通过组合汽车 1 位置及定向（其由所述汽车中的位置确定装置捕获）、激光扫描仪相对于汽车 1 的相对位置及定向及激光样本，创建如图 5 中所示的激光点地图。通过在垂直于所述汽车的行驶方向的方向上扫描的激光扫描仪获得图 5 中所示的激光点地图。如果使用多于一个激光扫描仪产生所述激光点地图，那么所述激光扫描仪可具有（举例来说）45°、90°及/或 135°的角度。如果仅使用一个激光扫描仪，垂直于行驶方向进行扫描的激光扫描仪在激光点地图空间中提供用于找到平行于行驶方向的垂直平面的最好分辨率。

在图 5 中，显示两个直方图：

1. 距离直方图 61-此直方图 61 显示在某一行进距离（例如，2 米）上相加的依据到汽车 1 的距离的激光扫描样本的数量，包括接近于汽车 1 的样本。当每 20 cm 制作激光扫描片时，将计及 10 片的激光扫描样本。图中显示接近于汽车 1 的峰值，其指示接近于汽车 1 的激光“回波”。由于激光扫描进行的角度扫掠，此峰值与接近于汽车 1 存在的许多回波相关。此外，较大距离处存在第二峰值，其与在距离汽车 1 的所述较大距离处识别的对象的垂直表面相关。
2. 距离直方图 63 仅显示距离汽车 1 的某一距离处的第二峰值，其指示仅一个对象。由于激光扫描的角分布，通过消除汽车 1 的直接附近区域中的较高密度的激光扫描样本来实现此直方图。此消除的作用是某人将更好地看到远离

汽车 1 的某一距离处的对象，即，建筑物 65 的正面。所述消除进一步具有在所述直方图中减小障碍物的影响的作用。此减小障碍物将错误地被辨识为垂直平面的机会。

直方图 63 上的峰值指示平行于汽车行进方向的平坦固体表面的存在。可通过任何可用方法确定汽车 1 与正面 65 之间的大约距离。举例来说，共用待决专利申请案 PCT/NL2006/050264 中所阐释的方法可用于所述目的，所述专利申请案以引用方式并入本文中。或者，可比较指示汽车 1 行进的轨道的 GPS（或其它）数据与显示建筑物的占地面积的位置的数据，且从而再现汽车 1 与正面 65 之间的大约距离数据。通过分析某一区域内关于此大约距离的直方图数据，将此区域内的局部最大峰值识别为是正面 65 的基点。将在（举例来说）此局部最大峰值之前 0.5 m 的垂直距离内的所有激光扫描样本视为正面 65 的建筑细节且标记为“平面点”。丢弃具有比最大峰值大的垂直距离的激光扫描样本或可将其标记为“平面点”。所有其它样本是具有在局部最大峰值的位置与汽车 1 的位置之间的位置的激光扫描样本，将其视为“鬼点”并这么标记。应注意，0.5 m 的距离仅作为实例给出。如果需要，可使用其它距离。

沿汽车 1 的轨迹，每 2 米执行一次直方图分析。以此方式，激光点地图划分成 2 米的片。在每个片中，直方图确定是否将激光扫描样本标记为“平面点”或“鬼点”。

B.动作 44：从激光点地图中抽取对象的平面坐标

标记为“平面点”的激光样本用于从激光点地图中抽取平面坐标。本发明在 3D 空间中对表示临街面（通常是建筑物正面）的表面进行处理。通过其中所述表面是多边形（其是表示建筑物正面的垂直矩形）的实例阐明本发明。应注意，所述方法可应用于任何‘垂直’表面。因此，下文说明中的术语“多边形”不应限于由笔直侧限定的闭合平面图，而是原则上可以是任何“垂直”表面。‘垂直’表面意指相机可看到的任何共用构造的表面。

从标记为“平面点”的激光扫描仪数据中抽取多边形。许多现有技术可用于找到平面或表面，包括基于 RANSAC（随机取样一致性）算法的方法。

简单的 RANSAC 算法直接用于标记为“平面点”的 3D 点上。对于仅垂直平面，本发明的简化的实施例首先通过丢弃 3D 点的高度值将所有非地面点投影在某一水平平面上。然后对所述水平平面的 2D 点使用 RANSAC 或霍夫变换（Hugh transform）来检测线。这些线用于导出平面沿所述线的下部及上部位置。

上文所述的算法需要额外处理来找到限制平面的多边形。已知用于找到限制平面的多边形的现有技术方法。在一个实例中，将来自所述平面的低于给定阈值的所有激光点投影在平面上。此平面类似于可对其应用聚类技术及图像分割算法以获得表示（举例来说）建筑物正面的边界的多边形的 2D 图像。图 6 显示多边形检测的实例性结果。通过组合来自两个激光扫描仪的激光扫描仪样本获得图 6 中所示的激光扫描仪地图。一个具有与汽车 1 的行驶方向 45°的角度且另一个具有与汽车 1 的行驶方向 135°的角度。因此，可紧在建筑物的前正面 600 的平面的多边形之后抽取侧正面 602、604 的平

面的两个多边形。对于每一所检测的平面，通过平面坐标描述多边形，所述平面坐标是预定坐标系统中平面的拐角的 3D 位置。

应注意，也可使用关于建筑物的地理参考 3D 位置（可从商业数据库获得）检索平面的多边形且确定来自激光扫描仪地图的激光扫描仪样本是否是“平面点”或“鬼点”。

应注意，当针对仅一个建筑物的临街面产生多视点全景图时，所述临街面的基点的定向可未必平行于行驶方向。

临街面的多视点全景图可用于产生路边多视点全景图。路边全景图是建筑物的多个多视点全景图的组合物。根据本发明的路边全景图的特性是：

全景图表示虚拟的共用构造的垂直表面；

全景图的每一像素列表示距离汽车的轨迹、街道的中心线或沿街道的线的任何其它表示的预定垂直距离处的垂直表面，及

全景图的每一像素表示表面的区域，其中所述区域具有固定高度。

如果产生街道的路边全景图，那么通常认为所述全景图的表面平行于行驶方向、沿道路延伸的道路的中心线或任何其它特征。因此，弯曲的街道的路边全景图的表面将遵循所述街道的曲率。认为所述全景图的每一点就像垂直于所述表面的定向看到的那样。因此，对于街道的路边全景图，在激光扫描仪地图中搜寻一直到最共用表面的距离或已给予所述距离预界定的值。此距离界定所述全景图在水平及垂直方向上的像素分辨率。所述垂直分辨率取决于所述距离，而所述水平分辨率取决于所述距离与沿所述街道的线的曲率的组合。然而，汽车的行驶方向与通过直方图分析找到的垂直表面的基点之间的垂直距离可包含不连续。此可在两个相邻建筑物不具有相同的建筑物线（即，不在同一平面上排成一行）时发生。为获得上文定义的路边全景图，每一建筑物表面的多视点全景图将变换为就像从一直到最共用表面的距离看到建筑物表面那样的多视点全景图。以此方式，每一像素将表示具有相等高度的区域。

在已知全景图中，具有相同大小但在不同距离处的两个对象在全景图中将以不同大小显示。根据本发明的实施例，将产生路边全景图，其中具有相对于行驶方向的不同垂直距离的两个类似对象在所述多视点全景图将具有相同大小。因此，当产生所述路边全景图时，每一正面的全景图将按比例缩放，使得所述路边全景图的每一像素将具有相同的分辨率。因此，在通过上述方法产生的路边全景图中，在 5 米的距离处的具有 10 米的实际高度的建筑物在所述路边全景图中将具有与在 10 米的距离处具有 10 米的实际高度的建筑物相同的高度。

具有上述特性的路边全景图显示沿街道的建筑物的正面，就像建筑物具有相同的建筑物线，而实际上其将不具有相同的建筑物线。全景图的重要视觉对象在同一平面中。此使得我们能够将前视全景图变换为透视图，而不存在令人烦恼的视觉变形。此具有所述全景图可用于在如图 3 中所示的系统上或具有最小的图像处理能力的任何种类的移动装置（例如，导航装置）上运行的应用程序中的优点。借助全景图（其中平

行于街道的方向的建筑物的正面按比例缩放以具有相同的建筑物线），可从任何观看角度呈现全景图的近现实视图。近现实视图是可表示现实但不对应于现实的易于理解的视图。

C.动作 46：源图像部分选择（使用阴影地图）

通过本发明获得的多视点全景图由来自通过相机 9（i）获得的图像序列的一组图像构成。每一图像具有相关联的位置及定向数据。未公开的专利申请案 PCT/NL2006/050252 中所描述的方法用于确定哪些源图像具有观看窗口，所述观看窗口包括在动作 44 中确定的表面的至少一部分。首先，从通过相机产生的至少一个源图像序列中选择具有包括必须为其产生全景图的表面的至少一部分的观看窗口的源图像。此可以完成，因为每一源图像具有捕获所述源图像的相机的相关联位置及定向。

在本发明中，表面对应于大致垂直的平面。知道相机的位置及定向以及观看角度及观看窗口，可确定所述观看窗口在表面上的投影。知道测角术数学的所属领域的技术人员能够将未公开的申请案 PCT/NL2006/050252 中所述的正射纠正方法重写为用于将具有任意观看角度的观看窗口投影在任意表面上的方法。通过三个操作执行多边形或表面区域在具有任意位置及定向两者的相机的观看窗口上的投影：相机焦点上的旋转，按比例缩放及平移。

图 7 显示源图像 700 的投影的透视图，其等于在虚拟表面 702 上的相机观看窗口。虚拟表面 702 对应于多边形且具有坐标（xt1, yt1, zt1）、（xt2, yt2, zt2）、（xt3, yt3, zt3）及（xt4, yt4, zt4）。参考 706 指示相机的焦点。相机的焦点 706 具有坐标（xf, yf, zf）。源图像 700 的边沿界定相机的观看窗口。穿过相机的焦点 706 的直线穿过观看窗口与虚拟表面 702 两者的交叉点界定从虚拟表面 702 的像素在源图像 700 的像素上的投影。此外，穿过相机的焦点 706 的直线与虚拟表面 702 的交叉点及标记为“鬼点”的激光扫描仪样本界定在观看窗口中不能够看到的虚拟平面的点。以此方式，障碍物 704 的阴影 708 可投影在虚拟表面 702 上。障碍物的阴影是虚拟表面（例如，正面）前方的一组邻接像素。由于所述虚拟表面的位置对应于临街面的位置，因此所述阴影可准确地投影在所述虚拟表面上。应注意，从临街面一直延伸 0.5 米的阳台被认为是共用结构表面的部分。因此，源图像中所述阳台的透视图在的细节将投影在多视点全景图上。所述透视图的细节是阳台的侧垂直于所述临街面，所述侧将不显像于建筑物的纯前视图像中。

以上投影方法用于选择观看表面的至少一部分的源图像。在选择观看所述表面的至少一部分的源图像之后，在激光扫描仪地图中，选择具有在相机的焦点的位置与所述表面的位置之间的位置的激光扫描仪样本。这些是标记为“鬼点”样本的激光扫描仪样本。选定的激光扫描样本表示妨碍相机记录虚拟表面 702 所表示的对象的障碍物。通过已知的算法将选定的激光扫描仪样本聚类以形成一个或一个以上固体障碍物。然后，在虚拟表面 702 上产生所述障碍物的阴影。此通过将穿过焦点 706 及所述固体障碍物的直线一直延伸到虚拟表面 702 的位置来完成。沿障碍物的边界的线撞击虚拟表

面 702 的位置对应于所述障碍物的阴影的边界点。

从图 7 中可看到，在图像中看到对象 704（即，树）在表面 702 前方。如果知道对象 704 相对于虚拟表面 702 及相机的焦点 706 的位置，那么可容易地确定对象 704 在虚拟表面 702 上的阴影 708。

根据本发明，使用从激光扫描仪地图检索的表面或来自商业数据库的关于建筑物正面的 3D 信息创建所述表面的地理定位多视点全景图。根据本发明的方法组合相机 9（i）位置及定向的 3D 信息、图像的焦距及分辨率（=像素大小）、所检测平面的 3D 信息及激光扫描仪地图的鬼点样本的 3D 位置。相机的位置及定向信息与激光扫描仪地图的组合使得所述方法能够针对每一个别图像确定：

1）相机所捕获的源图像是否包括表面的至少一部分；及

2）哪个对象妨碍相机显像将处于所述表面的所述部分的图像信息。

所述组合的结果使得所述方法能够确定虚拟平面所表示的正面在所述图像的哪些部分上可见。因此确定哪些图像可用于产生多视点全景图。将丢弃具有原本可捕获虚拟表面的至少一部分但由于相机前方的巨大障碍物而不能够捕获所述虚拟表面的任何部分的观看窗口的图像。表面的位置与相机位置之间的“鬼点”投影在源图像上。此使得所述方法能够找到障碍物在所述源图像上可见且因此在最终的多视点全景图上可见的表面或区域（阴影带）。

应注意，用以阐明本发明的实例使用多边形作为虚拟表面。已使用简单的实例减小所述实例的复杂性。然而，所属领域的技术人员将立即认识到本发明并不限于平坦表面而是可用于任何平滑表面，举例来说，垂直的弯曲表面。

图 8 及 9 分别显示将障碍物 806 投影在源图像 800 上及虚拟表面 804 上的俯视图及侧视图。从激光扫描仪地图获得障碍物 806 的位置。因此，根据本发明，不通过对多于一个图像使用图像分割及三角化算法以检测并确定平面及障碍物在图像中的位置的复杂的图像处理算法获得对象的位置，而是通过结合相机的位置及定向数据使用来自激光扫描仪地图的 3D 信息。结合相机的位置及定向数据使用激光扫描仪地图提供在图像中确定障碍物的位置的简单且准确的方法，所述障碍物妨碍相机显像在所述障碍物后方的对象的表面的区域。使用测角术来确定障碍物 806 在源图像 800 上的阴影 802 以及障碍物 806 在虚拟表面 804 上的阴影 808，所述虚拟表面描述对象（即，建筑物正面）的临街面的位置及定向。虚拟表面上的阴影 808 在本发明的以下说明中将称作阴影带。

通过找到源图像的以最好的方式显像已在激光扫描仪地图中找到的表面的区域且将所述区域投影在多视点全景图上来构成多视点全景图。应选择所述源图像的显像障碍物或在多视点全景图上显像具有最小阴影（=区域）的障碍物的区域并将其组合以获得多视点全景图。

将揭示用于找到所述源图像中用以产生多视点全景图的部分源图像的两个可能的实施方案。

第一实施例用于找到所述区域。

在所述第一实施例中已通过针对显像表面的一部分的每一源图像产生阴影地图实现以上目的。阴影地图是二进制图像，其中所述图像的大小对应于源图像的当投影在平面上时显像所述平面的区域且其中针对每一像素指示其在所述源图像中是否显像所述表面或障碍物。随后，将所有阴影地图叠置在对应于所述表面的主阴影地图上。以此方式，针对所述表面且因此针对将要产生的多视点全景图制作了一个主阴影地图。

在一个实施例中，产生主阴影地图，其中此主阴影地图中的阴影带指示选定的源图像中的至少一者在所述至少一个选定源图像的对应于所述阴影带的区域投影在多视点全景图上时显像障碍物。换句话说，此主阴影地图识别正面的哪些区域在所述图像中不被任何障碍物阻挡。应注意，主阴影地图的大小及分辨率类似于将要产生的多视点全景图的大小及分辨率。

所述主阴影地图用于将多视点全景图分成若干段。通过找到最好的“锯割路径”将所述主阴影地图切割为所述段来获得所述段，其中所述主阴影地图上的路径不将阴影带划分为两个部分。分割界定必须如何构成全景图。应注意，锯割路径总是跨越主阴影地图的已通过至少两个图像的阴影地图的叠置获得的区域。使所述路径在阴影带之间确保全景图中段之间的接缝在正面的可见部分中且不可能在将投影在所述正面上的障碍物的区域中。此使得所述方法能够选择用于将对应于段的区域投影在所述全景图上的最好图像。所述最好的图像可以是在对应于所述段的区域中不具有阴影带的图像或具有最小阴影带区域的图像。确定“锯割路径”的最好位置的额外标准可以是至少两个图像相对于将要产生的全景图的平面的定向的视角。由于所述至少两个图像具有不同的位置，因此相对于正面的视角将不同。已发现最垂直的图像将在全景图中提供最好的视觉质量。

可将每一段定义为多边形，其中通过预界定坐标系统中的 3D 位置界定多边形的边缘。由于“锯割路径”跨越在所有所述至少两个源图像中显像对应于所述平面的表面的像素，因此此允许所述方法在两个段之间创建平滑区。所述平滑减小多视点全景图中的视觉干扰。稍后将阐明本发明的此方面。所述平滑区的宽度可用作用于找到最好的“锯割路径”的另一个标准。所述平滑区的宽度可用于界定锯割路径与阴影带之间的最小距离。如果两个阴影带的边沿线之间的最近距离小于预界定的距离，那么将创建具有两个阴影带的段。此外，源图像的用于所述平滑区的像素不应表示障碍物。用于所述平滑区的像素是阴影周围的像素的边沿。因此，所述平滑区的宽度界定阴影带的边沿线与界定包含所述阴影带的段的多边形之间的最小距离。应注意，如果导致所述阴影带的障碍物在图像中部分可见，那么阴影带的边沿线与界定所述段的所述多边形之间的距离可为零。

通过组合源图像中与所述段相关联的部分源图像来产生多视点全景图。为获得多视点全景图的最佳显像，对于每一段，我们必须选择以最适当的方式显像对象的产生多视点全景图所必须针对的所述段的源图像。

以以下方式确定源图像的必须用于产生全景图的对应段的区域：

1. 选择具有显像段的整个区域的区域的源图像；

2. 从先前动作中的源图像中选择在与源图像相关联的阴影地图中的相关联段中包含最少数量的标记为阴影的像素的所述源图像。

第一动作确保仅从一个源图像中取源图像的对应于段的像素。此减小可见干扰的数量，例如部分地显像障碍物。举例来说，停放在建筑物的区域前方的汽车对应于可在三个图像中看到的段，一个显像前端，一个显像后端且一个显像整个汽车，那么在所述情况下将取来自显像整个汽车的图像的段。应注意，选择其它图像可产生显像将要通过全景图表示的对象的在选定图像中隐藏在汽车后方的更多细节的全景图。已发现，人们发现完全显像障碍物的图像比部分显像所述障碍物的图像更具吸引力。应进一步注意，可存在显像整个区域而不存在汽车的图像，然而其观看角度不如其它三个图像有利。在所述情况下，将选择此图像，因为其在与所述图像相关联的阴影地图中的相关联段中包含最少数量（零）的标记为阴影的像素。

此外，当存在显像整个区域而不存在任何对象（=零个标记为阴影的像素）的两个图像时，将选择具有最近的垂直观看角度的图像用于在多视点全景图中显像所述区域。

第一动作之后的第二动作确保选择显像通过全景图表示的对象的大部分的源图像。因此，对于每一段，选择在对应于所述段的区域中显像最小阴影带区域的源图像。

如果不存在显像对应于段的整个区域的任何图像，那么必须将所述段锯割为子段。在所述情况下，可使用图像边界作为锯割路径。将对所述子段重复先前的步骤以选择具有最有利区域的图像，以用于在多视点全景图中显像所述区域。确定所述最有利区域的参数是标记为阴影的像素的数量及观看角度。

换句话说，以以下方式组合用于多视点全景图的源图像：

1. 当主阴影地图中的阴影带间断时，在多视点全景图的位于所述主阴影地图所界定的阴影带之间的部分中执行拼接；

2. 当在投影在多视点全景图上的选定源图像中可见的障碍物的阴影带重叠或间断时，通过以下规则将所述多视点全景图的区域分成若干部分：

a）选择包含全阴影带的源图像放入多视点全景图中。当存在包含全阴影带的多于一个源图像时，选择以最接近于垂直向量的视角显像所述段的源图像。换句话说，显像所述段的前视源图像优选地为以上角度观看的源图像；

b）当不存在覆盖全阴影带的任何图像时，从显像所述段的源图像中的最垂直的部分源图像中取所述段。

第二实施例用于找到所述区域。

将通过图 16a-f 阐明所述第二实施例。图 16a 显示两个相机位置 1600、1602 及表面 1604 的俯视图。位于在两个相机位置 1600、1602 与表面 1604 之间的是第一障碍物 1606 及第二障碍物 1608。可在两个相机位置的观看窗口中看到第一障碍物 1606 且仅

可通过第一相机位置 1600 看到第二障碍物 1608。可通过将所述障碍物的阴影投影在表面 1604 上来导出三个（阴影）区。通过从第一相机位置 1600 将所述第二障碍物的阴影投影在所述表面上来获得区 1610。已通过分别从所述第二及第一相机位置将所述第一障碍物的阴影投影在所述表面上获得区 1612 及区 1614。将分别针对从第一及第二相机位置 1600、1602 捕获的源图像产生阴影地图。针对源图像的显像表面 1604 的一部分的每一部分，将产生阴影地图。此阴影地图（在与将要产生的表面 1604 的多视点全景图相同的坐标系统中参考）针对每一像素指示像素是否显像表面 1604 或由于障碍物而不显像所述表面。

图 16b 显示对应于从第一相机位置 1600 捕获的源图像的左阴影地图 1620 及对应于从第二相机位置 1602 捕获的源图像的右阴影地图 1622。所述左阴影地图显示表面 1604 的显像于所述源图像中的哪些区域不包含表面 1604 的视觉信息。区域 1624 是对应于第二障碍物 1608 的阴影且区域 1626 是对应于第一障碍物 1606 的阴影。可看到，第一障碍物 1606 高于第二障碍物 1608。右阴影地图 1622 仅显示一个区域 1628，区域 1628 不包含表面 1604 的视觉信息。区域 1628 对应于第一障碍物 1606 的阴影。

组合所述阴影地图以产生主阴影地图。主阴影地图是与必须针对其产生多视点全景图的表面相关联的地图。然而，根据第二实施例，对于所述主阴影地图中的每一像素，确定其是否可通过至少一个源图像来显像。所述主阴影地图的目的是找到所述全景图的不显像所述表面但将显像所述表面前方的障碍物的区域。

图 16c 显示已通过组合阴影地图 1620 与 1622 获得的主阴影地图 1630。可准确地进行此组合，因为准确地记录了每一相机的位置及定向。区域 1640 是表面 1604 的不能够通过从第一相机位置 1600 或第二相机位置 1602 捕获的任一源图像显像的区域。此区域 1640 的像素是临界的，因为其将总是显示障碍物且从不显示表面 1604。区域 1640 中的像素获得对应的值，例如“临界”。区域 1640 在表面 1604 的多视点全景图中将显示第一障碍物 1606 的一部分或第二障碍物 1608 的一部分。其它像素中的每一者将获得值，所述值指示多视点全景图的相关联像素的值可从至少一个源图像获得以显像所述表面。在图 16c 中，区域 1634、1636 及 1638 指示对应于相应源图像的阴影地图中的区域 1624、1626 及 1628 的区域。所述区域 1634、1636 及 1638 获得值，所述值指示多视点全景图的相关联像素的值可从至少一个源图像获得以显像所述表面。

主阴影地图 1630 随后用于针对每一源图像产生使用地图。使用地图具有与所述源图像的阴影地图相等的大小。所述使用地图针对每一像素指示：

1）源图像中对应像素的值是否应该用于产生多视点全景图，

2）源图像中对应像素的值是否不应该用于产生多视点全景图，及

3）源图像中对应像素的值是否可用于产生多视点全景图。

可通过针对源图像的阴影地图中的每一阴影带检验主阴影地图中的对应区域是否包含指示像素不能够通过所述源图像中的任一者显像多视点全景图中的表面 1604 的至少一个像素来产生此地图。如果是，对应于整个阴影带的区域将标记为“应使用”。

如果否，对应于整个阴影的区域将标记为“不应使用”。剩余像素将标记为“可使用”。图 16d 显示已通过组合阴影地图 1620 中的信息与主阴影地图 1630 获得的左使用地图 1650。区域 1652 对应于第二障碍物 1608 的阴影。此区域 1652 已获得值“应使用”，因为阴影地图 1620 中的区域 1624 在主阴影地图中具有一个或一个以上标记为“临界”的对应像素。此意指，如果区域 1652 的一个像素必须用于产生多视点全景图，那么必须使用所述区域的所有其它像素。区域 1654 对应于第一障碍物 1606 的阴影。所述区域 1654 已获得值“不应使用”，因为对应阴影地图 1620 中的区域 1626 在所述主阴影地图中的对应区域 1636 中不具有标记为“临界”的任何像素，此意指可通过在通过第二相机 1602 捕获的源图像中选择对应的区域来从多视点全景图中移除第一障碍物 1606。因此，源图像中对应于区域 1654 的区域不应该用于产生表面 1604 的多视点全景图。已通过组合阴影地图 1622 中的信息与主阴影地图 1630 获得图 16d 的右使用地图 1656。区域 1658 对应于第二障碍物 1606 的阴影。此区域 1658 已获得值“应使用”，因为阴影地图 1622 中的区域 1628 在主阴影地图中具有一个或一个以上标记为“临界”的对应像素。此意指，如果区域 1658 的一个像素必须用于产生多视点全景图，那么必须使用所述区域的所有其它像素。

使用地图 1650 及 1656 来选择源图像中的哪些部分必须用于产生多视点全景图。将给出用以分派源图像中将要选择的部分源图像的算法的一个实施例。所属领域的技术人员应清楚，可使用其它可能的算法。图 17 中显示所述算法的流程图。所述算法以检索空选择地图开始，所述空选择地图针对多视点全景图的每一像素指示哪个源图像应该用于产生表面 1604 的多视点全景图及与每一源图像相关联的使用地图 1650、1656。

随后选择 1704 尚未向其分派源图像的选择地图的像素。在动作 1706 中，搜索在其相关联使用地图中具有标记为“应使用”或“可使用”的对应像素的源图像。优选地，如果所有使用地图中的对应像素标记为“可使用”，那么选择具有相对于所述像素的最垂直观看角度的源图像。此外，为优化全景图中的表面 1604 的可见性，在使用地图中的一者中的对应像素标记为“必须使用”的情况下，优选地借助主阴影地图，选择在使用地图中具有标记为“必须使用”的最小区域的源图像，其覆盖主阴影地图中标记为“临界”的区域。

在选择所述源图像之后，在动作 1708 中，使用选定图像的使用地图来确定所述源的在所述选定像素周围的哪一区域应该用于产生全景图。此可通过增长算法完成。举例来说，通过选择使用地图中标记为“应使用”及可使用的所有相邻像素（且其中尚未将源图像分派给选择地图中的对应像素）。

下一动作 1710 确定是否已向所有像素分派源图像。如果否，通过选择尚未向其分派源图像的像素来再次执行动作 1704 且将重复随后的动作直到将向每一像素分派源图像。

图 16e 显示两个图像，所述两个图像识别选择源图像中的哪些部分用于产生表面

1604 的多视点全景图。所述部分源图像的组合显示于图 16f 中，其对应于表面 1604 的多视点全景图的选择地图 1670。图 16e 的左图像 1660 对应于通过第一相机 1600 捕获的源图像且右图像 1662 对应于通过第二相机 1602 捕获的源图像。选择地图 1670 的左段 1672 中的像素被分派到从第一相机位置 1600 捕获的源图像中的对应区域，此区域对应于图 16e 的左图像 1660 中的区域 1664。选择地图 1670 的右段 1674 中的像素被分派到从第二相机位置 1602 捕获的源图像中的对应区域。此区域对应于图 16e 的右图像 1662 中的区域 1666。

当应用上述算法时，在选择地图的左部选择像素，例如左上像素。所述像素仅存在于一个源图像中。在动作 1708 中，相邻区域可增长直到其由选择地图的边沿及标记为“将不使用”的像素限定。以此方式，选择区域 1664 且在选择地图 1670 中，向段 1672 的像素分派第一源图像。随后，选择尚未向其分派源图像的新像素。此像素位于区域 1666 中。随后，选择所述像素的相邻区域。区域 1666 的边沿由源图像边沿及选择地图 1670 中已分派到其它源图像（即，分派到通过第一相机捕获的图像）的已经分派的像素界定。

从源图像中选择对应于段 1672 及 1674 的像素将产生多视点全景图，其中第一障碍物 1606 不可见且第二障碍物安全可见。

在图 16e 的右图像中，区域 1668 识别哪些对应的像素可用于产生表面 1604 的多视点全景图的区域。可通过按照以下标准扩展动作 1708 来获得此区域：当与其它源图像的重叠边沿的宽度超过预界定的阈值（例如，7 个像素）或在使用地图中标记为“应使用”或“不应使用”的像素处时，所述增长过程停止。区域 1668 是此种重叠边沿。此在图 16e 中由区域 1676 图解说明。此区域可用作平滑区。此使得所述方法能够掩饰两个相邻源图像之间的不规则性，例如图像之间的色彩差异。以此方式，色彩可从第一图像的背景色彩平滑地变为第二色彩的背景色彩。此减小正常应具有相同色彩的区域中突发色彩改变的数量。

用于选择源图像部分的上述两个实施例针对多视点全景图产生地图，其中每一像素被分派到源图像。此意指，将通过将对应的源图像部分投影在多视点全景图上来获得在多视点全景图中可见的所有信息。两个实施例尝试通过选择源图像中显像表面而不是障碍物的部分源图像消除尽可能多的障碍物。如果仅应用源图像部分的像素在全景图上的投影，那么表面的一些部分不在任何源图像中显像且因此将显像障碍物或障碍物的部分。然而，所述两个实施例可适于首先导出所述表面的不能够从所述源图像中的任一者看到的区域的特征。这些区域对应于所述第二实施例的主阴影地图中的阴影。可导出的一些特征是高度、宽度、形状、大小。如果区域的特征与预界定的标准匹配，那么多视点全景图中对应于所述区域的像素可从多视点全景图中包围所述区域的像素中导出。举例来说，如果所述区域的宽度在多视点全景图中不超过预定的像素数量（例如，街灯柱的阴影），那么可通过分派相邻像素的平均值或插入来获得所述像素值。应清楚，可应用其它阈值函数。

此外，可应用决定所产生的障碍物是否显著得足以以某一保真度重新产生的算法。举例来说，挡住正面的树显示在两个图像中，在一个图像中在图像的边沿处仅看到一小部分且在另一个图像中看到整棵树。所述算法可经布置以确定在全景图中包括所述小部分是否不会看起来愚蠢。如果是，则显示所述小部分，从而产生显像正面的最大部分的全景图及由于所述树而产生的小的视觉不规则性。如果否，那么将包括整棵树，从而产生显露正面的较小部分的全景图，但不存在关于所述树的视觉不规则性。以这些方式，可进一步减小可见障碍物的数量及在多视点全景图中的对应大小。此使得所述方法能够提供具有最好的视觉效果的全景图。可对相应的阴影地图执行所述函数。

D.动作 48：从选定的源图像部分构成全景图

在产生对应于多视点全景图的段地图并针对每一段选择源图像（其应该用于投影所述源图像中对应于所述段的区域）之后，将所述源图像中与所述段相关联的区域投影在全景图上。此过程可与未公开的专利申请案 PCT/NL2006/050252 中所述的正射纠正方法比较，所述正射纠正方法可描述为对源图像的区域执行三个操作，即，相机全焦点上的旋转、按比例缩放及平移，此均为图像处理中众所周知的算法。所有段一同形成组合图画，其是多视点全景图，因为使用具有不同位置的图像（=多视点）。

可通过沿两个段的边界界定平滑区来减小或消除从一个段到另一个段的交叉点处的视觉不规则性。

在一个实施例中，通过对第一及第二源图像中的对应像素的值求平均来获得所述平滑区的像素的值。在另一个实施例中，通过以下公式获得所述像素值：$value_{pan} = \alpha \times value_{image1} + (1-\alpha) \times value_{image2}$，其中 $value_{pan}$、$value_{image1}$ 及 $value_{image2}$ 分别是多视点全景图、第一图像及第二图像中的像素值且 α 是在 0 到 1 的范围内的值，其中当所述平滑区触及所述第一图像时 α = 1 且当所述平滑区触及所述第二图像时 α = 0，α 可从所述平滑区的一个侧线性地改变到另一个侧。在所述情况下，$value_{pan}$ 是所述平滑区的中部第一及第二图像的值的平均值，所述中部通常是拼接的地方。应注意，参数 α 在从 0 到 1 变化时可具有任何其它合适的过程。

在图像处理技术领域中，已知用以获得从一个段到另一个段的平滑交叉的许多其它算法。

将通过一些简单的实例阐明上述方法。

图 10 显示在不同位置 A、B 上且记录同一平面 1004 的两个相机 1000、1002 的俯视图。所述两个相机 1000、1002 安装在移动的车辆（未显示）上且所述车辆从位置 A 向位置 B 移动。箭头 1014 指示行驶方向。在所述给出的实例中，源图像序列仅包括显像平面 1004 的两个源图像。当车辆在位置 A 处时从第一相机 1000 获得一个源图像。当车辆在位置 B 时从第二相机 1002 获得另一个源图像。图 11 显示来自图 10 中所示的情形的透视图像。所述左及右透视图像分别对应于通过第一相机 1000 及第二相机 1002 捕获的源图像。两个相机具有相对于车辆的行驶方向的不同的视角。图 10 显

示障碍物 1006，举例来说位于位置 A 及 B 与平面 1004 之间的圆柱。因此平面 1004 的部分 1008 在通过第一相机 1000 捕获的源图像中不可见且平面 1004 的部分 1010 在通过第二相机 1002 捕获的源图像中不可见。

与通过相机 1000 捕获的源图像相关联的阴影地图在右半边具有阴影且与通过相机 1000 捕获的源图像相关联的阴影地图在左半边具有阴影。图 10 显示平面 1004 的主阴影地图的俯视图。所述阴影地图包含两个间断的阴影 1008 及 1010。根据本发明，拼接所述主阴影地图的地方 1012 在所述两个阴影 1008 与 1010 之间。在图 11 中，多边形 1102 及 1104 表示其中划分平面 1004 的两个段。

如上所述，根据本发明的方法针对每一段分析每一源图像的阴影地图中的对应区域。将选择以最小的阴影区域显像所述段的源图像。在所述给出的实例中，将选择在对应段中不包含阴影的源图像来表示所述区段。因此，将从通过第一相机 1000 捕获的图像中获得由图 11 中的多边形 1102 指示的平面 1004 的左部分且将从通过第一相机 1002 捕获的图像中获得由图 11 中的多边形 1104 指示的平面 1004 的右部分。

图 12 图解说明在针对每一段选择用以显像对应的段的对应的源图像之后从图 11 中所示的两个图像构成图 10 中的平面 1004 的全景图的过程。在一个实施例中，将多边形 1102 及 1104 所界定的段投影在平面 1004 的多视点全景图上。

所述两个段在拼接的地方 1202 处不能完美地匹配。原因可能是所述两个源图像在拼接的地方 1202 处在分辨率、色彩及其它视觉参数上的差异。当所述两个段在拼接的地方 1202 的两个侧处的像素值是直接从相应图像中的仅一者中导出时，用户可在全景图中注意到所述不规则性。为减小所述缺陷的可见性，可在拼接的地方 1202 周围界定平滑区 1204。

图 13 及 14 显示与上文给出的用于阐明本发明的实例类似的另一个简单实例。在此实例中，另一个障碍物阻碍显像平面 1304。图 13 显示在不同位置 C、D 上且记录同一平面 1304 的两个相机 1300、1302 的俯视图。所述两个相机 1300、1302 安装在移动的车辆（未显示）上且所述车辆从位置 C 向位置 D 移动。箭头 1314 指示行驶方向。在所述给出的实例中，源图像序列仅包括显像平面 1304 的两个源图像。当车辆在位置 C 处时从第一相机 1300 获得一个源图像。当车辆在位置 D 时从第二相机 1302 获得另一个源图像。图 14 显示来自图 13 中所示的情形的透视图像。图 14 中所示的左及右透视图像分别对应于通过第一相机 1300 及第二相机 1302 捕获的源图像。两个相机具有相对于车辆的行驶方向的不同的视角。图 13 显示障碍物 1306，举例来说，位于位置 C 及 D 与平面 1004 之间的圆柱。因此平面 1308 的部分 1304 在通过第一相机 1300 捕获的源图像中不可见且平面 1310 的部分 1304 在通过第二相机 1302 捕获的源图像中不可见。

图 13 显示与平面 1304 相关联的主阴影地图的俯视图。所述主阴影地图显示具有重叠区域的阴影 1008 与 1010。因为仅存在显像平面 1304 的两个图像，因此不能够在所述图像中的任一者中看到与所述阴影相关联的平面的对应于所述重叠的区域。因此

平面 1304 的全景图中对应于所述重叠的区域将显像障碍物 1306 的对应部分。现在，可将所述主阴影地图划分为三个部分，其中一个部分包含所述阴影。界定包含所述阴影的段的多边形的边沿线优选地以最小距离与所述阴影的边沿线间隔开。此允许我们界定平滑区。参考 1312 及 1316 指示所述段的左及右边沿线。当两个源图像完全显像所述段（在图 14 中可容易地看到的情景）时，将从具有相对于所述平面的最垂直的视角的源图像中取所述段。在所述给出的实例中，将从通过第二相机 1302 拍摄的源图像中取所述段。当将从同一源图像中取包含障碍物的段及所述平面的最右边部分时，可移除具有参考 1316 的边沿线且不必在那里界定平滑区。因此，最终剩下两个段构成平面 1304 的全景图。在图 14 中，多边形 1302 及 1304 表示源图像的用于构成平面 1304 的两个段。参考 1312 指示可在那里界定平滑区的边沿线。

上述方法自动地执行。可能碰巧多视点全景图的质量使得执行本发明的图像处理工具及对象辨识工具需要某一校正。举例来说，在激光扫描仪地图中找到的多边形对应于两个邻近的建筑物，而对于每一建筑物正面，必须产生全景图。在所述情况下，所述方法包括一些验证及手动调适动作以实现确认或调适中间结果的可能性。这些动作还可适于接受道路信息产生的中间结果或最终结果。此外，表示建筑物表面的多边形及/或关于一个或一个以上连续源图像的阴影地图的叠置可用于请求人来执行验证。

通过本发明产生的多视点全景图与合适的坐标系统中的相关联位置及定向数据一同存储在数据库中。所述全景图可用于测绘出伪现实、易于理解的视图及在如谷歌地球(Google Earth)、谷歌街景(Google Street View)及微软虚拟地球(Microsoft's Virtual Earth）等应用中产生世界各地的城市的视图或可方便地存储或安排在导航装置上。

如上所述，多视点全景图用于产生路边全景图。

图 15a-15d 显示通过本发明产生的路边全景图的应用。所述应用增强当前导航系统及因特网上的导航应用的视觉输出。执行所述应用的装置不需要专用的图像处理硬件来产生输出。图 15a 显示街道的伪透视图，其可在不使用路边的建筑物的复杂 3D 模型的情况下容易地产生。已通过处理所述街道的左及右路边全景图及两个多视点全景图之间的道路表面（地球表面）的图生相似性（map generated likeness）获得所述伪透视图。所述地图及两个图像可能已通过处理已在移动测绘活动时间期间记录的图像序列及位置/行进方向数据获得，或可能已使用虚拟平面的图像且将其与从数字地图数据库中导出的数据组合。图 15b 显示街道的左侧的路边全景图且图 15c 显示街道的右侧的路边全景图。图 15d 显示从地图数据库或也可从街道的经正射纠正的图像（也从移动测绘车辆收集）扩展的段。可看出，可借助非常有限数量的平面产生街道的伪现实视图。参考 1502 及 1506 分别指示已通过制作图 15b 及 15c 的全景图的伪透视图获得的图像的部分。所述部分 1502 及 1506 可容易地通过将图 15b 及 15c 的全景图变换为透视图像来产生，所述变化是通过依序（以具有距离观看位置最远的位置的像素列开始一直到具有距离观看点最近的位置的像素列）将所述路边全景图的像素列投影在所述伪现实视图上进行的。参考 1504 指示已通过制作地图数据库或道路表面的经正射

纠正的图像的透视图的扩展获得的图像的部分。

应注意，在伪透视图像中，道路的一侧的所有建筑物具有相同的建筑物线且因此其不能是完全透视图。实际上，每一建筑物可具有其自己的建筑物线。在通过缝隙扫描相机捕获的全景图中，所述建筑物则将具有不同的大小。在本应用中使用此类型的的全景图将产生看起来奇怪的透视图像。建筑物与道路之间的不同垂直距离在透视图像中将解释为建筑物的不同高度及大小。在此种情况下，本发明能够以更完全的3D表示所需要的处理能力的一小部分产生相当现实的视图图像。根据根据本发明的方法，在两个步骤中产生街道的路边全景图。首先，对于沿街道的建筑物，将制作一个或一个以上多视点全景图。其次，通过将所述一个或一个以上多视点全景图投影在一个共用平滑表面上来产生路边全景图。在一个实施例中，所述共用平滑表面平行于沿所述道路的线，例如，汽车的轨迹线、中心线、边沿线。“平滑”意指所述表面与沿所述道路的线之间的距离可变化，但不突发地变化。

在所述第一个动作中，针对沿路边的每一平滑表面产生多视点全景图。可通过具有相同建筑物线的一个或一个以上相邻建筑物正面形成平滑表面。此外，在此动作中，将移除所述表面前方尽可能多的障碍物。障碍物的移除可仅在表面的所确定位置对应于建筑物的正面的实际位置时准确地进行。所述表面沿所述道路的定向可变化。此外，道路的方向与沿街道的两个相邻多视点全景图的表面之间的垂直距离可变化。

在第二个动作中，从在第一个动作产生的多视点全景图产生路边全景图。假设所述多视点全景图是沿所述道路的平滑表面，其中认为每一像素表示就像从垂直于表面的所界定距离看到的所述表面。在根据本发明的路边全景图中，所述路边全景图的每一像素的垂直分辨率是类似的。举例来说，像素表示具有5 cm的高度的矩形。所述应用中所使用的路边全景图是虚拟表面，其中沿所述路边的建筑物的每一多视点全景图按比例缩放使得其在所述虚拟表面处具有类似的垂直分辨率。相应地，将在全景图中显像具有具有相等临街面但具有不同建筑物线的房屋的街道，就像房屋具有相同建筑物线及类似临街面那样。

对于上述路边全景图，深度信息可沿全景图的水平轴相关联。此使得在具有某一强大的图像处理硬件的系统上运行的应用能够根据建筑物的实际位置从全景图产生3D表示。

在当前的数字地图数据库中，街道及道路存储为道路段。可通过在数据库中使左及右路边全景图及任选地所述街道的道路表面的经正射纠正的图像与每一段相关联来改善使用数字地图的本应用的视觉输出。在所述数字地图中，可通过绝对坐标或关于段的预界定坐标的坐标来界定多视点全景图的位置。此使得所述系统能够准确地确定输出中的全景图的伪透视图相对于所述街道的位置。

将通过若干段表示具有交叉点或汇合点的街道。所述交叉点或汇合点将是段的开始点或结束点。当数据库针对每一段包含相关联的左及右路边全景图时，可容易地通过制作与可见且在合理的距离处的街道的段相关联的左及右路边全景图的透视图来产

生如图 15a 中所示的透视图。图 15a 是针对汽车具有平行于街道的方向的行驶方向的情形产生的透视图像。箭头 1508 指示汽车在道路上的定向及位置。当针对最共用的平面产生全景图时，全景图将以最左边的建筑物开始且以对应于道路段的路边的最右边的建筑物结束。因此，交叉点处的建筑物之间的空间不存在全景图。在一个实施例中，所述透视图像的这些部分将不与信息一同归档。在另一个实施例中，透视图像的这些部分将与全景图的与连接到交叉点或汇合点的段相关联的对应部分及扩展的地图数据或经正射纠正的表面数据一同归档。以此方式，交叉点的拐角处的建筑物的两个侧将显示在透视图像中。

在不具有专用图像处理硬件的导航系统中，当驾驶汽车时，仍可依据行进的距离频繁地刷新显示器，例如每一秒。在所述情况下，透视图每一秒将基于导航装置的实际 GPS 位置及定向产生并输出。

此外，根据本发明的多视点全景图适合在用于容易地提供街道、地址或所关心的任何其它点的周围的伪现实视图的应用中使用。举例来说，输出呈现线路规划系统可容易地通过添加根据本发明的地理参考路边全景图而增强，其中建筑物的正面已按比例缩放以使建筑物的像素的分辨率相等。此种全景图对应于街道的全景图，其中沿所述街道的所有建筑物具有相同的建筑物线。用户搜寻位置。然后，对应的地图呈现在屏幕上的窗口中。随后，在屏幕上的另一个窗口中（或临时在同一窗口上），根据对应于所述位置的垂直于道路的定向的路边呈现图像（像 15b 或 15c 的图像）。在另一个实施方案中，屏幕上的地图的方向可用于界定应以何种定向给出全景图的透视图。认为路边全景图的所有像素表示路边全景图的表面的位置处的临街面。所述路边全景图仅包含假设在所述表面上的视觉信息。因此，可针对路边全景图的任何任意观看角度容易地制作伪现实透视图。通过系统的旋转功能，所述地图可在所述屏幕上旋转。同时，可产生对应于所做的旋转的对应的透视伪现实图像。举例来说，当街道的方向是从屏幕的左侧到右侧表示数字地图的对应部分时，将仅显示如图 15b 中所示的全景图的一部分。可在无需变换所述图像的情况下显示所述部分，因为假设所述显示表示路边视图，其垂直于街道的方向。此外，所示部分从用户选择的位置对应于左及右全景图的预定区。当所述街道的方向是从屏幕的底部到顶部，那么将通过组合左及右路边全景图及任选地道路表面的经正射纠正的图像产生像图 15a 那样的透视图。

所述系统还可包含翻转功能，以通过一个指令在 180°上旋转所述地图及观看街道的另一侧。

系统的扫视功能可用于沿地图上的街道的方向行走且同时依据屏幕上的地图的定向显示街道的对应显像。每当将伪现实图像呈现为所使用的图像时，左及右路边全景图及经正射纠正的道路表面图像（如果需要）表示经纠正的图像。经纠正的图像是其中每一像素表示建筑物正面的纯前视图及道路表面的俯视图的图像。

图 15b 及 15c 显示街道的路边全景图，其中所有的房屋具有相同的地平面。然而，对于所属领域的技术人员显而易见的是，上述方法通常将产生其中具有不同地平面的

房屋在路边全景图中将显示为不同高度的路边全景图。图 18 显示此种路边全景图。在所述路边全景图中，在显示器上应仅显示对应于表示多视点全景图的表面的像素。因此，当在显示器上重新产生所述路边全景图时，不应计及区域 1802 及 1804 中的像素。优选地，将给予所述区域 1802 及 1804 能够检测沿所述路边的对象的区域的边沿线在哪里的值、图案或纹理。举例来说，所述区域 1802 及 1804 中的像素将获得图像中通常不存在的值，或在每一像素列中，所述像素的值以第一预界定的值开始且以具有第二预界定的值的像素结束，其中所述第一预界定的值不同于所述第二预界定的值。应注意，山上的建筑物可具有其中地平面具有坡度的临街面。则此也将在临街面的多视点全景图及包含所述多视点全景图的路边全景图中看到。

存在当在屏幕上产生数字地图的透视图像时显像道路的高度信息的应用。如图 18 中所示的路边全景图非常适合在用以提供街道的伪现实透视图的那些应用中使用。道路表面的高度在大多数情况下将与临街面的地平面匹配。可能已将临街面的多视点全景图投影在与路边全景图相关联的表面上。在所述情况下，道路表面的高度可能不与临街面的地平面的高度匹配。可给所述应用提供检测道路表面的高度与多视点全景图中的临街面的地平面之间的差异的算法。因此，所述应用经布置以通过检测区域 1802 的顶部像素的位置来在每一像素列中确定对应于所述路边全景图所表示的对象的像素的最低位置的垂直位置。由于每一像素表示具有预定高度的区域，因此可确定道路表面与地平面之间在高度上的差异。随后使用沿街道的此差异来校正全景图中的临街面的高度且产生道路表面与路边的伪透视图像，其中所述道路表面的高度与所述临街面的地平面的高度匹配。

存在使用不包含道路的高度的地图的应用。因此，其仅适于产生水平地图的透视图。图 18 的路边全景图的组合将产生透视图像，其中建筑物的地平面沿所述道路变化。此不一致性可能看起来不现实。将给出其中这些应用可提供伪现实透视图像的两个实施例。

在第一个实施例中，所述应用将从路边全景图中导出高度信息且使用所述高度信息增强水平地图的透视图。因此，所述应用经布置以通过检测区域 1802 的顶部像素的位置来在每一像素列中确定对应于所述路边全景图所表示的对象的像素的最低位置的垂直位置。由于每一像素表示具有预定高度的区域，因此可确定沿街道在高度上的差异。随后使用沿街道的此差异产生道路表面的伪透视图像，其显像沿所述街道在高度上的对应差异。以此方式，可组合所述路边全景图与道路表面，其中在所述伪现实透视图像中，所述道路表面与路边视图的表面将是邻接的。对于所属领域的技术人员显而易见的是，如果必须根据图 18 中所示的临街面地平面产生具有不同高度的道路表面，那么应产生逐渐增大/减小的道路表面。优选地，向从路边全景图导出的沿街道的地平面应用平滑功能。应用此平滑功能的结果是道路表面的高度平滑地改变，此是道路表面的更加现实的视图。

在第二实施例中，与第一实施例相反，所述应用将从路边全景图中移除区域 1802

且使用由此获得的图像与水平地图组合。区域 1802 的移除将产生与图 15c 中所示的路边全景图类似的图像。通过从所述路边全景图中移除高度信息，产生伪现实透视图像，表示其中沿道路的建筑物全部具有相同的地平面的水平道路表面。在所述情况下，路边全景图中的正面的地平面具有坡度，可通过门及窗户的视觉矩形性的扭曲在伪现实透视图像中看到所述坡度。

出于例示及说明目的，上文已提供了对本发明的详细说明。并不打算穷尽列举本发明的形式或将本发明限于所揭示的确切形式，且显然鉴于以上教示许多修改及变化均可行。举例来说，替代使用两个或多于两个相机的源图像，可仅使用一个相机的图像序列来产生建筑物表面的全景图。在所述情况下，对于在垂直于移动车辆的轨迹的预界定距离处的正面，两个连续图像应具有足够的重叠，举例来说，>60%。

为最好地阐释本发明的原理及其实际应用，因此选择所述实施例，以使所属领域的技术人员能够最好地利用各个实施例中的本发明且通过所涵盖的适用于特定用途的各种修改来最好地利用本发明。本发明的范围既定由所附权利要求书予以界定。

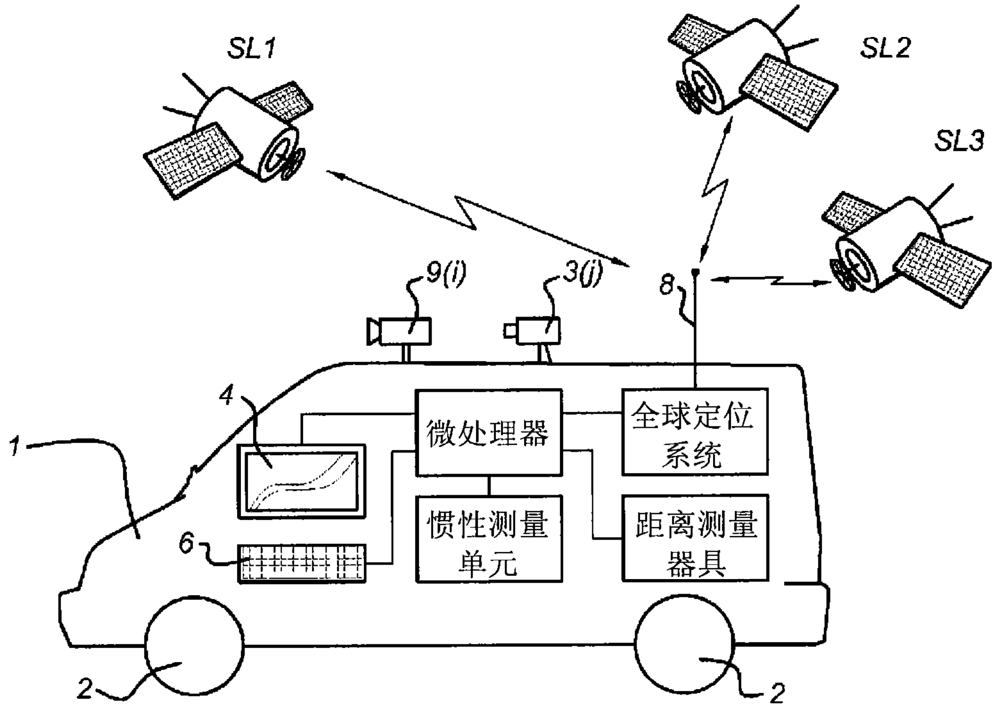

SL1
SL2
SL3
9(i)
3(j)
8
4
1
6
2
2
微处理器
全球定位系统
惯性测量单元
距离测量器具

图 1

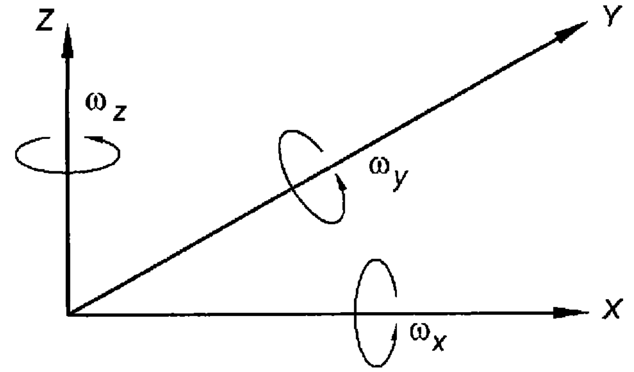

Z
Y
X
ω_z
ω_y
ω_x

图 2

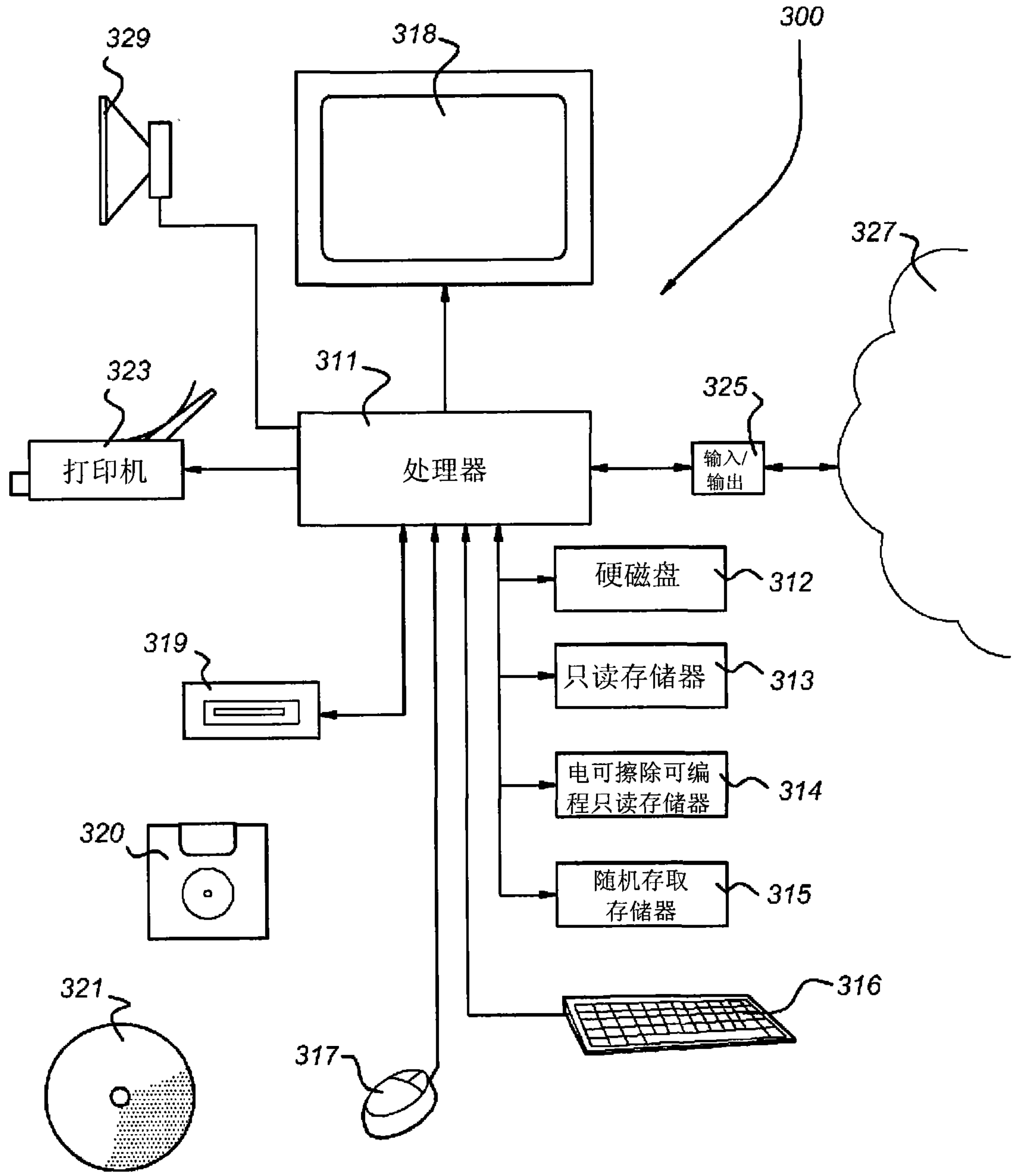

300
329
318
327
311
323
325
打印机
处理器
输入/
输出
硬磁盘
312
319
只读存储器
313
电可擦除可编
程只读存储器
314
320
随机存取
存储器
315
321
316
317

图 3

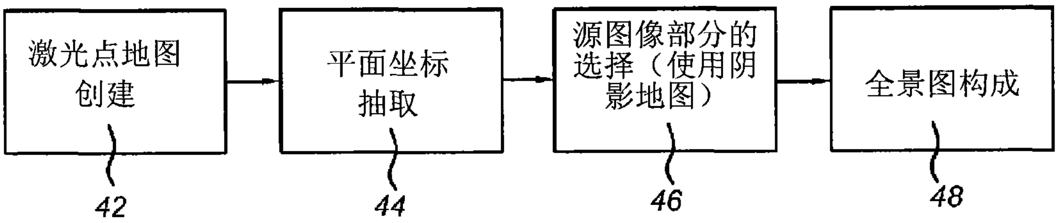


图 4

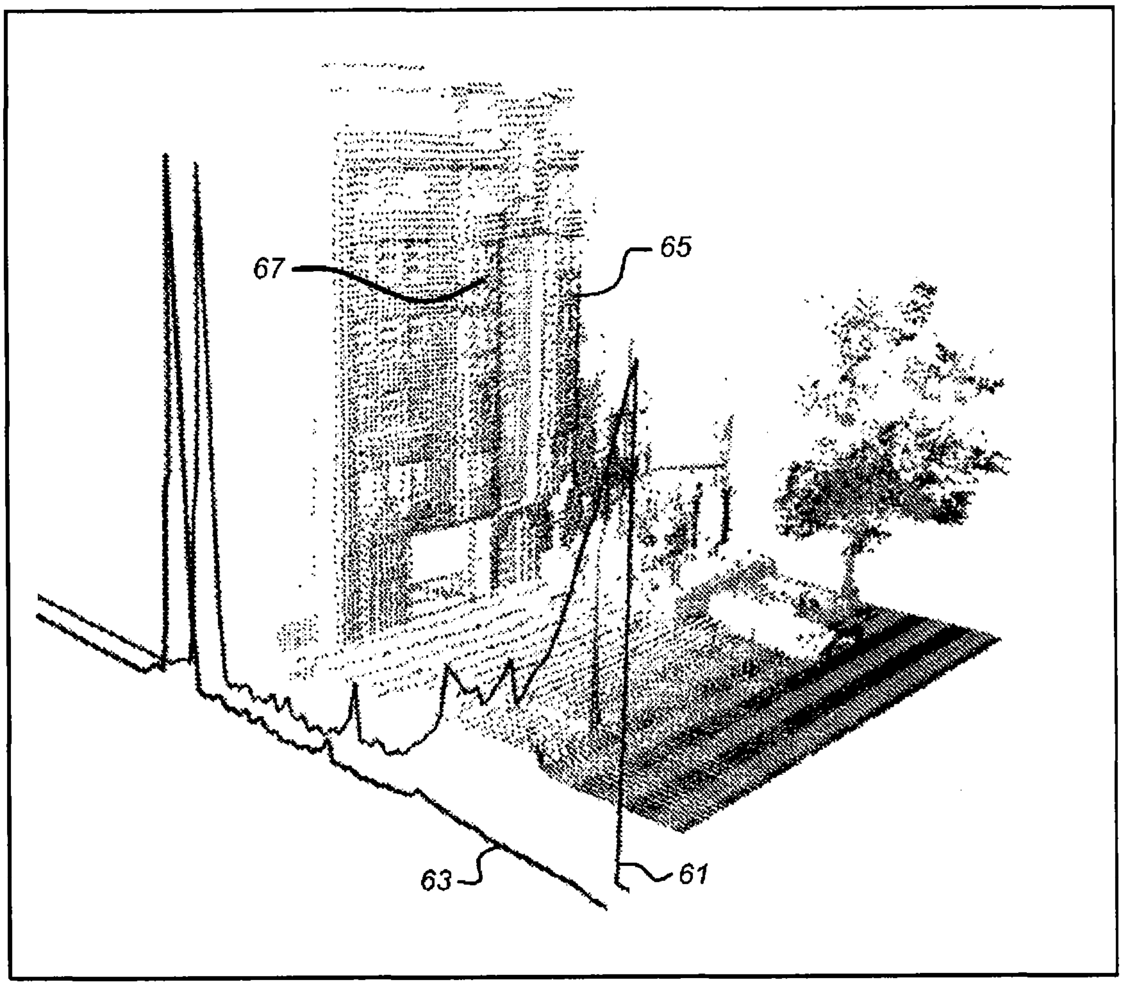


图 5

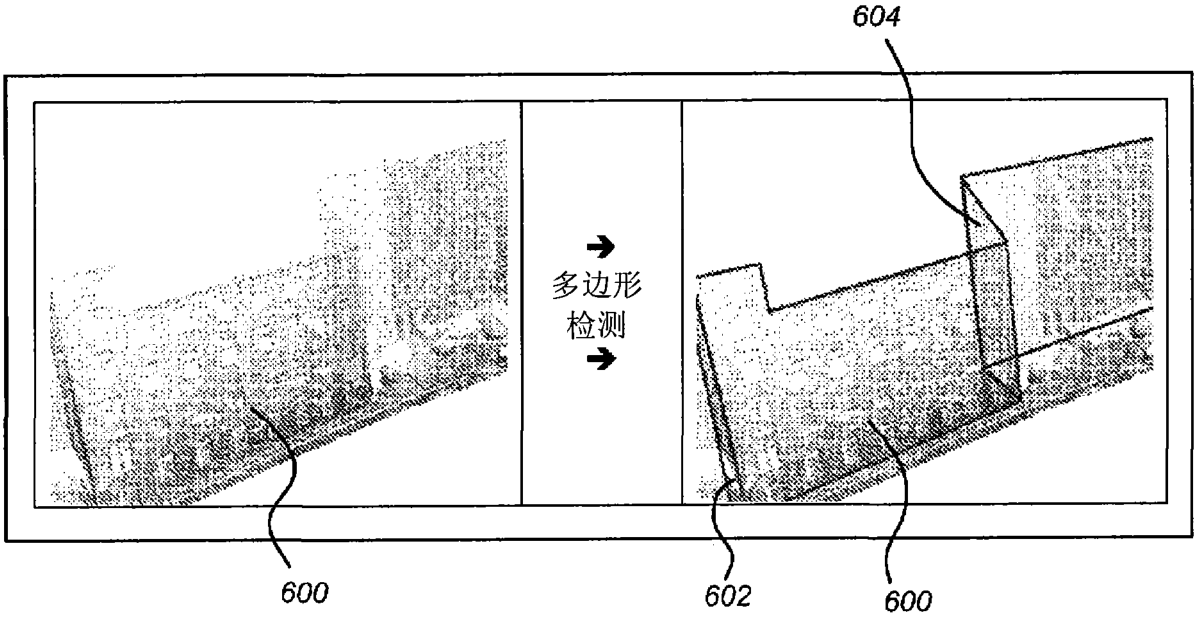

604
多边形
检测
600
602
600

图 6

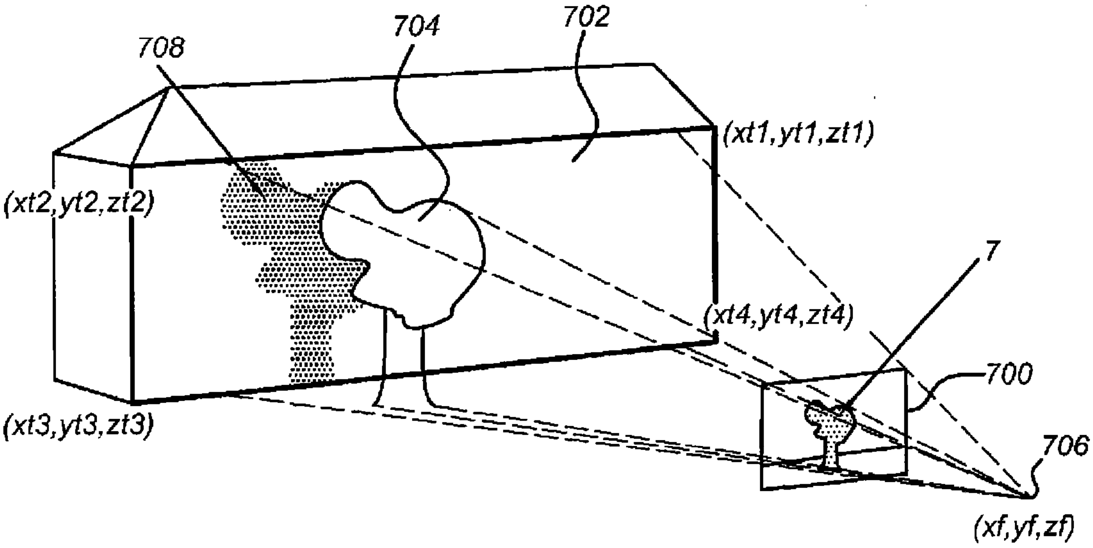

708
704
702
(xt1,yt1,zt1)
(xt2,yt2,zt2)
7
(xt4,yt4,zt4)
700
(xt3,yt3,zt3)
706
(xf,yf,zf)

图 7

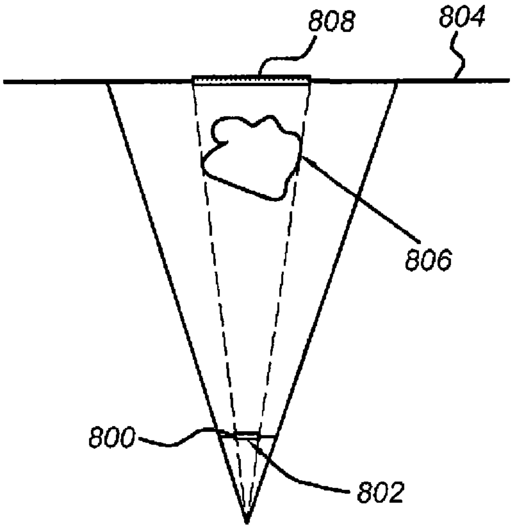

808
804
806
800
802

图 8

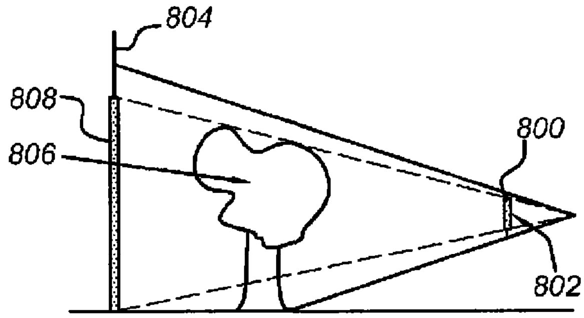

804
808
806
800
802

图 9

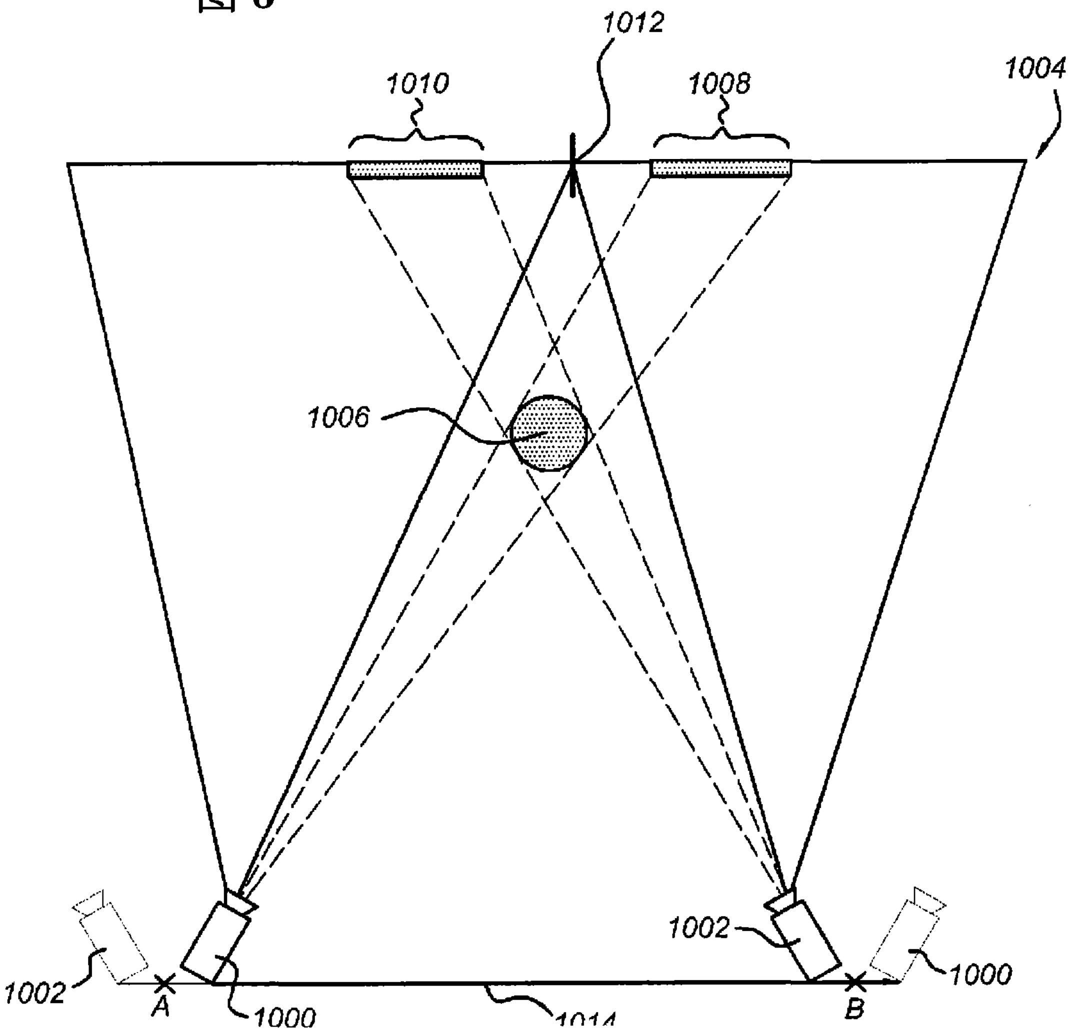

1012
1010
1008
1004
1006
1002
1000
A
B
1002
1000

图 10

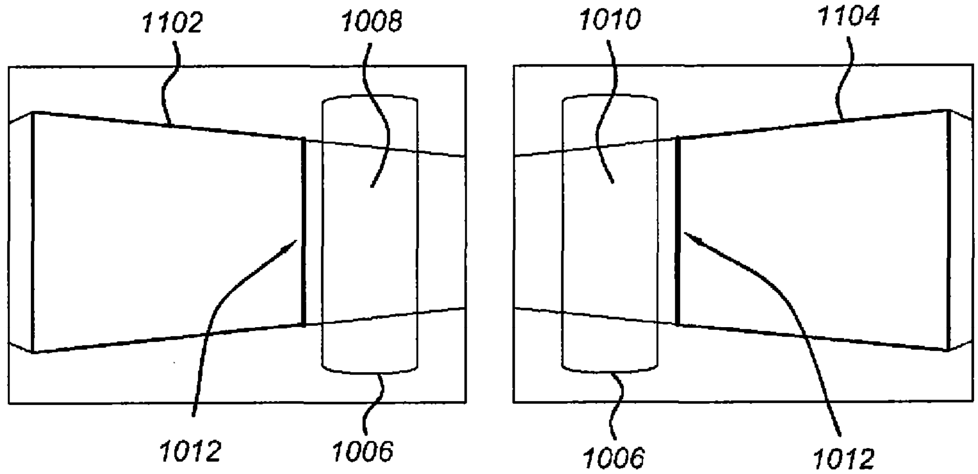

1102
1008
1010
1104
1012
1006
1006
1012

图 11

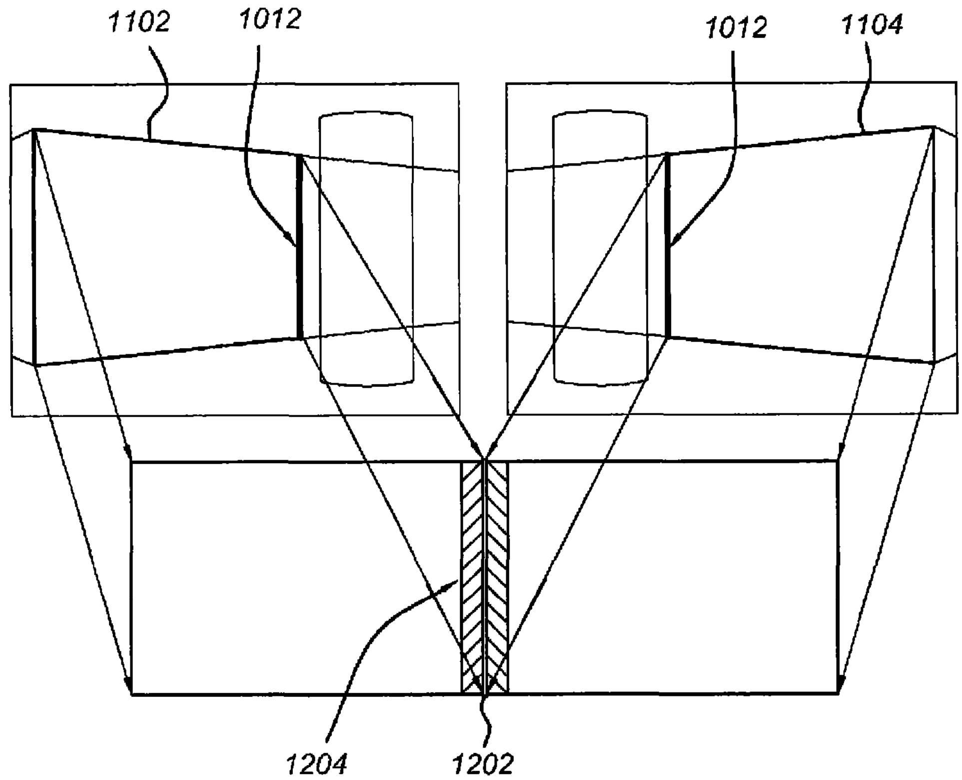

1102
1012
1012
1104
1204
1202

图 12

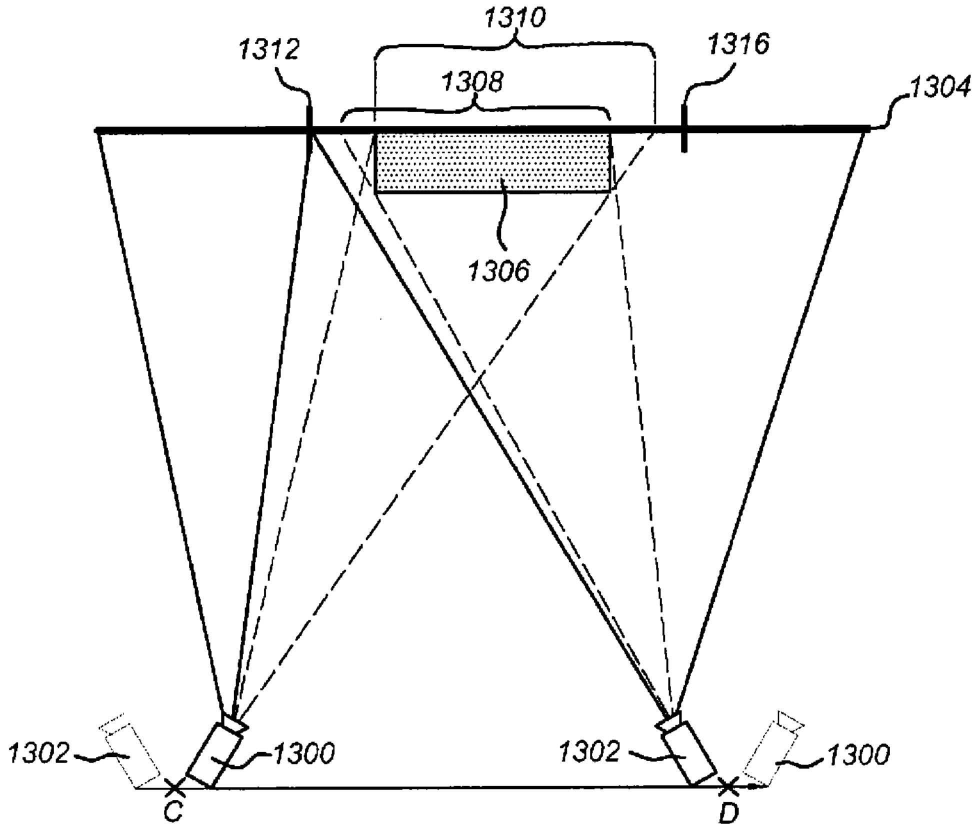

1310
1312
1316
1308
1304
1306
1302
1300
1302
1300
C
D

图 13

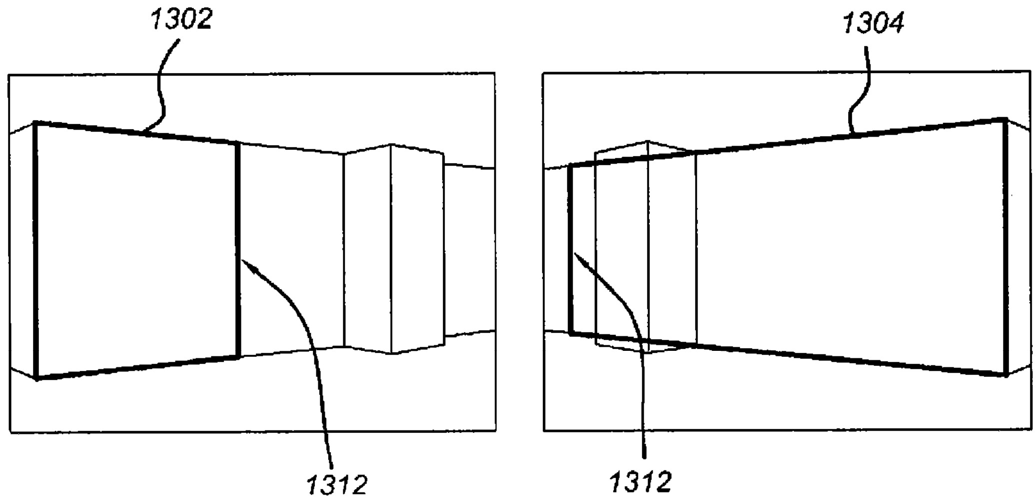

1302
1304
1312
1312

图 14

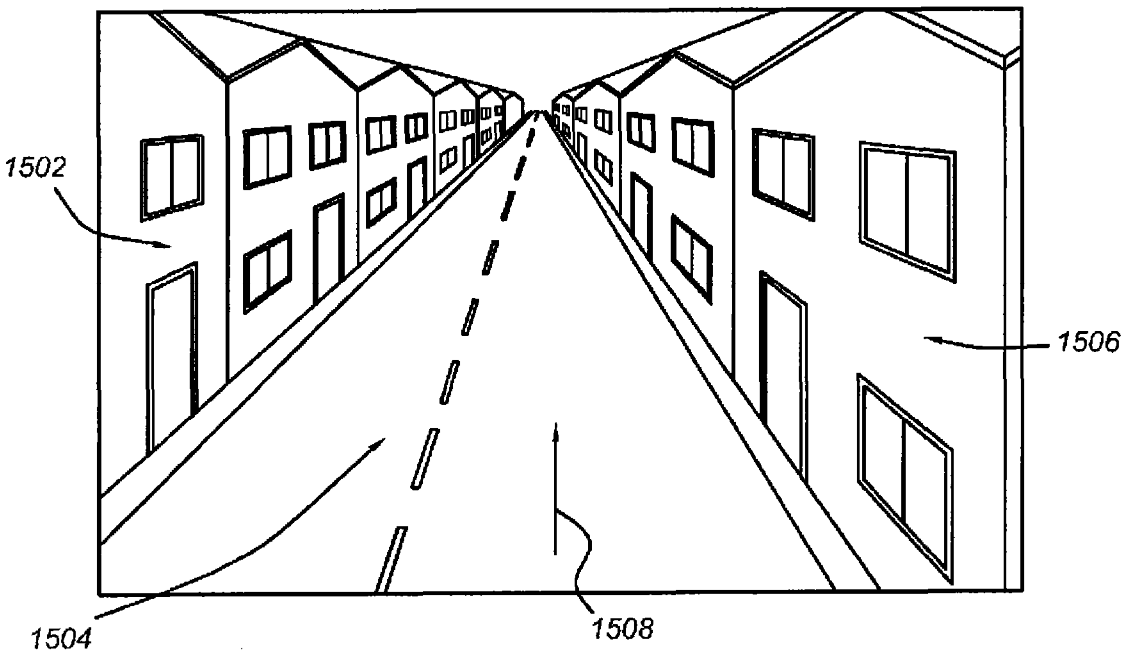


图 15a

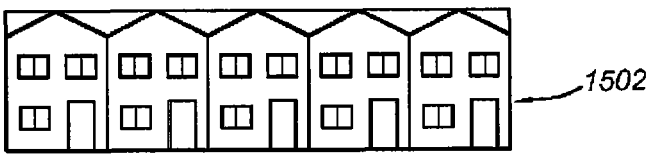


图 15b

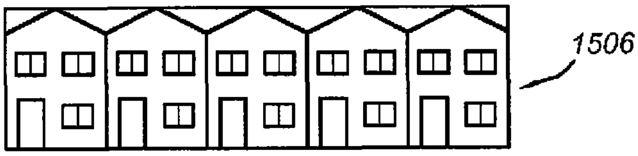


图 15c

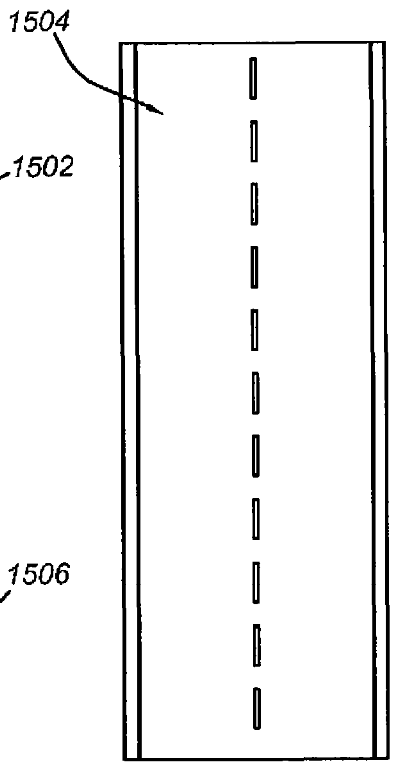


图 15d

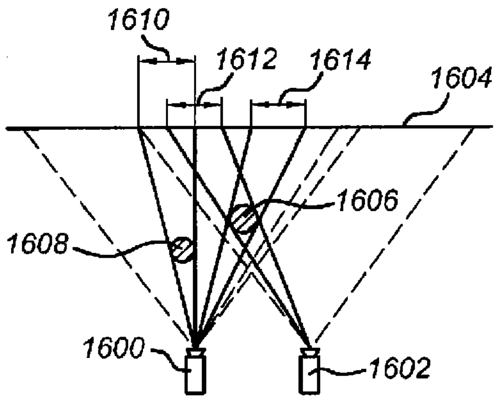


图 16a

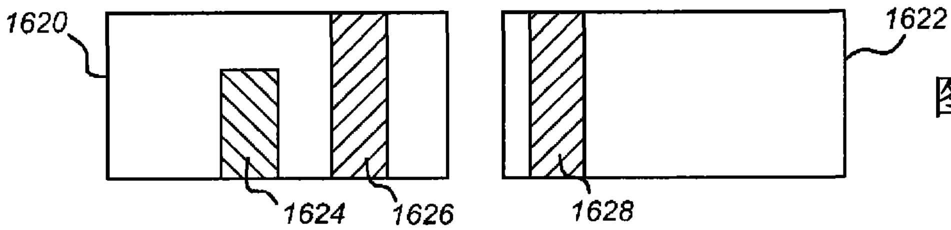


图 16b

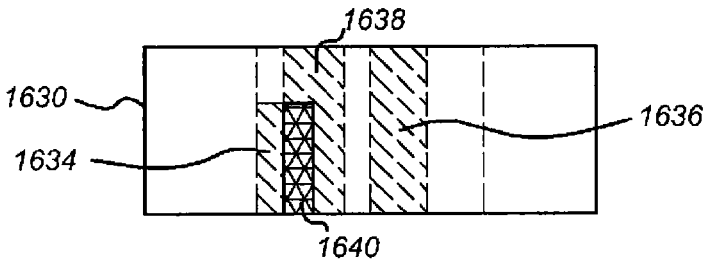


图 16c

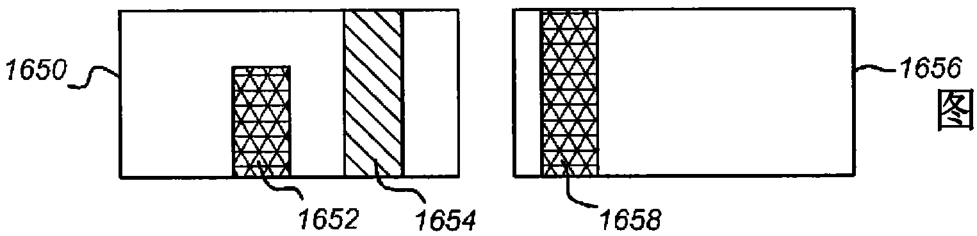


图 16d

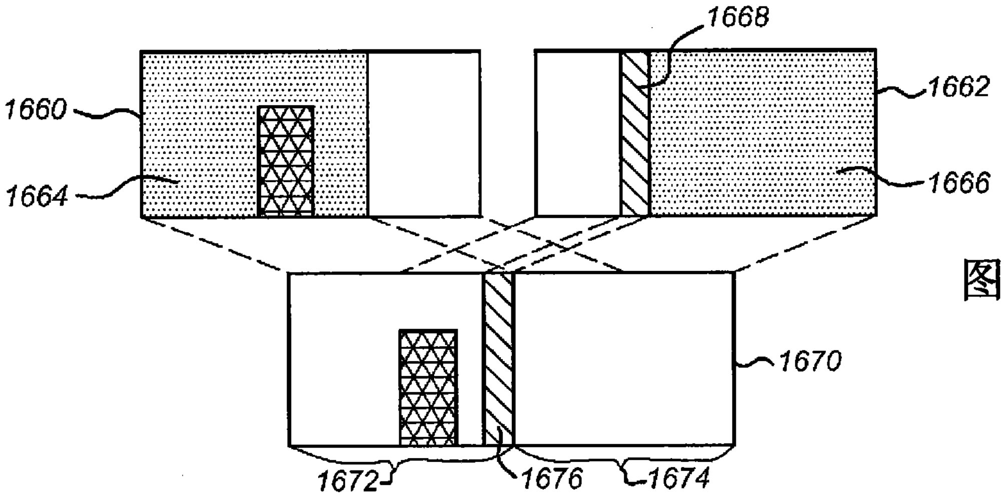


图 16e

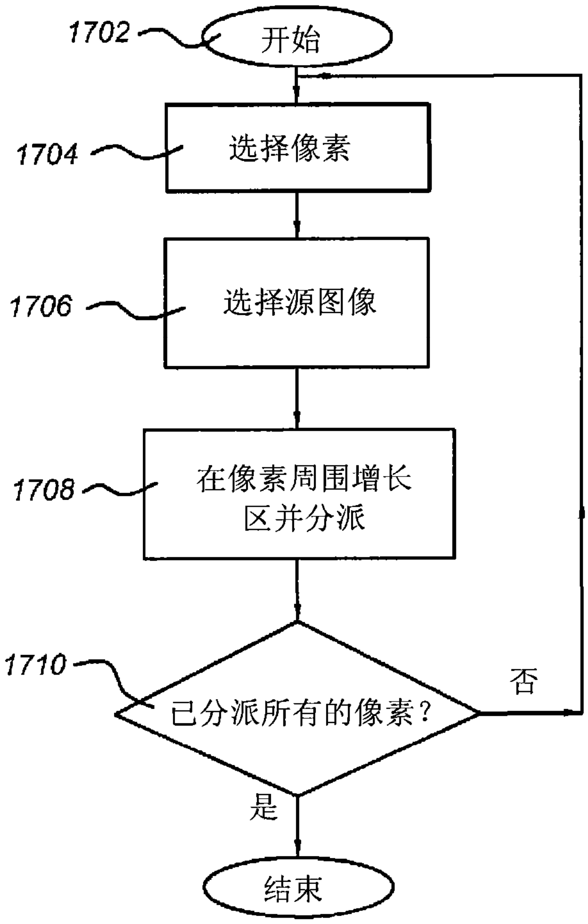

1702
开始
1704
选择像素
1706
选择源图像
1708
在像素周围增长
区并分派
1710
已分派所有的像素？
否
是
结束

图 17

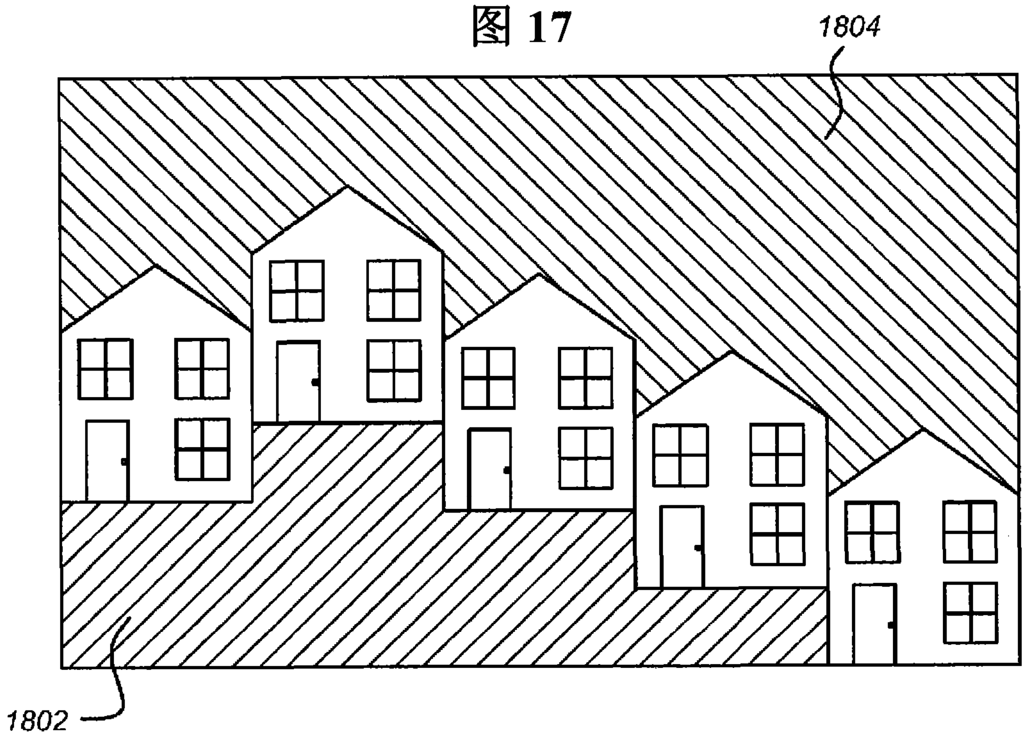

1804
1802

图 18