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(54) **METHOD FOR MODELLING A 3D SCENE AND CORRESPONDING DEVICE**

(71) Applicant: **THOMSON LICENSING**, Issy de Moulineaux (FR)

(72) Inventors: **Youssef Alj**, Rennes (FR); **Guillaume Boisson**, Pleumeleuc (FR); **Philippe Bordes**, Laille (FR); **Luce Morin**, Rennes (FR); **Muriel Pressigout**, Rennes (FR)

(73) Assignee: **THOMSON LICENSING**, Issy les Moulineaux (FR)

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G06T 17/10 (2006.01)

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CPC ***G06T 15/08*** (2013.01); ***G06T 17/10*** (2013.01)

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See application file for complete search history.

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Primary Examiner — Haixia Du
(74) *Attorney, Agent, or Firm* — Tutunjian & Bitetto, P.C.

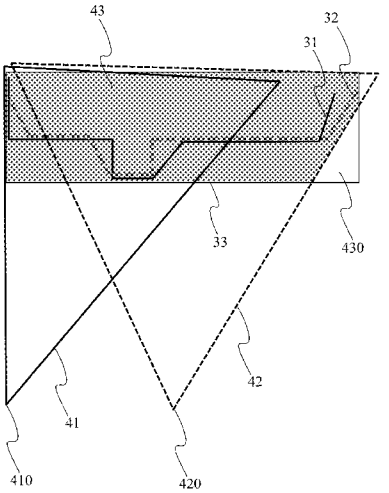
(57) **ABSTRACT**

The invention relates to a method for modeling a scene from a plurality of maps representative of depth, each map representative of depth being associated with a view of the said scene according to a particular viewpoint, To optimize the fidelity and precision of the scene modeling, the method comprises the following steps:

- generating, for each map representative of depth, a surface representative of the said depth map in world space;
- estimating a volume bounding all surfaces generated, the said bounding volume being discretised into a plurality of voxels;
- associating attributes representative of transparency with the said voxels of the bounding volume; and
- generating a resulting surface according to the attributes representative of transparency associated with the said voxels.

The invention also relates to a device for processing the data representative of the corresponding depth.

23 Claims, 8 Drawing Sheets



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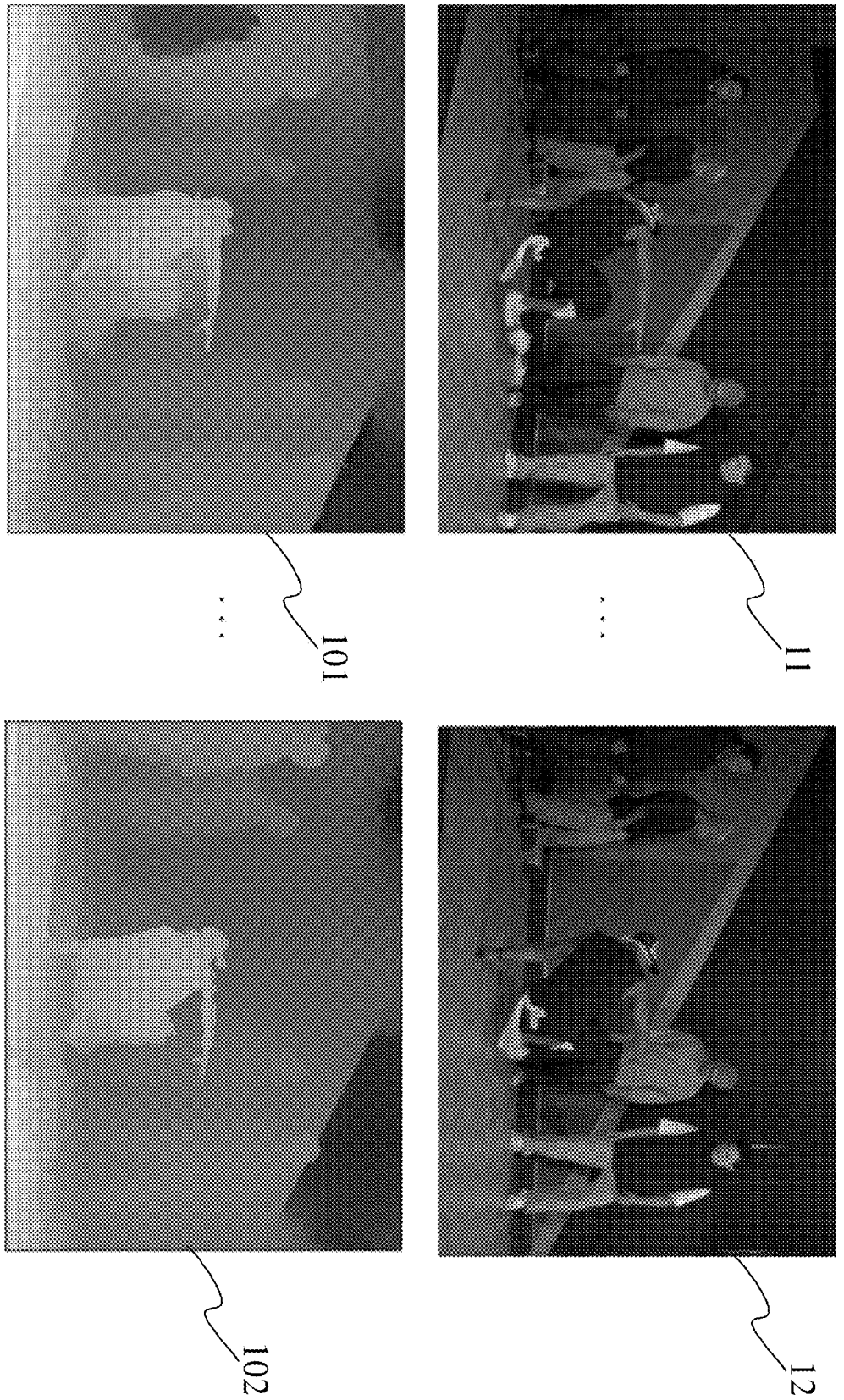


Fig 1

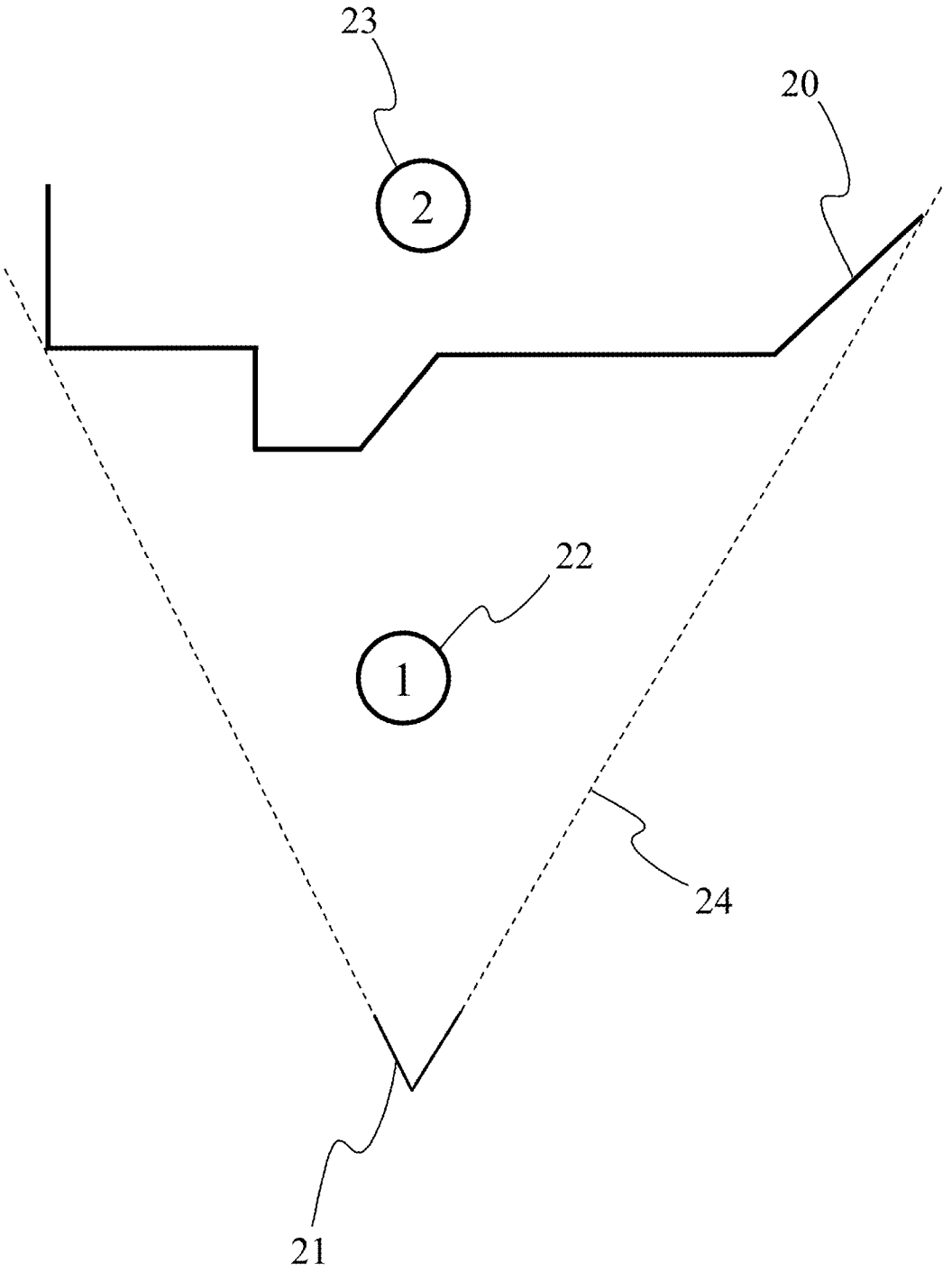


Fig 2

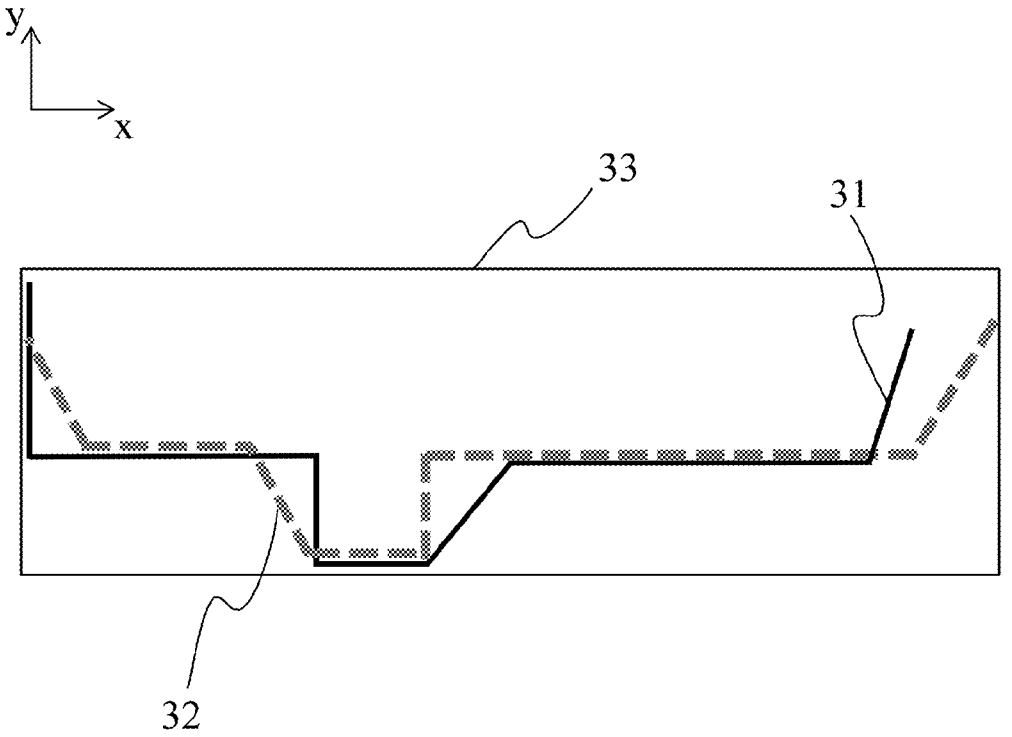


Fig 3

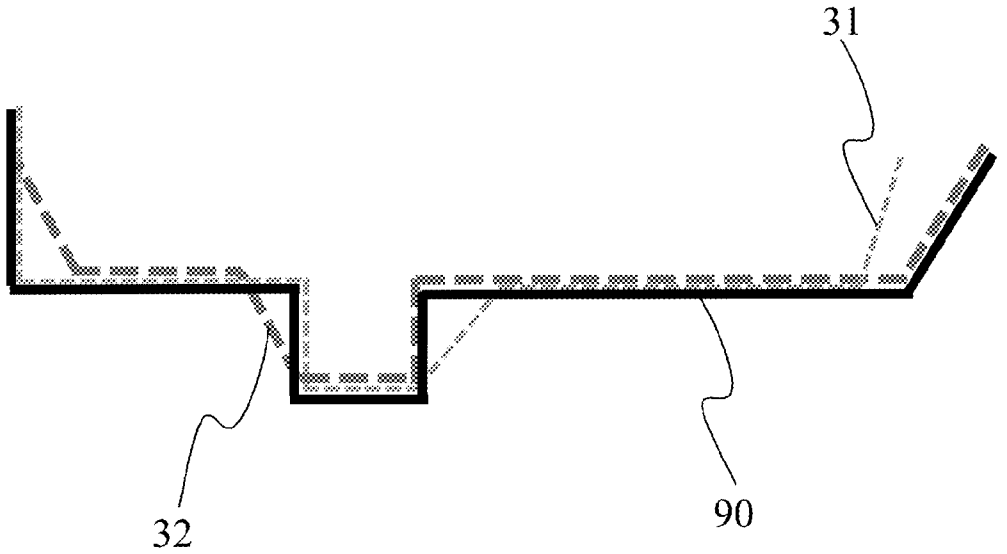


Fig 9

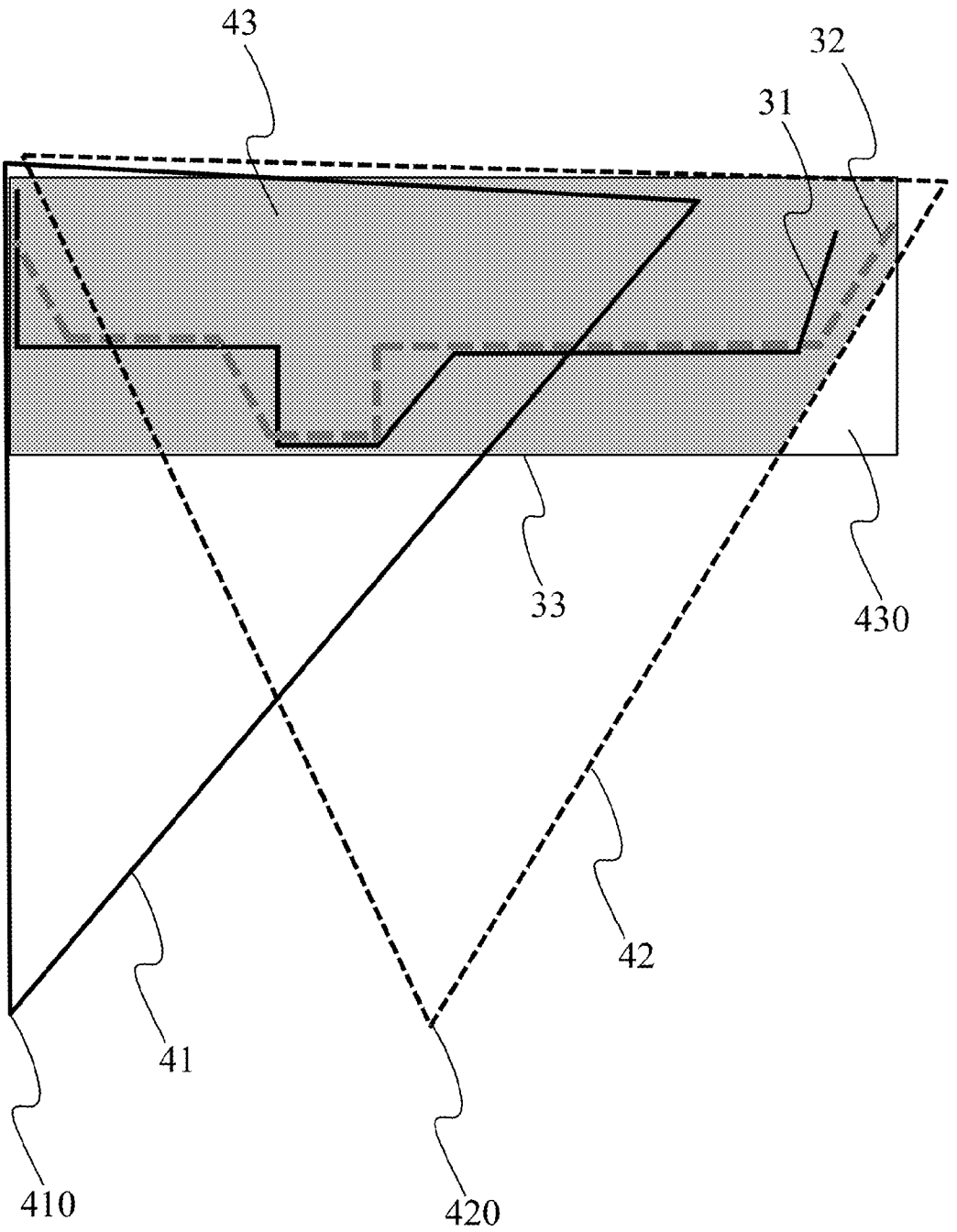


Fig 4

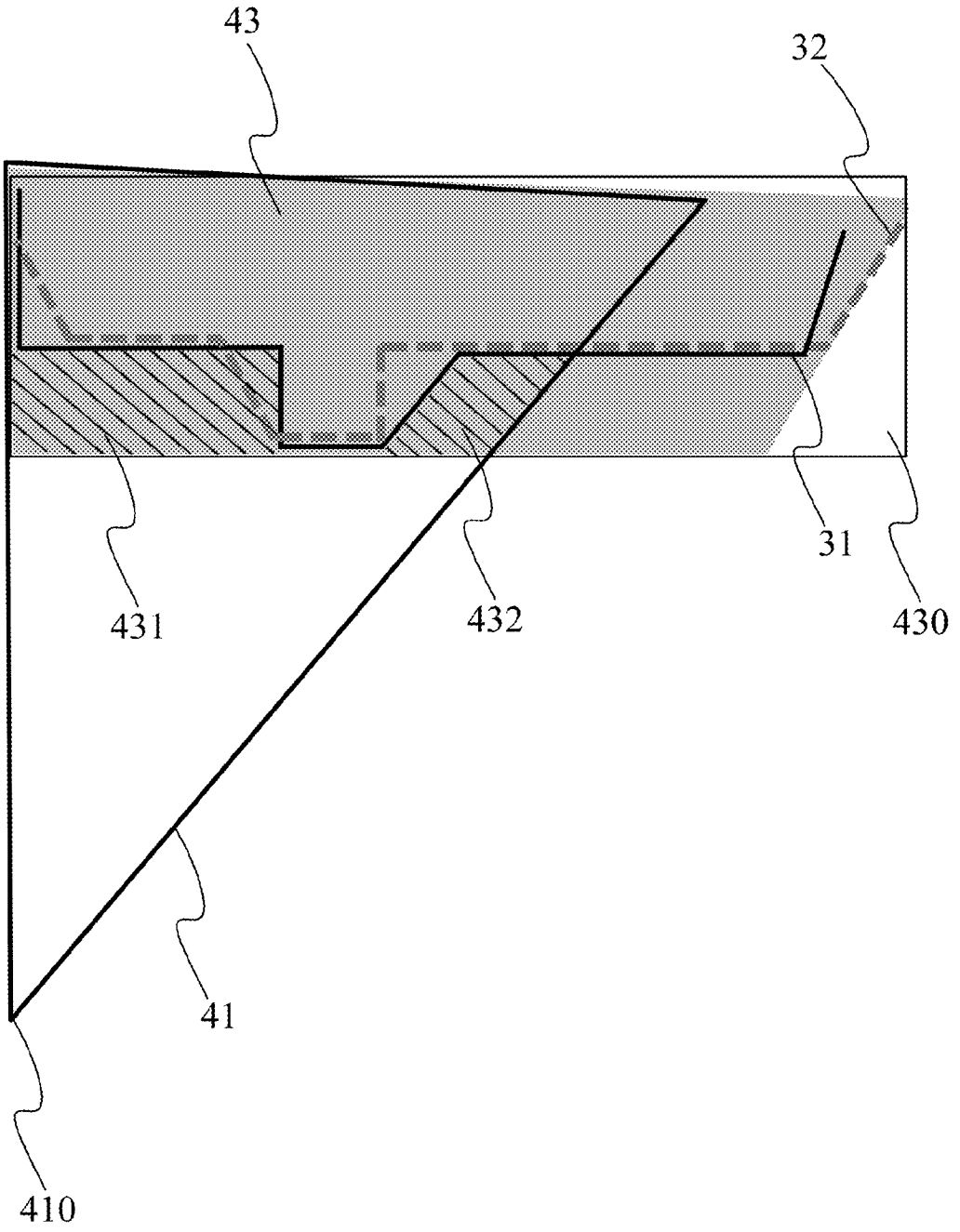


Fig 5

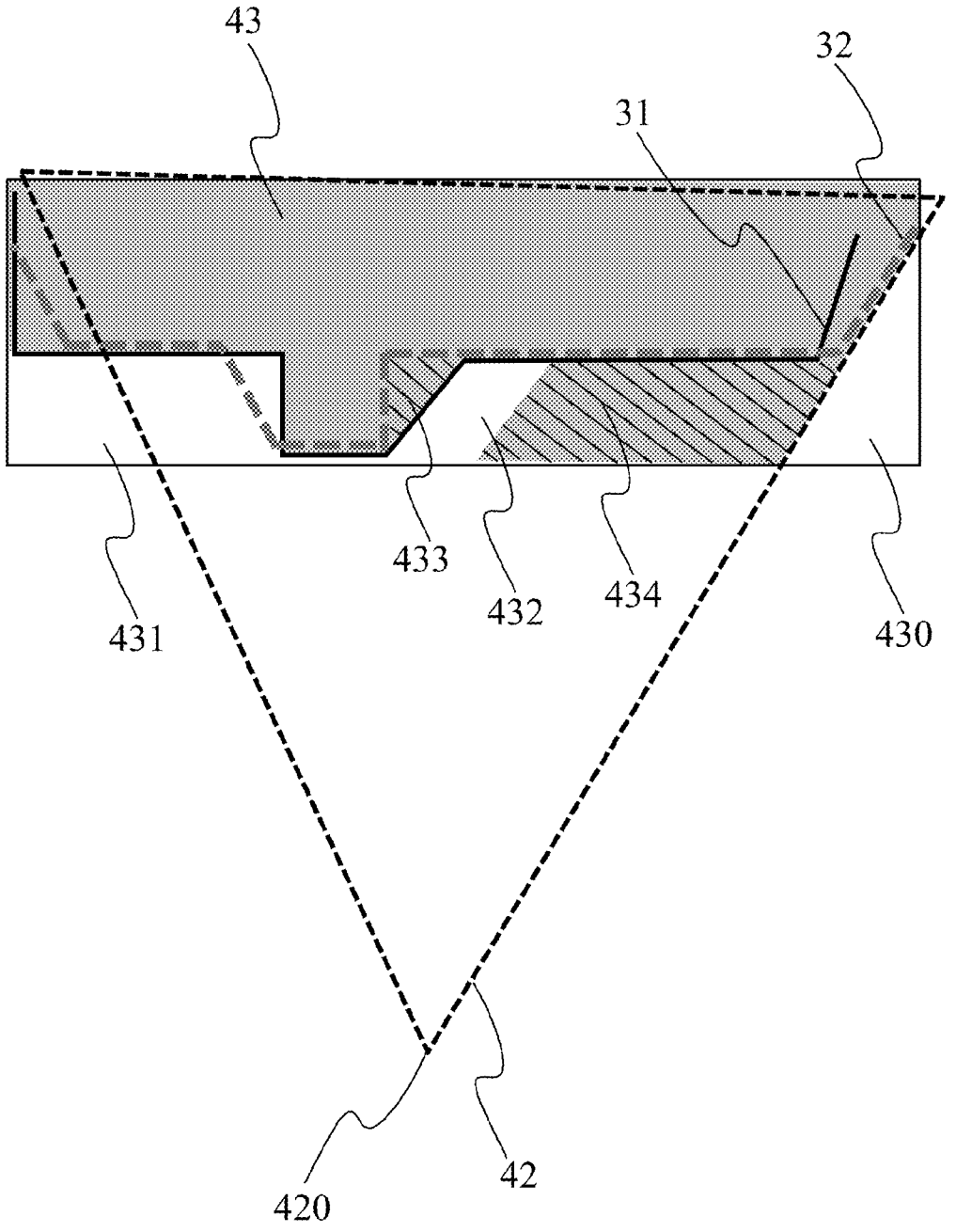
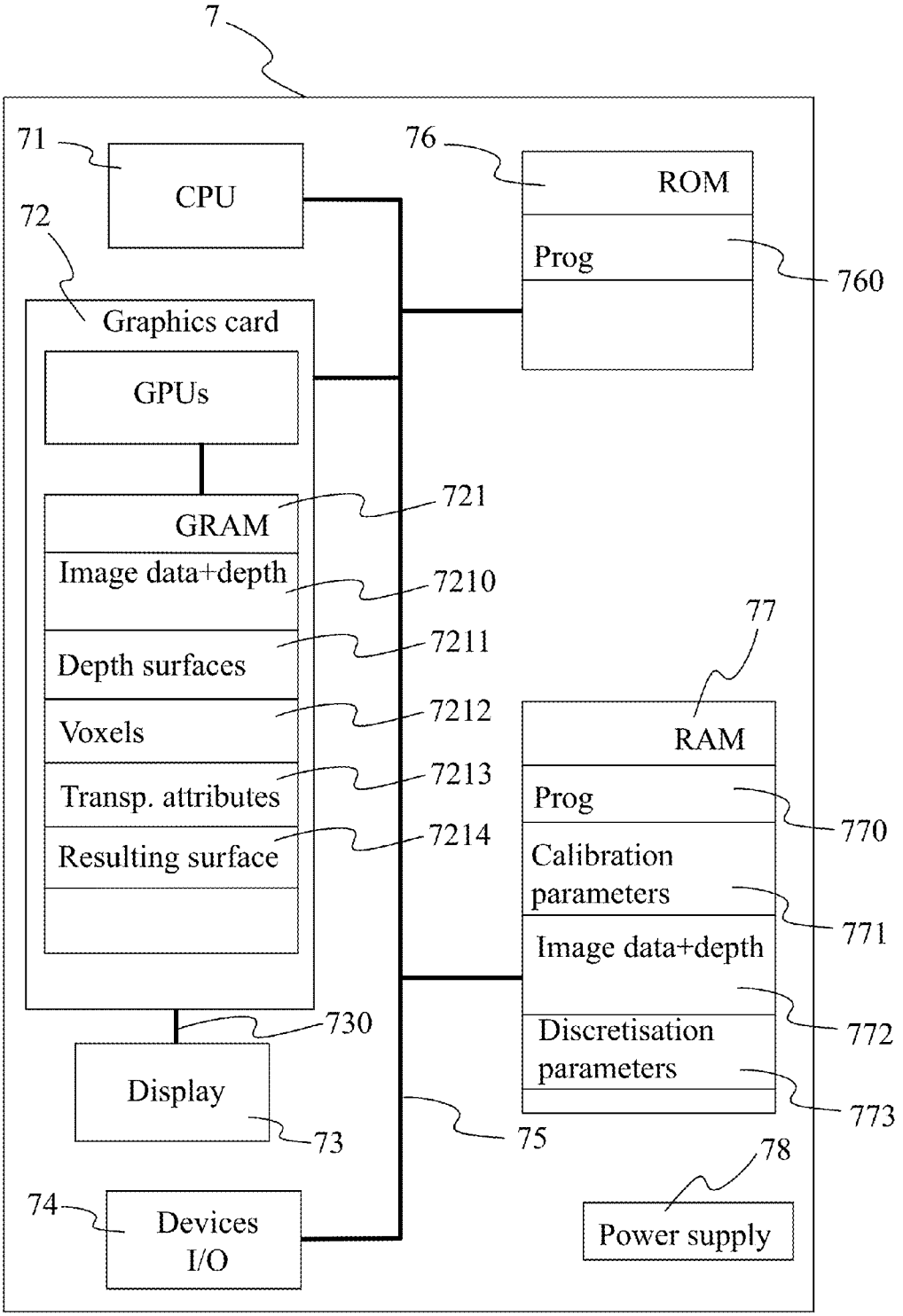


Fig 6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GRAM
Image data+depth
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Voxels
Transp. attributes
Resulting surface
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Fig 7

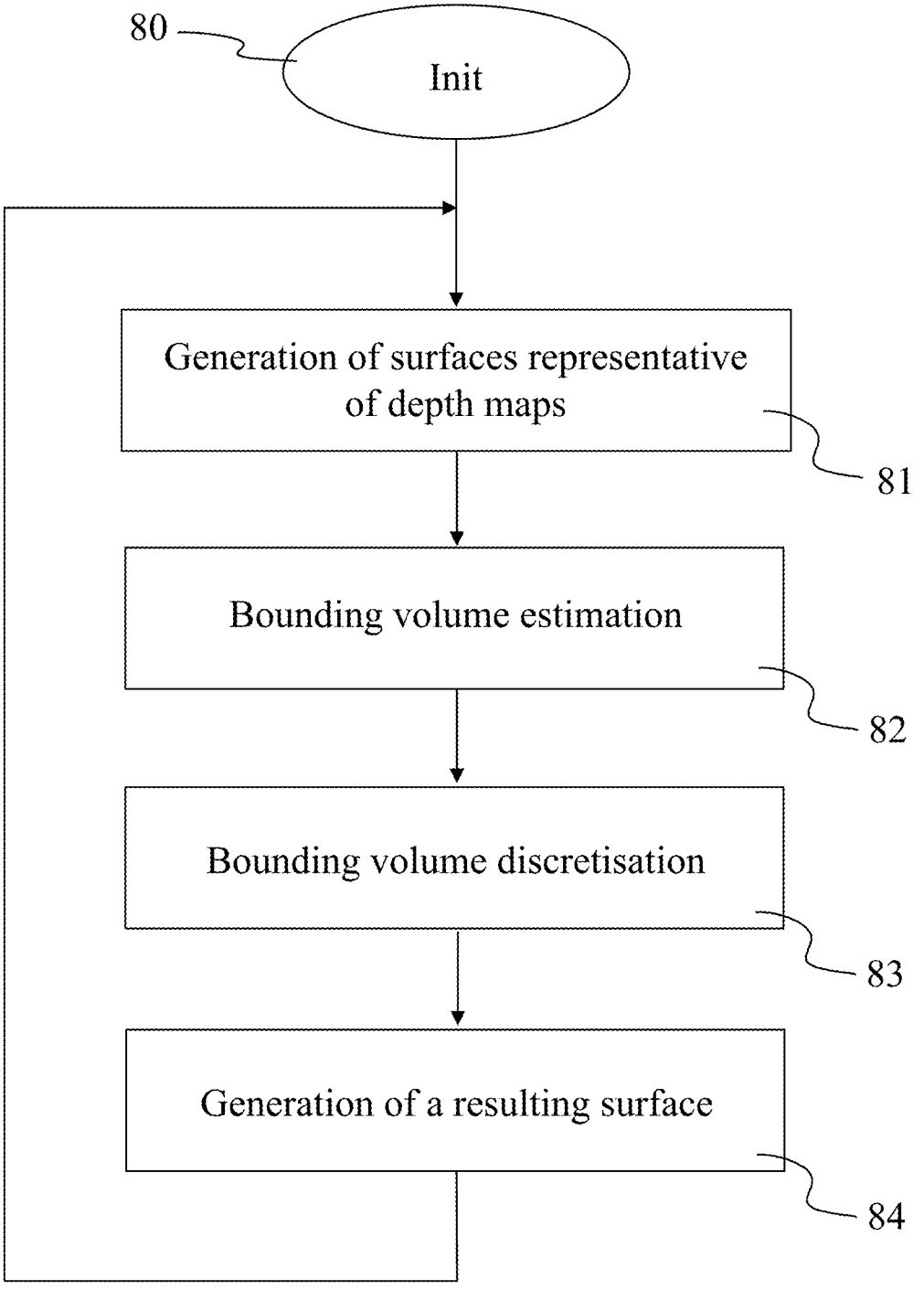
80
Init
Generation of surfaces representative of depth maps
81
Bounding volume estimation
82
Bounding volume discretisation
83
Generation of a resulting surface
84

Fig 8

METHOD FOR MODELLING A 3D SCENE AND CORRESPONDING DEVICE

This application claims the benefit, under 35 U.S.C. §119 of French Patent Application 1161788, filed Dec. 16, 2011.

1. DOMAIN OF THE INVENTION

The invention relates to the domain of image or video processing and more specifically to data processing representative of depth; for example depth maps or disparity maps associated with images of a video stream. The invention also relates to the domain of modelling of the geometry of a real scene using the depth data associated with images representative of the scene from several viewpoints.

2. PRIOR ART

According to the prior art, several methods of modelling a real scene in three dimensions (3D) are known. Among these methods, the technique called "Visual Hull" is used to reconstruct a 3D real scene from images of the scene captured by a set of cameras from several viewpoints. A silhouette of the scene is calculated for each image. A volumetric intersection of the de-projections of these silhouettes in world space enables a 3D model of the captured scene to be reconstructed. One disadvantage of this method is that it induces modelling errors of concave areas (see for example the document entitled "*Volumetric descriptions of objects from multiple views*" by W. N. Martin and J. K. Aggarwal published in *IEEE Transactions on Pattern Analysis and Machine Intelligence,* 5(2):150-158, March 1983).

Another technique called "Space carving" is used to model a real scene captured by multiple cameras from several viewpoints. According to this method, a volume bounding the objects in the captured scene is defined then discretised into a plurality of voxels. The photo-consistency of each voxel of the bounding volume is then defined by projecting each voxel onto the image planes associated with the cameras having captured the scene images, a voxel being photo-consistent if its projection is identical (that is to say that the variation of the colour associated with the projections of the voxel is less than a threshold value) on each image plane. To reconstruct a 3D model of the scene, the voxels which are not photo-consistent are eliminated (see the document entitled "*A theory of shape by space carving*" by K. N. Kutulakos and S. M Seitz published in *International Journal of Computer Vision,* 38 (3), 199-219 (2000)). The method known as "Space carving" presents several disadvantages. One of the disadvantages arises from the use of a threshold value to determine the photo-consistency of voxels, photo-consistency estimation errors being induced by an inappropriate threshold value. Another problem emerges when the captured scene comprises surfaces with significant light variations. Such areas, over-lighted or having significant light variations, induce erroneous photo-consistency determinations and therefore the elimination of incorrect voxels.

3. SUMMARY OF THE INVENTION

The purpose of the invention is to overcome at least one of these disadvantages of the prior art.

More specifically, the purpose of the invention is notably to optimise the scene modelling fidelity and accuracy.

The invention relates to a method of modelling a scene from a plurality of maps representative of depth, each map representative of depth being associated with a view of the scene according to a particular viewpoint. The method comprises the following steps:

- generating, for each map representative of depth of the plurality of maps, a surface representative of the map representative of depth in world space;
- estimating a volume bounding the surfaces generated in world space, the bounding volume being discretized into a plurality of voxels, an attribute representative of transparency being associated with the voxels of the bounding volume;
- generating, for each surface, a plurality of rays originating from a viewpoint associated with the generated surface and having as end point the intersection with the generated surface;
- running through the plurality of generated rays, the value of the attribute representative of transparency being changed for the voxels of the bounding volume having an intersection with one of the generated rays; and
- generating data representative of a resulting surface according to the attributes representative of transparency associated with the voxels.

Advantageously, the method comprises, for each surface generated and representative of a depth map associated with a viewpoint, an association of the voxels of the bounding volume with the generated surface to define the generated surface in accordance with a criterion of proximity of the voxels relative to the generated surface;

According to a particular characteristic, an attribute representative of transparency comprises two states, a first state corresponding to a transparent state of the voxel associated with the attribute, a second state corresponding to an opaque state of the voxel associated with the attribute, a voxel being in the transparent state when it has an intersection with one ray of the plurality of rays.

Advantageously, an attribute representative of transparency is determined according of the position of the voxel associated with the attribute with respect to a viewpoint and to the surface representative of a depth map associated with the viewpoint.

According to a specific characteristic, the attribute comprises two states, a first state corresponding to a transparent state of the voxel associated with the attribute, a second state corresponding to an opaque state of the voxel associated with the attribute, a voxel being in the transparent state when it is positioned between a viewpoint and the surface representative of the depth map associated with the viewpoint in the world space.

Advantageously, the position of the voxel is determined by estimating the intersection between the voxel and a ray launched from the viewpoint.

According to a particular characteristic, the surface representative of the depth map in the world space is generated using parameters representative of calibration associated with at least one camera used to capture the views of the scene associated with the plurality of depth maps.

According to another characteristic, the plurality of depth maps is obtained from a multi-view video stream.

Advantageously, the video stream is an MVD stream "Multiview Video plus Depth".

According to a specific characteristic, the method comprises a step of transmitting depth information representative of the resulting surface.

The invention also relates to a device for processing data representative of a plurality of maps representative of depth, each map representative of depth being associated with a view

of a scene according to a particular viewpoint, the device comprising at least a processor configured for:

- generating, for each map representative of depth of the plurality of maps, a surface representative of the map representative of depth in world space;
- estimating a volume bounding the surfaces generated in world space, the bounding volume being discretised into a plurality of voxels, an attribute representative of transparency being associated with the voxels of the bounding volume;
- generating, for each surface, a plurality of rays originating from a viewpoint associated with the generated surface and having as end point the intersection with the generated surface;
- running through the plurality of generated rays, the value of the attribute representative of transparency being changed for the voxels of the bounding volume having an intersection with one of the generated rays; and
- generating data representative of a resulting surface according to the attributes representative of transparency associated with the voxels.

4. LIST OF FIGURES

The invention will be better understood, and other specific features and advantages will emerge upon reading the following description, the description making reference to the annexed drawings wherein:

FIG. **1** illustrates a plurality of images representative of a scene and depth maps associated with this plurality of images, according to an example of a particular implementation of the invention;

FIG. **2** illustrates a surface representative of a depth map in FIG. **1**, according to a particular embodiment of the invention;

FIG. **3** illustrates a volume bounding a plurality of surfaces representative of the depth maps in FIG. **1**, according to a particular embodiment of the invention;

FIGS. **4**, **5** and **6** illustrate steps of the method for modelling the scene represented by the plurality of images in FIG. **1**, according to a particular embodiment of the invention;

FIG. **7** diagrammatically shows the structure of a unit for processing data representative of the depth maps in FIG. **1**, according to a particular embodiment of the invention;

FIG. **8** illustrates a method for modelling a scene from the depth maps in FIG. **1**, implemented on a processing unit in FIG. **7**, according to a particular embodiment of the invention;

FIG. **9** illustrates a surface resulting from the processing performed on the surfaces of the bounding volume in FIG. **3** according to the steps of the method shown in FIGS. **4**, **5** and **6**, according to a particular embodiment of the invention.

5. DETAILED DESCRIPTION OF THE EMBODIMENTS OF THE INVENTION

The invention will be described with reference to a first particular embodiment of a method for modelling a scene. The scene is advantageously represented according to several viewpoints in several images, each image being associated with information representative of depths. Information on depths is stored for example in depth maps or disparity maps. A particular viewpoint is associated with each map comprising depth information associated with the image captured according to the viewpoint considered. For each map comprising information representative of depth, a surface is generated in world space (that is to say in the space of the scene), the surface consequently representing the map comprising information representative of depth in world space according to the viewpoint associated with the map considered. A bounding volume is defined, which comprises all the generated and representative surfaces of maps comprising information representative of depth according to the different viewpoints. The bounding volume is then discretised, that is to say divided into a plurality of voxels, an attribute representative of transparency being associated with each voxel. A surface resulting from the fusion of all previously generated surfaces is then determined from the attributes representative of transparency associated with the voxels of the bounding volume.

Taking into account a geometric criterion (that is to say depth information) to determine a surface resulting from the fusion of several surfaces representing the depth information associated with the scene to be modelled according to several viewpoints has the advantage of overcoming the problems generated by taking into account a photometric criterion (that is to say the colour information associated with pixels of images representing the scene according to different viewpoints), while ensuring high fidelity in the modelling of the scene taking into consideration the concave and convex parts of the scene.

FIG. **1** illustrates a plurality of images **11**, **12** representative of a scene and the maps representative of depth **101**, **102** associated with each of the images **11**, **12**, according to an example of a particular and non-restrictive implementation of the invention. Images **11** and **12** represent the same scene from two different viewpoints. The video content of image **12** corresponds to the video content of image **11** shifted according to a horizontal axis towards the right. The scene represented in images **11** and **12** is advantageously captured by two acquisition devices, for example two cameras spatially offset in relation to one another. Each image **11**, **12** is associated with data representative of depth, for example a depth map (e.g. "z-buffer" type) or a disparity map. For the rest of the description we will make no distinction between a map representative of depth and a depth map, it being understood that it can concern any data structure representative of depth or disparity information. According to the example illustrated with respect to FIG. **1**, a depth map **101** is associated with image **11** and a depth map **102** is associated with image **12**. The depth map **101** (respectively **102**) represents in gray levels the depth associated with each pixel of the image **11** (respectively **12**), the closest pixels of the image (that is to say having the lowest depth values, the reference being the viewpoint of the image or the acquisition device having being used to capture the image) being the brightest and the most distant pixels of the image (that is to say having the highest depth values) being the darkest. Advantageously, the depth information associated with the pixels of images **11** and **12** are captured by means of suitable sensors, for example by means of infra-red sensors associated with an infrared transmitter (Kinect® type system) or by means of a system comprising a laser transmitter and an associated sensor to set the travel time of a laser ray emitted to the scene captured and reflected by the same scene, the travel time being representative of the distance travelled and therefore the depth associated with the scene point which reflected the laser ray.

According to a variant, a disparity map is associated with each image **11**, **12**. According to this variant, the disparity map associated with the image **11** is representative of the disparity between image **11** and image **12** and the disparity map associated with image **12** is representative of the disparity between image **12** and image **11**. Each disparity map is advantageously estimated by comparison and pairing of the

pixels of image **11** (respectively **12**) to the pixels of image **12** (respectively **11**). The disparity associated with a pixel of an image **11** (respectively **12**) advantageously corresponds to the pixel distance between this pixel of image **11** (respectively **12**) and the corresponding (or paired) pixel of image **12** (respectively **11**), that is to say, the pixel of the image **12** (respectively **11**) having video information (that is to say, colour information) identical or similar to that of the pixel of image **11** (respectively **12**).

According to another variant, the depth map **101**, **102** associated with each image **11**, **12** is deduced from the disparity map associated with each image **11**, **12**.

The images **11** and **12** belong to a multi-view video stream comprising a sequence of several images representative of the same scene. Advantageously, the multi-view video stream is of MVD type (Multiview Video plus Depth).

According to a variant, the colour and depth information associated with pixels of images **11** and **12** are stored in memories in the form of RGBa information, the RGB channels (Red, Green, Blue) being used to store the colour information associated with each pixel (e.g. 8, 10 or 12 bits per channel) and the channel a being used to store the depth (or disparity) information, for example on 8, 10 or 12 bits.

Advantageously, the intrinsic and extrinsic parameters of the acquisition devices used to acquire the plurality of images are known and for example stored in a memory. The intrinsic and extrinsic parameters correspond to the calibration parameters of acquisition devices. The intrinsic parameters comprise for example the focal length, magnification factors of the image, the projection coordinates of the optical centre of the acquisition device on the image plane and/or a parameter translating the potential non-orthogonality of lines and columns of photosensitive cells which compose the sensor of the acquisition device. The extrinsic parameters comprise for example the rotation matrix used to shift from the world space reference to the image space reference (and vice versa) and/or the components of the translation vector used to move from the world space reference to the image space reference (and vice versa).

Naturally, the number of images representative of a scene is not limited to 2 images but extends to any number greater than 2, e.g. 3, 4, 5, 10, 20, 50, 100 images, data representative of depth being associated with each image. Advantageously, each frame is captured by a particular acquisition device according to a particular viewpoint, the acquisition devices being spatially offset in relation to one another. According to a variant, only one pair of left and right images is captured using two acquisition devices, the other images of the plurality representative of the captured scene being calculated from the pair of left and right images by disparity-compensated interpolation. According to this variant, each image is also representative of the same scene according to a particular viewpoint and data representative of depth (for example a depth map or disparity map) is associated with each image, whether captured or interpolated.

FIG. **2** illustrates a surface **20** representative of a depth map **101**, **102**, according to a particular and non-restrictive embodiment of the invention. For obvious practical reasons, the surface **20** illustrated is a 2D representation of the surface representative of a depth map of an image, for example a sectional top view of the surface. The surface **20** also represents the surface of the visible points or elements of an image as viewed from a viewpoint **21**. We refer to points when the image is represented by a plurality of points (or pixels). We refer to elements when the image is represented by elements, for example the elements of a mesh (e.g. triangles or parallelepipeds). According to a variant, an element corresponds to a voxel and the surface is thus defined by the limit (or one face) of adjacent voxels.

The area (**1**) **22** delimited on the one hand by the view cone having for its vertex the viewpoint **21** and on the other hand the surface **20** corresponds to the geometric inconsistency area, that is to say the area comprising the geometrically inconsistent points (or voxels). By geometrically inconsistent points/voxels is understood the set of points or voxels that do not belong to an object of the 3D-modelled scene (the scene being represented in one of the images **11**, **12**). Such a point or voxel not belonging to an object of the scene is also called transparent. A point/voxel is called geometrically incoherent if the distance which separates it from the viewpoint **21** according to a ray originating from the viewpoint and passing through the point/voxel in question is less than the distance from the viewpoint **21** of the point of the surface **20** encountered by the ray passing through the point/voxel in question. According to a variant, any point/voxel belonging to a ray originating from the viewpoint **21** and having as an end point a point of the surface **20**, is called geometrically inconsistent.

The area (**2**) **23** comprises all points/voxels placed behind the surface **20**, if we are positioned at the viewpoint **21**, corresponds to an area of geometrical consistency, that is to say an area comprising the geometrically consistent points/voxels. By geometrically consistent points/voxels is understood the set of points or voxels belonging to an object in the 3D-modelled scene (the scene being represented in one of the images **11**, **12**). Such a point or voxel not belonging to an object of the scene is also called opaque. A point/voxel is called geometrically consistent if the distance which separates it from the viewpoint **21**, according to a ray originating from the viewpoint and passing through the point/voxel in question, is greater than the distance separating the viewpoint **21** from the point of the surface **20** encountered by the ray passing through the point/voxel in question. According to a variant, any point/voxel not belonging to a ray originating from the viewpoint **21** and having as an end point a point on the surface **20** is called geometrically consistent.

FIG. **3** illustrates a volume **33** bounding a plurality of surfaces **31**, **32** representative of the depth maps **101**, **102**, according to a particular and non-restrictive embodiment of the invention. The surface **31** shown in solid line is for example representative of the depth map **101** according to the viewpoint associated with the image **11**, the depth map **101** itself being associated with the image **11**. The surface **31** thus represents the set of points or elements of the scene represented by image **11** visible from the viewpoint associated with image **11**. The surface **32** shown in dotted line is for example representative of the depth map **102** according to the viewpoint associated with image **12**, the depth map **102** itself being associated with image **12**. The surface **32** thus represents the set of points or elements of the scene represented by image **12** visible from the viewpoint associated with image **12**. The surfaces **31** and **32** are two-dimensional representations of three-dimensional surfaces. The illustration in FIG. **3** of these surfaces **31** and **32** corresponds for example to a sectional top-view of 3D surfaces. The volume **33** (called bounding volume in the following description) is defined so that it fully comprises the surfaces **31** and **32**, the limits of the bounding volume being determined by points positioned at the end points of the surfaces **31** and **32**, that is to say the points of the surfaces **31** or **32** having the most extreme x, y and z coordinates (the lowest and highest values for each axis x, y and z). Once defined, the bounding volume **33** is discretised into a plurality of voxels, the voxels being advantageously all of the same dimensions (a voxel corresponds for

example to a cube or a rectangular parallelepiped). The discretisation parameters (such as the number of voxels per volume unit or the dimensions of a voxel in x, y and z) are advantageously predefined. According to a variant, the discretisation parameters are adjustable by a user, for example via a user interface. Advantageously, an attribute representative of transparency is associated with each voxel of the bounding volume **33**. The attribute representative of transparency comprises two distinct states, namely the transparent state and the opaque state. The opaque state is advantageously associated with each of the voxels of the bounding volume after the discretisation into voxels of the bounding volume.

The surfaces **31** and **32** are respectively representative of the depth maps **101** and **102** in world space, the depth maps **101** and **102** comprising information on depth in the image plane. By world space is understood the reference of the scene captured by the acquisition devices and represented by the images **11** and **12**, which correspond to a plurality of 2D views of a 3D scene. The generation of a surface **31** or **32** in the world space from a depth map **101** or **102** as represented in the image space is based on intrinsic and extrinsic parameters of acquisition devices that were used to capture the images **11** or **12** representing the scene that we seek to model.

FIGS. **4**, **5**, **6** and **9** illustrate the steps of a method for modelling the scene represented by the plurality of images **11**, **12**, according to a particular and non-restrictive embodiment of the invention.

FIG. **4** illustrates a first step of the method for modelling the scene based on the depth maps **101** and **102** associated with the images **11** and **12** representing the captured scene. In FIG. **4** we find the bounding volume **33**, which surrounds surfaces **31** and **32**, surface **31** being representative of the depth map **101** associated with image **11** and surface **32** being representative of the depth map **102** associated with image **12**. A first view cone **41** shown in solid line is defined, the first view cone **41** corresponding to what is seen from a first viewpoint **410** corresponding to the viewpoint from which the image **11** was captured. The first view cone **41** is consequently associated with the surface **31** representative of the depth map **101**. A second view cone **42** shown in dotted line is defined, the second view cone **42** corresponding to what is seen from a second viewpoint **420** corresponding to the viewpoint from which the image **12** was captured. The second view cone **42** is consequently associated with the surface **32** representative of the depth map **102**. Once the view cones **41**, **42** are defined, the intersection between these view cones **41**, **42** on the one hand and the bounding volume **33** on the other hand is determined. This intersection, which corresponds to a volume, is illustrated by an area **43** in gray on FIG. **4**. In other words, the volume of intersection **43** corresponds to the union of view cones **41**, **42** inside the bounding volume **33**. From the intersection volume **43**, we determine the voxels belonging to the bounding volume **33** but not to the intersection volume **43**. By voxels of the bounding volume **33** not belonging to the intersection volume **43** is understood those voxels whose centre, defined for example by its x, y, and z coordinates, does not belong to the intersection volume **43**. This plurality of voxels not belonging to the intersection volume **43** is represented by a blank area **430** corresponding to a volume inside the bounding volume **33**. Advantageously, the attribute representative of transparency associated with each of the voxels of the area **430** is modified and each voxel of the area **430** passes to the transparent state, the voxels belonging to the intersection volume **43** remaining in their initial state, that is to say in the opaque state as defined with respect to FIG. **3**.

FIG. **5** illustrates a second step of the method for modelling the scene based on the depth maps **101**, **102** associated with the images **11**, **12** representing the captured scene. During this second step, the first view cone **41** associated with the surface **31** representative of the depth map **101** is selected. A plurality of rays is launched inside the first view cone **41**, the launched rays originating from the first viewpoint **410**. Advantageously, the rays launched from the first viewpoint **410** have as an end point the intersection with the surface **31**. The intersection with the surface **31** corresponds advantageously to a voxel, a series of voxels being associated with the surface **31** according to a criterion of proximity of the voxels in relation to the surface **31**. The proximity of the voxels to the surface **31** is advantageously estimated by measuring the distance between an element of the surface **31** and the centre of the voxels surrounding this element. The selection of voxels associated with the surface **31** is advantageously performed using a method of filling by diffusion, for example the method called "scan-line fill", the method called "seed fill" or the method called "flood fill". Running through each of the launched rays, we determine the voxels of the bounding volume **33** having an intersection with these rays. The attribute representative of transparency associated with these voxels having an intersection with the launched rays (initialised in opaque state) is modified and each of these voxels passes to the transparent state. This means that the attributes representative of transparency associated with the voxels of the bounding volume are thus determined according to the result of the intersection estimate between the voxels and launched rays. The voxels having an intersection with these launched rays and whose state passes to transparent belong to the areas **431** and **432** showing as hatched in FIG. **5**.

According to a variant, the rays launched from the first viewpoint **410** have as an end point the second intersection with the bounding volume **33**, that is to say, the intersection with the face of the bounding volume farthest from the first viewpoint. For each ray launched and for each voxel belonging to one of these rays, the distance between the origin (that is to say the first viewpoint **410**) and the voxel considered is determined and compared to the distance separating the origin of the intersection point between the surface **31** and the ray considered. If the distance to the voxel is less than the distance to the surface **31**, then the voxel passes to the transparent state. In the contrary case, if the distance to the voxel is greater than the distance to the surface **31**, then the voxel remains in the opaque state. According to this variant the same voxels pass to the transparent state and belong to the areas **431** and **432** illustrated as hatched in FIG. **5**. This second step is used to define the geometrically inconsistent voxels according to the first viewpoint **410**, that is to say the voxels that do not belong to an object of the scene represented by image **11** associated with the first viewpoint **410**.

FIG. **6** illustrates a third step of the method for modelling the scene based on the depth maps **101**, **102** associated with the images **11**, **12** representing the captured scene. The third step is similar to the second step illustrated with respect to FIG. **5**, the difference being that it is applied to the second view cone **42**. During this third step, the second view cone **42** associated with the surface **32** representative of the depth map **102** is selected. A plurality of rays is launched inside the second view cone **42**, the launched rays originating from the second viewpoint **420**. Advantageously, the rays launched from the second viewpoint **420** have as an end point the intersection with the surface **32**. Running through each of the launched rays, we determine the voxels of the bounding volume **33** having an intersection with these rays. The attribute representative of transparency associated with these voxels having an intersection with the launched rays (initialised in opaque state) is modified and each of these voxels passes to the transparent state. The voxels having an intersection with these launched rays and whose state passes to the transparent state belong to the areas **433** and **434** which appear as hatched in FIG. **6**. According to a variant, the rays launched from the second viewpoint **420** have as an end point the second inter-

section with the bounding volume **33**, that is to say, the intersection with the face of the bounding volume farthest from the second viewpoint **420**. For each ray launched and for each voxel belonging to one of these rays, the distance between the origin (that is to say the second viewpoint **420**) and the voxel considered is determined and compared to the distance separating the origin of the intersection point between the surface **32** and the ray considered. If the distance to the voxel is less than the distance to the surface **32**, then the voxel passes to the transparent state. In the contrary case, if the distance to the voxel is greater than the distance to the surface **32**, then the voxel remains in the opaque state. According to this variant the same voxels pass to the transparent state and belong to the areas **433** and **434** illustrated as hatched in FIG. **5**. This second step is used to define the geometrically inconsistent voxels according to the second viewpoint **420**, that is to say the voxels that do not belong to an object of the scene represented by the image **12** associated with the second viewpoint **420**. The voxels whose attribute representative of transparency has passed to the transparent state during the second step are illustrated in white (in the areas **431**, **432**) with respect to FIG. **6**.

FIG. **9** illustrates a fourth step of the method for modelling the scene to generate a surface **90** resulting from the processing performed on the surfaces **31** and **32** of the bounding volume **33** according to the first, second, and third steps of the method illustrated with respect to FIGS. **4**, **5** and **6**. After the first, second and third steps previously described, the attribute representative of transparency associated with each voxel of the bounding volume **33** is either in the transparent state (geometrically inconsistent voxel, that is to say not belonging to an object of the scene to be modelled according to at least one of the capture viewpoints **410**, **420** of images **11**, **12** representative of the scene to be modelled), or in the opaque state (geometrically consistent voxel, that is to say a voxel belonging to an object in the scene to be modelled according to any capture viewpoint **410**, **420** of images **11** and **12** representative of the scene to be modelled). During this fourth step, a surface **90** resulting from the fusion of surfaces **31** and **32** is generated. This surface **90** is advantageously generated according to the attributes representative of transparency associated with the voxels of the bounding volume. The surface **90** is obtained by determining the border between the voxels in the transparent state and the voxels in the opaque state. This surface **90** advantageously corresponds to the exterior envelope of the scene to be modelled from the images **11**, **12** representing it. In other words, the surface **90** corresponds to the set of points or elements visible from any viewpoint and corresponds in this regard to the fusion of the surfaces **31**, **32** representative of points/elements visible from a particular viewpoint (respectively **410**, **420**).

FIG. **7** diagrammatically shows an example of material embodiment of a processing unit **7** adapted to the modelling of a 3D scene from data representative of depth and to the generation of display signals of one or more images, according to an example of a particular and non-restrictive implementation of the invention. Unit **7** corresponds for example to a personal computer PC, a laptop or a games console.

The unit **7** comprises the following elements, connected to each other by an address and data bus **75** that also transports a clock signal:

- a microprocessor **71** (or CPU);
- a graphics card **72** comprising:
  - several Graphics Processing Units **720** (or GPUs),
  - a Graphical Random Access Memory (GRAM) **721**;
- a non-volatile memory of ROM type (Read Only Memory) **76**;
- a Random Access Memory (RAM) **77**;
- one or more I/O (Input/Output) devices **74** such as for example a keyboard, a mouse, a webcam, and
- a power supply **78**.

The device **7** also comprises a display device **73** of display screen type directly connected to the graphics card **72** to display notably the synthesised images calculated and composed in the graphics card, for example live. The use of a dedicated bus to connect the display device **73** to the graphics card **72** offers the advantage of having much greater data transmission bitrates and thus reducing the latency time for the display of images composed by the graphics card. According to a variant, a display apparatus is external to the device **6** and is connected to the device **7** by a cable transmitting the display signals. The device **7**, for example the graphics card **72**, comprises a means for transmission or connector (not shown in FIG. **7**) adapted to transmit a display signal to an external display means such as for example an LCD or plasma screen or a video-projector.

It is noted that the word "register" used in the description of memories **72**, **76** and **77** designates in each of the memories mentioned, both a memory zone of low capacity (some binary data) as well as a memory zone of large capacity (enabling a whole program to be stored or all or part of the data representative of data calculated or to be displayed).

When switched-on, the microprocessor **71** loads and executes the instructions of the program contained in the RAM **77**.

The random access memory **77** notably comprises:

- in a register **770**, the operating program of the microprocessor **71** responsible for switching on the device **7**,
- calibration parameters **771** representative of the intrinsic and extrinsic parameters of the acquisition device(s) used to capture images representative of the scene to be modelled;
- the data **772** representative of images representing the captured scene (e.g. RGB data) and representative of depth associated with the captured images (e.g. corresponding to a depth map or to a disparity map);
- parameters of discretisation **773** used for the bounding volume discretisation (e.g. the number of voxels per volume unit; the number of voxels according to one, two or three dimensions x, y, z; the dimensions in x, y and z of a voxel).

The algorithms implementing the steps of the method specific to the invention and described hereafter are stored in the memory GRAM **721** of the graphics card **72** associated with the unit **7** implementing these steps. When switched on and once the data **772** is loaded into the RAM **77**, the graphics processors **720** of the graphics card **72** load these parameters into the GRAM **721** and execute the instructions of these algorithms in the form of "shader" type microprograms using for example HLSL (High Level Shader Language) or GLSL (OpenGL Shading Language).

The random access memory GRAM **721** notably comprises:

- in a register **7210**, the data representative of images representing the captured scene and the data representative of depth associated with the captured images;
- data **7211** representative of surfaces representative of depth data associated with the images (e.g. the coordinates of points/elements of a surface in world space);
- data **7212** representative of voxels (for example the position of the voxel in the bounding volume, the coordinates of the voxel centre, etc.);
- information **7213** representative of attributes representative of transparency associated with voxels (e.g. in the transparent state or the opaque state), and

data **7214** representative of the surface resulting from the fusion of surfaces representative of the depth data (e.g. coordinates of the points/elements of the resulting surface in world space).

According to a variant, a part of the RAM **77** is assigned by the CPU **71** for storage of the values **7211** to **7214** if the memory storage space available in GRAM **721** is insufficient. This variant however causes greater latency time in the composition of an image comprising a representation of the environment **1** composed from microprograms contained in the GPUs as the data must be transmitted from the graphics card to the random access memory **77** passing via the bus **75** for which the transmission capacities are generally inferior to those available in the graphics card for transmission of data from the GPUs to the GRAM and vice-versa.

According to another variant, the power supply **78** is external to the device **4**.

FIG. **8** illustrates a method for modelling a scene from maps representative of depth associated with images representative of the scene to be modelled, implemented in a processing unit **7**, according to an example of non-restrictive implementation of the invention.

During an initialisation step **80**, the different parameters of the unit **7** are updated. In particular, the data representative of images and associated maps representative of depth are initialised in any way.

Then, during a step **81**, for each map representative of depth associated with an image representative of the scene to be modelled (among the plurality of images representing the scene to be modelled according to different viewpoints), a surface representative of the depth map considered. The representative surface is calculated in world space from the depth information expressed in the image space and stored in the depth map concerned. Conversion of depth data from the image space to world space is obtained from the transformation arrays by taking into account the calibration parameters (intrinsic parameters and/or extrinsic parameters) of the acquisition device(s) used to capture images representative of the scene to be modelled. Each depth map is thus transformed into a surface represented by a set of geometrical coordinates in world space, the geometric coordinates being associated with any point of the surface if the surface is represented by points or geometric coordinates being associated with all elements (for example any mesh of a meshing) of the surface if the surface is represented by elements (the coordinates being associated with the vertices of the meshes of the meshing if the elements correspond to meshes).

Then, during a step **82**, a volume is estimated to include all surfaces representative of depth maps associated with the plurality of images representative of the scene. Once the bounding volume is defined, it is discretised into a plurality of voxels from discretisation parameters predefined or adjusted by a user. The density of voxels per volume unit is advantageously selected according to the quality of the desired final display and according to the number of calculations which can be performed by the processing unit during a given time. The higher the number of voxels per volume unit, the higher the quality of the display (of the scene once modelled), but in exchange the volume of calculations required to obtain the display will be high and require high calculation power. If live constraints exist for the modelling of the scene, the discretisation parameters are advantageously selected to obtain the best compromise between the necessary quantity of calculations and the display quality. If the voxels have dimensions which are too high, quantisation defects appear at the surface resulting from the fusion of the surfaces representative of the depth maps.

Then, during a step **83**, an attribute representative of transparency is associated with each voxel of the discretised bounding volume. The attribute representative of transparency advantageously takes two values, namely a first value corresponding to a transparent state of the associated voxel and a second value corresponding to an opaque state of the associated voxel. Advantageously, the second value of the attribute representative of transparency (corresponding to the opaque state) is associated with each voxel of the bounding volume after the discretisation of the bounding volume, this second value corresponding to the initialisation value associated with voxels during their generation. The value of the attribute associated with the voxels of the bounding volume is modified to change to the first value (corresponding to the transparent state) for voxels of the bounding volume corresponding to at least one of the following cases:

- the voxels of the bounding volume which do not belong to the view cones formed from each viewpoint associated with the surfaces representative of depth maps;
- the voxels of the bounding volume located between the viewpoint associated with a surface and the surface considered, for each surface representative of a depth map;

Finally, during a step **84**, a surface resulting from the fusion of surfaces representative of a depth map is generated according to the attributes representative of transparency associated with the voxels of the bounding volume. The resulting surface advantageously corresponds to the border formed between on the one hand the voxels whose associated transparency attribute takes the first value (voxels in a transparent state), and on the other hand the voxels whose associated transparency attribute takes the second value (voxels in the opaque state).

Naturally, the invention is not limited to the embodiments previously described.

In particular, the invention is not limited to a method of scene modelling but also extends to any device implementing this method and notably all devices comprising at least one GPU. The implementation of calculations necessary for modelling the scene is not restricted to an implementation in shader type microprograms but also extends to an implementation in any program type, for example programs that can be executed by a CPU type microprocessor.

According to an advantageous variant of the invention, depth information (for example a depth map or a disparity map) is transmitted to a remote unit (for example a receiver/decoder (or "set-top box"), a mobile phone, tablet, etc.) by any means of wired or wireless transmission (e.g. using a 3G or 4G type interface, Wifi® and a corresponding transmission channel). The depth information is advantageously obtained from the resulting surface generated from the surfaces representative of depth maps associated with the images representing the modelled scene, by converting the coordinates of the resulting surface in the world space into a representation in the image space. Such a variant presents the advantage of optimising the use of the bandwidth by optimising the quantity of information circulating on the transmission channel. In fact, according to this variant, a single piece of depth information (e.g. a single depth map) is transmitted instead of the plurality of depth maps associated with the images of the input video stream. The depth map generated from the resulting surface comprises depth information necessary for the display of the modelled scene by eliminating the information redundancy contained in the different depth maps associated with the images of the input video stream corresponding to different viewpoints and comprising redundant scene information (the scene being captured from several different viewpoints).

The present invention can be used in video games applications for example, whether by programs that can be executed in a PC, laptop computer or in specialised games consoles producing and displaying images live. The processing unit **7** described with respect to FIG. **7** is advantageously equipped with interaction means such as a keyboard and/or joystick, other command modes such as for example vocal recognition also being possible.

The invention claimed is:

1. A method for modelling a scene from a plurality of maps representative of depth, each map representative of depth being associated with a view of the scene according to a viewpoint, said method comprising:

generating, for each map representative of depth of said plurality, a surface representative of said map representative of depth in world space;

determining a volume bounding the surfaces generated in said world space, said bounding volume being discretized into a plurality of voxels,

associating an attribute representative of transparency with the voxels of the bounding volume;

changing a value of the attribute representative of transparency to a transparent state for the voxels of the bounding volume not belonging to view cones formed from each viewpoint associated with said surfaces;

associating an attribute representative of transparency with the voxels of the bounding volume;

generating, for each surface, a plurality of rays originating from a viewpoint associated with said each surface and having as end point an intersection with said each surface;

running through said plurality of generated rays, and changing the value of the attribute representative of transparency for the voxels of the bounding volume having an intersection with one of the generated rays; and

generating data representative of a resulting surface according to the attributes representative of transparency associated with said voxels.

2. The method according to claim **1**, further comprising, for each surface, associating voxels of the bounding volume with said each surface to define said each surface, according to a criterion of proximity of the voxels relative to said each surface, the end points of the generated rays corresponding to the voxels associated with said each surface.

3. The method according to claim **2**, wherein said attribute representative of transparency comprises two states, a first state corresponding to the transparent state of the voxel associated with said attribute, a second state corresponding to an opaque state of the voxel associated with said attribute, a voxel being in the transparent state when said voxel has an intersection with a ray of said plurality of rays.

4. The method according to claim **1**, wherein said attribute representative of transparency is determined according to a position of the voxel associated with said attribute with respect to a viewpoint and to the surface representative of a depth map associated with the viewpoint.

5. The method according to claim **4**, wherein said attribute comprises two states, a first state corresponding to the transparent state of the voxel associated with said attribute, a second state corresponding to an opaque state of the voxel associated with said attribute, a voxel being in the transparent state when positioned between a viewpoint and the surface representative of the depth map associated with the viewpoint in said world space.

6. The method according to claim **4**, wherein the position of the voxel is obtained by determining an intersection between said voxel and a ray launched from said viewpoint.

7. The method according to claim **1**, wherein said surface representative of the depth map in the world space is generated using parameters representative of calibration associated with at least one camera used to capture the views of the scene associated with the plurality of depth maps.

8. The method according to claim **1**, wherein the plurality of depth maps is obtained from a multi-view video stream.

9. The method according to claim **8**, wherein the video stream is an MVD (Multiview Video plus Depth) stream.

10. The method according to claim **1**, further comprising transmitting depth information representative of said resulting surface.

11. A device for processing data representative of a plurality of maps representative of depth, each map representative of depth being associated with a view of a scene according to a viewpoint, wherein the device comprises

at least one processor configured for:

generating, for each map representative of depth of said plurality, a surface representative of said map representative of depth in world space;

determining a volume bounding all surfaces generated in said world space, the said bounding volume being discretized into a plurality of voxels,

associating an attribute representative of transparency being associated with the voxels of the bounding volume;

changing a value of the attribute representative of transparency to a transparent state for the voxels of the bounding volume not belonging to view cones formed from each viewpoint associated with said surfaces;

generating, for each surface, a plurality of rays originating from the viewpoint associated with said each surface and having as an end point the intersection with said each surface;

running through said plurality of generated rays, and changing the value of the attribute representative of transparency for the voxels of the bounding volume having an intersection with one of the generated rays; and

generating data representative of a resulting surface according to the attributes representative of transparency associated with said voxels.

12. The device according to claim **11**, wherein the at least one processor is a Graphics Processing Unit.

13. The device according to claim **11**, wherein the at least one processor is further configured to, for each surface, associate voxels of the bounding volume with said generated surface to define said each surface, according to a criterion of proximity of the voxels relative to said each surface, the end points of the generated rays corresponding to the voxels associated with said each surface.

14. The device according to claim **11**, wherein said attribute representative of transparency comprises two states, a first state corresponding to the transparent state of the voxel associated with said attribute, a second state corresponding to an opaque state of the voxel associated with said attribute, a voxel being in the transparent state when said voxel has an intersection with a ray of said plurality of rays.

15. The device according to claim **11**, wherein said attribute representative of transparency is determined according to a position of the voxel associated with said attribute with respect to a viewpoint and to the surface representative of a depth map associated with the viewpoint.

16. The device according to claim 15, wherein said attribute comprises two states, a first state corresponding to the transparent state of the voxel associated with said attribute, a second state corresponding to an opaque state of the voxel associated with said attribute, a voxel being in the transparent state when positioned between a viewpoint and the surface representative of the depth map associated with the viewpoint in said world space.

17. The device according to claim 15, wherein the position of the voxel is obtained by determining an intersection between said voxel and a ray launched from said viewpoint.

18. The device according to claim 11, wherein said surface representative of the depth map in the world space is generated using parameters representative of calibration associated with at least one camera used to capture the views of the scene associated with the plurality of depth maps.

19. The device according to claim 11, wherein the plurality of depth maps is obtained from a multi-view video stream.

20. The device according to claim 19, wherein the video stream is an MVD (Multiview Video plus Depth) stream.

21. The device according to claim 11, wherein the at least one processor is further configured to transmit depth information representative of said resulting surface.

22. A method for modeling a scene from a plurality of maps representative of depth, each map representative of depth being associated with a view of the scene according to a viewpoint, said method comprising:

generating, for each map representative of depth of said plurality, a surface representative of said map representative of depth in world space;

determining a volume bounding surfaces generated in said world space, said bounding volume being discretized into a plurality of voxels,

associating an attribute representative of transparency with the voxels of the bounding volume;

changing a value of the attribute representative of transparency to a transparent state for the voxels of the bounding volume not belonging to view cones formed from each viewpoint associated with said surfaces;

generating, for each surface, a plurality of rays originating from the viewpoint associated with said each surface and having as end point an intersection with said each surface;

running through said plurality of generated rays, and changing the value of the attribute representative of transparency for the voxels of the bounding volume having an intersection with one of the generated rays;

generating data representative of a resulting surface according to the attributes representative of transparency associated with said voxels; and

displaying the modeled scene on a display device.

23. A device for processing data representative of a plurality of maps representative of depth, each map representative of depth being associated with a view of a scene according to a viewpoint, wherein the device comprises

at least one processor configured for:

generating, for each map representative of depth of said plurality, a surface representative of said map representative of depth in world space;

determining a volume bounding all surfaces generated in said world space, the said bounding volume being discretized into a plurality of voxels, an attribute representative of transparency being associated with the voxels of the bounding volume;

changing a value of the attribute representative of transparency to a transparent state for the voxels of the bounding volume not belonging to view cones formed from each viewpoint associated with said surfaces;

generating, for each surface, a plurality of rays originating from a viewpoint associated with said each surface and having as an end point the intersection with said each surface;

running through said plurality of generated rays, and changing the value of the attribute representative of transparency for the voxels of the bounding volume having an intersection with one of the generated rays;

generating data representative of a resulting surface according to the attributes representative of transparency associated with said voxels; and

displaying the scene on a display device.

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