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(54) **System and method for determination of a spatial property of a submerged object in a 3D-space**

(57) Method for determining a spatial property of a submerged object in a 3D-space, using an underwater moveable platform, that is provided with a camera and with a position and orientation measurement system adapted for outputting a position and orientation of the camera, the method comprising receiving user input for visually fitting a bounding volume to the object, and determining the spatial property of the object based on a corresponding spatial property of a bounding volume once the user is satisfied that the bounding volume sufficiently fits the object. The method provides an interactive manner of visually fitting the bounding box to the object, based on two or more images of the object taken at different positions and orientation of the camera relative to the object, as well as on a representation of a position and orientation of the camera in the 3D space at the time each image was captured.

System and method for determination of a spatial property of a submerged object in a 3D-space

Field of the invention

The present invention relates to a system and method for determination of a spatial property, such as heading, position, verticality, attitude, elevation and/or inclination, of an object in a 3D-space, when the object is partially or completely submerged in the water.

Background art

Offshore structures typically comprise objects, such as construction elements, that are completely or partially submerged below the water. During construction of an offshore structure it is desirable that one or more spatial properties of such a submerged object can be determined from a distance to the object and without physically contacting the object. Once an object has been installed or after the offshore structure has been completed, it is further desirable to be able to measure spatial properties of the object, e.g. to check whether it has been correctly positioned, during maintenance and/or when checking whether the object has been damaged. To facilitate surveying of submerged objects, particularly at depths greater than 10m below the water surface, submerged remote operated vehicles (ROV) are known to use sonar. However, the low spatial resolution of sonar makes it difficult to accurately determine spatial properties of the object based on the returned sonar signals.

EP 2 993 620 A1 describes a system for determining the position of an offshore structure, for example an offshore jacket, in a fixed reference frame by observations from a moving reference frame, comprising: a plurality of markers located at defined positions on the structure; an imaging device, arranged to view the markers and generate image data representative of the relative positions of the markers in the moving reference frame; a local positioning system, arranged to determine instantaneous positions of the imaging device in the fixed reference frame and generate position data; and a processing unit, arranged to receive the image data from the imaging device and the position data from the local positioning system and compute the position of the structure based on the defined positions of the markers.

From WO 2016/075231 a method of controlling a subsea platform is known, the method comprising the steps of: providing a database containing object information of objects identified in an environment wherein the platform is operating, generating visualization data of said objects, receiving camera image data from a camera unit disposed on the subsea platform, and composing an image structure based on the object visualization data and the camera image data, wherein the visualization data of said objects are generated using synthetic models thereof. In this process, knowledge of the expected subsea topology, known objects, recognisable landmarks, locations of cameras relative to a frame of reference and other factors may be used. This known system is particularly useful to facilitate navigation of a submerged ROV onto which the camera unit is mounted, if visibility in the water is limited.

A drawback of known systems is that in order for these systems to work, either markings must be attached to the object, or detailed information on an identified object, e.g. a CAD model thereof or its physical properties, dimensional properties, location properties, and display properties, must be known in advance, making these systems unsuitable for ad-hoc measurement of objects for which little or no information is known in advance.

The invention aims to provide a method which facilitates determining spatial properties of an object on an ad-hoc basis.

Summary of the invention

To this end, the present invention provides a method for determining a spatial property of a submerged object in a 3D-space, using an underwater moveable platform, such as a remote operated vehicle, that is provided with a camera and with a position and orientation measurement system adapted for outputting a position and orientation of the camera, the method comprising: capturing, at different positions of the camera with respect to the object, image data comprising an image of the object captured by the camera and a representation of a position and orientation of the camera in the 3D space at the time each image was captured, wherein said representation is obtained using the position and orientation output by the position and orientation measurement system; displaying, on a display, one of the captured images to a user; receiving from the user, at a processing unit connected to the display, dimensions of a 3D bounding volume for the object that is displayed in the captured image; constructing at the processing unit, for two or more of said captured images, a composite image in which the bounding volume is projected overlaid onto said image, displaying said composite image to the user, and receiving, at the processing unit, input from the user for interactively adjusting the position and/or orientation of the bounding volume to improve the visual fit of the bounding volume with the object displayed in the composite image; determining a heading, position, verticality, attitude, and/or inclination of the object based on the dimensions and orientation of the adjusted bounding volume in the 3D space, and outputting this to the user.

The invention allows spatial features such as heading, position, verticality, attitude, elevation and/or inclination of the object to be determined indirectly by calculating the heading, position, verticality, attitude, elevation and/or inclination of the bounding volume. In this manner it is possible to quickly estimate these properties for the submerged object while an underwater survey of the object is being carried out. By using interactive input from the user to improve the visual fit of the bounding volume with the object the accuracy of these estimates is significantly improved. The interactive adjustment by the user of the visual fit of the bounding box to the object is typically carried out without automated tracking of the object to the bounding box (in case of movement of the object), and without automated detection of features of the object and/or automated matching of such features previously identified features. The method can thus be carried out even when no detailed prior information on the submerged object is available, and as adjusting the bounding volume to visually fit the object is carried out by the user, the processing and memory requirements for a processing unit that is used in carrying out the method are kept low.

There are several manners in which the bounding volume may be shown overlain in the composite image, e.g. by showing the edges and vertices of the bounding volume, and/or by showing the surfaces of the bounding volume partially transparent so that the object and the bounding box are visible at the same time. Preferably, the spatial properties of the bounding box are displayed to the user during the interactive adjustment thereof.

The images are captured while the underwater moveable platform is spaced apart from the submerged object, so that collision between the underwater moveable platform and the object is avoided. The camera is typically adapted for capturing a range of visible light, in particular light in the range of green to blue, e.g. having a wavelength in the range of 420 to 570 nm. In order to provide a better view of the object, the underwater moveable platform may be provided with one or more light sources for illuminating the object, wherein the one or more light sources are preferably adapted for emitting a majority of its power in the wavelength range of 420 to 570 nm.

In an embodiment, the camera is adapted for capturing light in the non-visible UV region. This allows the user to better view movement of gas streams in the water.

In an embodiment the bounding volume is a bounding cylinder or a bounding box or a convex polyhedron. These shapes lend themselves to be particularly easily adjusted in an interactive manner by the user. Preferably, the method includes letting the user choose between using a bounding cylinder or a bounding box as the bounding volume.

In an alternative embodiment, the bounding volume is a 3D-CAD model of the object. When such a CAD model is available, visual fitting of the bounding volume to the captured images can be carried out particularly easily, e.g. by using a bounding box or bounding cylinder of the 3D-CAD model as the bounding volume for the object.

In an embodiment the dimensions of the bounding volume remain constant during the interactive adjustment of the position and/or orientation of the bounding volume. For some objects the user may have prior information about the expected dimensions of the bounding volume, e.g. when the object is an object having standardized dimensions. By adjusting only the position and orientation of the bounding box, but not its dimensions, the user can easily check visually whether the dimensions of the object still conform to the expected dimensions.

In an alternative embodiment the input device is further adapted for receiving input from the user to interactively adjust the dimensions of the bounding volume. This allows the spatial properties to be measured when no information on the dimensions of the submerged are available at all.

In an embodiment the method further comprises, subsequent to the step of receiving the dimensions of the bounding box from the user, setting at the processing unit and based on the entered dimensions, the position and orientation of the camera at the time the image was captured and on the height and width of the image, an initial position and orientation of the bounding volume such that, if the bounding volume is projected overlaid onto the captured image, the bounding volume is centered on the captured image and fits within the captured image, preferably wherein a main axis of the bounding volume extends parallel to the height or width direction of the captured image. It is thus ensured that the bounding volume fits within a view frustum the camera had at the time the image was captured.

In an embodiment the position and orientation measurement system is adapted for providing one or more position and orientation samples between each capture of an image by the camera, and wherein for each captured image the representation of the position and orientation of the camera is selected that was sampled at a time closest to the time the image was captured. To achieve this, the position samples, the orientation samples and the captured image are preferably all provided with a time stamp, wherein for a captured image that is provided with a time-stamp a position sample is selected which has a time-stamp closest to the image time-stamp, and an orientation sample is selected which has a time-stamp closest to the image time-stamp. The time stamp for the position and orientation samples and for the captures image are preferably provided by a central clock.

In an alternative embodiment the position and orientation measurement system is adapted for providing multiple position and orientation samples between each capture of an image by the camera, and wherein for each captured image the representation of the position and orientation of the camera in the 3D space at the time the image was captured is determined by interpolating two or more of said samples taken before and after the time the image was captured. Preferably the position and orientation measurement system are adapted for providing position samples at a first fixed rate and for providing orientation samples at a second fixed rate. In order to be able to correctly determine the position and orientation of the camera, the position and orientation measurement system typically operate at respective sampling rates at least 10-20 Hz and 50 Hz. Though the first and second sampling rate may be adjustable to higher rates, the camera typically has an image capture rate which is either fixed or lower than the first and second rates. By interpolating the samples from the position and orientation measurement system, the position and orientation information from each captured image may be improved.

In an embodiment the camera is adapted for capturing each image upon receipt of a trigger signal that is synchronized with or provided by the position and orientation measurement system. This embodiment is especially suitable to be used with a camera which does not have a fixed image sampling rate.

In an embodiment the method further comprises providing the user with an input device for determining an angle between a line in one of said captured images displayed to the user and the direction of earth gravity, and the user interactively drawing a measurement line in said displayed image and the user interactively adjusting the angle between said measurement line and the direction of earth gravity while displaying the angle to the user. In general, the input device will comprise a computer mouse, keyboard, joystick, or pen or the like. As the orientation and position of camera at the time the image was captured is known, the direction of earth gravity within the captured image is known as well, so that this direction can be shown to the user. However, when using this tool to align the measurement line with a line of the object shown in the image, it is important to ensure that the image has been captured from a suitable point of view, to avoid inaccurate measurements due to perspective distortion.

In an embodiment the composite image further comprises an overlay of a compass which shows the direction in which the camera is facing. This facilitates navigation of the underwater moveable platform during surveying.

To facilitate entry of the initial approximation of the position of the bounding volume, the method in an embodiment comprises refusing entry an approximation of the position and orientation of the bounding volume if the resulting bounding box does not lie partially or completely within the 3D viewing volume of the image displayed to the user. Based on the positional and orientation information of the camera and on the camera configuration, a 3D viewing volume can be calculated for each captured image, independent of whether the object is shown in captured image or not. For instance, if an image of the object was captured when camera was oriented north, then the 3D viewing volume for the image will exclude the volume south of the camera.

In an embodiment the processing unit is located on a vessel that is spaced apart from the underwater moveable platform and which floats on the water.

In an embodiment the method is performed while the underwater moveable platform is submerged in vicinity to the submerged object and while spaced apart therefrom. In vicinity here typically means that the camera is located anywhere in the range of 5 to 160 meters from the object.

According to a second aspect the present invention provides a computer readable medium comprising instructions which, when executed by a computer, cause the computer to carry out the method as described herein.

According to a third aspect, the present invention provides a system for determining a spatial property of a submerged object in a 3D-space, the system comprising: an underwater moveable platform that is provided with a camera and with a position and orientation measurement system adapted for outputting a position and orientation of the camera; and a vessel provided with a user display for displaying a composite image to a user, an input device for receiving input from the user, and a processing unit, wherein the processing unit is adapted for carrying out the method as described herein.

Short description of drawings

The present invention will be discussed in more detail below, with reference to the attached drawings, in which

Figs. 1A and 1B respectively show schematically a side view and a top view of an underwater moveable platform that is provided with a digital camera, and a submerged object;

Fig. 2A shows a view of user display on which an image of the submerged object captured with the digital camera is displayed;

Fig. 2B shows entry of dimensions of a bounding box to be fit around the object;

Fig. 2C illustrates how the orientation and position of the bounding box are adjusted by the user, while spatial properties of the bounding box are presented on the user display in real time;

Fig. 2D illustrates how the orientation and position of the bounding box are further adjusted by the user based on another image captured by the camera, while spatial properties of the bounding box are presented on the user display in real time;

Fig. 3 shows a flow chart of the method according to the invention;

Fig. 4 illustrates how the user can determine an angle between the direction of gravity and an line between two points of the object shown in a captured.

Description of embodiments

Figs. 1A and 1B schematically show a side view and a top view of an underwater platform, in this case a remote operated vehicle, ROV, 20 that is connected to a topside platform, in this case a ship 10, via a tether 19. The length of the tether 19 is between 200m and 6 km, allowing the ROV to reach submerged objects in deep waters and/or at positions remote from the ship 10. The tether includes a signal cable, usually a fiber optic cable, for transmitting control signals for steering the ROV. In the example shown, the ROV may be steered by controlling the orientation of steerable fins 22 relative to the main body 21 of the ROV, and/or by individually controlling the speed of rotation of the propellers 23 that are mounted on the steerable fins. The ROV is further provided with a module 30 comprising a camera 31 that is fixedly attached to a and position and orientation measurement system 32. The position and orientation measurement system 32 is adapted for providing information on the position (X,Y,Z) and orientation (Rx,Ry,Rz) of the camera in the 3D space, preferably at a rate of 25 Hz or more, and may comprise a GPS as well as an inertia measurement system or other kind of attitude measurement system. The position may be determined in a local reference frame or in the Earth's reference frame, depending on the requirements of the situation. In the following, reference will be made to positioning within the Earth's geodetic reference frame unless otherwise stated, although the invention is equally applicable to any chosen reference frame.

The ROV 20 may be controlled, from the vessel, to move about the object 50 from position P1 to position P2. In Fig. 1B, the ROV when in position P2 is referred to using reference numeral 20'. By moving the ROV relative to the object images of the object when the ROV's camera 31 is at different position and orientation with respect to the object 50 may be captured. The camera 31 can only detect objects that are at least partially within its field of view. In Figs. 1A and 1B, the camera's field of view when the ROV is in position P1 is illustrated by view frustum V, and the camera's field of view when the ROV is in position P2 is illustrated by view frustum V'. In positions P1,P2 the orientation and position of the camera 30 relative to submerged object 50, the object 50 lies completely within the view frustums V and V' respectively. The object 50 is completely submerged in the water 3 below the water surface 4, and is to form part of a mechanical base for supporting a wellhead. The object 50 comprises a frame 51 with a square bottom edge 52 that is supported on the sea bed 2, which frame tapers upwards towards a square top edge 53 having a smaller than the bottom edge 52.

Generally, the camera and position and orientation system will work at different sampling rates, with the position and orientation system typically sampling position and orientation data at a higher rate than the camera captures digital images. In order to be able to accurately determine the position and orientation of the camera at each time camera captures and image, each of the images captured by the camera and each position and orientation data sampled by the position and orientation system is provided with a timestamp. For a more detailed example on how such timestamps may be provided, reference is made to par. [0044] of European patent application EP 2 993 620 A1 by applicant.

The captured images and position and orientation data, together with the corresponding timestamps, are transmitted from the ROV to the ship 10. Within a control cabin 11 of the ship a user display 12 is arranged for showing the images captured by the digital camera to a user on the ship 10, together with an input device 13, e.g. a keyboard, mouse or touchscreen for receiving input from the user. A processing unit 14 is provided for calculating, based on captured image information which includes the captured image as well as positional and orientational data of the camera at the time the image was captured, a position and orientation of a bounding box that is to be shown overlaid onto the captured image.

Fig. 2A shows a user display 60 on which an image 64 of the submerged object 50 is displayed, wherein the image has been captured using the digital camera 31 when the underwater moveable platform was in position P1 of Fig. 1B. An information window 61 shows information to the user, such as position and orientation of the camera at the time the image was captured. Additionally, the information window 61 provides a space on the display in which spatial properties of a bounding volume, such as a bounding box or bounding cylinder, can be shown to the user. An input window 62 shown on the display allows the user to enter height, width and length dimensions of a rectangular bounding box into a processing unit, e.g. a computer, that is connected to the display. In the view of Fig. 2A no information has yet been input into the input window 62, and consequently, no bounding volume is shown.

In Fig. 2B the user has entered provided height, width and length dimensions for a rectangular bounding box 70 to the processing unit via input window 62 at the respective input sections labelled H:, W: and L:. In the example, the user has prior knowledge of the dimensions of the rectangular bounding, e.g. because schematics of the object indicating height width and length thereof, were available to the user before the image was displayed to the user.

As no information on the exact position and orientation of the bounding box 70 has been provided to the processing unit 14, the processing unit initially sets the position of the bounding box such that it is drawn centered on the image with a center C of the bounding box 70 coinciding with the center of the image 64. The orientation of the bounding box 70 is initially set such that a face of the bounding box that is closest to display is parallel to the display plane. In Fig. 2B this face contains vertices 70a, 70d, 70e and 70h of the bounding box. Additionally, the orientation of the bounding box is set such that a lower edge 77, in Fig. 2B between vertices 70e and 70h, of the bounding box is parallel to a lower edge 67 of the rectangular image 64. The orientation of the bounding box is thus partially defined based on the display plane of the display unit, and at least two of the three positional coordinates of the bounding box in the 3D space are initially based on the width and height of the captured image 64. The remaining third positional coordinate of the bounding box in 3D space is initially set by the processing unit such that the entire bounding box is visible on the display. Preferably the third coordinate is set such that, when the bounding box is displayed on the display, it is spaced apart from the horizontal and vertical edges of the display by a margin of at least 20 % of respectively the width and height of the display. For instance, if the captured image has 1600x1080 pixels, then the third coordinate would initially be set such that the bounding box is displayed to lie within a rectangle with lower left coordinate (320,216), lower right coordinate(1280, 216) and upper right coordinate (1280, 864).

Once initial position, dimensions and orientation of the bounding box have been set/entered, information on the spatial properties of the bounding box, such as heading, position, verticality, attitude, elevation and/or inclination of the bounding box, are instantly (e.g. within 0,2 s) displayed in the information window 61. T

Fig. 2B shows that initially the position and orientation of the bounding box 70 do not visually match with that of the submerged object 50. Consequently, the information displayed in the information window 61 about spatial properties of the bounding box does not provide accurate information about corresponding spatial properties of the submerged object.

In Fig. 2C the user has interactively adjusted the position and orientation of the bounding box, by entering adjustment values for the position and orientation of the bounding box 70 in input fields 65 and 65 respectively. As a result, there is an improved visual match between the bounding box 70 and the object 50. Instead of, or in addition to, entering adjustment values in input fields 65, 66 the user may adjust the position and/or orientation of the bounding box within the captured image 64 by dragging any one of vertices 70a-70h to translate or rotate the bounding box in the image.

In the view of Fig. 2C vertices 70e-70h of the bounding box 70 appear to substantially coincide with the vertices of rectangular bottom edge 52 of the object 50, while vertices of the rectangular top edge 53 of the object appear to lie substantially within a plane spanned by vertices 70a-70d of the bounding box. In order achieve this view, the user has slightly titled the bounding box around its z-axis, and has translated the bounding box along its X,Y, and Z axis, until satisfied with the shown visual match of the bounding box to the submerged object.

Fig 2D shows an image 64'of the object captured when the underwater platform 20' has moved to position P2' in Fig. 1B. The bounding box for which the dimensions, orientation and position have interactively adjusted to form the overlay shown in Fig. 2C, is now seen from a different perspective. From this perspective it is clear that the bounding box should be rotated slightly around Ry in order to let the square bottom edge 52 and the square top edge 53 lie within bottom plane and top plane of the bounding box. In the perspective view of the object shown on the display in Fig. 2C this difference between the bounding box and the submerged object was not as clearly visible. By interactively adjusting the orientation of the bounding box, the user further improves the visual match between the object and the bounding box. The user may view multiple captured images taken at different positions and orientation of the camera relative to the object, and based upon said images improve the visual fit of the bounding box that is shown overlain on each image.

Upon each adjustment of the bounding box, spatial properties of the bounding box are instantaneously (e.g. within 0,2 s) recalculated and displayed in the information window 61. Once the user is satisfied that the bounding box matches the object to a sufficient extent, he can read out the calculated spatial properties of the bounding box from the information window, for instance for further use later on.

With reference to figures 2A-2D a method according to the invention has been described which made use of predetermined dimensions of the bounding volume of the submerged object, wherein the dimensions of the bounding volume substantially correspond to the dimensions of the submerged object. It will however be appreciated that if no such predetermined dimensions are known, the method may still be carried out by letting the user enter an approximation of the dimensions of the bounding volume of the object, based on a captured image. Based on one or more further captured images, the user can then subsequently interactively adjust the dimensions of the bounding volume, as well as its orientation and/or position.

Additionally, for measuring some spatial properties of an object based on the corresponding spatial properties of a bounding volume, it is not required that the dimensions of the bounding volume accurately match the dimensions of the submerged volume. For instance, a heading or tilt a submerged object may accurately be determined if the orientation of the bounding volume sufficiently matches that of the submerged object, even if the dimensions and position of the bounding volume do not match accurately with those of the submerged object.

Fig. 3 shows an example of a bounding volume in the form of a bounding cylinder, which is more suitable to be visually matched to a cylindrical object such as pipe 58. Fig 3 shows the bounding cylinder 80 as it is initially displayed overlaid in a captured image 64'' on the user display, immediately after the user has entered an approximation of the dimensions of the bounding cylinder. The position, orientation and dimensions of the cylindrical volume can be interactively adjusted by the user, until it substantially is aligned with pipe 58. For reasons of brevity, Fig. 3 shows the cylinder 80 in its initial position and orientation, as well in its aligned position and orientation as cylinder 80' shown in dotted lines. It will however be understood that the user will only be shown either cylinder 80 in its initial position and orientation or the cylinder in an adjusted position and orientation. Once the user is satisfied that the bounding cylinder matches the object 58 to a sufficient extent, he can read out the calculated spatial properties of the bounding box from the information window 61, for instance for further use later on.

Besides the bounding box, a virtual compass tool 69 is overlaid onto the image 64''. As the ROV changes its direction, the virtual compass tool rotates correspondingly in the image that is displayed to the user. The virtual compass tool is motion compensated so that if the camera would look towards the center of the earth, the compass would take the form of a proper circle.

Fig. 4 shows an example of a virtual protractor tool for determining an angle between a line in one of the captured images and the direction of gravity. After selecting to use the virtual protractor tool, the user clicks at a point P3 on the image and pulls out a baseline L1 of the protractor. The virtual protractor is overlaid onto the 2D image with its center point on point P3, and oriented such that its zero degree line L2 is along the direction of gravity, along line L2. The end point of the base line in the captured 2D image can be adjusted interactively by the user, e.g. until it is aligned with an bar 54 of the object, wherein during the interactive adjustment the protractor angle α between line L1 and line L2 is instantaneously calculated and displayed in protractor information window 68.

Fig. 5 shows a flowchart of a method according to the present invention. In step 100 an underwater moveable platform captures first image data of a submerged object, the first image data comprising a digital image of the object, as well as a representation of a position and orientation of the camera in the 3D space at the time the first image was captured. In step 101 this captured image is displayed to a user. Subsequently, in step 102, input is received from the user on dimensions of a 3D bounding volume for the object that is shown in the image. In step 103 a composite image is constructed, in which the bounding box overlaid onto the first image, and the composite image is displayed to the user. In step 104 the underwater moveable platform captures second image data of the submerged object when the camera is at a different location that in step 100. The second image data comprises a second digital image of the object, as well as a representation of a position and orientation of the camera in the 3D space at the time the second image was captured. In step 105 a composite image is constructed, in which the bounding box overlaid onto the second image, and the composite image is displayed to the user. User input for adjusting the orientation and/or position of the bounding box in the second image to improve the visual fit of the bounding volume with the object, is received in step 106. Upon receipt of the user input, spatial properties of the bounding volume are instantaneously calculated and output to the user in step 107. Steps 105, 106 and 107 may be repeated, as indicated by the dotted arrow, until the user is satisfied with the visual fit of the bounding volume with the object that is displayed in the composite image. When the bounding volume sufficiently fits the submerged object, spatial properties such as heading, position, verticality, attitude, elevation and/or inclination, of the object in the 3D space substantially correspond to the same spatial properties of the bounding volume.

In the method described above, in step 105 only the position and/or orientation of the bounding volume are interactively adjusted by the user making the method suitable for situations in which dimensions of an object's bounding volume are known in advance.

If the dimensions of an object's bounding volume are not known in advance, e.g. when carrying out ad-hoc surveying, or when the existence of the submerged objects was not previously known to the user, step 105 may additionally comprise receiving user input for adjusting the dimensions of the bounding volume to improve the visual fit of the bounding volume with the object.

In summary, the invention provides a method for determining a spatial property of a submerged object in a 3D-space, using an underwater moveable platform that is provided with a camera and with a position and orientation measurement system adapted for outputting a position and orientation of the camera, the method comprising receiving user input for visually fitting a bounding volume to the object, and determining the spatial property of the object based on a corresponding spatial property of a bounding volume once the user is satisfied that the bounding volume sufficiently fits the object. The method provides an interactive manner of visually fitting the bounding box to the object, based on two or more images of the object taken at different positions and orientation of the camera relative to the object, as well as on a representation of a position and orientation of the camera in the 3D space at the time each image was captured.

The present invention has been described above with reference to a number of exemplary embodiments as shown in the drawings. Modifications and alternative implementations of some parts or elements are possible, and are included in the scope of protection as defined in the appended claims.

Conclusies

1. Werkwijze voor het bepalen van een ruimtelijke eigenschap van een ondergedompeld object (50; 58) in een 3D-ruimte, gebruikmakend van een beweegbaar onderwaterplatform (20), zoals een op afstand bediend voertuig, dat is voorzien van een camera (31) en een positie- en oriëntatiemeetsysteem (31) ingericht voor het uitvoeren van een positie en oriëntatie van de camera, de werkwijze omvattend:

het vastleggen, op verschillende posities (P1,P2) van de camera ten opzichte van het object, van beeldgegevens omvattend een beeld (64; 64') van het object vastgelegd door de camera en een representatie van een positie en oriëntatie van de camera in de 3D ruimte op het tijdstip dat elk beeld werd vastgelegd, waarbij de representatie wordt verkregen gebruikmakend van de door het positie- en oriëntatiemeetsysteem uitgevoerde positie en oriëntatie;

het aan een gebruiker weergeven, op een weergave-inrichting (12), van een van de vastgelegde beelden;

het ontvangen van de gebruiker, bij een verwerkingseenheid (14) die met de weergave-inrichting is verbonden, van afmetingen van een 3D begrenzend volume (70; 80) voor het in het vastgelegde beeld weergegeven object;

het construeren, bij de verwerkingseenheid, voor twee of meer van de vastgelegde beelden, van een composietbeeld waarin het begrenzend volume op het beeld gesuperponeerd is geprojecteerd, het weergeven van het composietbeeld aan de gebruiker, en het ontvangen, bij de verwerkingseenheid, van invoer van de gebruiker voor het interactief aanpassen van de positie en/of oriëntatie van het begrenzend volume om de visuele passing van het begrenzend volume met het in het composietbeeld weergegeven object te verbeteren;

het bepalen van een koers, positie, verticaliteit, stand en/of helling van het object op basis van de afmetingen en oriëntatie van het aangepaste begrenzend volume in de 3D ruimte, en het uitvoeren daarvan naar de gebruiker.

2. Werkwijze volgens conclusie 1, waarbij het begrenzend volume een begrenzende cilinder of een begrenzende doos is.

3. Werkwijze volgens conclusie1, waarbij het begrenzend volume een 3D CAD model van het object is.

4. Werkwijze volgens een der voorgaande conclusies, waarbij, tijdens de interactieve aanpassing van de positie en/of oriëntatie van het begrenzend volume, de afmetingen van het begrenzend volume constant blijven.

5. Werkwijze volgens conclusie1, 2 of 3, verder omvattend het ontvangen van invoer van de gebruiker voor het interactief aanpassen van de afmetingen van het begrenzend volume om de

visuele passing van het begrenzend volume met het in het composietbeeld weergegeven object te verbeteren.

6. Werkwijze volgens een der voorgaande conclusies, verder omvattend opeenvolgend aan de stap van het van de gebruiker ontvangen van de afmetingen van de begrenzende doos, het instellen, bij de verwerkingseenheid en op basis van de ingevoerde afmetingen, de positie en oriëntatie van de camera ten tijde dat het beeld werd vastgelegd en de hoogte en breedte van het beeld, van een initiële positie en oriëntatie van het begrenzend volume zodanig dat, als het begrenzend volume gesuperponeerd op het vastgelegde beeld wordt geprojecteerd, het begrenzend volume gecentreerd is op het vastgelegde beeld en binnen het vastgelegde beeld past, bij voorkeur waarin een hoofdas van het begrenzend volume zich parallel uitstrekt aan de hoogte of breedte richting van het vastgelegde beeld.

7. Werkwijze volgens een der voorgaande conclusies, waarbij het positie- en oriëntatiemeetsysteem is ingericht voor het verschaffen van een of meer positie- en oriëntatie monsters tussen elke vastlegging van een beeld door de camera, en waarbij voor elk vastgelegd beeld die representatie van de positie en oriëntatie van de camera geselecteerd wordt die werd bemonsterd op een tijdstip het meest nabij aan het tijdstip waarop het beeld werd vastgelegd.

8. Werkwijze volgens een der voorgaande conclusies, waarbij het positie- en oriëntatiemeetsysteem is ingericht voor het verschaffen van meerdere multiple positie- en oriëntatie monsters tussen elke vastlegging van een beeld door de camera, en waarbij voor elk vastgelegd beeld de representatie van de positie en oriëntatie van de camera in de 3D ruimte ten tijde dat het beeld werd vastgelegd wordt bepaald door interpolatie van twee of meer van de monsters die voor en na het tijdstip dat het beeld werd vastgelegd werden genomen.

9. Werkwijze volgens een der voorgaande conclusies, waarbij de camera is ingericht voor het vastleggen van elk beeld bij ontvangst van een triggersignaal dat gesynchroniseerd is met of verschaft wordt door het positie- en oriëntatiemeetsysteem.

10. Werkwijze volgens een der voorgaande conclusies, verder omvattend het de gebruiker voorzien van een invoerinrichting voor het bepalen van een hoek tussen een lijn in een van de aan de gebruiker weergegeven beelden en de richting van Aarde-zwaartekracht, en het interactief door de gebruiker tekenen van een meetlijn in het weergegeven beeld en het door de gebruiker interactief aanpassen van de hoek tussen de meetlijn en de richting van Aarde-zwaartekracht onderwijl de hoek weergevend aan de gebruiker.

11. Werkwijze volgens een der voorgaande conclusies, waarbij het composietbeeld verder een superponering van een kompas omvat die de richting toont waarnaar de camera is gekeerd.

12. Werkwijze volgens een der voorgaande conclusies, omvattend het weigeren van invoer een benadering van de positie en oriëntatie van het begrenzend volume als de resulterende begrenzende doos niet deels of geheel binnen het 3D zicht frustum van de camera ligt dat correspondeert met het beeld dat aan de gebruiker wordt weergegeven.

13. Werkwijze volgens een der voorgaande conclusies, waarbij de verwerkingseenheid op een voertuig is geplaatst dat op afstand is geplaatst van het beweegbare onderwaterplatform en dat op het water drijft.

14. Werkwijze volgens een der voorgaande conclusies, waarbij de werkwijze wordt uitgevoerd terwijl het beweegbaar onderwaterplatform is ondergedompeld in de nabijheid van het ondergedompelde object.

15. Computer leesbaar medium omvattend instructies welke, wanneer uitgevoerd door een computer, bewerkstelligen dat de computer de werkwijze volgens een der voorgaande conclusies uitvoert.

16. System voor het bepalen van een ruimtelijke eigenschap van een ondergedompeld object in een 3D-ruimte, het system omvattend: een beweegbaar onderwaterplatform dat is voorzien van een camera en van een positie- en oriëntatiemeetsysteem ingericht voor het uitvoeren van een positie en oriëntatie van de camera; en een voertuig dat is voorzien van een gebruikersweergave-inrichting voor het weergeven van een composietbeeld aan een gebruiker, een invoerinrichting voor het ontvangen van invoer van de gebruiker, en een verwerkingseenheid, waarbij de verwerkingseenheid is ingericht voor het uitvoeren van de werkwijze volgens een der conclusies 1-14.

Fig.1A

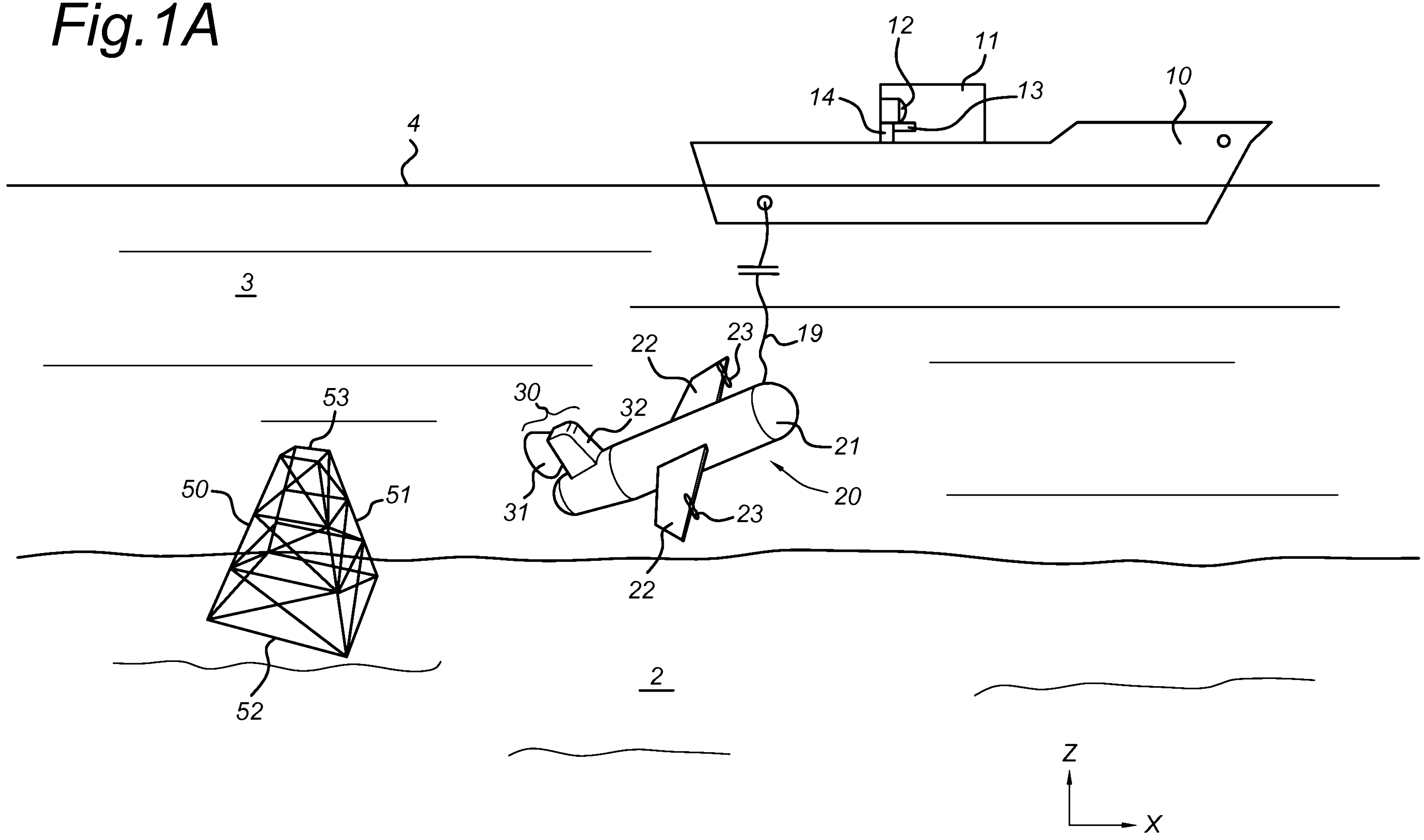

Fig.1B

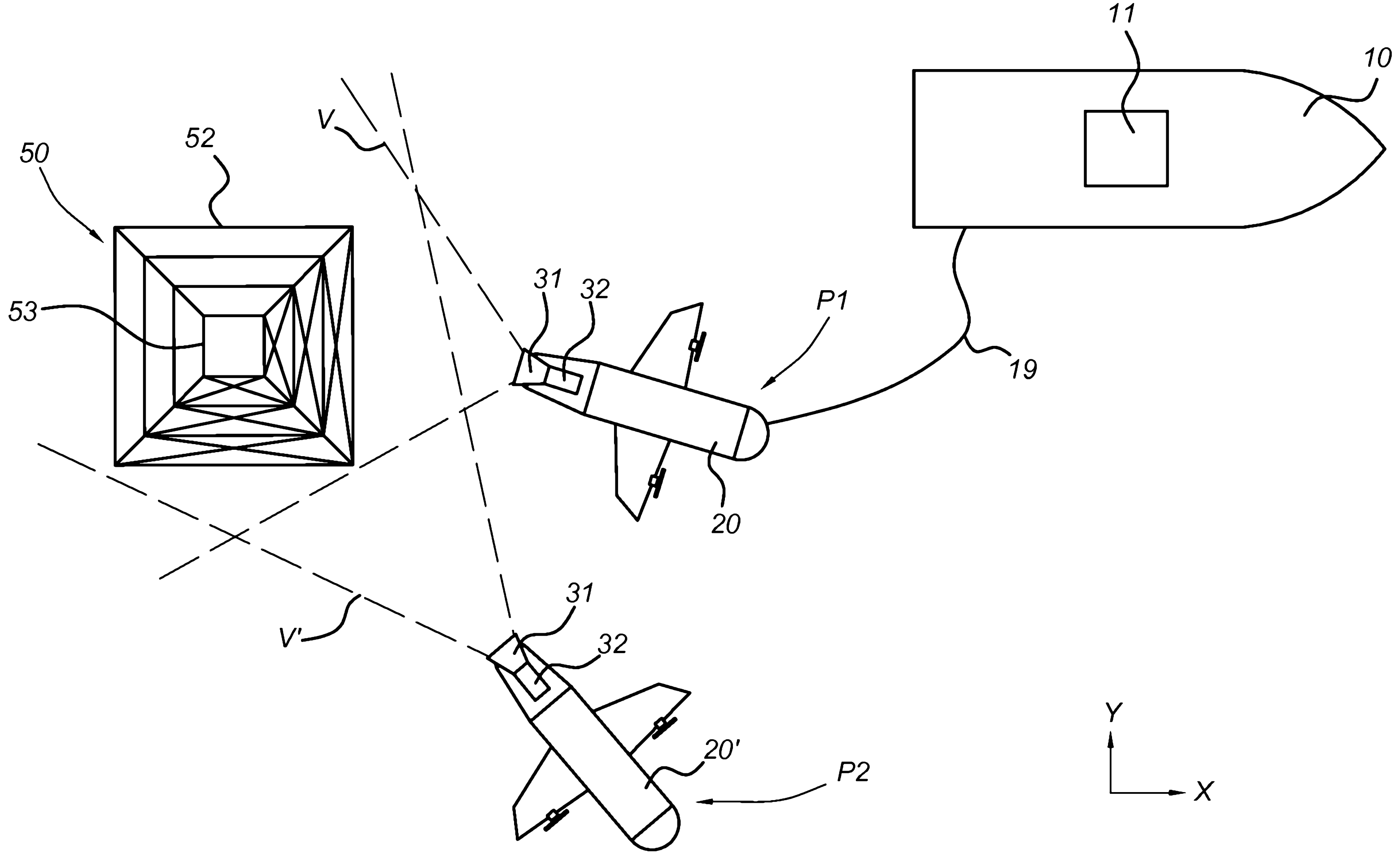

Fig.2A

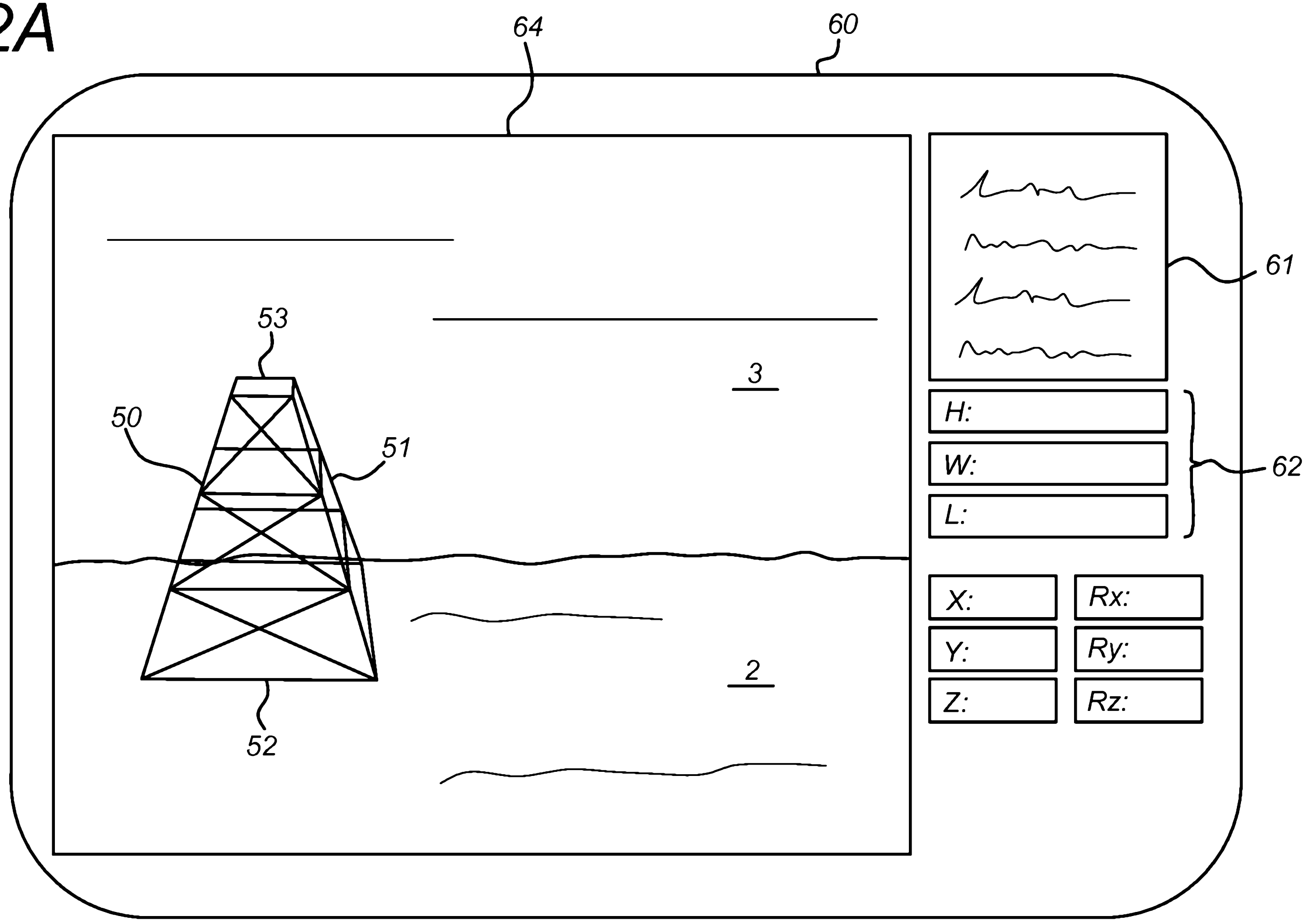

Fig.2B

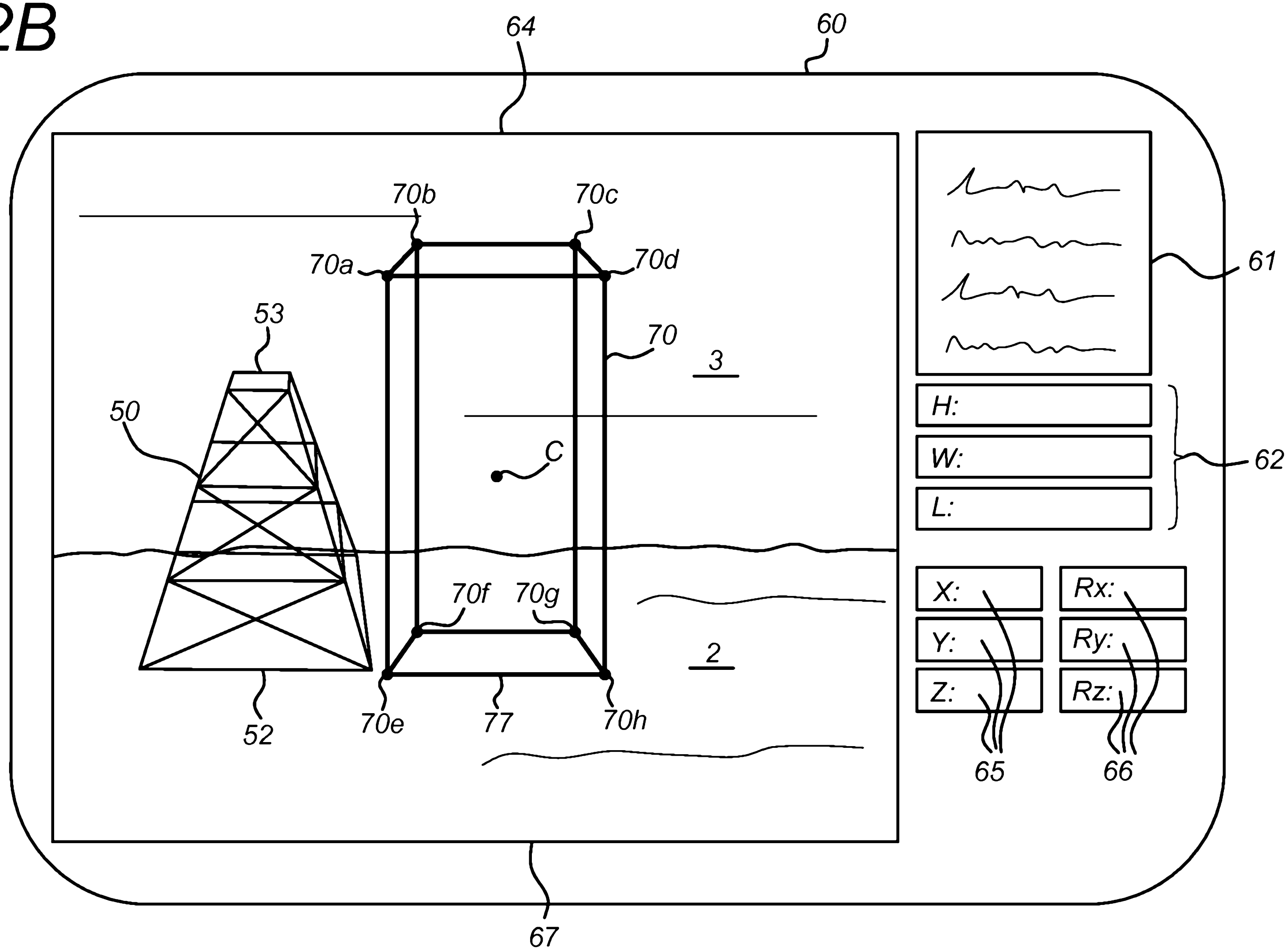

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Fig.2C

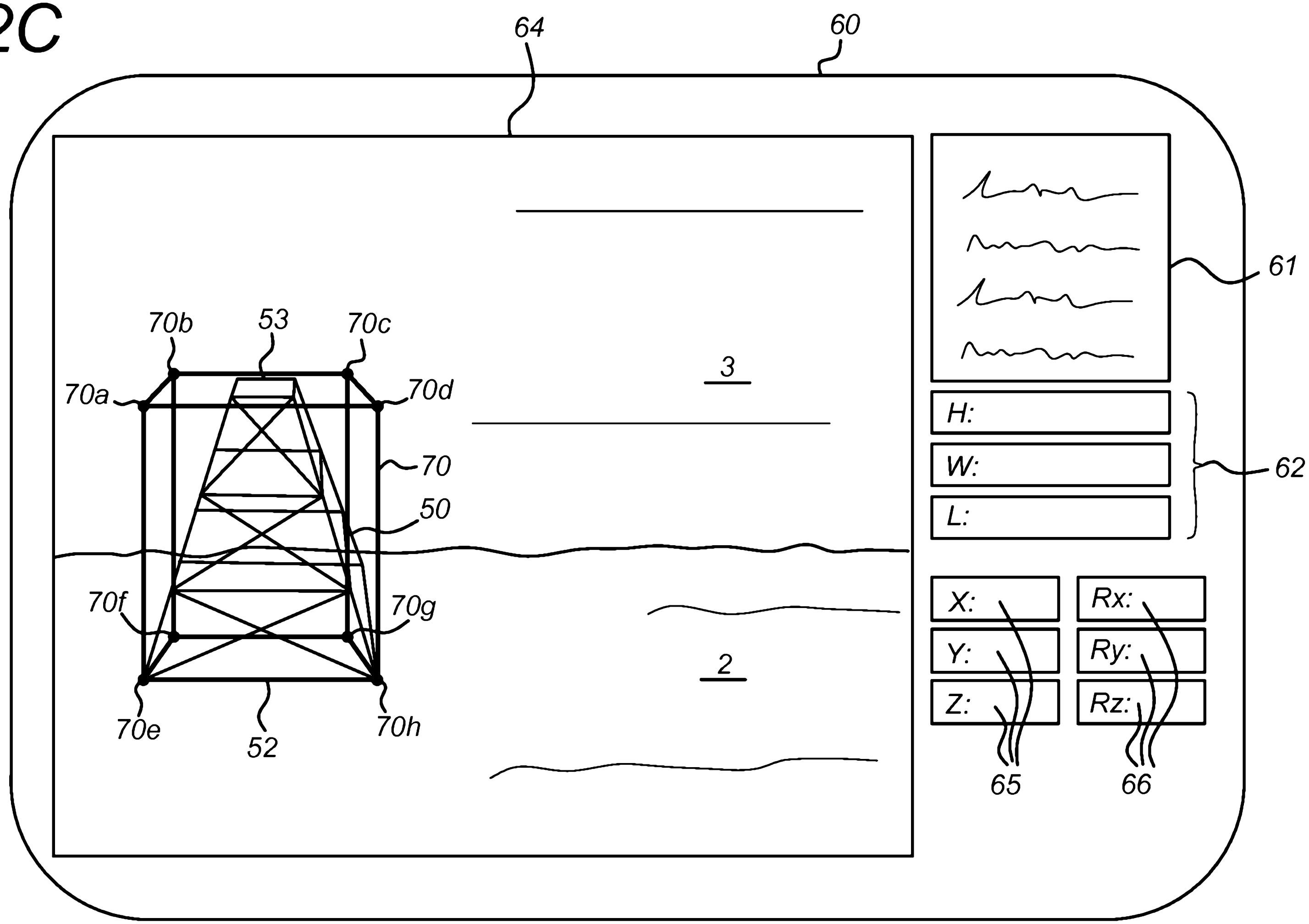

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Fig.2D

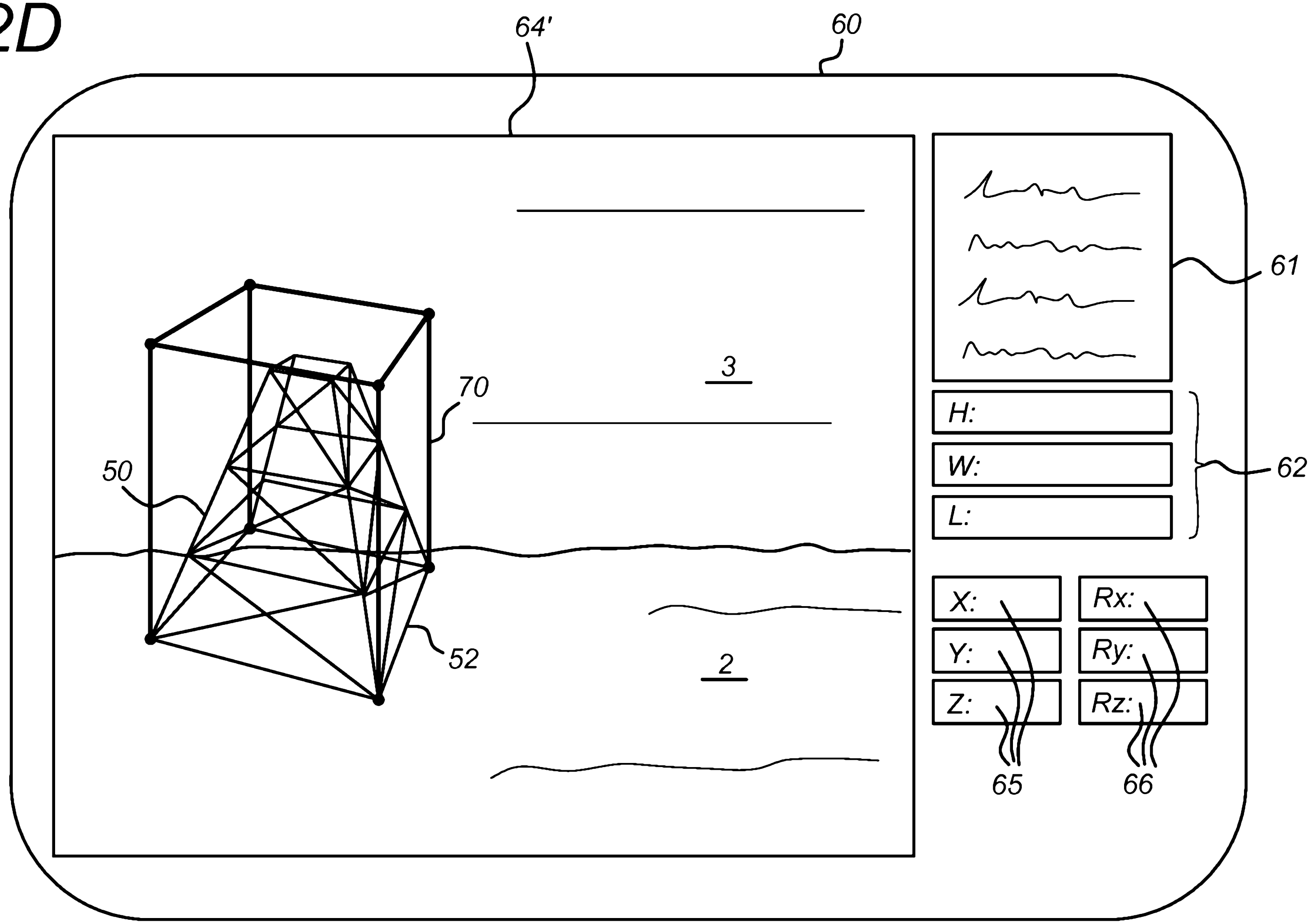


Fig.3

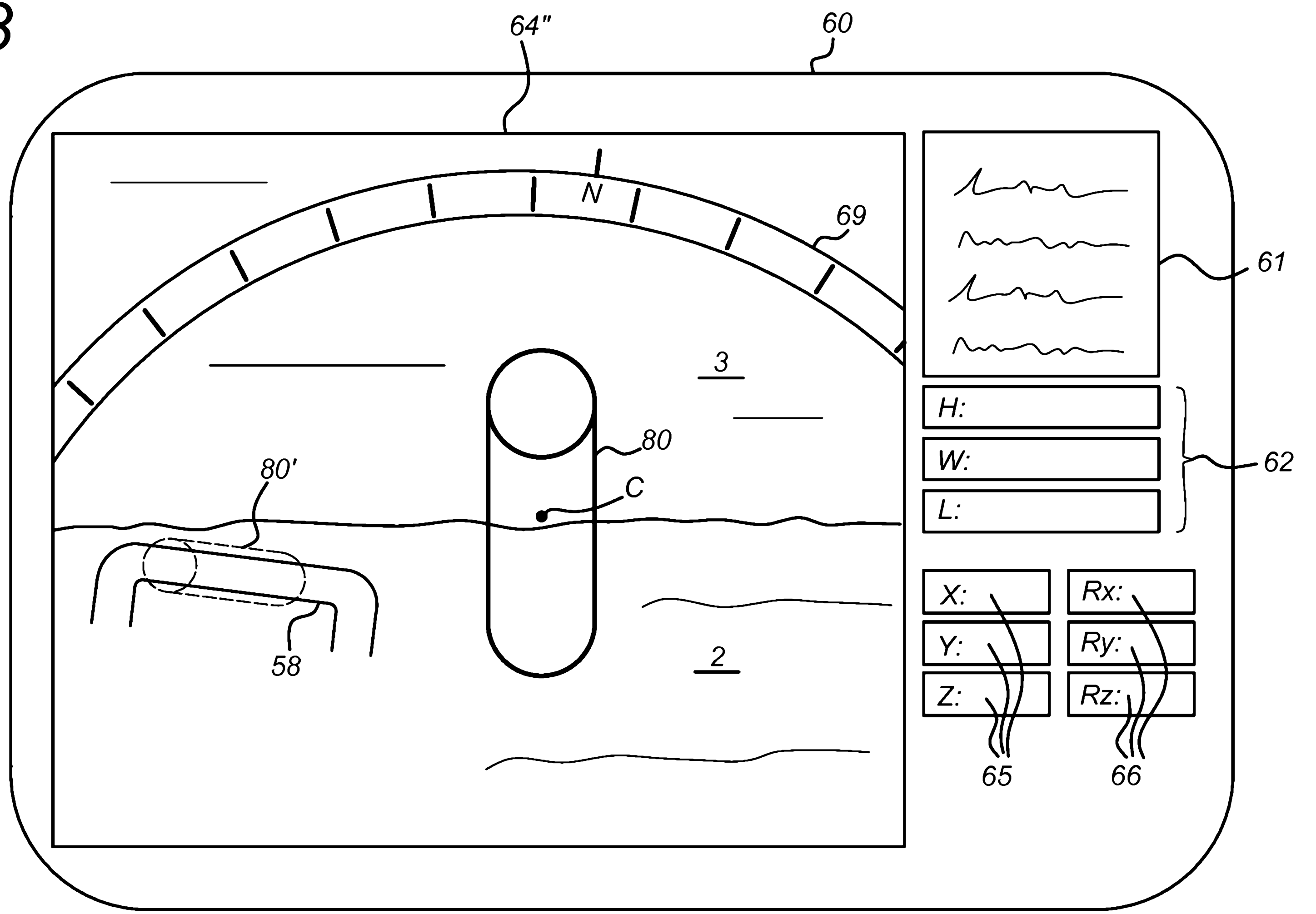


Fig.4

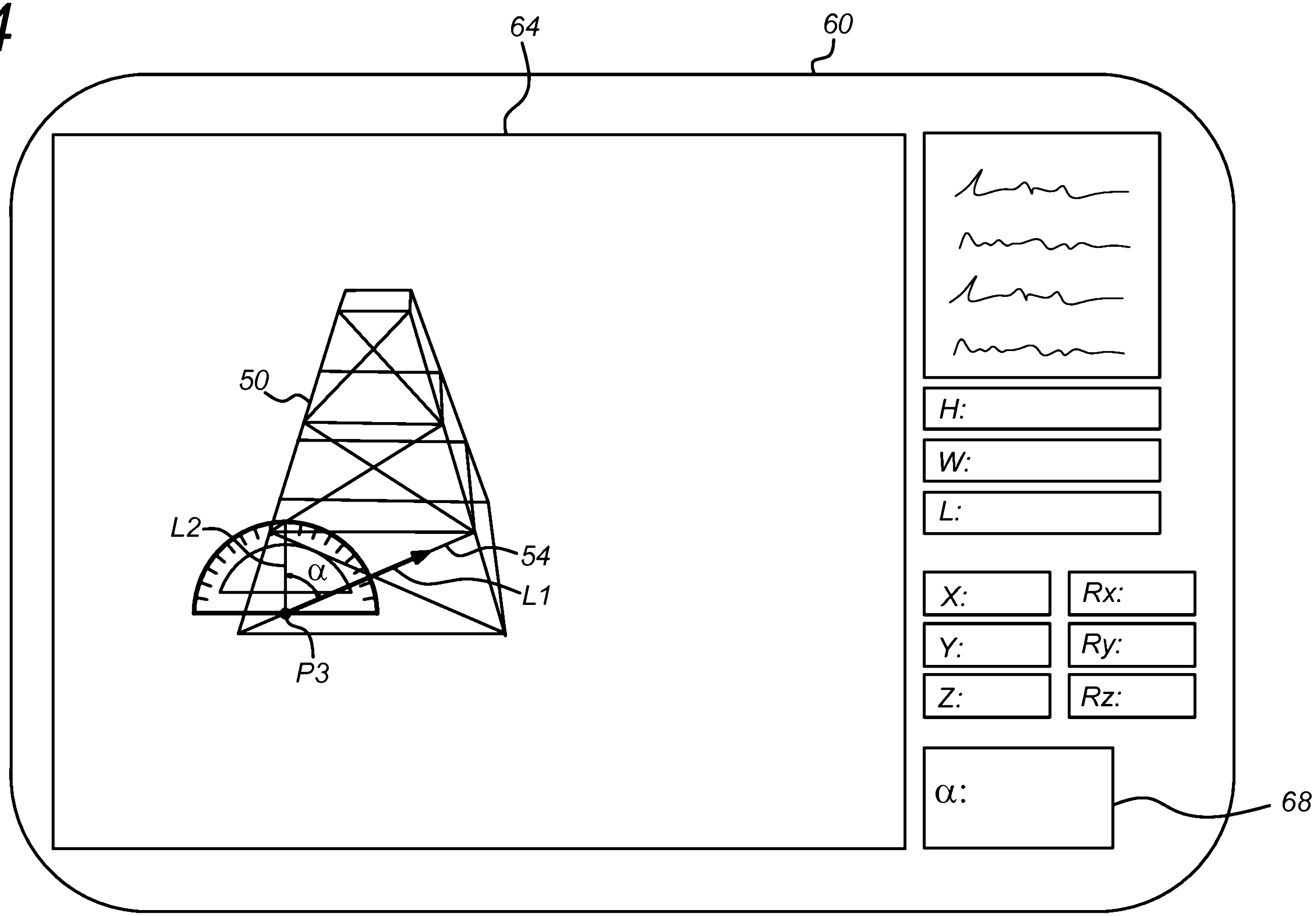
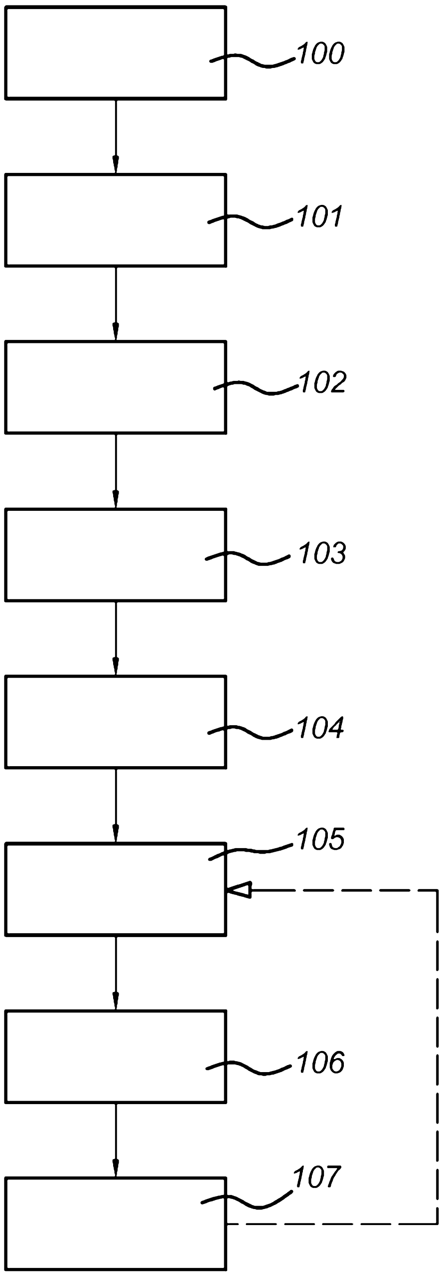


Fig 5



Abstract

Method for determining a spatial property of a submerged object in a 3D-space, using an underwater moveable platform, that is provided with a camera and with a position and orientation measurement system adapted for outputting a position and orientation of the camera, the method comprising receiving user input for visually fitting a bounding volume to the object, and determining the spatial property of the object based on a corresponding spatial property of a bounding volume once the user is satisfied that the bounding volume sufficiently fits the object. The method provides an interactive manner of visually fitting the bounding box to the object, based on two or more images of the object taken at different positions and orientation of the camera relative to the object, as well as on a representation of a position and orientation of the camera in the 3D space at the time each image was captured.

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE **P6069679NL**
Nederlands aanvraag nr. **2019516**	Indieningsdatum **08-09-2017**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Fugro N.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **14-10-2017**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN69828**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

G01B21/04;G01B11/00;G06T7/70

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC	**G01B;G06T**

Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

III.	☐	**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	☐	**GEBREK AAN EENHEID VAN UITVINDING**	(opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Nummer van het verzoek om een onderzoek naar de stand van de techniek
NL 2019516

A. CLASSIFICATIE VAN HET ONDERWERP
INV. G01B21/04 G01B11/00 G06T7/70
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)
G01B G06T

Onderzochte andere documentatie dan de mimimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie *	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
A,D	WO 2016/075231 A1 (FUGRO SUBSEA SERVICES LTD [GB]) 19 mei 2016 (2016-05-19) in de aanvraag genoemd * samenvatting; figuren 1-4 * * bladzijde 2, regel 20 - bladzijde 4, regel 18 * -----	1-16
A	US 2015/360877 A1 (SHIN SANG HOON [KR]) 17 december 2015 (2015-12-17) * samenvatting; figuren 2,4,9-11 * * alineas [0079] - [0087] * -----	1-16

☐ Verdere documenten worden vermeld in het vervolg van vak C.

☒ Leden van dezelfde octrooifamilie zijn vermeld in een bijlage

* Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvrage, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid	Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type
2 november 2017	

Naam en adres van de instantie	De bevoegde ambtenaar
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Passier, Martinus

ONDERZOEKSRAPPORT BETREFFENDE HET RESULTAAT VAN HET ONDERZOEK NAAR DE STAND VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar de stand van de techniek

NL 2019516

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
WO 2016075231 A1	19-05-2016	AU 2015345061 A1	22-06-2017
		EP 3218777 A1	20-09-2017
		US 2017315548 A1	02-11-2017
		WO 2016075231 A1	19-05-2016
US 2015360877 A1	17-12-2015	KR 20150142923 A	23-12-2015
		US 2015360877 A1	17-12-2015

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN69828	08.09.2017		NL2019516

International Patent Classification (IPC)
INV. G01B21/04 G01B11/00 G06T7/70

Applicant
Fugro N.V.

This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the application
- ☐ Box No. VIII Certain observations on the application

Examiner
Passier, Martinus

Application number

WRITTEN OPINION

NL2019516

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.

2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:

   a. type of material:

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material:

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing:

   ☐ contained in the application as filed.

   ☐ filed together with the application in electronic form.

   ☐ furnished subsequently for the purposes of search.

3. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes:	Claims	1-16
	No:	Claims	
Inventive step	Yes:	Claims	1-16
	No:	Claims	
Industrial applicability	Yes:	Claims	1-16
	No:	Claims	

2. Citations and explanations

   see separate sheet

Re Item V

Prior art

1 Reference is made to the following documents:

D1 WO 2016/075231 A1

D2 US 2015/360877 A1

Technical field

2 The application relates to the determination of a spatial property of a submerged object in a 3D-space.

Novelty and inventive step

3 The subject-matter of **claims 1, 15 and 16** is novel and involves an inventive step.

3.1 Document **D1** (see passages cited in the search report) is considered to represent the closest state of the art and discloses a method for determining a spatial property of a submerged object in a 3D-space (p.4,l.17,18), using an underwater moveable platform (ROV), that is provided with a camera (32) and with a position and orientation measurement system adapted for outputting a position and orientation of the camera (implicit from p.3,l.26,27).

The method comprises (i) capturing, at different positions of the camera with respect to the object, image data comprising an image of the object captured by the camera and a representation of a position and orientation of the camera in the 3D space at the time each image was captured (p.3,l.25-28), wherein said representation is obtained using the position and orientation output by the position and orientation measurement system, and (ii) displaying, on a display, one of the captured images to a user (fig.3).

At a processing unit, for two or more of said captured images, a composite image is constructed in which a bounding volume is projected overlaid onto said image and the composite image is displayed to the user (p.4,l.15,16)

The orientation of the object is determined based on the dimensions and orientation of the adjusted bounding volume in the 3D space, and is output to the user (p.4,l.17,18).

3.2 The method of **claim 1**, and thus also of **claims 15 and 16**, differs from **D1** essentially in that it defines the steps of receiving from the user, at the processing unit, (a) dimensions of a 3D bounding volume for the object that is displayed in the captured image, and (b) input from the user for interactively adjusting the position and/or orientation of the bounding volume to improve the visual fit of the bounding volume with the object displayed in the composite image.

The user input facilitates the generation of an optimal bounding volume, which, in turn, leads to an improved determination of the spatial property of the submerged object.

Hence, the problem solved by the subject-matter of **claims 1, 15 and 16** is how to improve the determination of the spatial property of the submerged object.

3.3 User input regarding the bounding volume and its interactive adjustment is neither disclosed not hinted at in document **D2**. **D2** describes how a 3D bounding volume is used to determine the rotational position of a parcel on a conveyor belt. There is no disclosure of or hint at generating and adjusting this bounding volume according to user input.

4 **Claims 2-14** are dependent on **claim 1**, and as such are also novel and inventive.

Industrial applicability

5 The subject-matter of **claims 1-16** is industrially applicable, particularly in the offshore construction industry and in hydrocarbon exploration and production.