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(54) MOBILE TARGET AND METHOD OF HIT DETECTION

(57) The shooting target includes a chassis (1), mannequin (3) placed on this chassis and means of detecting a bullet hit on the mannequin (3). The mannequin (3) has the form of a thin-walled rigid curvilinear dome shell (5,6) with an open base (4) facing the drive chassis (1). This shell has a part closer (5) to the chassis (1), symbolising the torso, and a part farther away (6), symbolising the head. linner surface of the shell is generally smooth and has an uniform colour, advantageously black. Each subsequent cross-section of the inner surface of the mannequin (3) onto the plane of its base (4) along a plane parallel to this base (4), starting from the base (4) of the mannequin (3) towards its top, fits within the area of an analogous cross-section of the said surface along the previous plane. Means for hit detection on the mannequin (3) and for the recognition of the hit area consist in the image analysis system with the image sensor and the illuminator (8), working in infrared. The lens (7) of the image sensor and the illuminator (8) are located at the base (4) of the mannequin (3) and directed at its interior. The method of detection takes advantage of the change to optical properties of the interior of the mannequin (3) described above. The image analysis system is used to continuously record a view of the inner surface of the mannequin (3) reduced to its projection on plane (10) and are identified sudden and essentially local changes (P1, P2) in the recorded image this image as well as time when these changes (P1, P2) occurred.

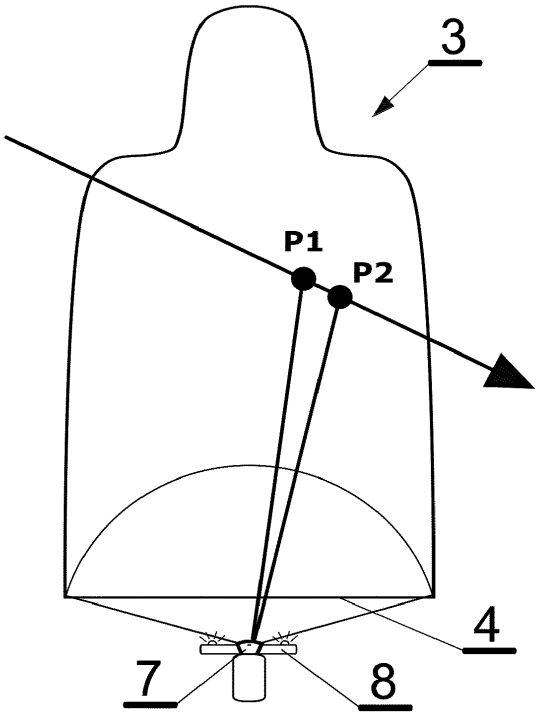

Fig.4

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Description

[0001] The subject of the invention is a mobile training shooting target that allows detection of bullet hits and a method of detecting a hit on a training shooting target, consisting in the identification of the point where the bullet hit changes the visual state of the target.

[0002] An example of a mobile shooting training target, containing a drive chassis, a mannequin mounted on the chassis and means for detecting a hit of a bullet on the mannequin, has been disclosed in CN107218848. In this case hit detection consists in detecting electrical impulses resulting from the penetration of a metal bullet, by means of numerous sensors located in the "body" of the mannequin. Among the aforementioned sensors, those in critical locations for the life of the human, as symbolised by the mannequin, are separated in terms of signalling. Thanks to this, in addition to hit detection itself, additional verification is performed whether the hit was in a critical spot. To allow the shooter to observe the effects of their shooting even from a long distance, upon hit detection the target mannequin changes its position from vertical to strongly inclined in order to symbolise a fall, and subsequently when the detection system recognises the hit was not in a critical spot, the mannequin rises to a vertical position.

Publication EP3504506B1 discloses a similar shooting target with a mannequin on a drive chassis, equipped with multiple pressure sensors, which register a local increase in pressure caused by a bullet.

Publication No. EP3504506B1 discloses a similar shooting target with a mannequin on a drive chassis, equipped with multiple pressure sensors, which register a local increase in pressure caused by a bullet.

Publication No. US2017/370683 discloses a stand intended for dynamic sport shooting by many competitors at one paper target, which does not require close-range observation of a punctured target for assessment of the shooter's accuracy before a subsequent competitor is allowed to shoot. In this solution, a traditional paper target is placed in a metal frame and observed at close range, but out of the line of fire, by a vision camera with an image analysis system. The aforementioned system records, on an ongoing basis, local visible spectrum reflectivity changes caused by the penetration of the paper target by a bullet. The image analysis system needs to ensure recognition and rejection of changes in reflectivity resulting from target vibrations, including strong vibrations caused by the bullet hitting the aforementioned metal frame and changes in illumination intensity of the target resulting from available light.

The publication PL227256B1 discloses a method of detecting bullet impacts on a target using an external thermal imaging camera and a thermal image analysis system for the hit target. The hit detection procedure consists in comparing the thermal image of the target before shooting with the live image, in which the spots with a point temperature increase of the target surface by a set value are distinguished.

[0003] The goal of the invention is to improve shooting training effectiveness. The goal is implemented by a mobile training shooting target with a drive chassis, a mannequin mounted on this chassis, means of detecting a bullet hitting the mannequin, means of recognising a hit in a critical area of the mannequin and means of visual signalling a hit of the mannequin. The invention consists in that the mannequin has a form of a thin-wall rigid curvilinear dome shell with an open base facing the drive chassis. The mannequin shell has a part closer to the chassis of the target, symbolising the torso, and a part farther away from the chassis, symbolising the head. Inner surface of the said shell is generally smooth and a has an uniform colour, advantageously black. Each subsequent projection of a section view of the inner surface of the mannequin on its base plane along a plane parallel to this base, starting from the base of the mannequin to its top, fits within the area of the analogous cross-section projection of this surface along the previous plane. Bullet hit detection means and hit area recognition means consist of an image analysis system with an image sensor and an illuminator, working in the infrared spectrum. The image sensor lens and illuminator are located at the base of the mannequin and directed at its interior.

In one of variants of the target according to the invention, the base of the mannequin shell has an elliptical outline, the image sensor lens is located substantially centrally at the said base, and the illuminator consists in an array of light emitting diodes surrounding the lens.

In next variant of the target according to the invention the illuminator comprises luminescent diodes for the target emitting electromagnetic radiation with a 940 nm wavelength and the image sensor lens is corrected for distortion and equipped with a 940-960 nm bandpass filter.

In another variant of the target according to the invention, the mannequin is made from paper pulp, for example of two vertical paper extrusions glued together, with a thickness between 2 and 4 mm.

In yet another variant of the target according to the invention, the visual means for signalling impact on the mannequin consist in a mechanism tilting the said mannequin in relation to the drive chassis.

The above-mentioned target also implements a method according to the invention, in which locations are identified, where the hitting bullet changes the optical properties of the target. The invention consists in that as the target a mannequin in the form of a thin-wall rigid curvilinear dome shell with an open base is used. Inner surface of the said shell is generally smooth and has an uniform colour, advantegously black. Each subsequent projetion of a cross-section of the inner surface of the mannequin on its base plane along a plane parallel to this base, starting from the base of the mannequin to its top, fits within the area of the analogous cross-section projection of this surface along the previous plane. At the base of the mannequin, at a generally central location, an infrared image sensor lens is placed and connected to the image anal-

ysis system, and also assures uniform infrared illumination of the mannequin inner surface. Subsequently, the image analysis system registers on an ongoing basis the view of the inner surface of the mannequin reduced to its projection on the plane, and sudden and essentially point changes to this image and the time of the said changes are identified in the recorded image.

In one of variants of the method according to the invention, is used a mannequin whose shell has a part closer to the chassis, symbolising the torso, and a part farther away from the chassis, symbolising the head.

In next variant of the method according to the invention is used a mannequin with an elliptical form of its base and an illuminator in the form of a set of electroluminescent diodes surrounding the lens of the image sensor. A hit is identified based on an analysis of an image constituting a projection of the inner surface of the mannequin onto an ellipse.

In nest variant of the method according to the invention, areas corresponding to critical areas are distinguished on the analysed image and, additionally, a check is performed whether the registered hit is in such an area.

In next variant of the method according to the invention, two hits with a time interval not exceeding 3 ms are searched for and the direction from which the shot causing the two hits is determined based on their location in relation to the drive chassis.

In another variant of the method according to the invention, the illuminator uses luminescent diodes that emit electromagnetic radiation with a wavelength of 940 nm and the image sensor uses a lens corrected for distortion and equipped with a 940-960 nm bandpass filter.

In yet another variant of the method according to the invention, is used a mannequin made of paper pulp, which can be made of two vertical paper extrusions glued together with a thickness between 2 and 4 mm.

[0004] The invention facilitates shooting training held for officers, soldiers and competitors in dynamic shooting competition by improving exercise realism while maintaining an appropriate level of safety. It assures easy implementation of various training scenarios imitating actual combat conditions. A human-like mannequin can be dressed accordingly to the type of training, increasing its realism without affecting the system's accuracy. The invention facilitates quick assessment of shot accuracy by clearly indicating the hit location, and in many cases also the direction from which the shot was fired, which is of particular importance especially in a situation where several shooters are firing at the same target from different locations. The invention also allows for the use of inexpensive and environmentally friendly paper mannequins, with relatively high wear resistance, as they can withstand at least two hundred hits with only slight deterioration in the detection of subsequent shot holes. The thin-walled mannequin is light, so it does not significantly raise the centre of gravity of the chassis, which is particularly important when the target moves in more difficult terrain conditions.

[0005] The invention in an exemplary embodiment is illustrated schematically on drawing, where Fig.1 is an axonometric front view of the mobile target according to the invention, and Fig.2 is a side view of the target. Fig.3 is a front view of the mobile target mannequin. Fig.4 is a front view of the system detecting two bullet holes through the mannequin of Fig.3, while Fig.5 is a side view of the same system. Fig.6 shows the projections of the shot holes from Fig.4 and Fig.5 on the plane of the base of the mannequin and the method to identify the location of both holes, while Fig.7 shows an embodiment of a mannequin interior illuminator, shown schemnatically in Fig. 4 and Fig.5.

[0006] The examplary mobile target has a drive chassis 1 with four wheels 2, as known from other mobile robots. On the chassis 1 a rigid paper humanoid mannequin 3 is placed, made of 2 to 4 mm thick paper pulp and glued together from two symmetrical vertical halves 3' and 3". The mannequin 3 has the form of a rigid curvilinear domed shell with an elliptical open base 4 featuring two visually distinct parts. The part of the shell closer to the chassis 1 symbolises the torso 5 and is topped with a part symbolising the head 6, with part 5 smoothly transitioning into part 6. The sizes of parts 5 and 6 of the mannequin 3 correspond to the average size of the human body parts they symbolise. In the described embodiment, the elliptical base 4 of the mannequin 3 fits in a rectangle with dimensions 450 x 300 mm, while the overall height of the mannequin 3 is between 750 and 800 mm. The inner surface of the mannequin 3 is generally smooth and covered with matte black paint. It is essential for the inner surface of the mannequin 3 to be fully visible from the centre of its base 4. This condition is met by a shell, in which each subsequent projection crofg a osssection of its inner surface onto the plane of its base 4 along a plane parallel to this base, starting from the base 4 of the mannequin 3 towards its top, fits within the area of an analogous cross-section projection of the said surface along the previous plane. The upper part of the chassis 1 features a system for detecting a bullet hit on the mannequin 3 and recognising the hit area of the mannequin. Detection of hits on the mannequin 3 is performed by an image analysis system with an image sensor with a resolution of 3000 x 2000 pixels, working in the infrared wavelength. The lens 7 of the image sensor is located centrally, approx. 160 mm below the base 4 and pointed vertically towards the interior of the mannequin. 3. In the described embodiment, the lens used has a 3 mm focus length, is corrected for distortion and equipped with a 940-960 nm bandpass filter. An illuminator 8 of the inner surface of the mannequin 3 containing electroluminescent diodes (LEDs) 9 with a 940 nm wavelength, shining into the interior of the mannequin 3 is placed around the lens 7. Fig. 7 shows rectangular LEDs 9', used for surface mounting, with different lighting angles, and classic LEDs for through-hole mounting 9", where a change of the light direction of the latter can be corrected easily and without tools. Thanks to this illuminator 8 solution, it is easy to

obtain uniform infrared illumination of the entire inner surface of the mannequin. The method used for detecting a hit on mannequin 3 is described below on the example of detection by the image analysis system of two holes made in the shell of the mannequin 3 by one bullet, i.e. entry hole P1 and exit hole P2. The flight path of the bullet is indicated by a dashed line with an arrow in Fig.4, Fig.5 and Fig.6. Where the matte black inner surface of the mannequin is punctured, as observed by lens 7, the bullet hole rapidly and locally changes the ability of this surface to reflect radiation. Such a change can be easily detected by the image analysis system, especially with the colour of the material used to make the mannequin 3 contrasting with the interior colour of its shell and this contrast becoming visible at the moment of bullet penetration. The state of the inner surface of mannequin 3 is analysed in its projection onto the horizontal elliptical surface 10. In such a projection a grid of horizontal 11 and vertical 12 lines, shown as broken lines in Fig.3, can be represented on the elliptical surface 10 in the form of concentric ellipses 13 and straight line segments 14, extending from the geometric centre 15 of the elliptical surface 10. By placing the origin of an X-Y rectangular coordinate system in point 15 it is possible to determine on mannequin 3 the location of a bullet hole whose projection onto the elliptical surface 10 was detected and registered by the image analysis system. Apart from the X1 and Y1 coordinates of the P1 shot hole projection and the X2 and Y2 coordinates of the P2 shot hole projection, the image analysis system also records the time of appearance of the P1 and P2 shot holes. If the time interval between the appearance of shot holes P1 and P2 is sufficiently small, in practice not longer than 3 ms, shot holes P1 and P2 are assumed to be caused by one bullet. In such a situation, the direction of the shot that caused the P1 and P2 shot holes in relation to the chassis 1 can also be determined. If both the mobile target and the shooter are equipped with a geographic positioning system, for example a GPS system, it is also possible to determine the location in the field from which the recorded shot was fired. Projection of the inner surface of the mannequin 3 on the surface 10 allows for the identification of critical areas on this surface. For example, the "head" 6 projection is in the centre of the surface 10 and the detection of two consecutive shot holes with one bullet in this projection area can be interpreted as a fatal shot. The results of the hit detection system can be analysed both post-factum, for example during a discussion of the training results of an entire shooting team, as well as in real time through observing hits on the display of a terminal connected wirelessly to the mobile target. Detected hits can also be signalled to shooters participating in the training. In the described example, this is done by changing the position of the mannequin 3 with respect to the chassis 1. For example, after a hit of a non-critical area of mannequin 3, the mobile target stops and a mechanism, not shown in the drawing, tilts mannequin 3, after which it returns to vertical, and the mobile target continues moving. A hit of a critical area can be signalled with a longer stop of the target and a deeper "tilt" of the mannequin than in the previous case 3.

Claims

1. A mobile training shooting target, with a drive chassis (1), a mannequin (3) mounted on the said cassis (1), means of detecting a bullet hit on the mannequin, means of recognising a hit on the critical area of the mannequin (3) and means of visual signalling of a hit on the mannequin (3), **characterised in that** the mannequin (3) has the form of a thin-walled rigid curvilinear dome shell (5,6) with an open base (4) facing the drive chassis (1), with the shell having a part closer (5) to the chassis (1), symbolising the torso, and a part farther away (6) from the chassis (1), symbolising the head, with the inner surface of the said shell generally smooth and has a uniform colour, advantageously black, while each subsequent projection of a cross-section of its inner surface onto the plane of its base (4) along a plane parallel to this base (4), starting from the base (4) of the mannequin (3) towards its top, fits within the area of an analogous cross-section projection of the surface along the previous plane, wherein the means of detecting a bullet hit and recognising the hit area consist in an image analysis system with an image sensor and illuminator (8) working in the infrared wavelength, while the lens (7) of the image sensor and the illuminator (8) are located at the base (4) of the mannequin (3) and face its interior.

2. The shooting target according to claim 1, **characterised in that** the base (4) of the mannequin (3) shell has an elliptical shape, the lens (7) of the image sensor is located substantially centrally at this base (4), and the illuminator (8) consists of a set of electroluminescent diodes (9) surrounding the lens (7).

3. The shooting target according to claim 1 or 2, **characterised in that** the illuminator (8) contains luminescent diodes (9) emitting electromagnetic radiation in the 940 nm wavelength while the image sensor lens (7) is corrected for distortion and equipped with a 940-960 nm bandpass fi lter.

4. The shooting target according to one of the claims 1 to 3, **characterised in that** the mannequin (3) is made of paper pulp.

5. The shooting target according to claim 4, **characterised in that** the mannequin (3) is made of two glued together vertical paper extrusions (3', 3") with a thickness ranging from 2 to 4 mm..

6. The shooting target according to one of the claims

1 to 5, **characterised in that** the means of visual signalling of a hit on the mannequin is a mechanism tilting the mannequin (3) in relation to the drive chassis (1).

7. A method of identifying a hit on the training shooting target, which consists in identifying the location where the hitting bullet changes the optical properties of the target, **characterised in that** the target is a mannequin (3) in the form of a thin-walled rigid curvilinear dome shell with an open base (3,5,6), wherein an inner surface of the shell being generally smooth and uniform in colour, advantageously black, while each subsequent projection of a cross-section of its inner surface onto the plane of its base (4) along a plane parallel to this base (4), starting from the base (4) of the mannequin (3) towards its top, fits within the area of an analogous cross-section of the said surface along the previous plane, at the base (4) of the mannequin (3) a lens (7) of the image sensor operating in infrared is placed essentially in the centre and connected to the image analysis system, and the inner surface of the mannequin is uniformly illuminated with infrared radiation, with the image analysis system continuously recording the view of the inner surface of the mannequin (3) reduced to its projection onto the plane (10) and are identified sudden and essentially local changes (P1, P2) in the recorded image this image as well as time when these changes (P1, P2) occurred.

8. The method according to claim 7, **characterised in that** a mannequin (3) is used with a shell that has a part (5) closer to the chassis (1), symbolising the torso, and a part (6) farther away from the chassis (1), symbolising the head.

9. The method according to claim 7 or 8, **characterised in that** are used a mannequin (3) with an elliptical form of its base (4) and an illuminator (8) in the form of a set of electroluminescent diodes (9) surrounding the lens (7) of the image sensor, whil the identification of the hit is based on analysis of the image being a projection of the inner surface of the mannequin on the ellipse (10).

10. The method according to claim 9, **characterised in that** areas corresponding to critical areas are determined for the analysed image and an additional check is performed whether the registered hit was to such an area.

11. The method according to claim 9 or 10, **characterised in that** two hits (P1, P2) recorded at a time interval of not more than 3 ms are sought and the direction from which the shot causing the two mentioned hits (P1, P2) is determined based on their position (X1, Y1 X2, Y2) in relation to the target's drive chassis (1).

12. The method according to one of claims 9 to 11, **characterised in that** the illuminator (8) uses luminescent diodes (9) emitting electromagnetic radiation with a 940 nm wavelength and the image sensor uses a lens (7) that is corrected for distortion and equipped with a 940-960 nm bandpass filter.

13. The method according to one of claims 7 to 12, **characterised in that** a mannequin (5) made of paper pulp is used.

14. The method according to claim 13, **characterised in that** a mannequin made of two glued vertical paper extrusions (3', 3"), with a thickness ranging from 2 to 4 mm, is used.

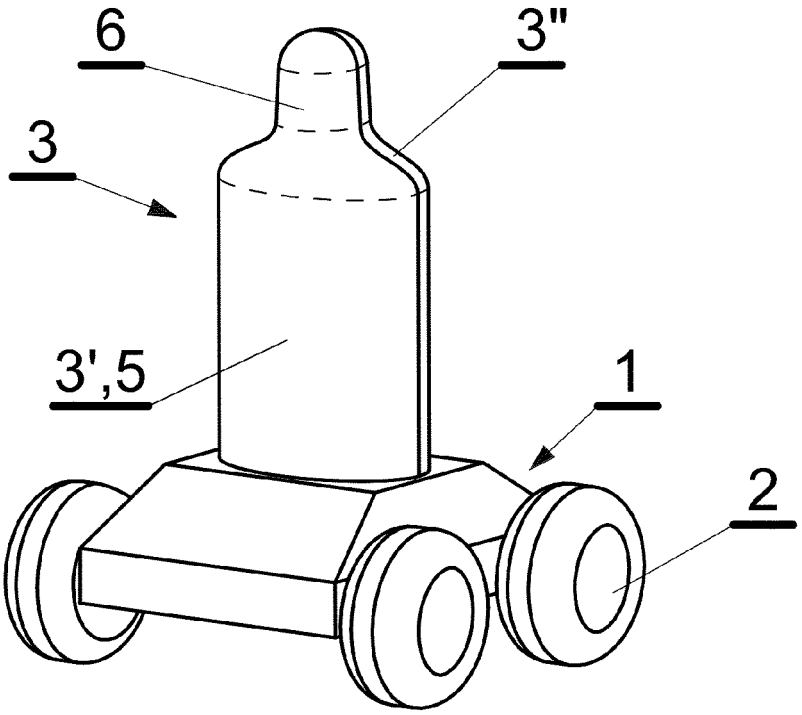

Fig.1

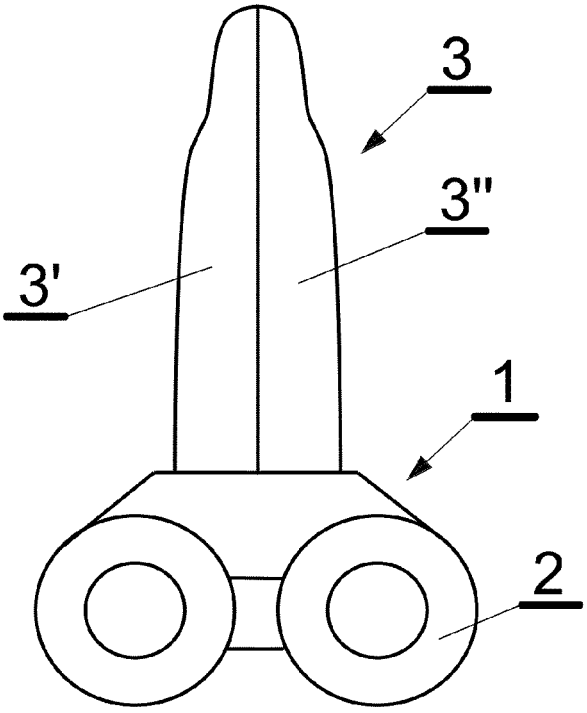

Fig.2

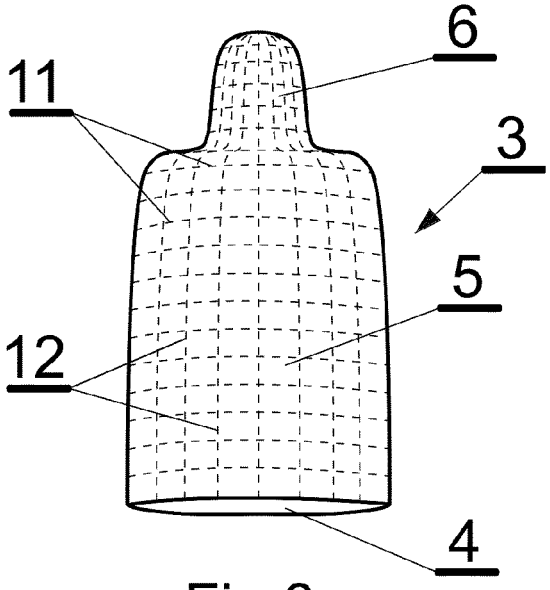

Fig.3

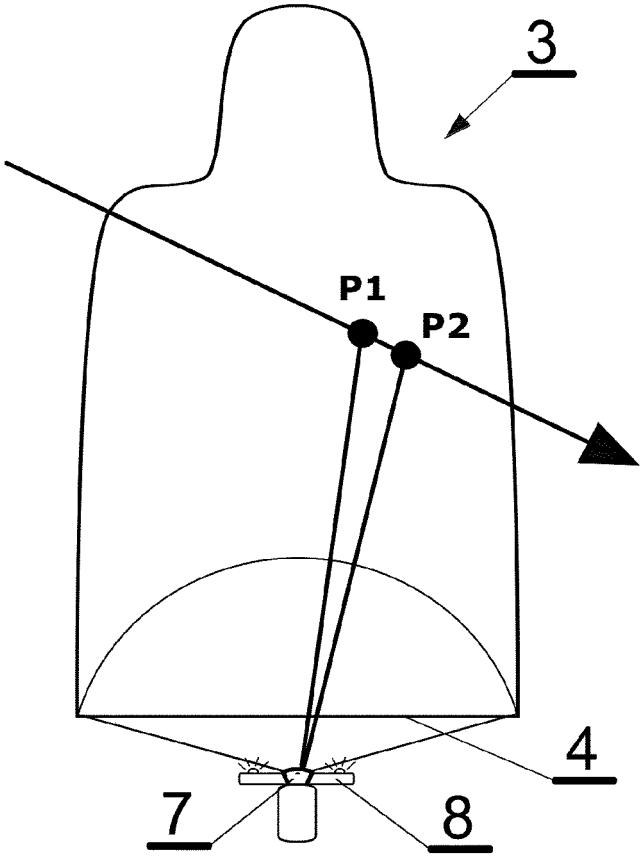

Fig.4

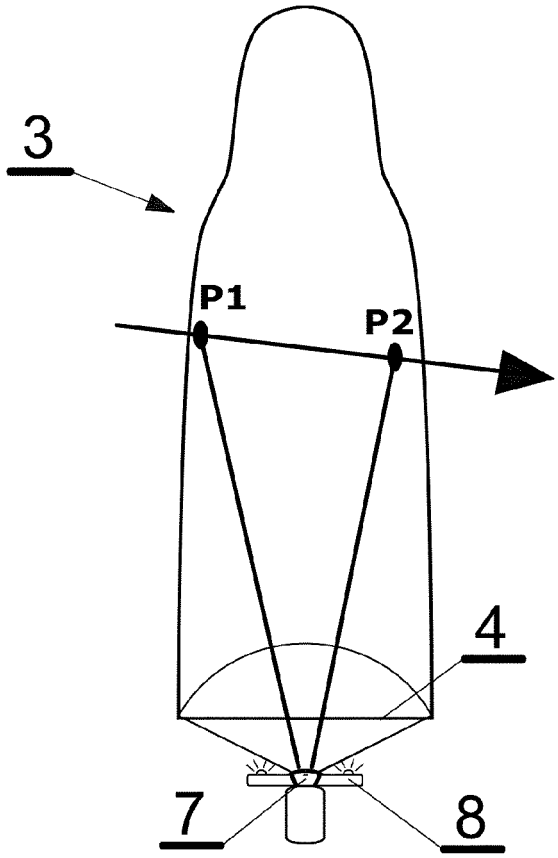

Fig.5

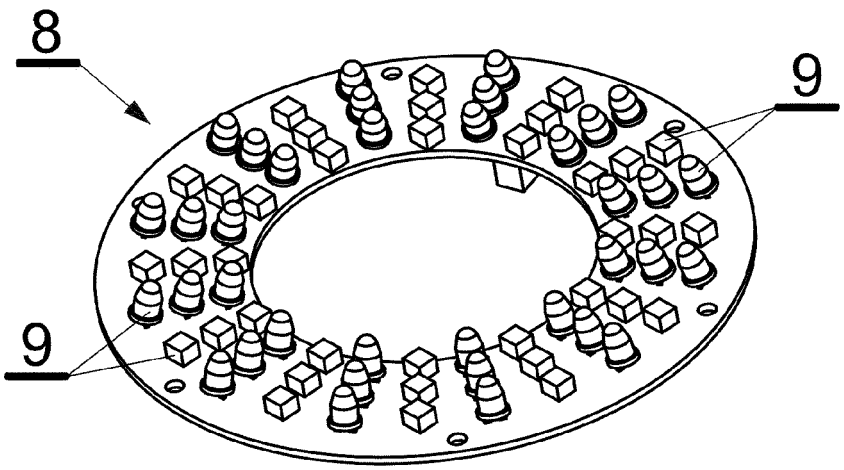

Fig.7

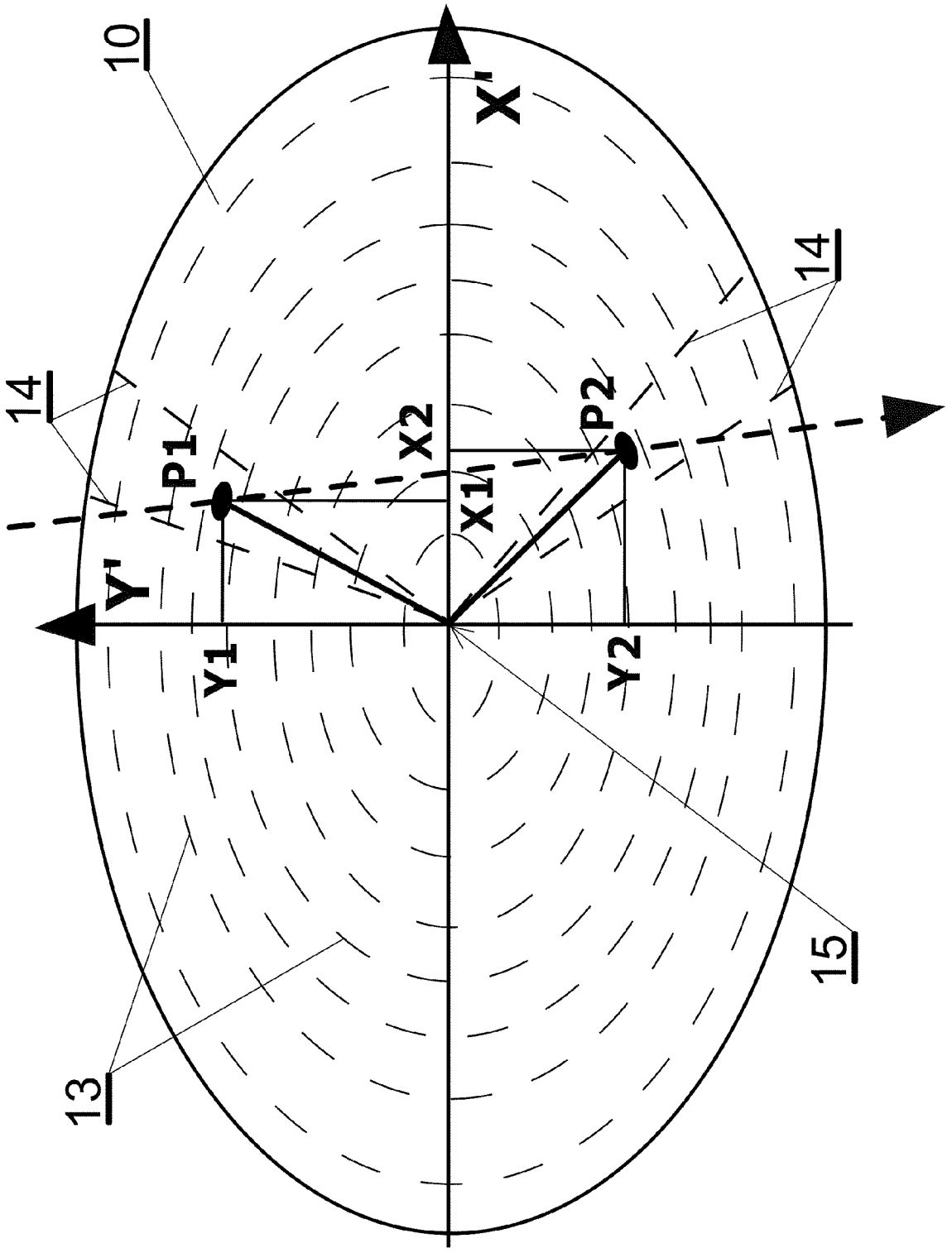

Fig.6

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EUROPEAN SEARCH REPORT

Application Number
EP 21 17 7882

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	26 October 2021	Vermander, Wim

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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EUROPEAN SEARCH REPORT

Application Number
EP 21 17 7882

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	26 October 2021	Vermander, Wim

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X : particularly relevant if taken alone
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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- CN 107218848 **[0002]**
- EP 3504506 B1 **[0002]**
- US 2017370683 A **[0002]**
- PL 227256 B1 **[0002]**