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(54) SYSTEM AND METHOD FOR THE MEASUREMENT OF THE RELATIVE POSITION OF AN OBJECT WITH RESPECT TO A POINT OF REFERENCE

SYSTEM UND VERFAHREN ZUR MESSUNG DER RELATIVEN POSITION EINES OBJEKTES
BEZÜGLICH EINES BEZUGSPUNKTES

SYSTEME ET PROCEDE DE MESURE DE LA POSITION RELATIVE D'UN OBJET PAR RAPPORT
A UN POINT DE REFERENCE

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Description

[0001] The present invention refers to a system and to a method for the measurement of the relative position of an object with respect to a predetermined point of reference.

[0002] An exemplary application of the system and of the method according to the present invention is that of the measurement of the relative position of a ball with respect to a specific line of a field of play.

[0003] In several sports, a referee acknowledges an event depending on the relative position of a ball with respect to a specific line of the field of play. E.g., in Soccer a referee awards a score to a team only when the ball has crossed over the goal line.

[0004] However, the referee can autonomously note the scoring of a goal solely when the latter is apparent, e.g. due to the swelling out of the netting or to the ball remaining inside of the goal. However, quite frequently the ball crosses over the goal plane and, without touching the net, immediately exits therefrom due to an odd rebound onto the soccer field, a contact with the goal posts, or a player's clearance.

[0005] When the ball speed is not overly high (it could even reach the 120 Km/h) the referee, in order to decide on the event at issue, can be aided by assistants, who however should have ideal observing conditions, i.e. be positioned on the goal line having the goal in sight. Otherwise the referee, having to decide one way or the other, runs the risk of awarding a non-existent (phantom) scored goal, or of not awarding an actually scored goal.

[0006] To solve this problem, several known systems, all referable to the same category, provide the use of sensors, inserted inside of the goal structure, receiving a signal from transmitters applied into the playing ball when the latter crosses the goal mouth.

[0007] However, such systems entail the remarkable disadvantage of being invasive, requiring electronic devices to be inserted in the playing structures (goals and ball). Hence, in order to use the former a general modification to the fields of play and the use of specific balls would be required. These devices are not always applicable, as the modification required to the playing structures could interfere with the laws of the game.

[0008] Moreover, a known visual-type system relies instead on the observation of the field of play by suitably positioned cameras. This system determines the position of the vertical projection of the center of mass of the ball onto the plane of the field of play, exploiting the information (known a priori) on the dimensions of the various areas thereof.

[0009] However, this system entails the disadvantage of exclusively detecting the ball crossing over a determined line, yet providing no indication about the height above ground of the ball during its crossing, an information crucial in order to confidently claim that the ball has crossed over the goal plane.

[0010] A first system for determining the position of an

object in a space is known by WO 00/72264. Such system provides for the identification of the object into the images by means of the so-called chroma-key system that operates by comparing areas of the images with a threshold.

[0011] Another system is disclosed in EP 0662600. In such case a system is provided for determining the absolute spatial position of an object.

[0012] Nevertheless, such system has several drawbacks. In particular the system is only capable of determining the position of an object that moves on a single plan, in a predetermined direction.

[0013] Furthermore, the recognition of the object into the acquired images is simply performed by comparison with fixed thresholds, making the result dependent from the environmental conditions.

[0014] Purpose of the present invention is to solve the above-mentioned problems of the known art providing a method for the measurement of the relative position of an object with respect to a point of reference, comprising the following steps:

- acquiring a plurality of images, each of said images being apt to display said point of reference;
- processing each image of said plurality of acquired images; and
- computing said relative position of said object with respect to said point of reference,

characterised in that said step of processing each image further comprises a step of recognizing said object inside each of said images, said step of recognizing said object being performed by a classifier.

[0015] The present invention further provides a system for the measurement of the relative position of an object with respect to a point of reference comprising:

- one or more image acquisition subsystems, each subsystem being apt to acquire a plurality of images, each of said images displaying said point of reference; and
- a unit for the processing of said acquired images,

characterised in that said processing unit comprises a classifier for recognising said object inside each of said images.

[0016] Hence, a field of play comprising such system could advantageously be provided. For simplicity's sake, hereinafter reference will still be made to the application of the system in the case of Soccer. Of course, it is understood that the described system and method could be useful in any other application entailing the same technical problem.

[0017] The main advantage of the method and of the system according to the present invention lies in that those entail no modification to any component of the field of play, or to the ball.

[0018] A second advantage lies in the robustness and in the reliability of the detection of the scored goal event.

Said method integrates a geometrical measurement of the position of the ball in the three-dimensional space (obtained by a binocular system) to a qualitative assessment of the observed event (obtained with a monocular system) thereby emulating the activity of a human observer enjoying the best observing conditions. The integration of the measurements provided by said systems ensures a high precision rate and a minimum error probability in any situation, including those of partial ball obstruction, e.g. by one or more players.

[0019] A third advantage lies in the completeness of the information on the position of the object with respect to a point of reference, as the method provides the three-dimensional coordinates thereof.

[0020] A fourth advantage lies in that the system according to the present invention uses, for image acquisition, high-speed digital cameras, whose performances surpass those of the common cameras as well as those of the human eye.

[0021] A further advantage lies in that the system according to the present invention provides an objective digital recording of the event itself, obtained by an advantageous positioning of the cameras and the concomitant acquisition of the observed scene. This recording enable to subsequently review the scene at will, to validate the signaled event (goal/non-goal), as it typically happens in the case of a digital viewer having high time resolution and simultaneous multivision.

[0022] Further advantages, features and operation modes of the present invention will be made apparent by the following detailed description of preferred embodiments thereof, given by way of a non-limiting example, making reference to the figures of the attached drawings, wherein:

figure 1 is a block diagram of a first embodiment of the system according to the present invention;

figure 2 is a block diagram of a monocular subsystem according to the present invention;

figure 3 shows an exemplary positioning of the camera, and the related view of the observed scene, for a monocular subsystem according to the present invention;

figures 4a and 4b show some images of examples processed during the training step of a Support Vector Machine for classification used in a first embodiment of the monocular subsystem according to the present invention;

figures 5a and 5b show some images of examples processed during the training step of a neural network used in a second embodiment of the monocular subsystem according to the present invention;

figure 6 is a block diagram of a binocular subsystem according to the present invention;

figure 7 sketches the operation principle of the binocular subsystem according to the present invention;

figure 8 shows an exemplary positioning of the cameras and the views of the observed scene thereof,

for a binocular subsystem according to the present invention;

figure 9 shows an exemplary positioning of the cameras and the views of the observed scene thereof, for the system of figure 1;

figure 10 is the block diagram of a second embodiment of the system according to the present invention;

figure 11 shows an exemplary positioning of the cameras with the views of the observed scene thereof, for the system of figure 10;

figure 12 is the block diagram of a third embodiment of the system according to the present invention;

figure 13 shows an exemplary positioning of the cameras with the views of the observed scene thereof, for the system of figure 12;

figure 14 is the block diagram of a fourth embodiment of the system according to the present invention; and

figure 15 shows an exemplary positioning of the cameras with the views of the observed scene thereof, for the system of figure 14.

[0023] With initial reference to figure 1, a first embodiment of the system according to the present invention is shown.

[0024] According to this embodiment, the system 1 comprises one or more subsystems 2, 3 apt to concomitantly acquire images of the portion of the field of play at issue comprising the selected point of reference, in particular of the goal area.

[0025] The subsystem 2 is of a monocular type, apt to process images acquired from a single position, whereas the subsystem 3 is of a binocular type, apt to process pairs of acquired images from two distinct positions. The operation of the two types of subsystems will be detailed hereinafter.

[0026] The monocular subsystem 2 and the binocular subsystem 3 are independent therebetween, each one being apt to provide information data related to the position of the ball when the latter enters the respective visual field.

[0027] These data are forwarded to a processing unit 4 comparing them therebetween and computing an end result 5.

[0028] Next, figure 2 is a block diagram depicting a monocular-type subsystem 2.

[0029] The subsystem 2 comprises an image transducer 11, e.g. a camera. This camera 11 should be selected from those enabling to acquire the greatest possible number of images per second, so as to minimize the ball translation Δs between two successive images. In fact, the camera can detect with certainty the goal-scoring event solely when the ball has crossed the goal line of a distance at least equal to $\Delta s/2$.

[0030] By way of an example, using a 'Dalsa Motion® Vision progressive Scan Area' - type camera and in particular an CA-D6 0512 model, enabling the acquisition of 262 images/sec with a 536x516 pixel resolution, for a

hypothetical ball speed of 120 Km/h, the subsystem 2 can detect with certainty the goal scoring event when the ball has crossed the goal line of 6.5 cm.

[0031] The format of the data outputted by the camera is digital, and it meets the standard EIA-644, i.e. it is apt to be interfaced with other electronic apparatuses for the storing and the processing of the acquired images. In particular, high-speed storing means 12, based e.g. on Ultra 2 SCSI technology with 10000 rpm disks (Seagate®) are provided. Thus, all the acquired images are stored in a database 13.

[0032] The acquired images are processed by specific computing means 14. Such computing means 14 comprises dedicated systems, like e.g.:

- DATA CUBE MAXPCI®, based on an architecture consisting of several components (convolutor, ALU, Warper, etc.), enabling to perform an 8x8 convolution step on a 512x512x8 bit image in 7 ms;
- MATROX GENESYS®, based on a TI C80 DSP multiprocessor architecture, providing up to three processors for each card, up to a maximum of six cards, with 100 Bops performances; or
- ALACRON FANTISMAGE®, based on a PCI multiprocessor (up to eight) TRIMEDIA 1x100 architecture (Philips Semiconductor) enabling 500 Mflop performances. Alike architectures are required due to the considerable amount of required computing and for the real-time obtainment of the result.

[0033] Figure 3 shows a preferred positioning for a camera A with respect to the field of play 100 during the use of a monocular subsystem 2 and the image Va thereof acquired by the camera A.

[0034] According to this first embodiment of the system 1, the monocular subsystem 2 comprises a camera A positioned with the optical axis lying on the goal line plane in the direction of the goal, apt to autonomously detect the goal scoring event represented by the ball crossing over the goal plane.

[0035] Of course, other positionings could be provided in order to attain improved system performances.

[0036] The use of a monocular subsystem 2 as the one hereto described enables to implement a qualitative-type method for the detection of the goal scoring event according to the visual information obtained by a camera with no measuring, merely referring the position of the ball observed on each image to several fixed points of reference. In this context, the latter are provided by the goal structure. Hence, hardware and software processing means implement a first qualitative-type decision-making system. The latter, upon being inputted an image, outputs in real-time a signal indicating whether the image be an instance of the considered event.

[0037] According to a first embodiment of the monocular subsystem 2, the processing of the acquired images comprises two essential steps:

- Recognizing the object ball inside of the image; and
- Locating the ball with respect to predetermined points of reference.

5 [0038] The recognizing of the object ball can be performed by object recognition technologies based on contour or area analysis.

[0039] These methodologies are well known to those skilled in the art, hence a further detailing thereof will be omitted. In particular, according to this first embodiment of the monocular subsystem, a recognition technique based on example learning called SVM (Support Vector Machine) was used.

[0040] Next, figures 4a and 4b show some sets of exemplary images used to this end.

[0041] The ball-recognizing step is performed so as to solve various problems, which may be encountered in a likewise application.

[0042] In particular, the difficulties related to the environmental conditions (intensity and direction of the lighting of the taken area, presence of shadows), to the indistinctness of the ball onto the background of the taken scene and to the measurement of 'false positives' and/or of 'false negatives' are taken into account and overcome.

[0043] These problems are tackled and solved by a preprocessing of each acquired image, substantially performed by carrying out software-type procedures aimed at:

- reducing the search area of the object in each image; and
- extracting identifying information of the object, useful to the detection and to the localization thereof inside of the image.

35 [0044] In order to solve the above-mentioned problems, a preprocessing module, acting on an analysis of the gray tones, on the correlation among consecutive images and on a windowing around the position of the preceding image, is provided.

[0045] The method according to the present invention provides a training step with examples aimed at implementing a classifier, e.g. of the two-class (ball/non-ball) type, apt to catalogue each image in one of the two classes with the least possible error.

[0046] This training step comprises the following steps:

- acquiring a plurality of exemplary images, positive and negative examples of the object ball to be extracted therefrom;
- preprocessing of each extracted example, consisting in an equalizing of the histogram, quantizing the gray level thereof and masking in order to eliminate the edge effects; and
- training the classifier by an SVM-type technique.

[0047] Hence, the method for the detection of the con-

sidered event provides:

- the continuous acquisition of images of the goal area;
- for each acquired image, the extraction of all viable subimages having dimensions equal to that of the examples used during the SVM ball recognition training step;
- each subimage is preprocessed as described above and it is classified as ball or non-ball by the SVM classifier;
- when a subimage is an instance of the ball, its position in the image with respect to that of the goalpost (known a priori) is used to decide whether the goal-scoring event has occurred.

[0048] According to a second embodiment of the monocular subsystem 2, the processing of the acquired images provides a training step aimed at implementing a classifier, in particular of the two-class type, apt to catalogue with the least possible error each image in one of the two goal/non-goal classes.

[0049] With respect to the previous embodiment, the classifier directly provides the end result, i.e. a decision on the occurrence of the considered event (goal/non-goal).

[0050] This training step comprises the following steps:

- acquiring a plurality of images, positive and negative examples of the goal scoring concept to be extracted therefrom, as illustrated in the subsequent figures 5a and 5b;
- preprocessing of each extracted example, consisting in an equalizing of the histogram and a subsequent quantizing of the gray levels thereof; and
- training the classifier, by a neural network-based technique.

[0051] In this case, the method for the detection of a goal scoring provides:

- the continuous acquisition of images of the goal area;
- for each acquired image, the extraction of all the viable subimages having dimensions and typology alike to those of the examples used during the training step;
- each subimage is preprocessed as hereto described and it is classified as goal/non-goal by the neural network.

[0052] The neural network used consists of three levels: a first input level, a second intermediate level and a third output level.

[0053] The number of nodes of the levels is determined according to the size of the problem at issue. The first level has a number of nodes, defined by the dimension of the input subimages, whereas the output level has a single node, as the problem requires a binary-type

(goal/non-goal) response.

[0054] The operation principles of a neural network are well known to those skilled in the art, hence will not be detailed hereinafter.

5 **[0055]** Figures 5a and 5b show some subimage sets, respectively used as positive and negative examples, of goal scoring during the training step of the decision-making system. These examples substantially consist of real images depicting a side view of the goal with a ball taken in all the possible positions and under different visibility conditions.

[0056] During the training step, the neural network classifier learns to recognize the occurrence of the goal-scoring event according to the information contained in

10 the exemplary images provided.

[0057] Each taken image is processed by the decision-making system, which returns a response on the actual detection of a goal scoring.

[0058] The image sets employed during the classifier training step should cover most of the actual situations which might occur, thereby ensuring a correct operation of the system and reliable responses even under less-than-ideal conditions, e.g. of visibility.

[0059] Of course, the classification techniques (SVM and neural network) adopted in the abovedescribed two different embodiments of the monocular subsystem 2 can indifferently be used in the two cases, without thereby changing the overall operation principle of the system. I.e., for the ball recognition also a neural network-based

25 classifier or an SVM-type classifier for the identification of the goal-scoring event could be used.

[0060] However, the abovedescribed classification techniques are not the only ones useful in tackling the problem at issue. Actually, any two-class classifier based **30** on an example-learning technique could be used in both embodiments of the monocular subsystem 2 according to the present invention.

[0061] Figure 6 is a block diagram of the binocular sub-system 3.

40 **[0062]** A pair of image transducers 11, e.g. high-speed cameras of the abovedescribed type, acquires images of the area of the field of play at issue.

[0063] These images are stored by storing means 12' on a file 13' and processed by computing means 14'.

45 **[0064]** These computing means are alike those hereto described in connection with the monocular systems, hence will not be detailed anew hereinafter.

[0065] With reference to figure 7, the binocular sub-system 3 is based onto the measuring of the three-di-

50 mensional position of the center of mass B of the ball taken as point of intersection of the lines of sight {R_i} generated by two cameras 11 taking the area from different points of sight:

55

$$\mathbf{B} = \mathbf{R}_1 \times \mathbf{R}_2$$

[0066] For each point of sight considered a line of sight R_i is generated by the optical center of the camera, intersecting the center of mass B of the ball in the three-dimensional space and the center b_i of the projection of the ball on the image plane I_i .

[0067] For each camera, the line of sight intersecting the ball center is determined by the two intersections thereof with the goal plane Π and the field of play plane Γ . These intersections are estimated from the position of the ball on the image plane and from information known a priori on the spatial position of the goalposts and of the lines delimiting the goal area.

[0068] In particular, each line of sight is computed as follows:

- estimating a first projective transformation $H_{\Gamma i}$ between a first known three-dimensional plane, e.g. the plane of the field Γ , and the projection thereof on the image plane I_i (homography $H_{\Gamma i}$), from the correspondences of the four intersection points $\{P_j\}_{j=1,..,4}$ of the four orthogonal field lines $\{L_j\}_{j=1,..,4}$ delimiting the goal area, whose positions in the Euclidean space are known a priori, and the respective projections $\{p_j\}_{j=1,..,4}$ in the image I_i ;
- estimating a second projective transformation $H_{\Pi i}$ between a second known three-dimensional plane, e.g. the goal plane Π , and the projection thereof on the image plane I_i (homography $H_{\Pi i}$), from the correspondences of the four points of intersection $\{Q_j\}_{j=1,..,4}$ of the two vertical lines, onto which the outside edges of the two goalposts lie, to the goal line and to the horizontal line onto which the outside edge of the crossbar lies, and the respective projections $\{q_j\}_{j=1,..,4}$ in the image I_i ;
- estimating the projection $B_{\Gamma i}$ of the center of mass of the ball B onto the field of play plane Γ projecting the image b_i thereof with the homography $H_{\Gamma i}$:

$$B_{\Gamma i} = H_{\Gamma i} b_i ;$$

- estimating the projection $B_{\Pi i}$ of the center of mass of the ball B onto the goal plane Π projecting thereon the image b_i thereof with the homography $H_{\Pi i}$:

$$B_{\Pi i} = H_{\Pi i} b_i ;$$

- estimating the line of sight R_i from the two points of intersection thereof with the field of play plane $B_{\Gamma i}$ and the plane onto which the ball $B_{\Pi i}$ lies:

$$R_i = B_{\Gamma i} \times B_{\Pi i} .$$

[0069] The binocular subsystem requires the following information input:

- two images (I_1, I_2) referring to two different sights obtained by two uncalibrated cameras;
- the coordinates, on any image plane, of the ball center b_i , estimated adopting the technique based on example learning with the SVM algorithm used in the monocular system as well. Alternatively, any one known pattern recognition technique could be adopted;
- the intersections $\{p_{ij}\}$ of the field of play lines delimiting the goal area in any image plane;
- the intersections $\{q_{ij}\}$ of the lines delimiting the goal in any image plane;
- the intersections $\{P_j\}$ of the field of play lines delimiting the goal area onto the Euclidean plane Γ of the field of play; and
- the intersections $\{Q_j\}$ of the lines delimiting the goal structure in the three-dimensional Euclidean space.

[0070] Figure 8 is a top plan view of the field of play showing an advantageous positioning of the two cameras B, C of the binocular subsystem 3 near the goal, apt to minimize the error in the estimate of the distance of the ball from the goal plane. The cameras acquire images alike those indicated with V_b and V_c in the figure.

[0071] Figure 9 shows the system 1 according to the disclosed first embodiment, providing the combined use of a monocular subsystem 2 (camera A) and of a binocular subsystem 3 (cameras B and C) and the respective views of the acquired images V_a, V_b and V_c .

[0072] In this case as well, other positions could be provided in order to better adjust the system operation to the specific application.

[0073] The binocular subsystem 3 can autonomously detect the goal scoring event, intended as the crossing over of the goal line by the ball, via a second metric-type decision-making system using the measurement of the three-dimensional positioning, yet, generally speaking, it cannot provide a visually assessable confirmation thereof.

[0074] The monocular subsystem 2 can autonomously determine only the position of the ball with respect to the goal plane, providing an objective confirmation thereof in the related recording. In fact, without additional sights, a ball having crossed over the goal line yet lying outside of the goal can appear to lie therein.

[0075] According to the first embodiment, the system 1 integrates the two subsystems, overcoming the limitations that each one thereof would entail when individually used.

[0076] As the monocular subsystem 2 enables to determine solely the position of the ball with respect to the goal plane, the addition of the sights of the binocular subsystem 3 allows to recognize also those crossings of the goal line taking place outside of the goal.

[0077] The addition of the monocular subsystem to the binocular one, besides enhancing the reliability of the automated detection of the event, further enables an advantageous visual confirmation thereof.

[0078] The binocular 3 and the monocular 2 subsystems independently assess the crossing of the goal line. The redundancy of the assessments provided by the two subsystems increases the reliability of the automated detection of the goal-scoring event. The integration of the results provided by the two hereto described subsystems enables to obtain a single final assessment of the event with the utmost rate of certainty available.

[0079] Making reference to figure 10, a second embodiment of the system according to the present invention is shown. According to this embodiment, the system 1 comprises two monocular subsystems 2, 2' of the here-to-described type.

[0080] Next, figure 11 is a plan view of the field of play 100 onto which the cameras A and D of the monocular subsystems 2 and 2' are positioned. The cameras A and D acquire images alike those shown in views Va and Vd, respectively.

[0081] In particular, the camera D is positioned with the optical axis perpendicular to the goal plane and passing through the center thereof.

[0082] The processing of the acquired images by the camera D consists in singling out the ball in the image, inside of the goal structure.

[0083] This step is implemented using an SVM-type classifier, referring the position of the ball to the goalposts and crossbar.

[0084] Then, this information is integrated to that provided by the monocular subsystem 2, i.e. to the information on the position of the ball with respect to the goal plane enabling the qualitative detection the crossing over of the goal line by the ball.

[0085] Figure 12 shows a third embodiment of the system 1 according to the present invention. According to such third embodiment the system 1 comprises three monocular subsystems 2, 2' and 2".

[0086] In this case the system 1 provides redundant information, however the redundancy enhances the reliability of the measurement of the scored goal event.

[0087] Next, figure 13 shows a plan view of the field of play 100 and a preferred positioning of the three cameras A, E and D related to the three monocular subsystems. The views Va, Ve and Vd are examples of images acquired by the three cameras.

[0088] The use of redundant information is advantageous in order to solve cases of ball obstruction with respect to one of the two symmetrical cameras A and E.

[0089] Figures 14 and 15 show a fourth embodiment of the system 1 comprising two binocular subsystems 3, 3' of the abovedisclosed type.

[0090] In this case, four cameras B, C, F and G are positioned onto the field of play 100, so as to provide respective images alike those shown in views Vb, Vc, Vf and Vg. The combined use of the four cameras and the processing of the images provided enhances the reliability of the detection of the scored goal event and reduces the instances of non-detection, caused e.g. by ball obstruction.

[0091] The present invention has hereto been described according to preferred embodiments thereof given as non-limiting examples. It is understood that other embodiments may be provided, all however to be construed as falling within the protective scope thereof, as defined by the appended claims.

Claims

10. 1. A method for the measurement of the relative position of an object with respect to a point of reference, comprising the following steps:
 15. - acquiring a plurality of images, each of said images being apt to display said point of reference;
 - processing each image of said plurality of acquired images; and
 - computing said relative position of said object with respect to said point of reference,

characterised in that said step of processing each image further comprises a step of recognizing said object inside each of said images, said step of recognizing said object being performed by a classifier.
20. 2. The method according to claim 1, wherein said object recognizing step comprises a step of preprocessing each of said images.
25. 3. The method according to claim 2, wherein said preprocessing step comprises the steps of:
 30. - analyzing the gray levels of each of said images;
 - performing a windowing of each of said images apt to reduce the search area of said object;
 - extracting identifying information of said object.
35. 4. The method according to claim 3, wherein said step of extracting said identifying information is performed by techniques based on contour or area analysis.
40. 5. The method according to any of the claims 1 to 4, wherein said classifier is based on SVM-type techniques.
45. 6. The method according to any of the claims 1 to 4, wherein said classifier is neural network-based.
50. 7. The method according to any of the claims 1 to 6, wherein said step of computing said relative position of said object with respect to said point of reference is performed by a first qualitative-type decision-making system.

8. The method according to any one of the claims 1 to 7, further comprising a step of training with examples, apt to the construction of said classifier.
9. The method according to claim 8, wherein said step of training with examples comprises the following steps:
- acquiring a plurality of exemplary images;
 - equalizing the histogram of each of said exemplary images;
 - quantizing the gray levels of each of said exemplary images; and
 - providing each of said exemplary images to said classifier.
10. The method according to claim 9, wherein each image of said plurality of exemplary images is an instance of said object.
11. The method according to claim 9, wherein each image of said plurality of exemplary images is an instance of said object with respect to said point of reference.
12. The method according to any one of the preceding claims, further comprising a step of measuring the three-dimensional position of the center of mass of said object with respect to said point of reference.
13. The method according to claim 12, wherein said step of measuring comprises a step of computing the point of intersection of the lines of sight generated by two points of observation.
14. The method according to claim 13, wherein for each of said points of observation, the computation of said line of sight comprises the following steps:
- estimating a first projective transformation (H_{Γ_1}) between a first known three-dimensional plane (Γ), and the projection thereof on the image plane (I_1);
 - estimating a second projective transformation (H_{Π_1}) between a second known three-dimensional plane (Π) and the projection thereof on the image plane (I_1);
 - estimating a first projection (B_{Γ_1}) of the center of mass (B) of said object from said image plane (I_1) to said known three-dimensional plane (Γ) by the first projective transformation (H_{Γ_1});
 - estimating a second projection (B_{Π_1}) of the center of mass (B) of said object from said image plane (I_1) to said three-dimensional plane (Π) by the second projective transformation (H_{Π_1});
 - estimating said line of sight, from respective points of intersection with the plane (Γ) and the plane (Π).
15. The method according to any one of the preceding claims, wherein said step of computing said relative position of said object with respect to said point of reference is performed by a second metric-type decision-making system.
16. The method according to any one of the preceding claims, further comprising a step of storing each of said acquired images.
17. A system for the measurement of the relative position of an object with respect to a point of reference comprising:
- one or more image acquisition subsystems (2, 2', 2'', 3, 3'), each subsystem being apt to acquire a plurality of images, each of said images displaying said point of reference; and
 - a unit (4) for the processing of said acquired images,
- characterised in that** said processing unit (4) comprises a classifier for recognising said object inside each of said image.
18. The system according to claim 17, wherein at least one of said one or more image acquisition subsystems is a monocular-type subsystem (2, 2', 2'').
19. The system according to claim 18, wherein each of said monocular subsystem (2, 2', 2'') comprises a single image transducer (11).
20. The system according to any one of the claims 17 to 19, wherein at least one of said one or more image acquisition subsystems is a binocular-type subsystem (3, 3').
21. The system according to claim 20, wherein each binocular-type subsystem (3, 3') comprises two image transducers (11).
22. The system according to any one of the claims 19 to 21, wherein each of said image transducers is a camera (11).
23. The system according to claim 22, wherein each camera is apt to acquire at least 262 images/sec, with a resolution of at least 512 X 512 pixels.
24. The system according to any one of the claims 17 to 23, further comprising means (12, 13, 12', 13') for storing said acquired images.
25. The system according to any one of the claims 17 to 24, wherein each image acquisition subsystem (2, 2', 2'', 3, 3') further comprises computing means (14, 14') apt to compute said relative position of said ob-

ject with respect to said point of reference.

26. The system according to any one of the claims 17 to 25, apt to implement a method according to any one of the claims 1 to 16.

27. A field of play (100) comprising a system for the measurement of the relative position of an object with respect to a point of reference according to any one of the claims 17 to 26.

Patentansprüche

1. Verfahren zum Messen der relativen Position eines Objekts in Bezug auf einen Referenzpunkt, die folgenden Schritte umfassend:

- Akquirieren einer Vielzahl von Bildern, jedes der Bilder geeignet, um den Referenzpunkt anzuzeigen,
- Verarbeiten jedes der Vielzahl von akquirierten Bildern und
- Berechnen der relativen Position des Objekts in Bezug auf den Referenzpunkt

und dadurch gekennzeichnet, dass der Schritt der Verarbeitung jedes Bildes des Weiteren einen Schritt des Erkennens des Objekts in jedem der Bilder umfasst, wobei der Schritt des Erkennens des Objekts durch einen Klassifikator durchgeführt wird.

2. Verfahren nach Anspruch 1, wobei der Objekterkennungsschritt einen Schritt der Vorverarbeitung jedes der Bilder umfasst.

3. Verfahren nach Anspruch 2, wobei der Vorverarbeitungsschritt die folgenden Schritte umfasst:

- Analysieren der Graustufen von jedem der Bilder,
- Durchführen einer Fensterung von jedem der Bilder, die geeignet ist, um den Suchbereich des Objekts zu verkleinern,
- Extrahieren von Erkennungsinformation der Objekte.

4. Verfahren nach Anspruch 3, wobei der Schritt des Extrahierens der Erkennungsinformation durch Techniken durchgeführt wird, die auf Kontur- oder Flächenanalyse basieren.

5. Verfahren nach einem der Ansprüche 1 bis 4, wobei der Klassifikator auf Techniken des SVM-Typs basiert.

6. Verfahren nach einem der Ansprüche 1 bis 4, wobei der Klassifikator neuralnetzbasiert ist.

7. Verfahren nach einem der Ansprüche 1 bis 6, wobei der Schritt des Berechnens der relativen Position des Objekts in Bezug auf den Referenzpunkt durch ein erstes Entscheidungssystem qualitativen Typs durchgeführt wird.

8. Verfahren nach einem der Ansprüche 1 bis 7, das des Weiteren das Trainieren mit Beispielen, angepasst an den Aufbau des Klassifikators, umfasst.

9. Verfahren nach Anspruch 8, wobei der Schritt des Trainierens mit Beispielen die folgenden Schritte umfasst:

- Akquirieren einer Vielzahl von Beispielbildern,
- Egalisieren des Histogramms von jedem der Beispielbilder,
- Quantisieren der Graustufen von jedem der Beispielbilder,
- Bereitstellen jedes der Beispielbilder für den Klassifikator.

10. Verfahren nach Anspruch 9, wobei jedes Bild der Vielzahl von Beispielbildern eine Instanz des Objekts ist.

11. Verfahren nach Anspruch 9, wobei jedes Bild der Vielzahl von Beispielbildern eine Instanz des Objekts in Bezug auf den Referenzpunkt ist.

12. Verfahren nach einem der vorhergehenden Ansprüche, das des Weiteren einen Schritt des Messens der dreidimensionalen Position des Schwerpunktes des Objekts in Bezug auf den Referenzpunkt umfasst.

13. Verfahren nach Anspruch 12, wobei der Messschritt einen Schritt des Berechnens des Schnittpunktes von den Sichtlinien, die durch zwei Beobachtungspunkte erzeugt werden, umfasst.

14. Verfahren nach Anspruch 13, wobei für jeden der Beobachtungspunkte die Berechnung der Sichtlinie die folgenden Schritte umfasst:

- Schätzen einer ersten Projektivtransformation ($H_{\Gamma i}$) zwischen einer ersten bekannten dreidimensionalen Ebene (Γ) und der Projektion davon auf die Bildebene (I_i),
- Schätzen einer zweiten Projektivtransformation ($H_{\Pi i}$) zwischen einer zweiten bekannten dreidimensionalen Ebene (Π) und der Projektion davon auf die Bildebene (I_i),
- Schätzen einer ersten Projektion ($B_{\Gamma i}$) des Schwerpunktes (B) des Objekts von der Bildebene (I_i) zu der bekannten dreidimensionalen Ebene (Γ) durch die erste Projektivtransformation ($H_{\Gamma i}$),

- Schätzen einer zweiten Projektion ($B_{\Pi p}$) des Schwerpunktes (B) des Objekts von der Bildebene (Π) zu der dreidimensionalen Ebene (Π') durch die zweite Projektivtransformation ($H_{\Pi \Pi'}$) und
 - Schätzen der Sichtlinie von jeweiligen Schnittpunkten mit der Ebene (Γ) und der Ebene (Π').
- 15.** Verfahren nach einem der vorhergehenden Ansprüche, wobei der Schritt des Berechnens der relativen Position des Objekts in Bezug auf den Referenzpunkt durch ein zweites Entscheidungssystem metrischen Typs durchgeführt wird.
- 16.** Verfahren nach einem der vorhergehenden Ansprüche, das des Weiteren den Schritt des Speicherns jedes der akquirierten Bilder umfasst.
- 17.** System zum Messen der relativen Position eines Objekts in Bezug auf einen Referenzpunkt, umfassend:
- ein Bildakquisitions-Subsystem oder mehrere Bildakquisitions-Subsysteme (2, 2', 2'', 3, 3'), jedes Subsystem geeignet, um eine Vielzahl von Bildern zu akquirieren, wobei jedes von den Bildern den Referenzpunkt anzeigt,
 - eine Einheit (4) zum Verarbeiten der akquirierten Bilder
- und dadurch gekennzeichnet, dass die Verarbeitungseinheit einen Klassifikator zum Erkennen des Objekts in jedem der Bilder umfasst.
- 18.** System nach Anspruch 17, wobei wenigstens eines von dem einen Bildakquisitions-Subsystem oder den mehreren Bildakquisitions-Subsystemen (2, 2', 2'') ein Subsystem monokularen Typs ist.
- 19.** System nach Anspruch 18, wobei jedes Monokulartyp-Subsystem (2, 2', 2'') einen einzelnen Bildwandler (11) umfasst.
- 20.** System nach einem der Ansprüche 17 bis 19, wobei wenigstens eines von dem einen Bildakquisitions-Subsystem oder den mehreren Bildakquisitions-Subsystemen (3, 3') ein Subsystem binokularen Typs ist.
- 21.** System nach Anspruch 18, wobei jedes Binokulartyp-Subsystem (3, 3') zwei Bildwandler (11) umfasst.
- 22.** System nach einem der Ansprüche 19 bis 21, wobei jeder der Wandler eine Kamera (11) ist.
- 23.** System nach Anspruch 22, wobei jede Kamera geeignet ist, um wenigstens 262 Bilder/s mit einer Auflösung von 512 x 512 Pixeln zu akquirieren.
- 24.** System nach einem der Ansprüche 17 bis 23, das des Weiteren Einrichtungen (12, 13, 12', 13') zum Speichern der akquirierten Bilder umfasst.
- 25.** System nach einem der Ansprüche 17 bis 24, wobei jedes Bildakquisitions-Subsystem (2, 2', 2'', 3, 3') des Weiteren Recheneinrichtungen (14, 14') umfasst, die geeignet sind, um die relative Position des Objekts in Bezug auf den Referenzpunkt zu berechnen.
- 26.** System nach einer der vorhergehenden Ansprüche 17 bis 25, geeignet, um ein Verfahren nach einem der Ansprüche 1 bis 16 zu implementieren.
- 27.** Spielfeld (100), das ein System zum Messen der relativen Position eines Objekts in Bezug auf einen Referenzpunkt nach einem der Ansprüche 17 bis 26 umfasst.

Revendications

1. Procédé de mesure de la position relative d'un objet par rapport à un point de référence, comprenant les étapes consistant à :

- acquérir plusieurs images, chacune desdites images étant apte à visualiser ledit point de référence ;
- traiter chaque image parmi lesdites plusieurs images acquises ; et
- calculer ladite position relative dudit objet par rapport audit point de référence,

caractérisé en ce que ladite étape de traitement de chaque image comporte en outre une étape consistant à reconnaître ledit objet à l'intérieur de chacune desdites images, ladite étape de reconnaissance du dit objet étant exécutée par un classifieur.

2. Procédé selon la revendication 1, dans lequel ladite étape de reconnaissance d'objet comporte une étape consistant à prétraiter chacune desdites images.

3. Procédé selon la revendication 2, dans lequel ladite étape de prétraitement comporte les étapes consistant à :

- analyser les niveaux de gris de chacune desdites images ;
- réaliser un fenêtrage de chacune desdites images, apte à réduire la zone de recherche dudit objet ;
- extraire des informations d'identification dudit objet.

4. Procédé selon la revendication 3, dans lequel ladite étape d'extraction desdites informations d'identification

- tion est exécutée par des techniques reposant sur l'analyse du contour ou de la surface.
5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel ledit classifieur repose sur des techniques du type SVM. 5
6. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel ledit classifieur est à base de réseaux neuronaux. 10
7. Procédé selon l'une quelconque des revendications 1 à 6, dans lequel ladite étape de calcul de ladite position relative dudit objet par rapport audit point de référence est exécutée par un premier système de prise de décision de type qualitatif. 15
8. Procédé selon l'une quelconque des revendications 1 à 7, comprenant en outre une étape d'apprentissage à l'aide d'exemples, permettant de construire ledit classifieur. 20
9. Procédé selon la revendication 8, dans lequel ladite étape d'apprentissage à l'aide d'exemples comporte les étapes consistant à : 25
- acquérir plusieurs exemples d'images ;
 - égaliser l'histogramme de chacun desdits exemples d'images ;
 - quantifier les niveaux de gris de chacun desdits exemples d'images ; et
 - fournir chacun desdits exemples d'images audit classifieur.
10. Procédé selon la revendication 9, dans lequel chaque image parmi lesdits plusieurs exemples d'images est un exemple dudit objet. 30
11. Procédé selon la revendication 9, dans lequel chaque image parmi lesdits plusieurs exemples d'images est un exemple dudit objet par rapport audit point de référence. 40
12. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre une étape consistant à mesurer la position, en trois dimensions, du centre de masse dudit objet par rapport audit point de référence. 45
13. Procédé selon la revendication 12, dans lequel ladite étape de mesure comporte une étape consistant à calculer le point d'intersection des lignes de visée générées par deux points d'observation.
14. Procédé selon la revendication 13, dans lequel, pour chacun desdits points d'observation, le calcul de ladite ligne de visée comprend les étapes consistant à : 50
- estimer une première transformation projective (H_{Γ}) entre un premier plan connu en trois dimensions (Γ) et la projection de celui-ci dans le plan (I_1) de l'image ;
 - estimer une seconde transformation projective (H_{Π}) entre un second plan en trois dimensions connu (Π) et la projection de celui-ci dans le plan (I_1) de l'image ;
 - estimer une première projection (B_{Γ}) du centre de masse (B) dudit objet depuis ledit plan (I_1) de l'image vers ledit plan en trois dimensions connu (Γ) à l'aide de la première transformation projective (H_{Γ}) ;
 - estimer une seconde projection (B_{Π}) du centre de masse (B) dudit objet depuis ledit plan (I_1) de l'image vers ledit plan en trois dimensions (Π) à l'aide de la seconde transformation projective (H_{Π}) ;
 - estimer ladite ligne de visée, d'après des points d'intersection respectifs avec le plan (Γ) et le plan (Π).
15. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite étape de calcul de ladite position relative dudit objet par rapport audit point de référence est exécutée par un second système de prise de décision de type métrique. 55
16. Procédé selon l'une quelconque des revendications précédentes, comprenant en outre une étape consistant à mémoriser chacune desdites images acquises. 60
17. Système de mesure de la position relative d'un objet par rapport à un point de référence, comprenant : 65
- un ou plusieurs sous-systèmes d'acquisition (2, 2', 2'', 3, 3') d'images, chaque sous-système étant apte à acquérir plusieurs images, chacune desdites images visualisant ledit point de référence ; et
 - une unité (4) pour le traitement desdites images acquises,
- caractérisé en ce que** ladite unité de traitement (4) comporte un classifieur pour reconnaître ledit objet à l'intérieur de chacune desdites images. 70
18. Système selon la revendication 17, dans lequel au moins un desdits un ou plusieurs sous-systèmes d'acquisition d'images est un sous-système de type monoculaire (2, 2', 2''). 75
19. Système selon la revendication 18, dans lequel chacun desdits sous-systèmes monoculaires (2, 2', 2'') comprend un seul transducteur (11) d'image. 80
20. Système selon l'une quelconque des revendications

17 à 19, dans lequel au moins un desdits un ou plusieurs sous-systèmes d'acquisition d'images est un sous-système de type binoculaire (3, 3').

- 21.** Système selon la revendication 20, dans lequel chaque sous-système de type binoculaire (3, 3') comprend deux transducteurs (11) d'images. 5
- 22.** Système selon l'une quelconque des revendications 19 à 21, dans lequel chacun desdits transducteurs d'images est une caméra (11). 10
- 23.** Système selon la revendication 22, dans lequel chaque caméra est apte à acquérir au moins 262 images/s, avec une résolution d'un moins 512 x 512 pixels. 15
- 24.** Système selon l'une quelconque des revendications 17 à 23, comprenant en outre des moyens (12, 13 ; 12', 13') pour mémoriser lesdites images acquises. 20
- 25.** Système selon l'une quelconque des revendications 17 à 24, dans lequel chaque sous-système d'acquisition (2, 2', 2'', 3, 3') comporte en outre des moyens de calcul (14 ; 14') aptes à calculer ladite position relative dudit objet par rapport audit point de référence. 25
- 26.** Système selon l'une quelconque des revendications 17 à 25, apte à mettre en oeuvre un procédé selon l'une quelconque des revendications 1 à 16. 30
- 27.** Champ de jeu (100) comprenant un système de mesure de la position relative d'un objet par rapport à un point de référence selon l'une quelconque des revendications 17 à 26. 35

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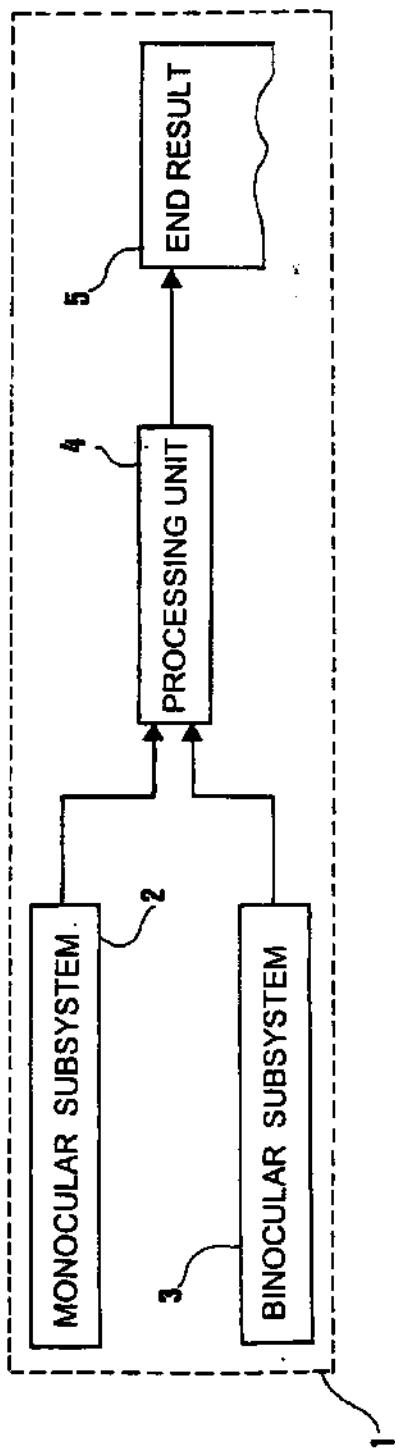


Fig.1

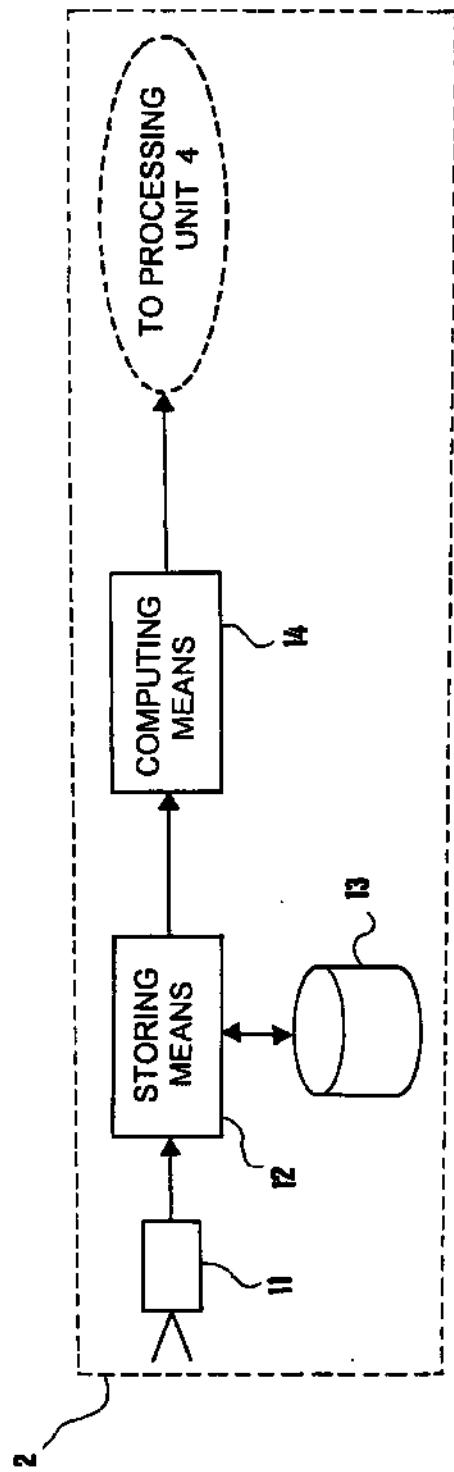


Fig.2

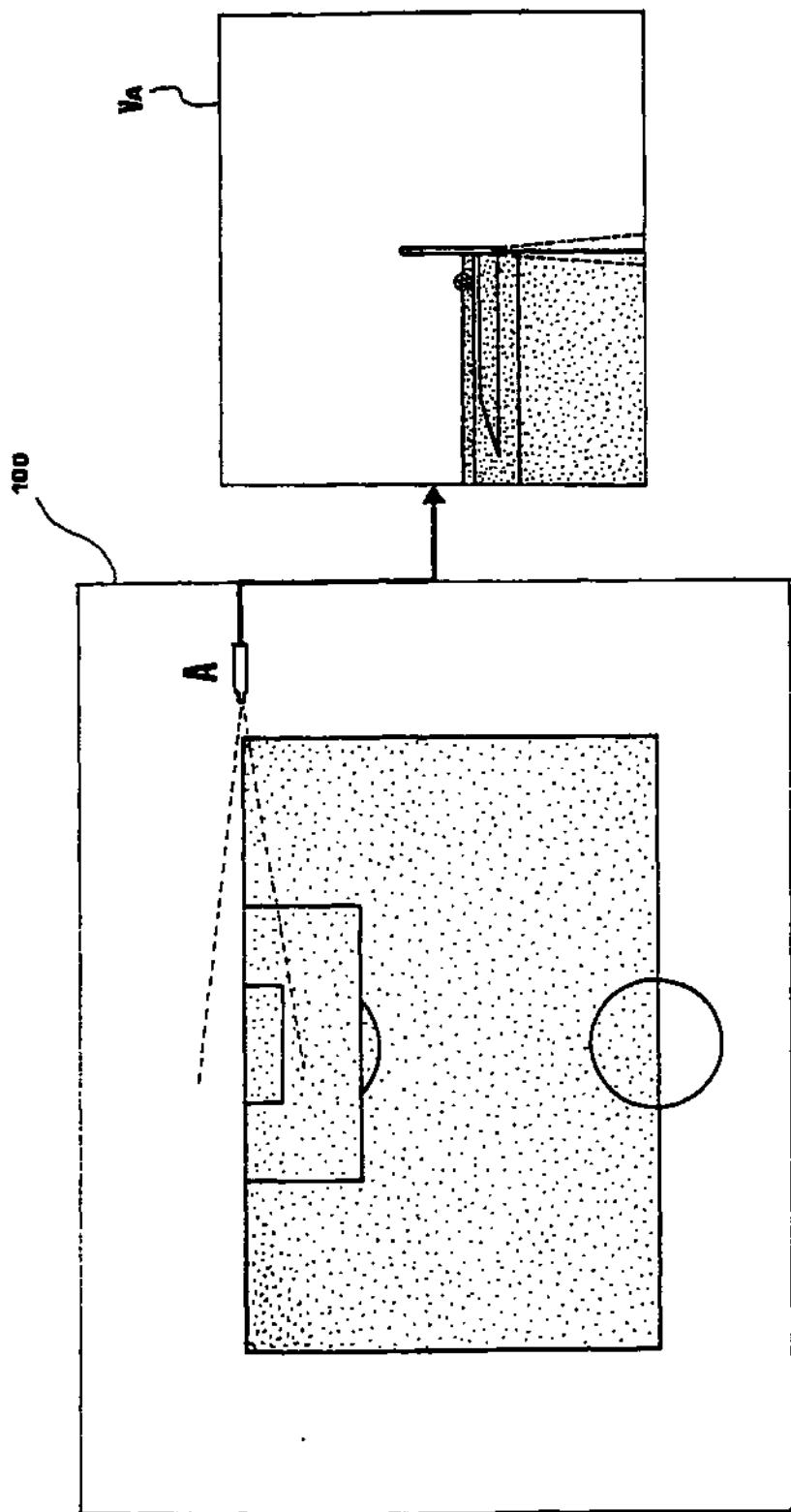


Fig.3

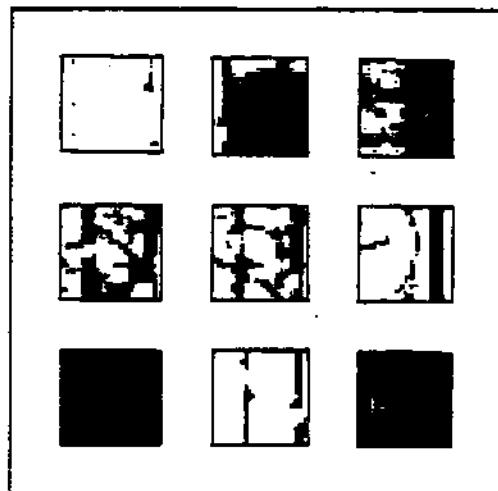


Fig. 4b

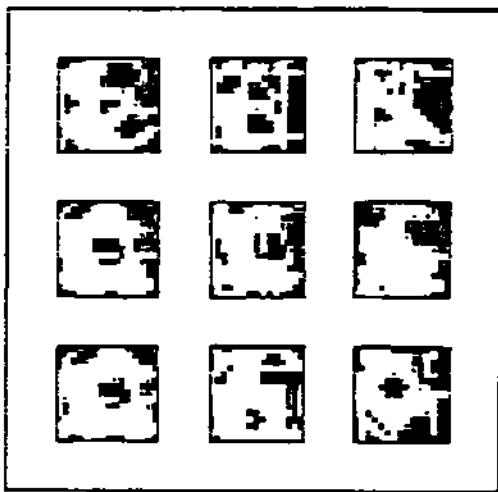


Fig. 4a

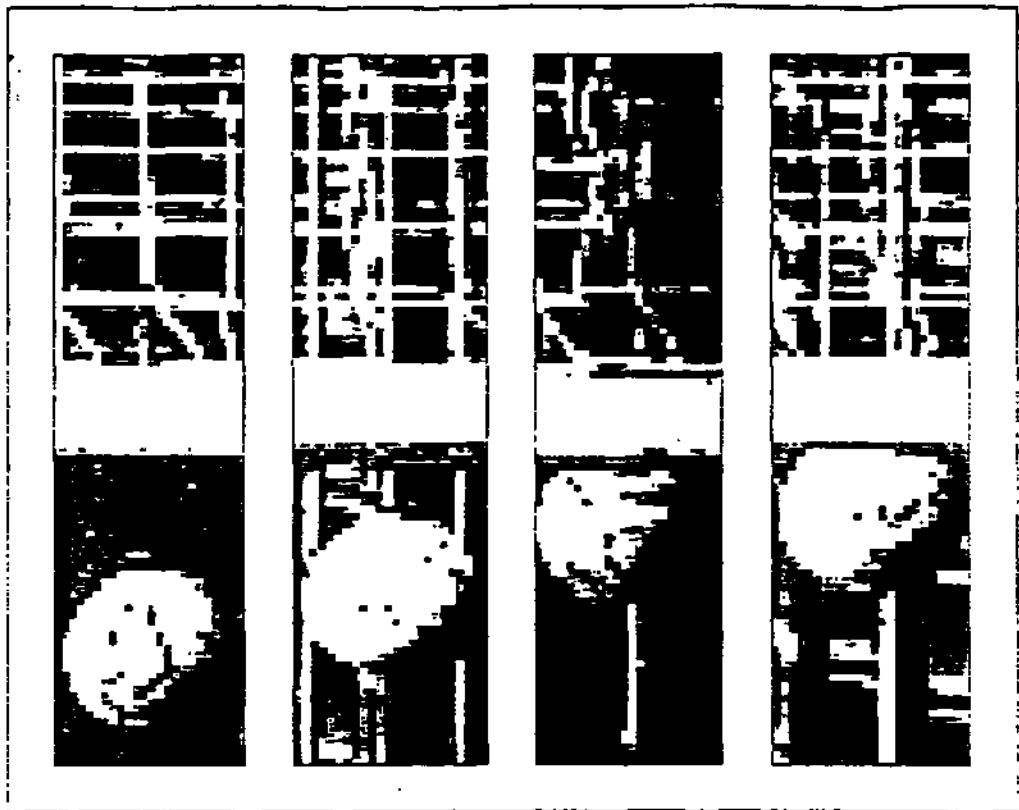


Fig. 5b

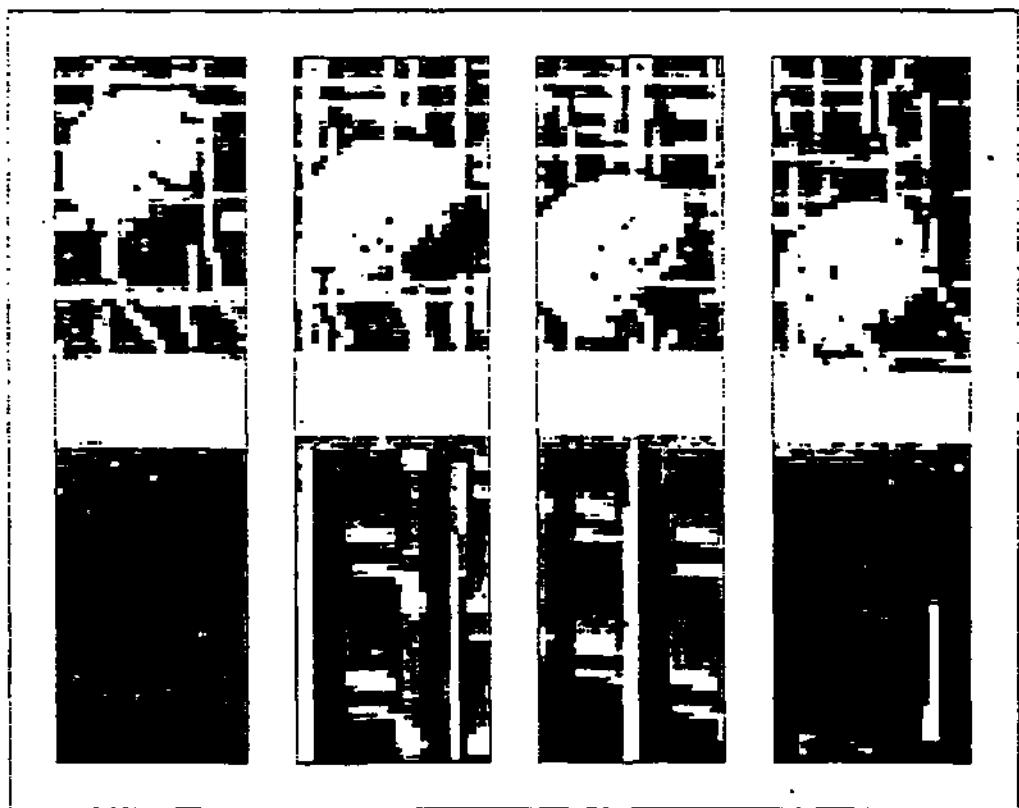


Fig. 5a

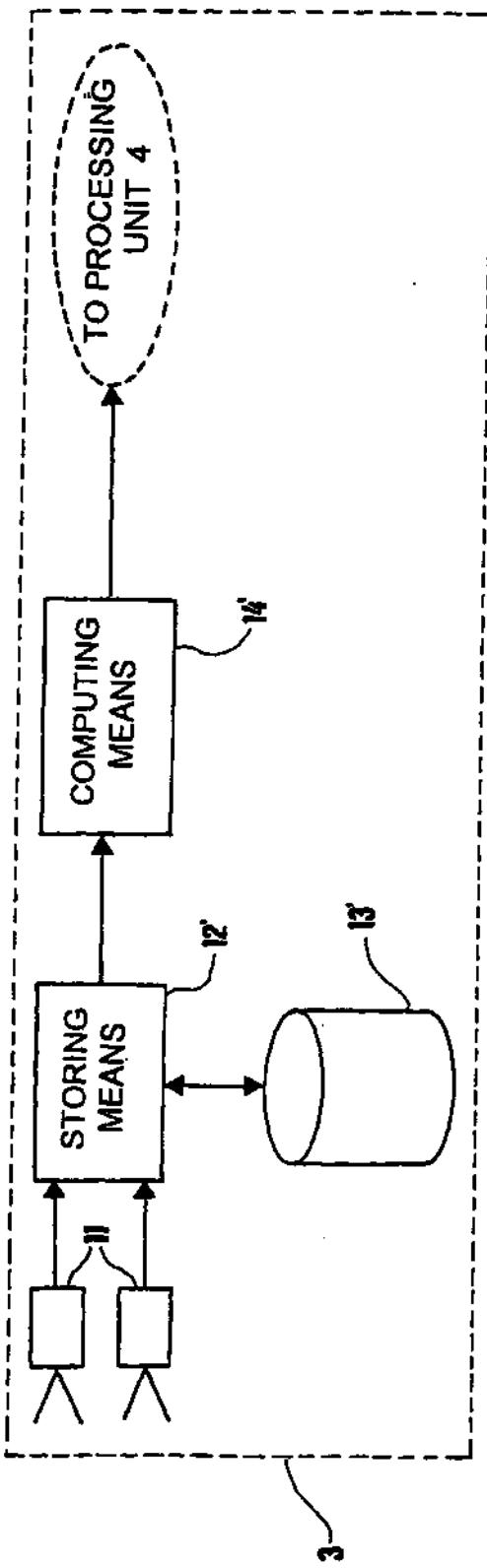


Fig. 6

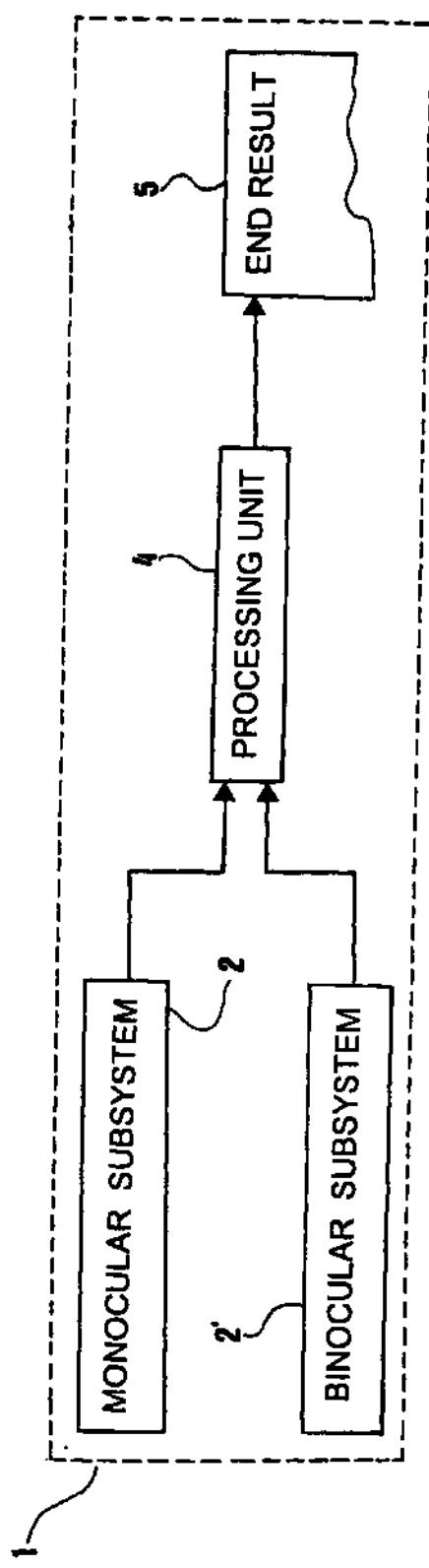


Fig. 10

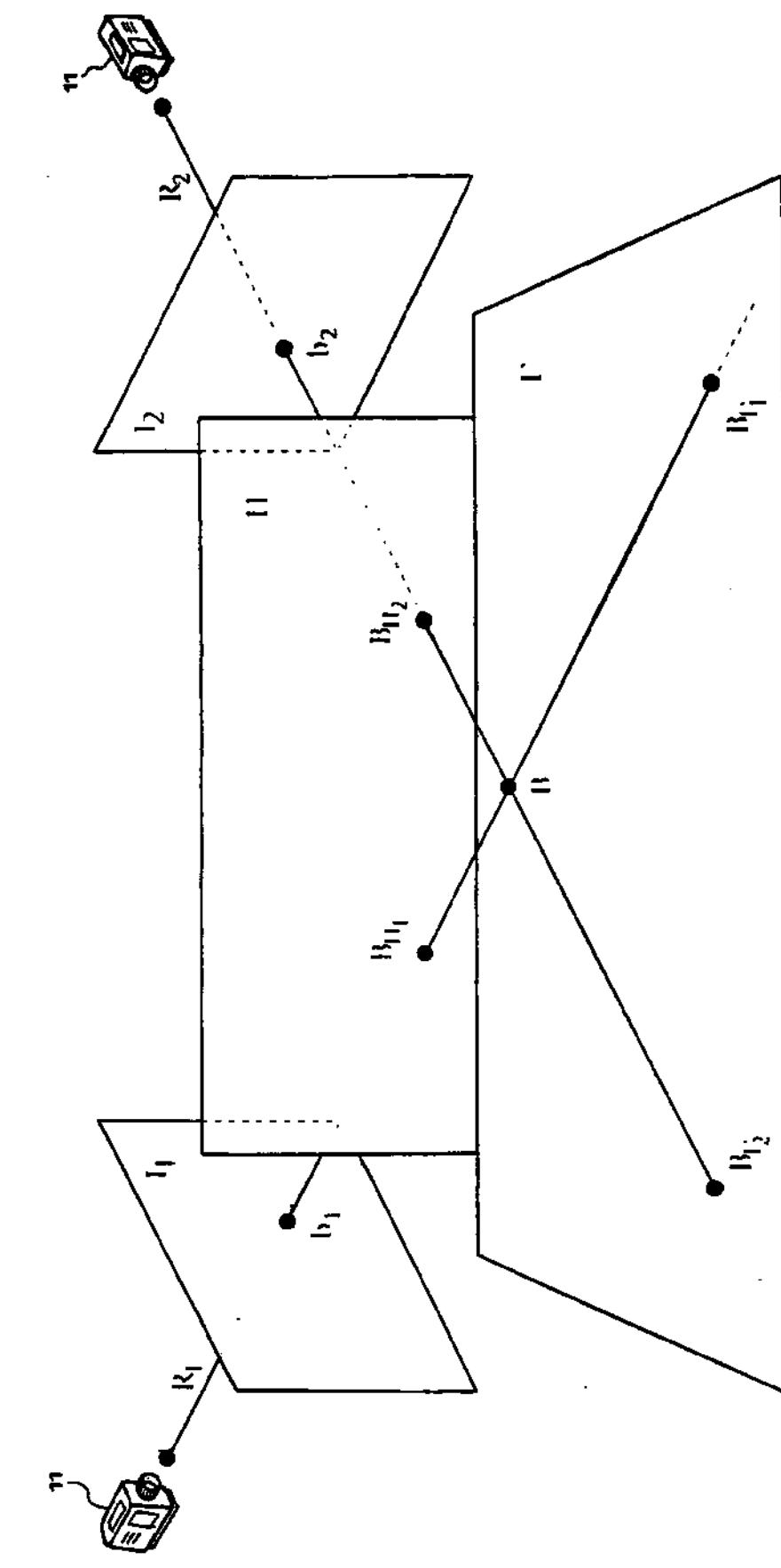


Fig.7

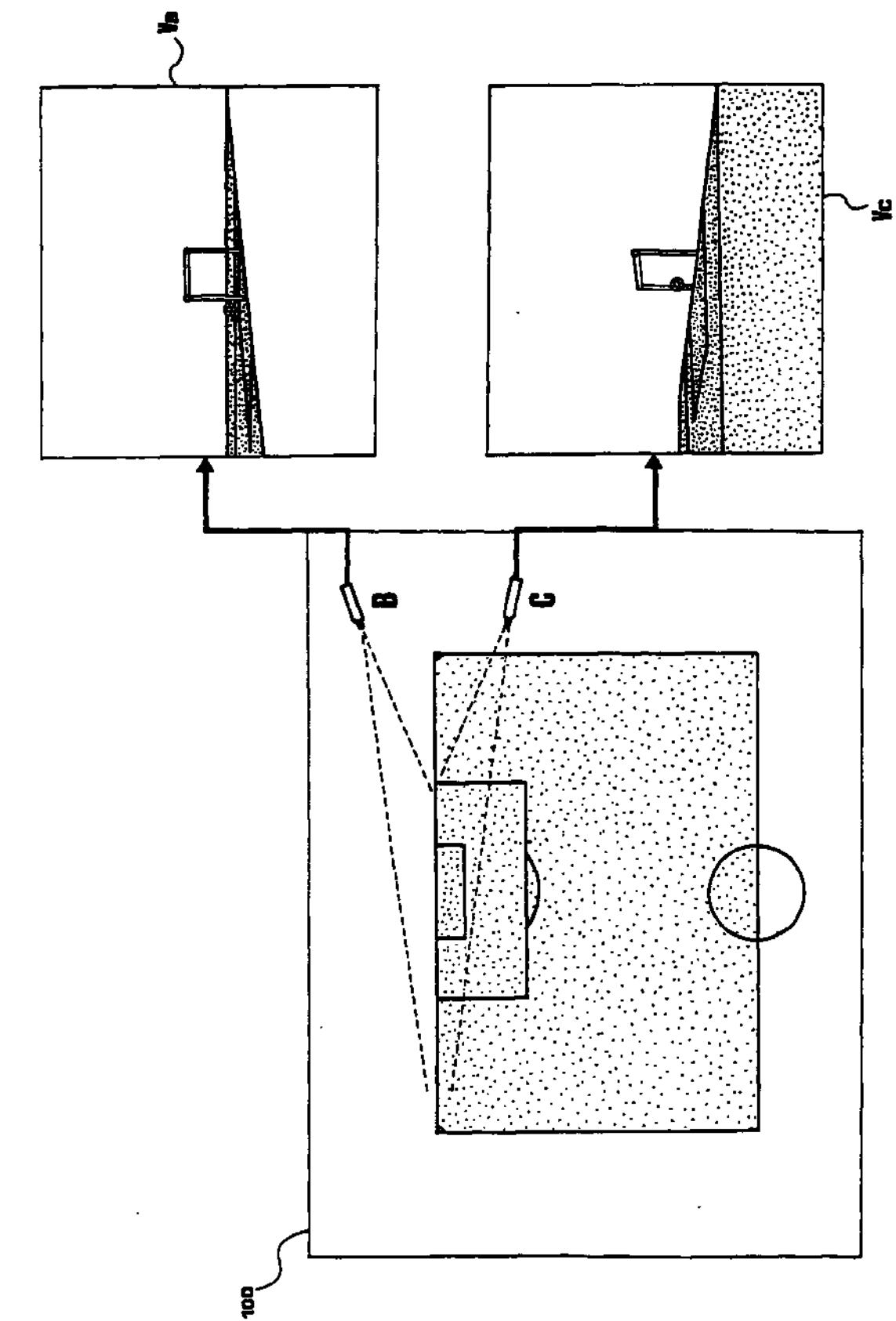


Fig.8

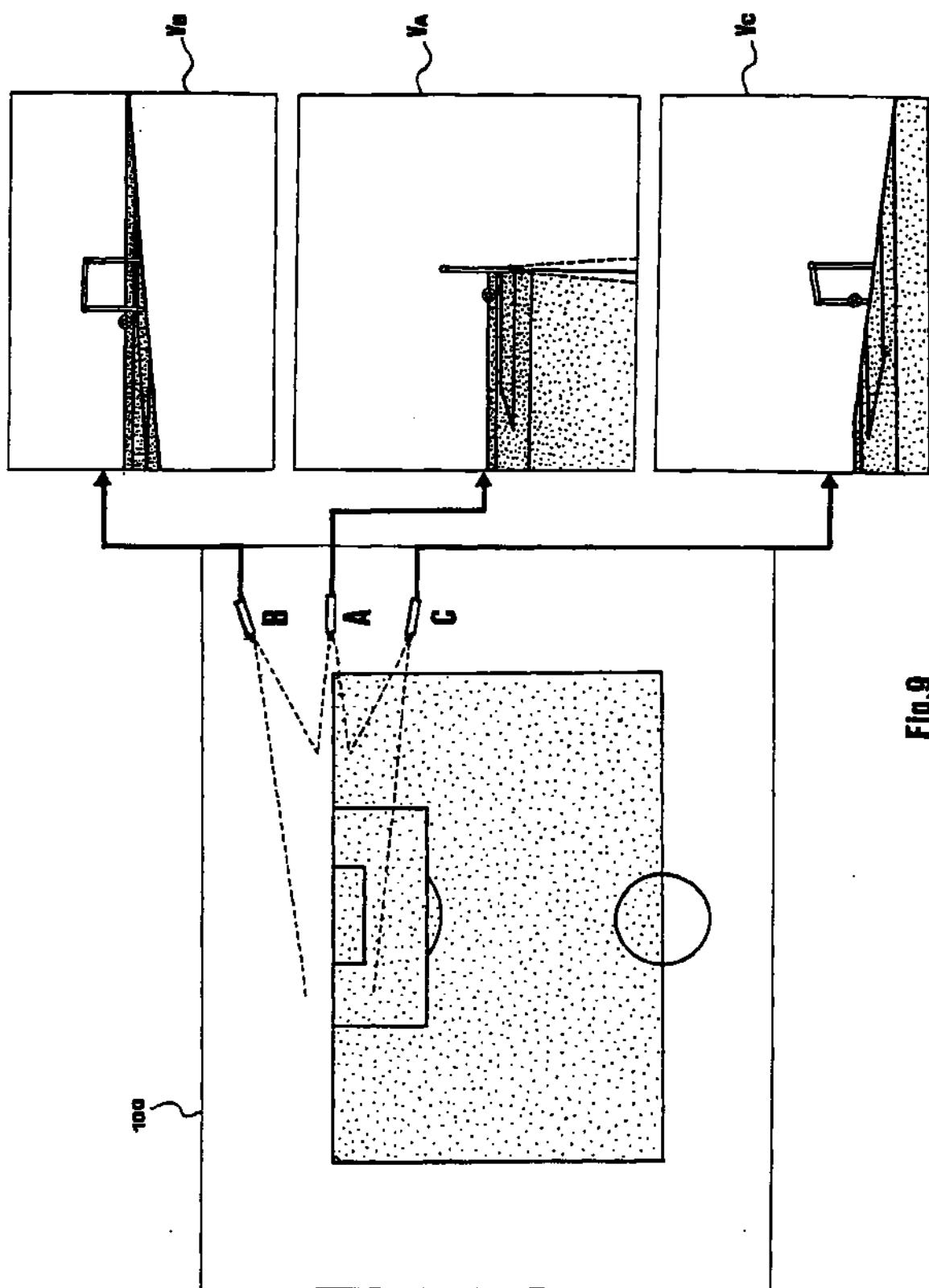


Fig.9

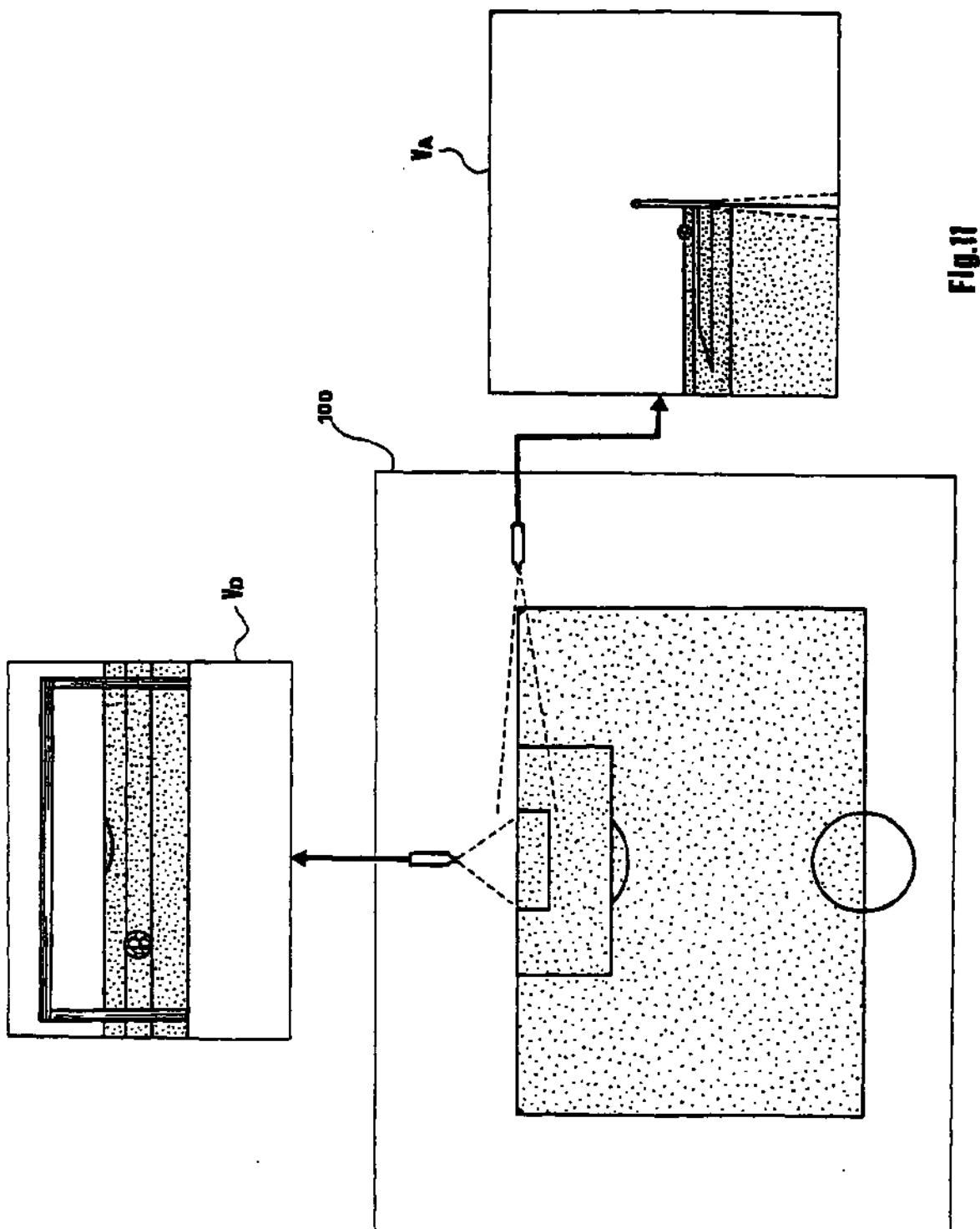


Fig.11

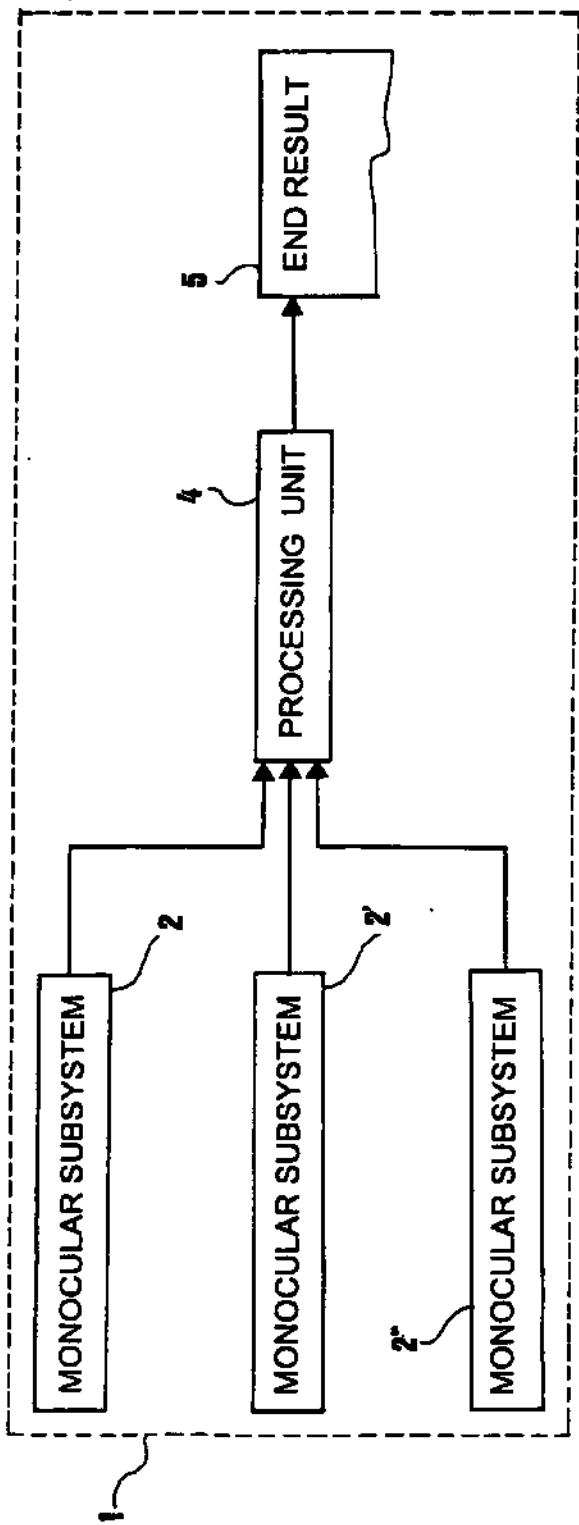


fig.12

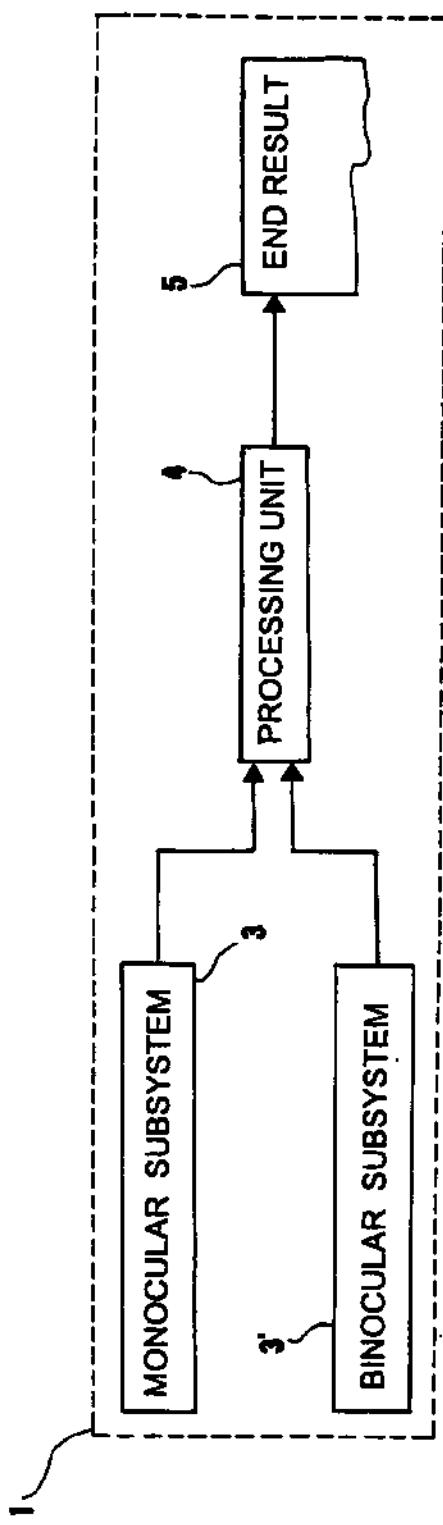


fig.14

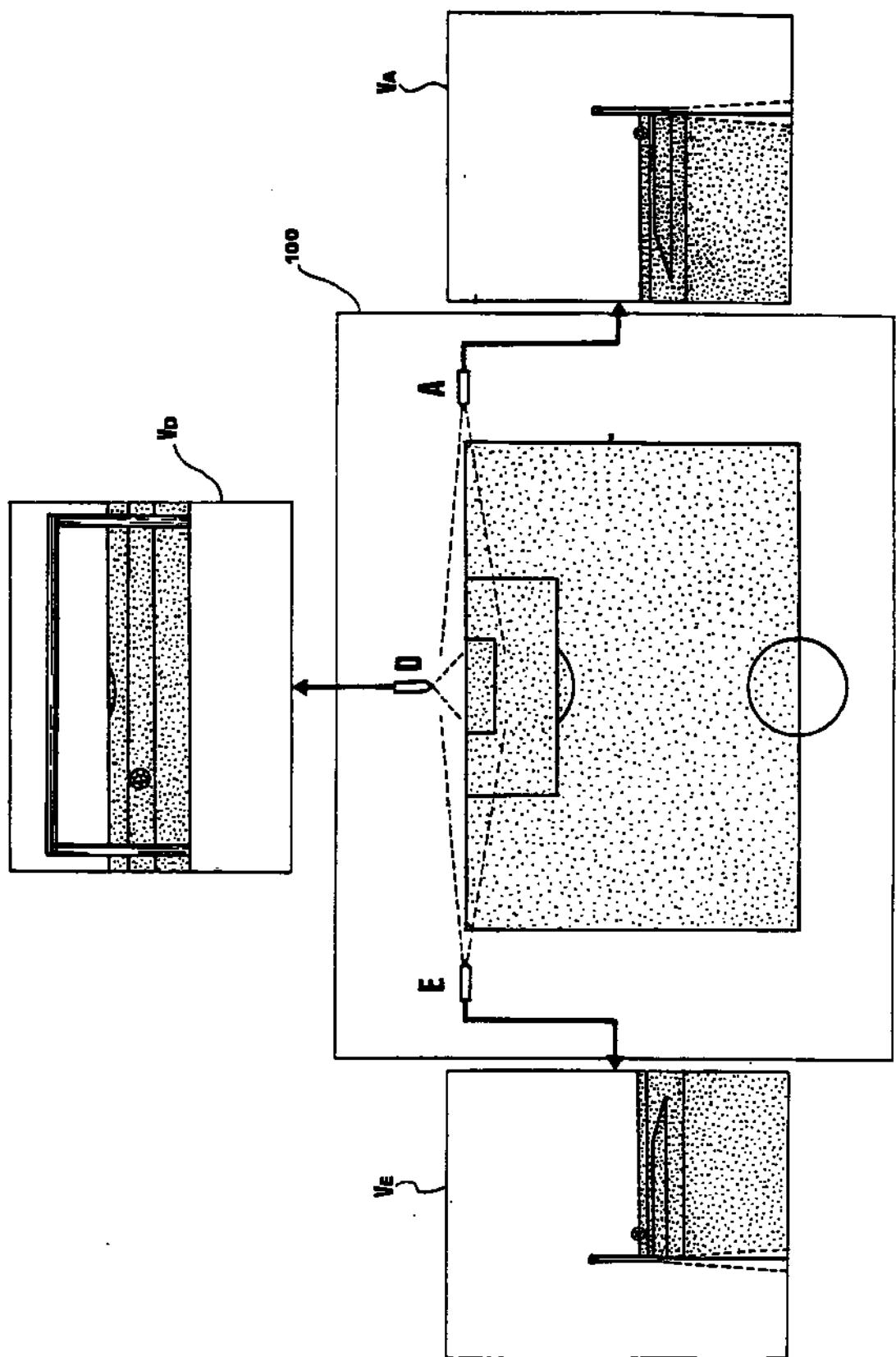


Fig.13

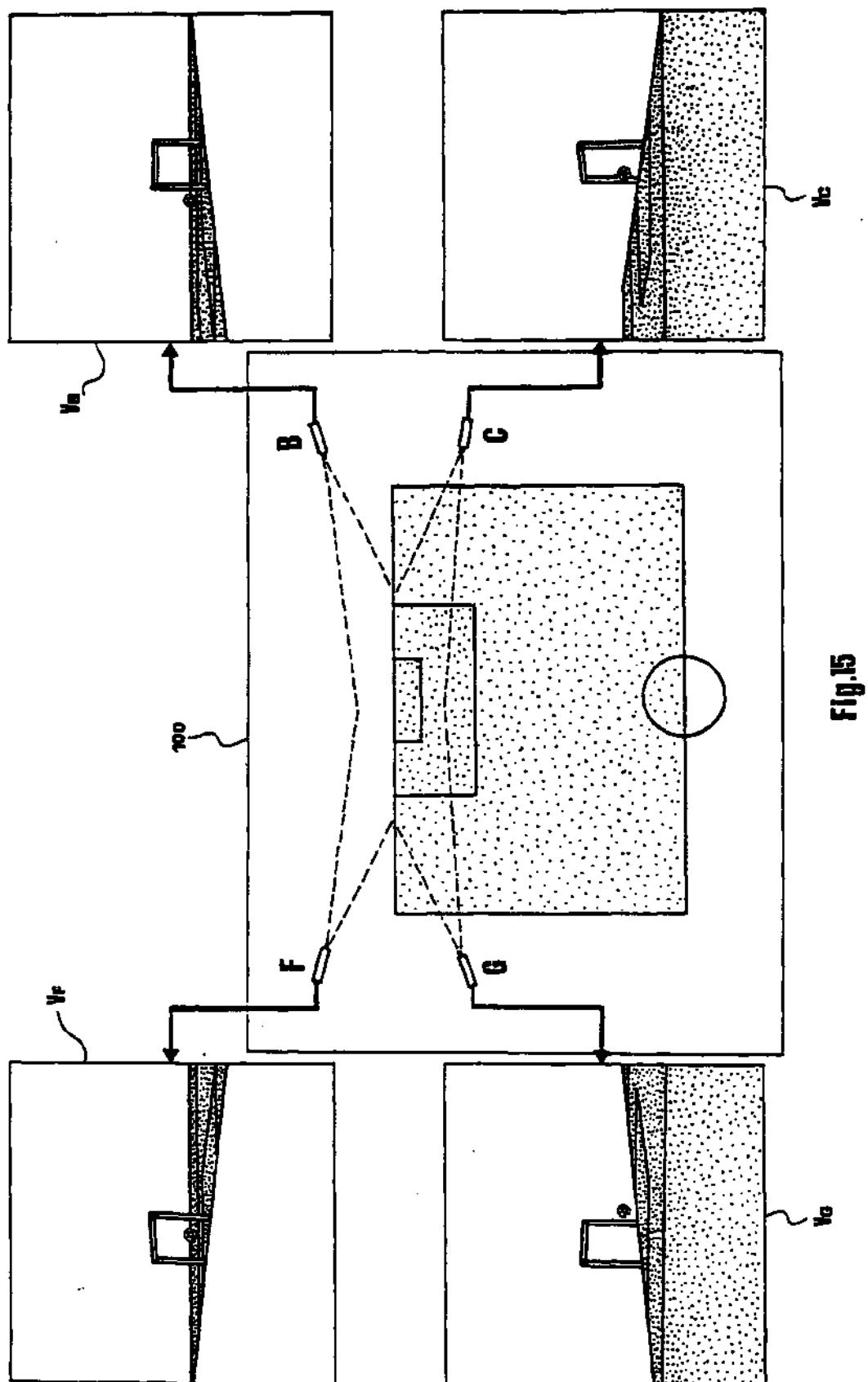


Fig.15

REFERENCES CITED IN THE DESCRIPTION

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