Object Recognition Method

Technical Field

The present invention relates to the field of object recognition in 3-dimensional space as may be used as part of an artificial intelligence system.

Background

Computer based object recognition has become widely used in 2-dimensional space, for example character recognition in document scanners and automotive number plate recognition for policing roads. However, to date at least, the development of object recognition in 3-dimensional space has been fairly limited, and has not yet entered the commercial market. Nevertheless many of the associated technologies required for 3-dimensional object recognition have already entered the commercial market, such as 3-dimensional scanners which enable a 3-dimensional object to be scanned and a 3-dimensional digital model to be generated. For example 3-dimensional scanners enable the human face to be scanned for computer games and for the generation of 3-dimensional laser images in crystal.

Some current 3-dimensional object recognition systems rely upon environment-dependant conditions such as the distinct colouring of objects.

Other current 3-dimensional object recognition systems rely upon a complete 3-dimensional image of an object in order to create a normalised set of data pertaining to the object, for example normalisation methods employing an inferred centre of mass of an object. This method is demonstrated in the paper “A Geometric Approach to 3D object Comparison”, Novotni et al, smi, pp.0167, International Conference on Shape Modelling and Applications, 2001.

Other current 3-dimensional object recognition systems rely upon the extraction of affine invariant localised planar surface patches, where these patches can be normalised for object recognition. This method is demonstrated in the paper “3D Object Modelling and Recognition Using Affine-Invariant Patches and Multi-View Spatial Constraints”, Rothganger et al, Proceedings of the 2003 IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Vol. 2, 2003, pp. II-272-7. This technology enables both the use of appearance and 3-dimensional structure in object recognition.

It is an object of the present invention to provide a 3D object recognition algorithm which will operate independently of the object position and orientation and the viewpoint position and orientation, operate in a large range of lighting conditions and, operate efficiently. The object recognition method will also operate without the need for artificial colouring to be applied to the objects, does not require a complete 3D image of the object to be obtained (does not require an object to be viewed from all angles during either the characterisation or recognition phase), will make use of both the appearance and 3-dimensional structure in object recognition, and will operate on objects without planar surfaces or sharp edges to aid identification.

It should be realized that the method according to the present invention will reduce in performance where object features (points of interest on the object) cannot be extracted. This can occur in the scenario where an object being recognised has both no distinct areas of high curvature in shape, for example corners, and no distinct areas of high curvature in surface texture. However there are potentially other methods well known by those skilled in the art to identify object features to identify such objects with a minimum of object features. Also some "degenerate" objects may look the same regardless of the viewing angle and, hence, may still be recognisable regardless of the accuracy and repeatability of the object feature extraction method.

Summary of Invention

The present invention consists in a method for generating data for one or more objects residing in one or more scenes in a 3-dimensional cartesian space defined by an (X, Y, Z) axis system passing through an origin, comprising the steps of:

1. for each of the objects, deriving a set of 3-dimensional object data comprising coordinates, one or more of the coordinates corresponding to coordinates of object features;
2. for each of the objects, grouping permutations of the coordinates of object features of the set of 3-dimensional object data as the coordinates of apexes of one or more object triangles orientated in the space, each object triangle comprising three sides and three apexes and defining a plane;
3. for each of one or more of the sides of each of the object triangles of each of the objects, shifting the position of the origin to a new origin position and reorientating the axis system to a new axis orientation such that, in a new (X', Y', Z') axis system defined by a first new axis (X'), a second new axis (Y'), and a third new axis (Z'), the new axis orientation and new origin position are a function of the coordinates of the apexes of the object triangle, transforming one or more of the coordinates (x, y, z) of the set of 3-

dimensional object data into transformed coordinates (x', y', z') in the new axis system and forming a set of transformed 3-dimensional object data; and

4. for each of the one or more sides of each of the object triangles of each of the objects, generating data relating to the set of transformed 3-dimensional object data.

Preferably the set of 3-dimensional object data comprises a set of data points pertaining to the object, wherein each data point comprises coordinates and an associated one or more light intensity values, and one or more of the coordinates of the set of 3-dimensional object data are the coordinates of these data points.

Preferably the set of transformed 3-dimensional object data comprises either a set of data points with transformed coordinates, or a set of coordinates of object features with transformed coordinates or, or both, wherein each data point comprises one or more transformed coordinates and an associated one or more light intensity values.

Preferably the new axis orientation is a function of the 3-dimensional orientation of the side and the 3-dimensional orientation of the plane, and the new origin position is a function of the coordinates of one or more of the apexes.

Preferably a further new axis system (X'', Y'', Z'') is positioned and aligned such that a third further new axis (Z'') of the further new axis system is aligned perpendicular to the plane of the object triangle, and passing through the mid point between the two apexes at the extremities of the side, a first further new axis (X'') of the further new axis system is aligned parallel to the side, and a second further new axis (Y'') of the further new axis system is directed through the mid point in the direction of the third apex of the triangle, and the position and orientation of the first, second and third new axes of the new axis system are equivalent to a function of the position and orientation of the first, second and third further new axes of the further new axis system.

Alternatively the third new axis (Z') is aligned perpendicular to the plane of the object triangle, and passing through the mid point between the two apexes at the extremities of the side, the first new axis (X') is parallel to the side, and the second new axis (Y') axis is directed through the mid point in the direction of the third apex of the triangle.

Preferably one or more coordinates of the set of coordinates of object features of the set of 3-dimensional object data comprise virtual texture corners where virtual texture corners are regions of high local curvature of light intensity on the surface of the object.

Preferably at least one of the one or more of the coordinates of the set of 3-dimensional object data comprise the coordinates of object features pertaining to the apexes of the object triangle.

Preferably a unique object index is assigned for each of the objects.

Preferably a unique transformation index is assigned for each of the sides of each of the object triangles of each of the objects.

Preferably the data generated also includes data relating to the object index.

Preferably the data generated also includes data relating to the transformation index.

Preferably the data generated also includes data relating to the new origin and the new axis orientation.

Preferably the data relating to the set of transformed 3-dimensional object data comprises the set of coordinates of object features of the set of transformed 3-dimensional object data.

The set of data points of a set of 3-dimensional object data may be used to form an interpolated or non-interpolated 3-dimensional mesh defined by mesh points, the coordinates of each mesh point corresponding to a coordinate or an interpolation of one or more of the coordinates of the data points, and each polygon of the surface mesh formed by proximate mesh points having associated with it one or more light intensity values derived as a function of the one or more light intensity values associated with nearby data points.

Preferably one or more coordinates of the set of coordinates of object features of the set of 3-dimensional object data comprise virtual texture corners where virtual texture corners are regions of high local curvature of light intensity on the surface of the object.

Preferably virtual texture corners are a function of the one or more light intensity values and the coordinates of the data points of the 3-dimensional object data.

Preferably the one or more coordinates associated with the object are located on the surface of the object.

Preferably the one or more light intensity values associated with the one or more coordinates associated with the object correspond to the one or more light intensity values measured as coming from these coordinates.

Preferably one or more coordinates of the set of coordinates of object features of the set of 3-dimensional object data comprise virtual corners where virtual corners are regions of high local curvature in the directions of one or more axes of the axis system.

Preferably the virtual corners are a function of the coordinates of the data points of the 3-dimensional object data.

Preferably, for each of the objects, data is also generated containing one or more data points of the set of 3-dimensional object data or a functional transform of one or more data points of the set of 3-dimensional object data.

Preferably the one or more sets of 3-dimensional object data are derived by 3-dimensionally imaging the one or more scenes from one or more viewpoints of defined relative positions and orientations in the space and, for each of the viewpoints, a 2-dimensional image of the one or more objects is generated, each image comprising an array of pixels, each pixel corresponding to a viewable point in the scene at a distance from the viewpoint, the viewable point being characterised by one or more light intensity values and a coordinate (x, y, z) in space, and, either during the calculating of the coordinates for each viewpoint or after the calculating of the coordinates for all viewpoints, determining the set of data points of the set of 3-dimensional object data for each of the objects and, either during the calculating of the coordinates for each viewpoint or after the calculating of the coordinates for all viewpoints, deriving the set of coordinates of object features of the set of 3-dimensional object data for each of the objects.

Preferably the coordinate (x, y, z) of each viewable point in space is based on the location of the pixel in the array, the distance between the viewable point and the viewpoint, and the position, orientation, and viewing properties of the viewpoint.

Preferably the positions and orientations of at least one of the one or more viewpoints are calculated based on a functional transformation of the coordinates of the data points of one or more sets of 3-dimensional object data or of the positions and orientations of one or more viewpoints, or the viewing properties of one or more viewpoints.

Preferably the viewable point resides on one or more of the objects.

Preferably the position and orientation of one viewpoint is set to an absolute position and orientation in the space, thereby determining both the position of the origin and the orientation of the axis system and the absolute positions and orientations of all viewpoints.

Preferably the set of data points of the set of 3-dimensional object data pertaining to each of the objects is isolated by determining boundaries between the one or more objects based on a boolean depth (distance) contrast map derived by applying an arbitrary threshold to a depth contrast map of the image, or a boolean depth gradient contrast map derived by applying an arbitrary threshold to a depth gradient contrast map of the image, or a boolean luminosity (light intensity) contrast map derived by applying an arbitrary threshold to a luminosity contrast map of the image, or any function or linear or nonlinear combination of these maps.

Preferably the virtual corners (object features) of each of the objects are derived, for each viewpoint, by firstly creating a boolean threshold outline map then, secondly, based on the light intensities and corresponding 3-dimensional coordinates of each pixel in the array, deriving the pixels and their associated coordinates which (a) pass the threshold and are therefore pixels which reside on an outline of the object in the image and (b) when their corresponding 3-dimensional coordinates are dot-producted with particular unit vector combinations, give a maximum of the dot-product as compared to all other coordinates for any given unit vector combination.

Preferably the boolean threshold outline map is a boolean depth contrast map derived by applying a first arbitrary threshold to a depth contrast map, or a boolean depth gradient contrast map derived by applying a second arbitrary threshold to a depth gradient contrast map, or a boolean luminosity contrast map derived by applying a third arbitrary threshold to a luminosity contrast map, or any function or linear or nonlinear combination of these maps.

Preferably the virtual corners (object features) are calculated by first deriving a depth gradient map from a depth map, and then deriving a depth gradient contrast map from the depth gradient map, hence deriving regions of high local curvature in the directions of one or more axes of the axis system.

Preferably, for each viewpoint, the imaging comprises creating at least two 2-dimensional images from two different viewpoints, either sequentially or using at least two cameras, and a parallax offset between the positions in the resulting pixels arrays of the corresponding viewable points, and/or the difference between their corresponding one or more light intensity values is used to calculate the distance.

Preferably the coordinates of object features are calculated based on the one or more light intensity values of the pixel array, or the distances associated with each pixel in the array, or the one or more light intensity values of the data points of the set of 3-dimensional object data or the coordinates (x, y, z) of the data points of the set of 3-dimensional object data, or a function of these.

Preferably the viewing properties of the viewpoint comprise a view width angle and a view height angle.

Preferably the light intensity values are quantitative values representing the intensity of one or more light frequencies or frequency bands or a function of these, for example RGB values.

Preferably the set of coordinates of object features of the set of transformed 3-dimensional object data comprises coordinates, pertaining to the transformed coordinates of the apexes of the object triangle.

Preferably the data relating to the set of transformed 3-dimensional object data comprises, the one or more light intensity values of the data points or a function of the light intensity values of the data points or the coordinates of the data points or any subset of the coordinates of the data points of the set of transformed 3-dimensional object data, or the one or more light intensity values of the data points or a function of the light intensity values of the data points or the coordinates of the data points generated by one or more functional transformations of the data points of the set of transformed 3-dimensional object data.

Preferably the set of data points of a set of transformed 3-dimensional object data is used to form an interpolated or non-interpolated 3-dimensional mesh defined by mesh points, the coordinates of each mesh point corresponding to a coordinate or an interpolation of one or more of the coordinates of the data points, and each polygon of the surface mesh formed by proximate mesh points having associated with it one or more light intensity values derived as a function of the one or more light intensity values associated with nearby data points.

Preferably the one or more functional transformations of the data points of the set of transformed 3-dimensional object data are based on a 3-dimensional mesh of the set of data points of the set of transformed 3-dimensional object data, wherein the data points resulting from the functional transformation are snapshot 3-dimensional mesh surface data points.

Preferably the snapshot 3-dimensional mesh surface data points are calculated as the coordinates or array positions and one or more light intensity values of data points in a 2-dimensional array of data points generated by interpolating the mesh surface at particular first new axis (X’) and second new axis (Y’) coordinate intervals, each data point corresponding to a point on or off of the 3-dimensional mesh surface and having one or more light intensity values derived as a function of the light intensity values of data points proximate to the point, and a coordinate derived as a function of the coordinates of the data points proximate to the point.

Alternatively, the snapshot 3-dimensional mesh surface data points are calculated as the coordinates or array positions and one or more light intensity values of pixels in the 2-dimensional image generated when a virtual mesh viewpoint is aligned to the third new axis (Z’), or aligned at a predetermined angular deviation from the third new axis (Z’), with the mesh viewpoint positioned at the new origin, or at a predetermined offset deviation from the new origin, each pixel corresponding to a mesh viewable point on or off of the 3-dimensional mesh surface and having one or more light intensity values derived as a function of the light intensity values of data points proximate to the mesh viewable point, and a coordinate derived as a function of the coordinates of the data points proximate to the mesh viewable point.

Preferably the data is generated for one scene and this data is generated as training data, and the data is also later generated for a different scene and this data is generated as test data, and the training data and test data is compared using an algorithm to recognise the one or more objects.

Preferably the data is generated for multiple scenes and this data is generated as training data, and the data is also later generated for a different scene and this data is generated as test data, and the training data and test data is compared using an algorithm to recognise the one or more objects.

Preferably the algorithm comprises the comparison of the test data pertaining to one of the one or more sides of an object triangle with the training data pertaining to one of the one or more sides of the same or another object triangle.

Preferably the algorithm is an artificial intelligence algorithm.

Preferably the artificial intelligence algorithm is a neural network algorithm, the method enabling the training of the neural network algorithm with the training data or a subset thereof such that, within a recognition phase, the trained neural network can be tested against the test data or a subset thereof, and thereby determining whether or not a test object is recognised and which of the trained objects this test data corresponds to.

Preferably the side of the object triangle side is recognised by verifying a neural network error for the neural network algorithm is below an arbitrary value, and an object is recognised based upon a function of the number of sides of the object triangles associated with that object that were recognised.

Preferably the neural network requires input values and class target values for training and testing respectively, and the input values are the set of coordinates of object features of the set of transformed object data, or a function of the light intensity values or the one or more light intensity values or the coordinates of the data points generated by one or more functional transformations of the set of data points of the set of transformed 3-dimensional object data, and the class targets are the object index or the object transformation index, or a function of these.

Preferably the one or more sets of 3-dimensional object data are derived by 3-dimensionally imaging the scene from one or more viewpoints of defined relative positions and orientations in the space and, for each of the viewpoints, a 2-dimensional image of the one or more objects is generated, each image comprising an array of pixels, each pixel corresponding to a viewable point in the scene and being characterised by one or more light intensity values and a coordinate (x, y, z) in space, and, either during the calculating of the coordinates for each viewpoint or after the calculating of the coordinates for all viewpoints, deriving the set of coordinates of object features of the set of 3-dimensional object data for each of the objects.

Preferably the coordinates of object features are calculated based on the one or more light intensity values of the pixel array, or the distances associated with each pixel in the array, or a function of these.

Preferably the coordinate (x, y, z) of each viewable point in space is based on the location of the pixel in the array, the distance between the viewable point and the viewpoint, and the position, orientation, and viewing properties of the viewpoint.

Preferably the positions and orientations of at least one of the one or more viewpoints are calculated based on the positions and orientations of one or more viewpoints, or the viewing properties of one or more viewpoints.

Preferably one or more coordinates of the set of coordinates of object features of the set of 3-dimensional object data comprise virtual corners where virtual corners are regions of high local curvature in the directions of one or more axes of the axis system.

The data points of the snapshot 3-dimensional mesh data points may have their coordinates set to an arbitrary coordinate value and their one or more light intensity values to an arbitrary one or more light intensity values if, in the X Y space, their coordinates lie outside of the triangle formed by the set of coordinates of object features of the set of transformed 3-dimensional object data pertaining to the transformed apexes of the object triangle.

Brief Description of Drawings

Fig 1. shows a cubic object residing the a 3-dimensional space and viewed from two viewpoints,

Fig 2. shows a flow diagram of the data generation method according to the present invention,

Fig 3. shows an image produced from one of the viewpoints in Fig. 2

Fig 4. shows the data points produced from the image in Fig. 3

Fig 5. shows an RGB map of the image in Fig. 3,

Fig 6. shows a luminosity map based on the RGB map in Fig. 5,

Fig 7. shows a luminosity contrast map based on the luminosity map in Fig. 6,

Fig 8. shows a depth map based on the image in Fig. 3 and other depth data,

Fig 9. shows a depth contrast map based on the depth map in Fig. 8,

Fig 10. shows a depth gradient map based on the depth map in Fig. 8,

Fig 11. shows a depth gradient contrast map based on the depth gradient map in Fig. 10 and the depth contrast map in Fig 9, Fig 12. shows a luminosity contrast map in Fig. 7 minus the depth contrast map in Fig. 9,

Fig 13. shows a combination of the corners based on the luminosity contrast map minus the depth contrast map in Fig 12. and the corners based on the luminosity contrast map in Fig 7.

Fig 14. shows the corners map in Fig. 13, also with relevant object triangles,

Fig 15. shows the start of the axis transformation method with the object triangle in the original coordinates system,

Fig 16. shows step A of the axis transformation method in which a third new axis (Z') is aligned perpendicular to the plane of the object triangle,

Fig 17. shows step B of the axis transformation method in which the third new axis (Z') is positioned such that it passes through the mid-point between the two apexes at the extremities of the side,

Fig 18. shows step C of the axis transformation method in which a first new axis (X') is aligned parallel to the side, and a second new axis (Y') is directed through the mid point in the direction of the third apex of the triangle,

Fig 19. shows step D of the axis transformation method in which the coordinates (x, y, z) of the 3-dimensional object data are transformed into transformed coordinates (x', y', z') in the new axis system,

Fig 20. interpolated 3-dimensional Mesh with Data Points shown

Fig 21. shows an interpolated 3-dimensional mesh with light intensity values of the mesh surface polygons,

Fig 22. shows the interpolated 3-dimensional mesh in Fig. 20 with object triangles included,

Fig 23. shows a snapshot of the interpolated 3-dimensional mesh in Fig. 20, and

Fig 24. shows the a method of calculating the distance of viewable points using a parallax technique.

Best Mode for Carrying out the Invention

Referring to Fig. 1, the data generating method according to the present invention will be described based, for simplicity, on a single cubic object 1 residing in a single scene 2 in a 3-dimensional cartesian space defined by an X, Y, Z axis system passing through an origin 3. Fig. 1 also shows two alternative viewpoints 4 and 5 of object 1, each with respective viewpoint positions 6 and 7 and respective viewpoint orientations 8 and 9 in the space. It will be recognised by those skilled in the art of object recognition that the same method could also be used to generate data pertinent to an object where multiple objects reside in one or more scenes.

Referring to the flow diagram in Fig. 2, it can be seen that the method described can therefore be “looped through” for more than one scene, for more than one viewpoint and for more than one object. For example, it might be necessary in a particular application for a vision system of an industrial robot to be able to recognise a set of three objects, say objects O1, O2 and O3 in relatively complex scenes in which one or more of the objects O1, O2 and O3 are resident. The vision system could, for example, be trained by arranging the vision system to successively view O1 in a first scene from a number of viewpoint positions and orientations in that scene, then view O2 in a second scene also from a number of viewpoint positions and orientations, and then view O3 in the third scene also from a number of viewpoint positions and orientations. The transformed 3-dimensional object data generated for each object according to the present invention would then constitute “training data”.

After this training process, the capability of the object recognition system of the industrial robot could be measured by arranging the (or another) vision system to view a scene comprising one or more of the objects O1, O2 and O3, plus also potentially previous “untrained” objects introduced in an attempt to contaminate the scene. The method according to the present invention allows the segmentation of the transformed 3-dimensional object data pertinent to a particular object (say O2) and this “testing data” to be compared to the “training data” for that object (O2), in order to quantifiably measure the “recognition level’ of that object.

However, for reason described above, the method will herein be described by passing through the data generation procedure once, based on a single object 1 residing in a single scene 2 and viewed from a single viewpoint 4. For clarity, repeatable procedures will be identified in the description by the designation “Perform the following procedure x” and “end of procedure x”.

Perform the following procedure 1 for each scene.

Procedure 1 comprises of 4 steps.

<u>Step 1:</u>

Set up a digital camera (or other digital imaging system) at an arbitrary original viewpoint 4, with viewpoint position 6 and viewpoint orientation 8 in space, to image the scene 2, with known optics parameters, for example view width angle 10 and view height angle 11. Also set a set 2-dimensional pixel resolution for the camera.

Perform the following procedure 1.1 for each viewpoint.

Each new viewpoint during each pass through this loop must be at a known relative position and orientation from the original viewpoint. This loop firstly involves generation of a 2-dimensional image 12 of object 1 shown in Fig. 3, comprising an array of pixels, each pixel 14 (for example) corresponding to a viewable point 13 (for example) in scene 2. Viewable points are shown here in Fig. 3 as all being positioned on the surface of object 1. However, in the general sense, viewable points can also be located somewhere else in scene 2, not on object 1. In this embodiment each pixel has associated with it Red-Green-Blue (RBG) light intensity values, however other well known colour or monochrome light intensity value parameter sets could also be employed.

A distance 15 of each viewable point 13 from viewpoint 4 is now calculated using a parallax technique. This is facilitated by creating at least two 2-dimensional images from two different sub-viewpoints, each sub-viewpoint itself of known position and orientation and, by implication, separated by a known separation 16. Then, either sequentially or using different cameras, distance 15 can be calculated by techniques well known in the art, using the parallax offset between the differential positions of the corresponding viewable point 13 in the resulting pixels arrays 12.

Now referring in more detail to one particular embodiment of this technique in Figs. 24(a) - 24(d), the calculation of distance 15 involves creation of a contrast map (refer to Fig. 24(a)), and then performing sub-pixel edge detection on this contrast map (refer to Fig. 24(b)). This is repeated for a number of pixel value offset positions, adjusting the position, in the direction of the sub-viewpoint separation 16, of pixel values in one sub-image (refer to Fig. 24(c)), testing the sub-image of both sub-viewpoints, and measuring how similar they (refer to Fig. 24(d)). Upon locating the most similar sub-image, distance 15 between viewable point 13 of the surface of object 1 and viewpoint 4 can be calculated based upon their separation pixel value offset in the sub-image.

A depth map as shown in Fig. 8 can now be generated based on the distances calculated for all the viewable points 13 as visible from viewpoint 4.

The coordinates (x, y, z) in space 2 of each viewable point 13 can now be calculated based on the location of the corresponding pixel 14 in the array, its corresponding distance 15, viewpoint position 6 and viewpoint orientation 8 in space 2, and the viewing properties of viewpoint 4 such as the view width angle 10 and the view height angle 11. Data points 17 are generated for object 1 based on the “view” from viewpoint 4 as shown in Fig. 4.

Based on the light intensity values (RBG values in this case) and corresponding coordinates of each pixel 14 in image 12, a set of “object features” can be now identified. In the embodiment described herein in respect to the present invention one type of object feature, specifically “corners” of the object or regions of high curvature on object 1, are derived as follows.

Using the RGB map shown in Fig. 5 (the light intensity RGB values of every pixel in image 12), a corresponding luminosity map shown in Fig. 6 is generated, in which each luminosity map pixel value is equal to the red plus green plus blue component values of the corresponding RGB map pixel.

Using the luminosity map, a luminosity contrast map shown in Fig. 7 is generated, in which each pixel value is equal to a function of the difference in luminosity between neighbouring pixels.

Also, using the depth map already described in reference to Fig. 8 (the distance values of every pixel in image 12), a depth contrast map is generated shown in Fig. 9, in which each pixel value is equal to a function of the difference in depth between neighbouring pixels.

Also using the depth map, a depth gradient map is generated shown in Fig. 10, in which each pixel value has a vector associated with it which is equal to the change in depth between neighbouring pixels.

Using this depth gradient map, a depth gradient contrast map is generated shown in Fig. 11, in which each pixel value is equal to a function of the difference in depth gradient (in all directions) between neighbouring pixels.

The luminosity contrast map, or the depth contrast map, or the depth gradient contrast map, or a function of these maps, are then used to form a boolean threshold outline map indicating object external edges and internal edges, and isolate those pixels and their associated coordinates belonging to the object using the boolean threshold outline map. For every object isolated, a unique object index is assigned. It should be noted that if procedure 1.1 is executed for more than one viewpoint, the indices of the objects isolated with the indices of the objects isolated for previous viewpoints are mapped based upon the coordinates of the viewable points in the current image and the coordinates of the viewable points in previous images and their corresponding object indices. Fig 12. shows a new map generated based on the luminosity contrast map (Fig. 7) minus the depth contrast map (Fig. 9).

Those pixels are now determined which (a) pass the boolean threshold (have a value of '1' in the boolean threshold outline map) and are therefore pixels which reside on the outline of the object in the image and (b) when their corresponding 3-dimensional coordinates are dot-producted with particular unit vector combinations, give a maximum of the dot-product, as compared to all other pixels for any given unit vector combination. The following unit vector combinations can be used for this pixel filtering process, or a subset of these unit vector combinations: (x, y, z) = (0, 0, 0), (-1, 0, 0), (1, 0, 0), (0, 0, 1), (-1, 0, 1), (1, 0, 1), (0, 1, 0), (-1, 1, 0), (1, 1, 0), (0,-1, 0), (-1,-1, 0), (1,-1, 0), (0, 0,-1), (-1, 0,-1), (1, 0,-1), (0,-1,-1), (-1,-1,-1), (1,-1,-1), (0, 1, 1), (-1, 1, 1), (1, 1, 1), (0, 1,-1), (-1, 1,-1), (1, 1,-1), (0,-1, 1), (-1,-1, 1), and (1,-1, 1). The coordinates corresponding to these pixels are designated as the coordinates of virtual corners 18 of object 1 for the particular viewpoint 4 and shown in the corner map in Fig. 13. This corner map is in fact a concatenation of the corners based on the luminosity contrast map minus the depth contrast map in Fig 12. and the corners based on the luminosity contrast map in Fig 7.

For each of the object isolated from the viewpoints, a set of “3-dimensional object data” is created. For every object isolated from this viewpoint, add to the relevant set of 3-dimensional object data (a) a set of coordinates (x, y, z) of object features, virtual corners 18 in this case, and (b) a set of data points where each data point contains the 3-dimensional coordinates (x, y, z) of the respective viewable point 13 in image 12 pertaining to object 1 when viewed from viewpoint 4, and it's associated light intensity values, three RGB values in this case.

End of procedure 1.1.

Step 2:

Referring to Fig. 14, for each of the objects permutations of the coordinates of virtual corners 18 of the set of 3-dimensional object data pertaining to object 1 are now grouped as apexes of object triangles, for example the three apexes 19, 20 and 21 of object triangle 22 bounded by three sides 23, 24 and 25. The triangles, twelve in the case of Fig. 14, are differently 3-dimensionally orientated in space 2. The specific orientation of plane 26 which is coplanar with object triangle 22 is fully defined by the coordinates of the three respective apexes 19, 20 and 21.

Step 3:

For each of the one or more of the sides 23, 24 and 25 of each of the object triangles 22 of each of the objects 1 for each of the viewpoints, a unique transformation index assigned, and the following transformation procedure is followed.

Referring to the sequence shown in Fig 15., 16, 17 and 18, the origin 3 is now shifted to a new origin position 27 and reorientated to a new axis orientation 28 such that, in the new X', Y', Z' axis system, a third new axis (Z’) is aligned perpendicular to the plane of object triangle (Fig. 16), this third new axis (Z’) passes through a mid-point 29 between the apexes 19 and 21 at the extremities of side 25 (Fig. 17), a first new axis (X’) of the new axis system is aligned parallel to side 25, and a second new axis (Y') of the new axis system is directed through mid-point 28 in the direction 35 of the third apex 20 of the triangle (Fig. 18).

The coordinates (x, y, z) of data points of the set of 3-dimensional object data and the coordinates of the object triangle apexes (coordinates of object features of the set of 3-dimensional object data pertaining to the apexes of the object triangle) are therefore appropriately transformed into new coordinates (x', y', z') in the new X', Y', Z' axis system, hence forming a set of transformed 3-dimensional object data as shown in Fig. 19.

Step 4:

Referring to Figs. 20 and 21, for each of the new axis transformations, an interpolated 3-dimensional surface mesh 30 is formed defined by mesh points 31, the coordinates of each mesh point 31 corresponding to a coordinate of a data point from the set of transformed 3-dimensional object data associated with the object and that particular axis transformation (31), or an interpolation of one or more of the coordinates of the data points (31B). Each polygon 32 of the surface mesh 30 formed by proximate mesh points 31 and 31B have associated with it the light intensity values (henceforth referred to as "RGB values" in this embodiment) derived as a function of the RGB values associated with nearby data points.

Referring to Figs. 22 and 23, for each of the new axis transformations, a set of snapshot mesh data points 33 are generated, where the snapshot 3-dimensional mesh surface data points 33 are calculated as the coordinates (or array positions) and RGB values of pixels in the 2-dimensional image generated when, in computer graphics, a virtual mesh viewpoint is aligned to the Z' axis, with the mesh viewpoint positioned at the respective new origin position 27, each pixel corresponding to a mesh viewable point on the 3-dimensional mesh surface 34 and having RGB values derived as a function of the RGB values of data points proximate to the mesh viewable point, and a coordinate derived as a function of the coordinates of the data points proximate to the mesh viewable point 31. A viewable mesh depth map (a 2-dimensional array of Z' values of each of the mesh viewable points 31), and a viewable mesh RGB map (a 2-dimensional array of RGB values of each of the mesh viewable points) are then generated. It may be noted that when a neural network comparison algorithm is used (see below) and the data currently being generated is training data, multiple sets of snapshot mesh data points may be generated for every new axis transformation, each with slight positional or orientation variations, to improve the performance of the neural network.

For each of the new axis transformations, the viewable mesh RGB map(s), the viewable mesh depth map(s), the transformed coordinates of the object triangle apexes (those coordinates of the coordinates of object features of the set of transformed 3-dimensional object data pertaining to the apexes of the object triangle), the object index, and the transformation index, are recorded as data.

End of procedure 1.

As mentioned at the start of the description of this embodiment, the data recording method can be executed sequentially for multiple scenes, each with multiple objects and viewpoints. Training data can be initially recorded and this training data later compared with test data, also recorded using the method, using algorithms to match (recognise) the object in the test data with objects from the training data.

In this embodiment, this method of comparison of the training data with the test data is as follows.

For each of the one or more sides of each of the object triangles of the objects of the test data, for each of the one or more sides of each of the object triangles of each of the objects of the training data, the data pertaining to the side of the test data is compared with the data pertaining to the side of the training data. This is achieved by comparing the transformed coordinates of the object triangle apexes (those coordinates of the coordinates of object features of the set of transformed 3-dimensional object data pertaining to the apexes of the object triangle) of the test data and training data. The actual comparison is performed by comparing the distance each apex in the test data object triangle is away from the corresponding apex in the training data object triangle. For each of the one or more sides of each of the object triangles of the objects of the test data the maximum comparison accuracy value experienced across all training data sets is calculated, and the transformation indices of the training data where their maximum comparison accuracy is above a certain arbitrary value is recorded. This creates a subset of the test data called in this specification the “geometry matched test data” (GMTD), and for each transformation index of the geometry matched test data, the transformation indices of the object triangle side(s) of the training data that gave comparison accuracies above the certain arbitrary value, called in this specification the “geometry matched test data training data matches” (GMTDTDM) are also recorded.

Now light intensity recognition is performed on those testing data object triangle sides and their corresponding training object triangle sides which were found to have a high geometric comparison accuracy i.e. the GMTD and their corresponding GMTDTDM, by performing the following procedure.

As described below, a neural network (artificial intelligence) algorithm is used to train a neural network with the training data. Note that the neural network requires input values and class target values for training and testing respectively. In this embodiment the input values are the values of a viewable mesh RGB map and/or the values of a colour saturation contrast map of the viewable mesh RGB map and/or the values of a viewable mesh depth map, and the class targets are a function of an object index or an object transformation index (for example the object index x 3 + the transformation index).

For each of the one or more sides of each of the object triangles of each of the objects of the training data, the neural network is trained with an experience, where the input values are the values of the viewable mesh RGB map(s) and/or the values of the colour saturation contrast map(s) of the viewable mesh RGB map(s) and/or the values of the viewable mesh depth map(s) from the training data, and the class target is the training class target value (for example the object index x 3 + the transformation index).

The neural network (artificial intelligence) algorithm can now be used to test the trained neural network against the testing data object(s), thereby determining whether or not the testing object(s) is/are recognised and which of the trained objects this testing data object(s) corresponds to.

For each of the one or more sides of each of the object triangles of the object of the GMTD, and for every possible training class target value, the testing data experience is tested against the trained neural network, where the input values are the values of the viewable mesh RGB map and/or the values of the colour saturation contrast map of the viewable mesh RGB map and/or the values of the viewable mesh depth map from the testing data, and the class target is the training class target value. The neural network error value is noted.

An object triangle side (and therefore an object) is recognised by verifying the neural network error is below an arbitrary value for any given test scenario, where a “pass” value indicates the testing data object (index) equates to the training data object (index).

It is also verified that the object triangle side (transformation index) recognised in the light intensity recognition phase was also recognised as the same object triangle side (transformation index) in the geometric recognition phase. The transformation indices of the object triangle sides of the GMTD and training data matched by use of the neural network in the light intensity recognition phase are compared with the transformation indices of GMTD and each of their GMTDTDM matched in the geometric recognition phase.

An object is recognised based upon a function of the number of object triangle sides associated with that object that were recognised.

The term “comprising” as used herein is used in the inclusive sense of “including” or “having” and not in the exclusive sense of “consisting only of”.

Claims

<u>Claim 1 (independent)</u>

A method for generating data for one or more objects residing in one or more scenes in a 3-dimensional cartesian space defined by an (X, Y, Z) axis system passing through an origin, comprising the steps of:

1. for each of the objects, deriving a set of 3-dimensional object data comprising coordinates, one or more of the coordinates corresponding to coordinates of object features;
2. for each of the objects, grouping permutations of the coordinates of object features of the set of 3-dimensional object data as the coordinates of apexes of one or more object triangles orientated in the space, each object triangle comprising three sides and three apexes and defining a plane;
3. for each of one or more of the sides of each of the object triangles of each of the objects, shifting the position of the origin to a new origin position and reorientating the axis system to a new axis orientation such that, in a new (X', Y', Z') axis system defined by a first new axis (X’), a second new axis (Y’), and a third new axis (Z’), the new axis orientation and new origin position are a function of the coordinates of the apexes of the object triangle, transforming one or more of the coordinates (x, y, z) of the set of 3-dimensional object data into transformed coordinates (x', y', z') in the new axis system and forming a set of transformed 3-dimensional object data; and
4. for each of the one or more sides of each of the object triangles of each of the objects, generating data relating to the set of transformed 3-dimensional object data.

<u>Claim 2</u>

A method as claimed in Claim 1, wherein the set of 3-dimensional object data comprises a set of data points pertaining to the object, wherein each data point comprises coordinates and an associated one or more light intensity values, and one or more of the coordinates of the set of 3-dimensional object data are the coordinates of these data points.

<u>Claim 3</u>

A method as claimed in step 3 of Claim 1 wherein the set of transformed 3-dimensional object data comprises either a set of data points with transformed coordinates, or a set of coordinates of object features with transformed coordinates or, or both, wherein each data point comprises one or more transformed coordinates and an associated one or more light intensity values.

Claim 4

A method as claimed in step 3 of Claim 1, wherein the new axis orientation is a function of the 3-dimensional orientation of the side and the 3-dimensional orientation of the plane, and the new origin position is a function of the coordinates of one or more of the apexes.

Claim 5

A method as claimed in Step 3 of Claim 1, wherein a further new axis system (X'', Y'', Z'') is positioned and aligned such that a third further new axis (Z'') of the further new axis system is aligned perpendicular to the plane of the object triangle, and passing through the mid point between the two apexes at the extremities of the side, a first further new axis (X'') of the further new axis system is aligned parallel to the side, and a second further new axis (Y'') of the further new axis system is directed through the mid point in the direction of the third apex of the triangle, and the position and orientation of the first, second and third new axes of the new axis system are equivalent to a function of the position and orientation of the first, second and third further new axes of the further new axis system.

Claim 6

A method as claimed in Step 3 of Claim 1, wherein the third new axis (Z') is aligned perpendicular to the plane of the object triangle, and passing through the mid point between the two apexes at the extremities of the side, the first new axis (X') is parallel to the side, and the second new axis (Y') axis is directed through the mid point in the direction of the third apex of the triangle.

Claim 7

A method as claimed in Claim 1 wherein one or more coordinates of the set of coordinates of object features of the set of 3-dimensional object data comprise-virtual texture corners where virtual texture corners are regions of high local curvature of light intensity on the surface of the object.

Claim 8

A method as claimed in step 3 of Claim 1, wherein at least one of the one or more of the coordinates of the set of 3-dimensional object data comprise the coordinates of object features pertaining to the apexes of the object triangle.

Claim 9

A method as claimed in Claim 1 wherein a unique object index is assigned for each of the objects.

Claim 10

A method as claimed in Claim 1 wherein a unique transformation index is assigned for each of the sides of each of the object triangles of each of the objects.

Claim 11

A method as claimed in Claim 9 wherein the data generated also includes data relating to the object index.

Claim 12

A method as claimed in Claim 10 wherein the data generated also includes data relating to the transformation index.

Claim 13

A method as claimed in Claim 1 wherein the data generated also includes data relating to the new origin and the new axis orientation.

Claim 14

A method as claimed in Claim 1, wherein the data relating to the set of transformed 3-dimensional object data comprises the set of coordinates of object features of the set of transformed 3-dimensional object data.

Claim 15

A method as claimed in Claim 2 wherein the set of data points of a set of 3-dimensional object data is used to form an interpolated or non-interpolated 3-dimensional mesh defined by mesh points, the coordinates of each mesh point corresponding to a coordinate or an interpolation of one or more of the coordinates of the data points, and each polygon of the surface mesh formed by proximate mesh points having associated with it one or more light intensity values derived as a function of the one or more light intensity values associated with nearby data points.

Claim 16

A method as claimed in Claim 2wherein one or more coordinates of the set of coordinates of object features of the set of 3-dimensional object data comprise virtual texture corners where virtual texture corners are regions of high local curvature of light intensity on the surface of the object.

Claim 17

A method as claimed in Claim 16 wherein virtual texture corners are a function of the one or more light intensity values and the coordinates of the data points of the 3-dimensional object data.

Claim 18

A method as claimed in Claim 2 wherein the one or more coordinates associated with the object are located on the surface of the object.

Claim 19

A method as claimed in Claim 2 wherein the one or more light intensity values associated with the one or more coordinates associated with the object correspond to the one or more light intensity values measured as coming from these coordinates.

Claim 20

A method as claimed in Claim 2 wherein one or more coordinates of the set of coordinates of object features of the set of 3-dimensional object data comprise virtual corners where virtual corners are regions of high local curvature in the directions of one or more axes of the axis system.

Claim 21

A method as claimed in Claim 20 wherein virtual corners are a function of the coordinates of the data points of the 3-dimensional object data.

Claim 22

A method as claimed in Claim 2, wherein for each of the objects, data is also generated containing one or more data points of the set of 3-dimensional object data or a functional transform of one or more data points of the set of 3-dimensional object data.

Claim 23

A method as claimed in Claim 2, wherein one or more sets of 3-dimensional object data are derived by 3-dimensionally imaging the one or more scenes from one or more viewpoints of defined relative positions and orientations in the space and, for each of the viewpoints, a 2-dimensional image of the one or more objects is generated, each image comprising an array of pixels, each pixel corresponding to a viewable point in the scene at a distance from the viewpoint, the viewable point being characterised by one or more light intensity values and a coordinate (x, y, z) in space, and, either during the calculating of the coordinates for each viewpoint or after the calculating of the coordinates for all viewpoints, determining the set of data points of the set of 3-dimensional object data for each of the objects and, either during the calculating of the coordinates for each viewpoint or after the calculating of the coordinates for all viewpoints, deriving the set of coordinates of object features of the set of 3-dimensional object data for each of the objects.

Claim 24

A method as claimed in Claim 23, wherein the coordinate (x, y, z) of each viewable point in space is based on the location of the pixel in the array, the distance between the viewable point and the viewpoint, and the position, orientation, and viewing properties of the viewpoint.

Claim 25

A method as claimed in Claim 24 wherein the positions and orientations of at least one of the one or more viewpoints are calculated based on a functional transformation of the coordinates of the data points of one or more sets of 3-dimensional object data or of the positions and orientations of one or more viewpoints, or the viewing properties of one or more viewpoints.

Claim 26

A method as claimed in Claim 23 and Claim 49, wherein the viewable point resides on one or more of the objects.

Claim 27

A method as claimed in Claim 23 and Claim 49, wherein the position and orientation of one viewpoint is set to an absolute position and orientation in the space, thereby determining both the position of the origin and the orientation of the axis system and the absolute positions and orientations of all viewpoints.

Claim 28

A method as claimed in Claim 23 and Claim 49, wherein the set of data points of the set of 3-dimensional object data pertaining to each of the objects is isolated by determining boundaries between the one or more objects based on a boolean depth (distance) contrast map derived by applying an arbitrary threshold to a depth contrast map of the image, or a boolean depth gradient contrast map derived by applying an arbitrary threshold to a depth gradient contrast map of the image, or a boolean luminosity (light intensity) contrast map derived by applying an arbitrary threshold to a luminosity contrast map of the image, or any function or linear or nonlinear combination of these maps.

Claim 29

A method as claimed in Claim 23 and Claim 49, wherein the virtual corners (object features) of each of the objects are derived, for each viewpoint, by firstly creating a boolean threshold outline map then, secondly, based on the light intensities and corresponding 3-dimensional coordinates of each pixel in the array, deriving the pixels and their associated coordinates which (a) pass the threshold and are therefore pixels which reside on an outline of the object in the image and (b) when their corresponding 3-dimensional coordinates are dot-producted with particular unit vector combinations, give a maximum of the dot-product as compared to all other coordinates for any given unit vector combination.

Claim 30

A method as claimed in Claim 29 where in the boolean threshold outline map is a boolean depth contrast map derived by applying a first arbitrary threshold to a depth contrast map, or a boolean depth gradient contrast map derived by applying a second arbitrary threshold to a depth gradient contrast map, or a boolean luminosity contrast map derived by applying a third arbitrary threshold to a luminosity contrast map, or any function or linear or nonlinear combination of these maps.

Claim 31

A method as claimed in Claim 23 and Claim 49, wherein the virtual corners (object features) are calculated by first deriving a depth gradient map from a depth map, and then deriving a depth gradient contrast map from the depth gradient map, hence deriving regions of high local curvature in the directions of one or more axes of the axis system.

Claim 32

A method as claimed in Claim 23 and Claim 49 wherein, for each viewpoint, the imaging comprises creating at least two 2-dimensional images from two different viewpoints, either sequentially or using at least two cameras, and a parallax offset between the positions in the resulting pixels arrays of the corresponding viewable points, and/or the difference between their corresponding one or more light intensity values is used to calculate the distance.

Claim 33

A method as claimed in Claim 23 wherein the coordinates of object features are calculated based on the one or more light intensity values of the pixel array, or the distances associated with each pixel in the array, or the one or more light intensity values of the data points of the set of 3-dimensional object data or the coordinates (x, y, z) of the data points of the set of 3-dimensional object data, or a function of these.

Claim 34

A method as claimed in Claim 24 and Claim 51, wherein the viewing properties of the viewpoint comprise a view width angle and a view height angle.

Claim 35

A method as claimed in Claim 2 and Claim 3 where the light intensity values are quantitative values representing the intensity of one or more light frequencies or frequency bands or a function of these, for example RGB values.

Claim 36

A method as claimed in Claim 3 wherein the set of coordinates of object features of the set of transformed 3-dimensional object data comprises coordinates, pertaining to the transformed coordinates of the apexes of the object triangle.

Claim 37

A method as claimed in Claim 3, wherein the data relating to the set of transformed 3-dimensional object data comprises, the one or more light intensity values of the data points or a function of the light intensity values of the data points or the coordinates of the data points or any subset of the coordinates of the data points of the set of transformed 3-dimensional object data, or the one or more light intensity values of the data points or a function of the light intensity values of the data points or the coordinates of the data points generated by one or more functional transformations of the data points of the set of transformed 3-dimensional object data.

Claim 38

A method as claimed in Claim 3 wherein the set of data points of a set of transformed 3-dimensional object data is used to form an interpolated or non-interpolated 3-dimensional mesh defined by mesh points, the coordinates of each mesh point corresponding to a coordinate or an interpolation of one or more of the coordinates of the data points, and each polygon of the surface mesh formed by proximate mesh points having associated with it one or more light intensity values derived as a function of the one or more light intensity values associated with nearby data points.

Claim 39

A method as claimed in Claim 37 wherein the one or more functional transformations of the data points of the set of transformed 3-dimensional object data are based on a 3-dimensional mesh of the set of data points of the set of transformed 3-dimensional object data, wherein the data points resulting from the functional transformation are snapshot 3-dimensional mesh surface data points.

Claim 40

A method as claimed in Claim 39 wherein the snapshot 3-dimensional mesh surface data points are calculated as the coordinates or array positions and one or more light intensity values of data points in a 2-dimensional array of data points generated by interpolating the mesh surface at particular first new axis (X') and second new axis (Y') coordinate intervals, each data point corresponding to a point on or off of the 3-dimensional mesh surface and having one or more light intensity values derived as a function of the light intensity values of data points proximate to the point, and a coordinate derived as a function of the coordinates of the data points proximate to the point.

Claim 41

A method as claimed in Claim 39 wherein the snapshot 3-dimensional mesh surface data points are calculated as the coordinates or array positions and one or more light intensity values of pixels in the 2-dimensional image generated when a virtual mesh viewpoint is aligned to the third new axis (Z'), or aligned at a predetermined angular deviation from the third new axis (Z'), with the mesh viewpoint positioned at the new origin, or at a predetermined offset deviation from the new origin, each pixel corresponding to a mesh viewable point on or off of the 3-dimensional mesh surface and having one or more light intensity values derived as a function of the light intensity values of data points proximate to the mesh viewable point, and a coordinate derived as a function of the coordinates of the data points proximate to the mesh viewable point.

Claim 42

A method as claimed in Claim 3 wherein the data is generated for one scene and this data is generated as training data, and the data is also later generated for a different scene and this data is generated as test data, and the training data and test data is compared using an algorithm to recognise the one or more objects.

Claim 43

A method as claimed in Claim 3 wherein the data is generated for multiple scenes and this data is generated as training data, and the data is also later generated for a different scene and this data is generated as test data, and the training data and test data is compared using an algorithm to recognise the one or more objects.

Claim 44

A method as claimed in Claim 42 or Claim 43 wherein the algorithm comprises the comparison of the test data pertaining to one of the one or more sides of an object triangle with the training data pertaining to one of the one or more sides of the same or another object triangle.

Claim 45

A method as claimed in Claim 42 or Claim 43, wherein the algorithm is an artificial intelligence algorithm.

Claim 46

A method as claimed in Claim 45, wherein the artificial intelligence algorithm is a neural network algorithm, the method enabling the training of the neural network algorithm with the training data or a subset thereof such that, within a recognition phase, the trained neural network can be tested against the test data or a subset thereof, and thereby determining whether or not a test object is recognised and which of the trained objects this test data corresponds to.

Claim 47

A method as claimed in Claim 46 wherein the side of the object triangle side is recognised by verifying a neural network error for the neural network algorithm is below an arbitrary value, and an object is recognised based upon a function of the number of sides of the object triangles associated with that object that were recognised.

Claim 48

A method as claimed in Claim 46 wherein the neural network requires input values and class target values for training and testing respectively, and the input values are the set of coordinates of object features of the set of transformed object data, or a function of the light intensity values or the one or more light intensity values or the coordinates of the data points generated by one or more functional transformations of the set of data points of the set of transformed 3-dimensional object data, and the class targets are the object index or the object transformation index, or a function of these.

Claim 49

A method as claimed in Claim 1, wherein one or more sets of 3-dimensional object data are derived by 3-dimensionally imaging the scene from one or more viewpoints of defined relative positions and orientations in the space and, for each of the viewpoints, a 2-dimensional image of the one or more objects is generated, each image comprising an array of pixels, each pixel corresponding to a viewable point in the scene and being characterised by one or more light intensity values and a coordinate (x, y, z) in space, and, either during the calculating of the coordinates for each viewpoint or after the calculating of the coordinates for all viewpoints, deriving the set of coordinates of object features of the set of 3-dimensional object data for each of the objects.

Claim 50

A method as claimed in Claim 49 wherein the coordinates of object features are calculated based on the one or more light intensity values of the pixel array, or the distances associated with each pixel in the array, or a function of these.

Claim 51

A method as claimed in Claim 49, wherein the coordinate (x, y, z) of each viewable point in space is based on the location of the pixel in the array, the distance between the viewable point and the viewpoint, and the position, orientation, and viewing properties of the viewpoint.

Claim 52

A method as claimed in Claim 51 wherein the positions and orientations of at least one of the one or more viewpoints are calculated based on the positions and orientations of one or more viewpoints, or the viewing properties of one or more viewpoints.

Claim 53

A method as claimed in Claim 1 wherein one or more coordinates of the set of coordinates of object features of the set of 3-dimensional object data comprise virtual corners where virtual corners are regions of high local curvature in the directions of one or more axes of the axis system.

Claim 54

A method as claimed in Claim 41 and Claim 40 wherein data points of the snapshot 3-dimensional mesh data points have their coordinates set to an arbitrary coordinate value and their one or more light intensity values to an arbitrary one or more light intensity values if, in the X Y space, their coordinates lie outside of the triangle formed by the set of coordinates of object features of the set of transformed 3-dimensional object data pertaining to the transformed apexes of the object triangle.

Abstract

A method is described for generating data for one or more objects residing in one or more scenes in a 3-dimensional cartesian space defined by an axis system passing through an origin. The steps involve deriving a set of 3-dimensional object data comprising coordinates, one or more of the coordinates corresponding to coordinates of object features. Object triangles are then defined based on the apexes formed from permutations of the coordinates of object features. The axis system is then transformed based on the apexes of each object triangle, and thereby forming a set of transformed 3-dimensional object data. Data is then generated based on the set of transformed 3-dimensional object data for one or more side of each object triangle of each object. This method enables a similar object, with an arbitrary position and orientation, to be recognised by an observer at an arbitrary position and orientation.

Figures

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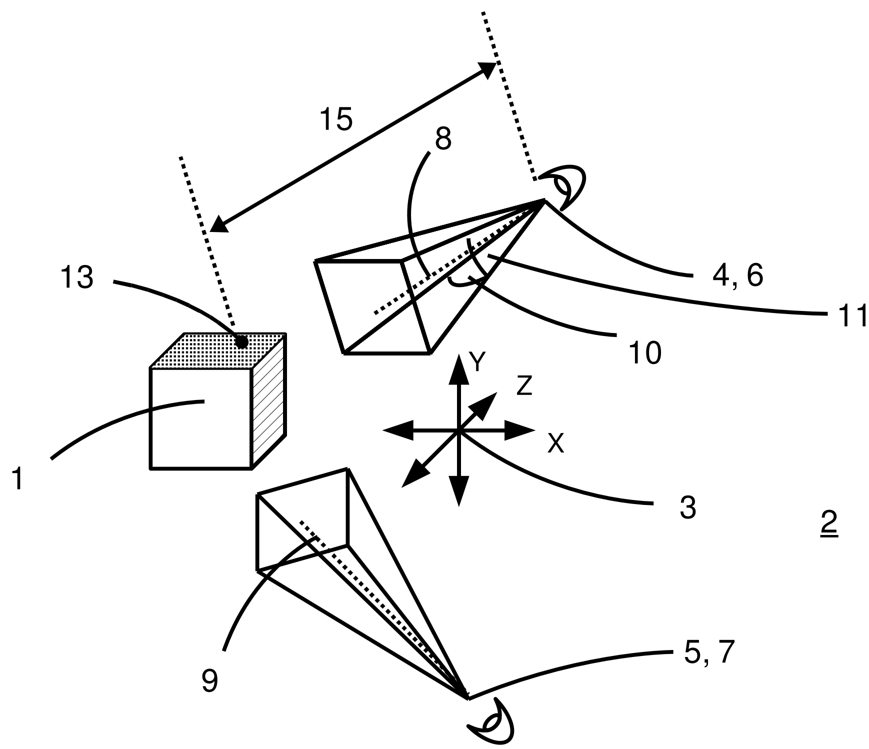

Fig 1.

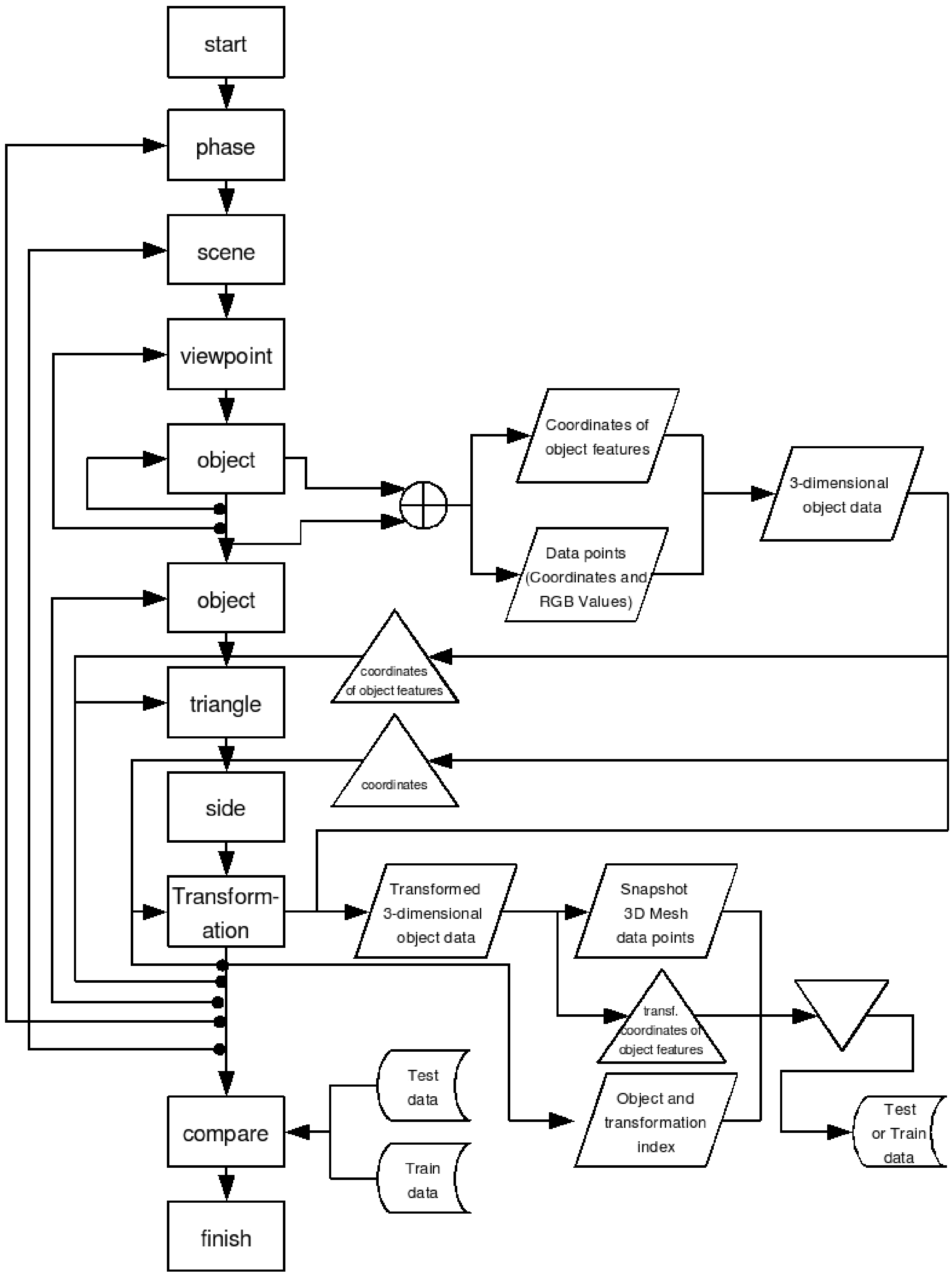
start
phase
scene
viewpoint
object
Coordinates of object features
3-dimensional object data
Data points (Coordinates and RGB Values)
object
coordinates of object features
triangle
coordinates
side
Transform-ation
Transformed 3-dimensional object data
Snapshot 3D Mesh data points
transf. coordinates of object features
Object and transformation index
Test or Train data
Test data
compare
Train data
finish

Fig 2.

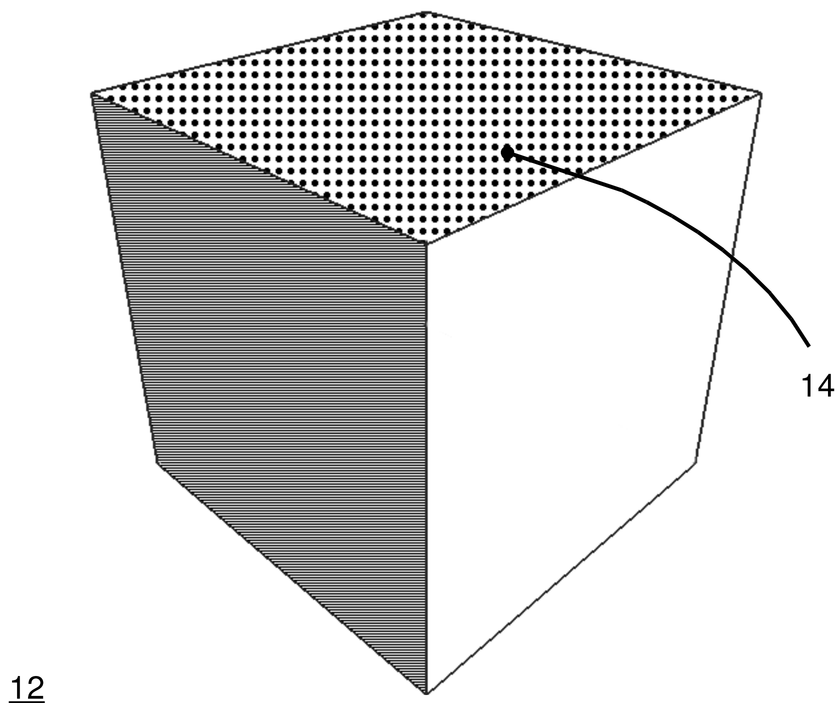

Fig 3.

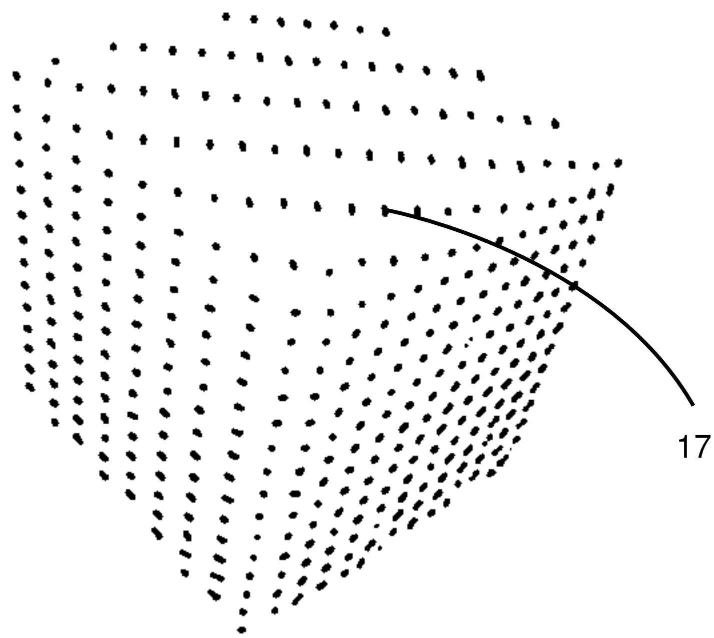

Fig 4.

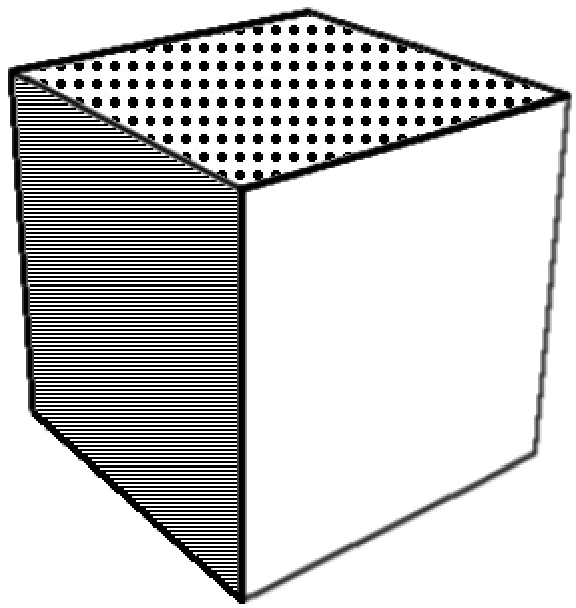

Fig 5.

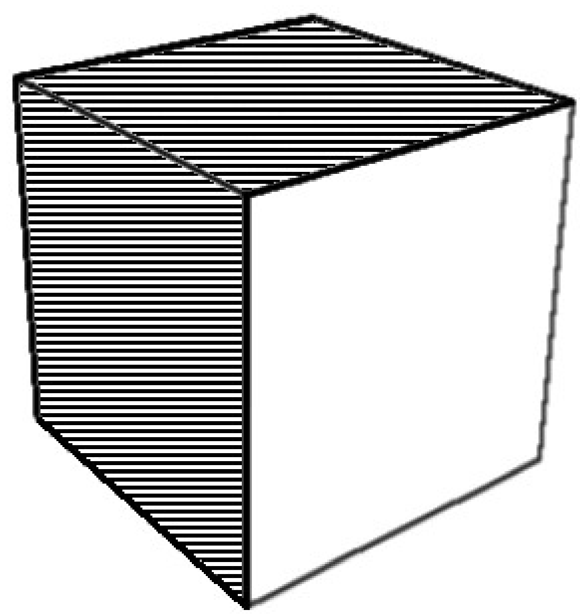

Fig 6.

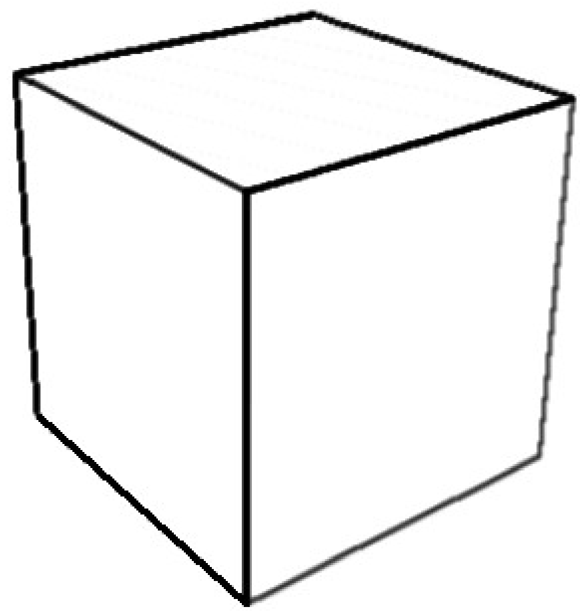

Fig 7.

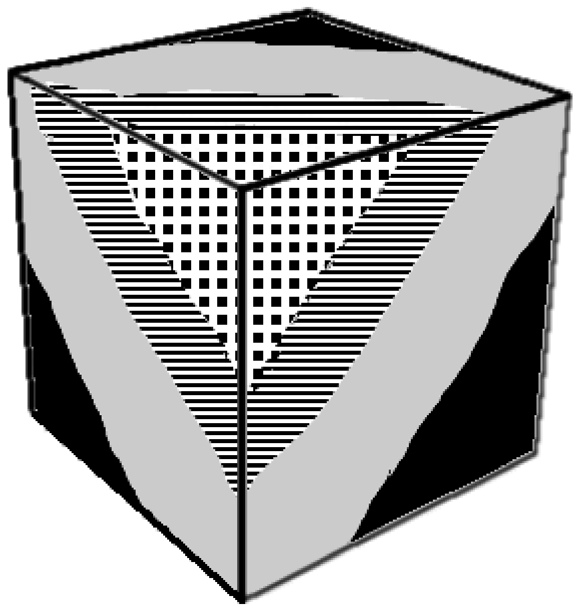

Fig 8.

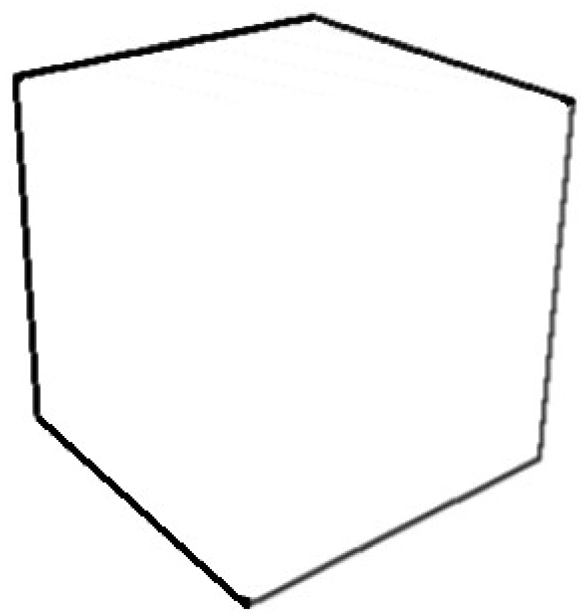

Fig 9.

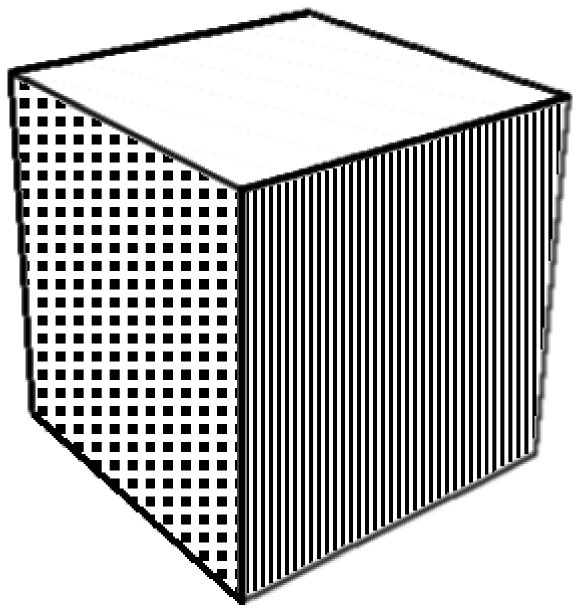

Fig 10.

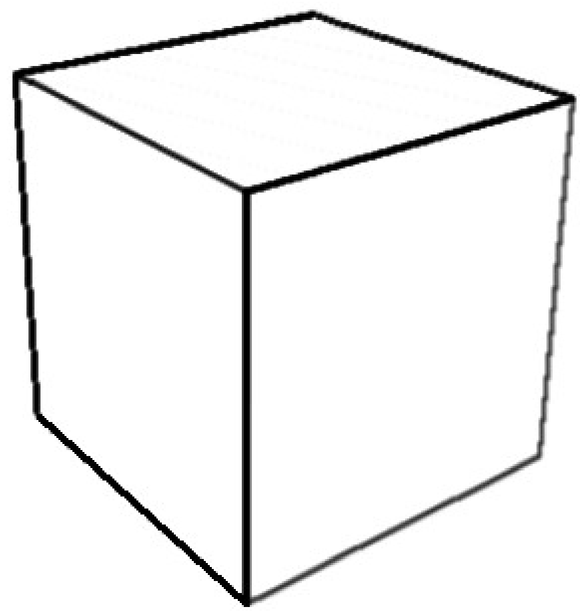

Fig 11.

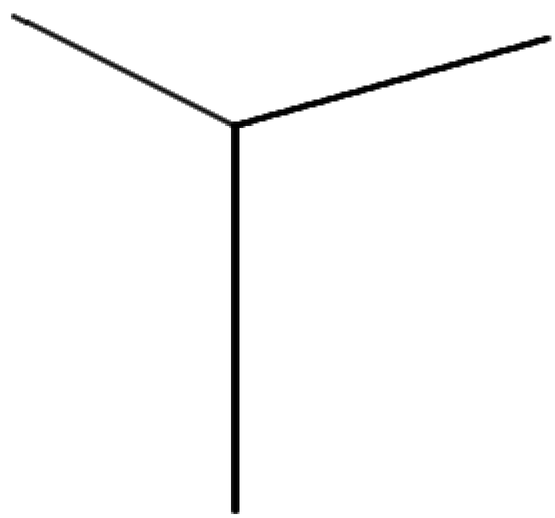

Fig 12.

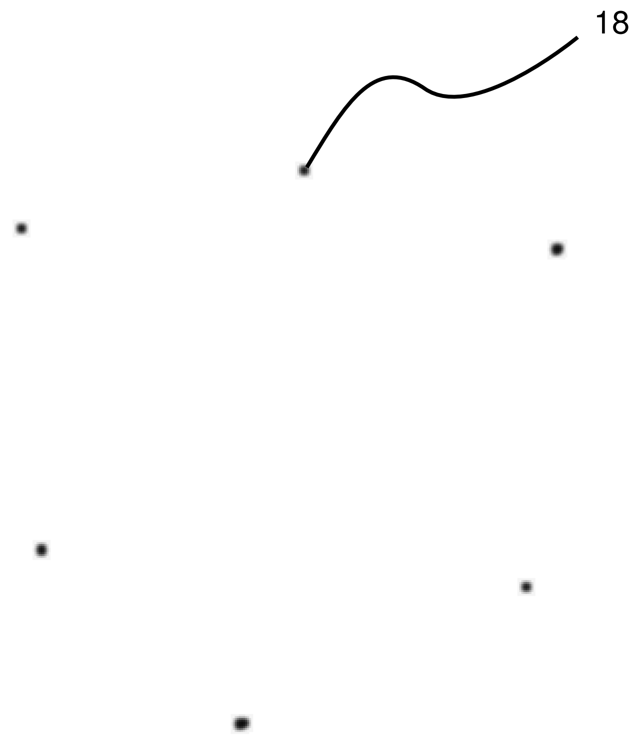

Fig 13.

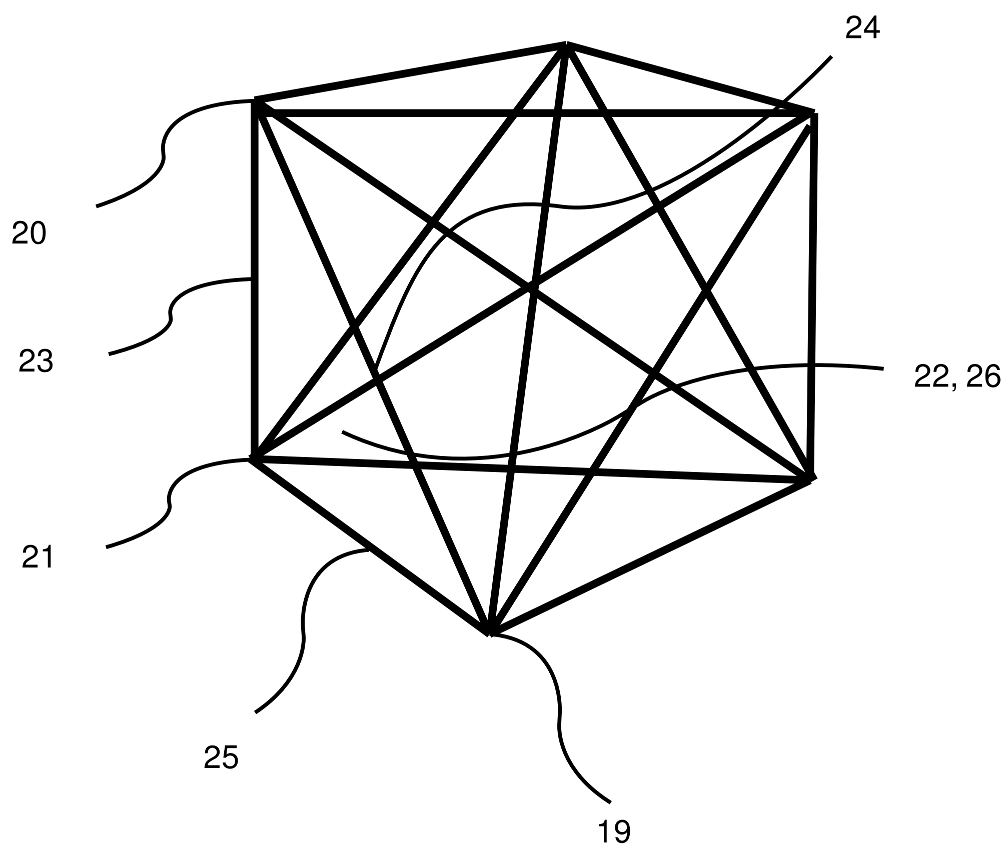

Fig 14.

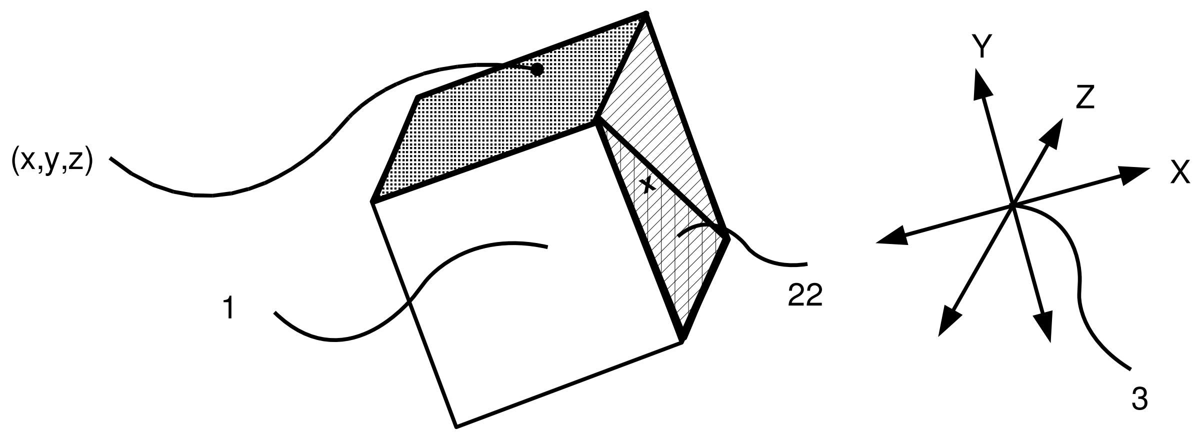

Fig 15.

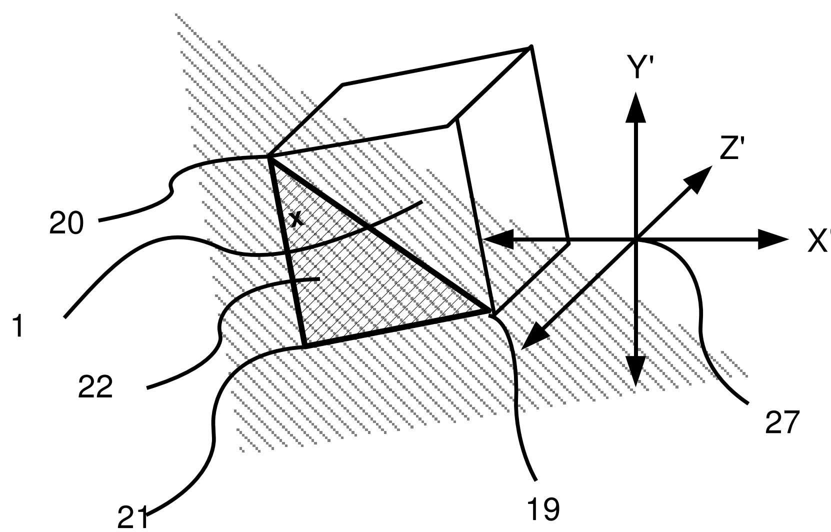

Fig 16.

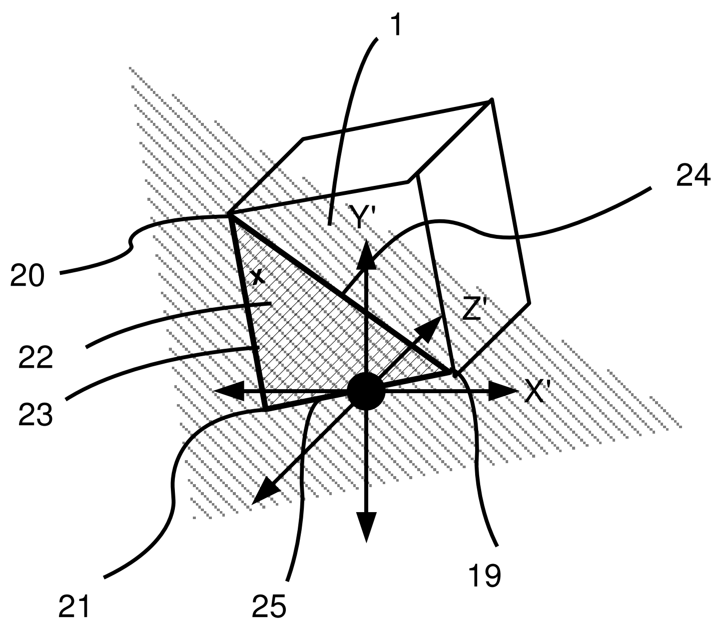

Fig 17.

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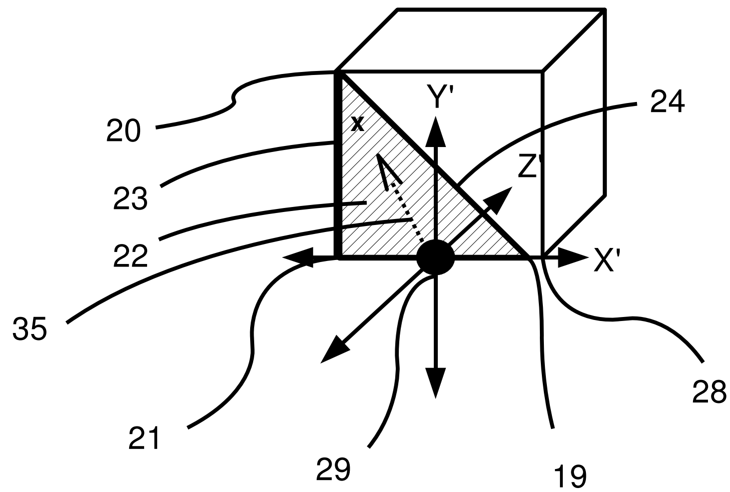

Fig 18.

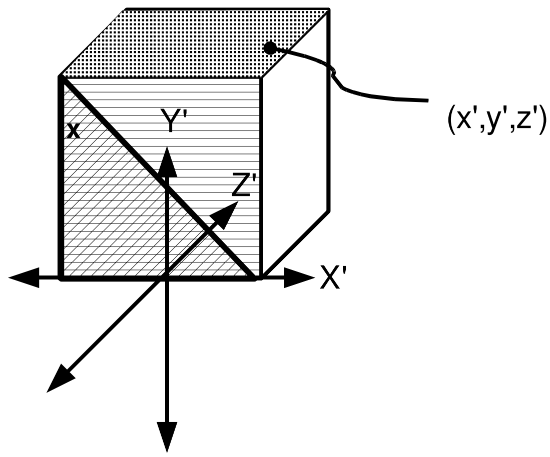

Fig 19.

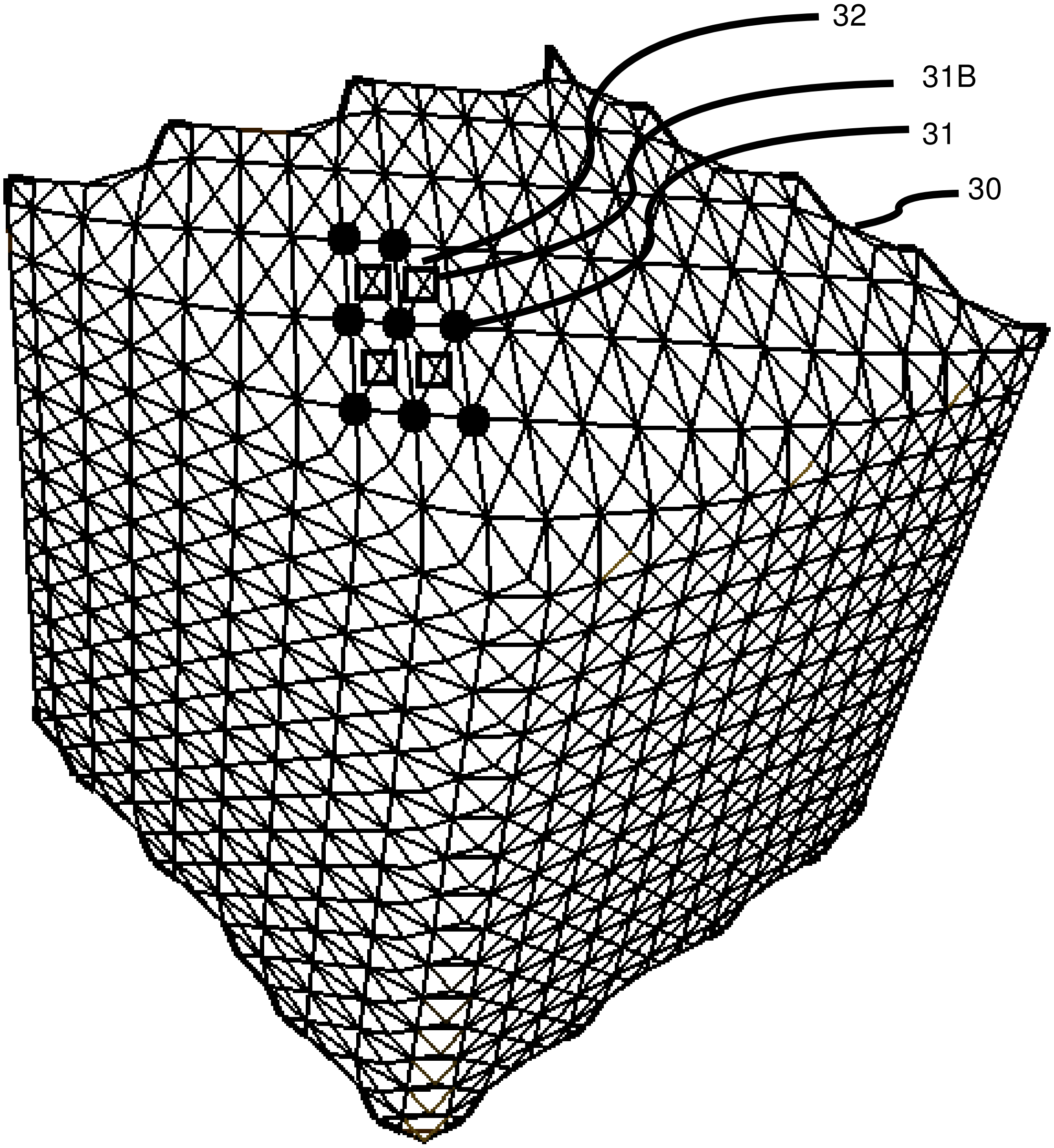

Fig 20.

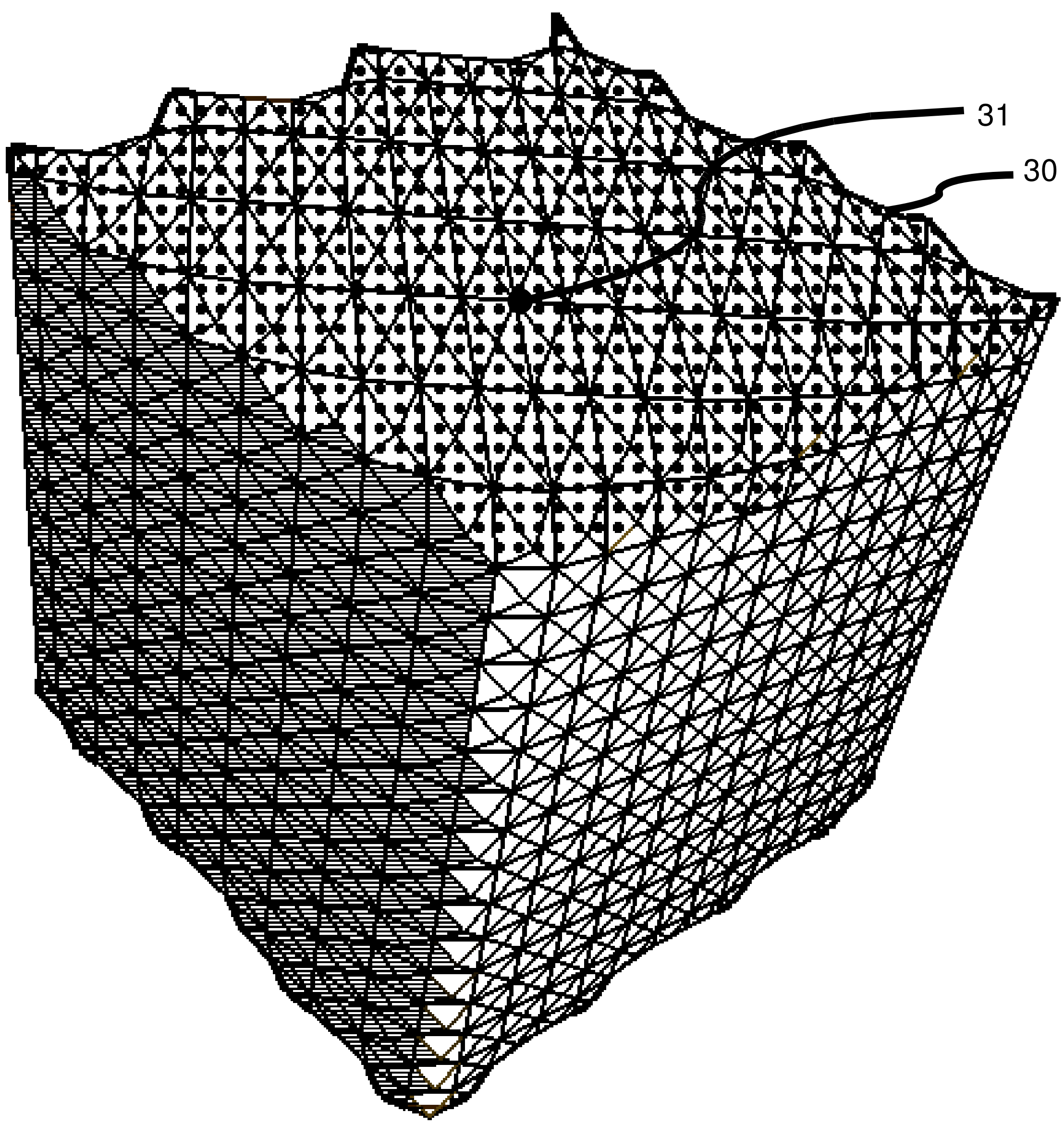

Fig 21.

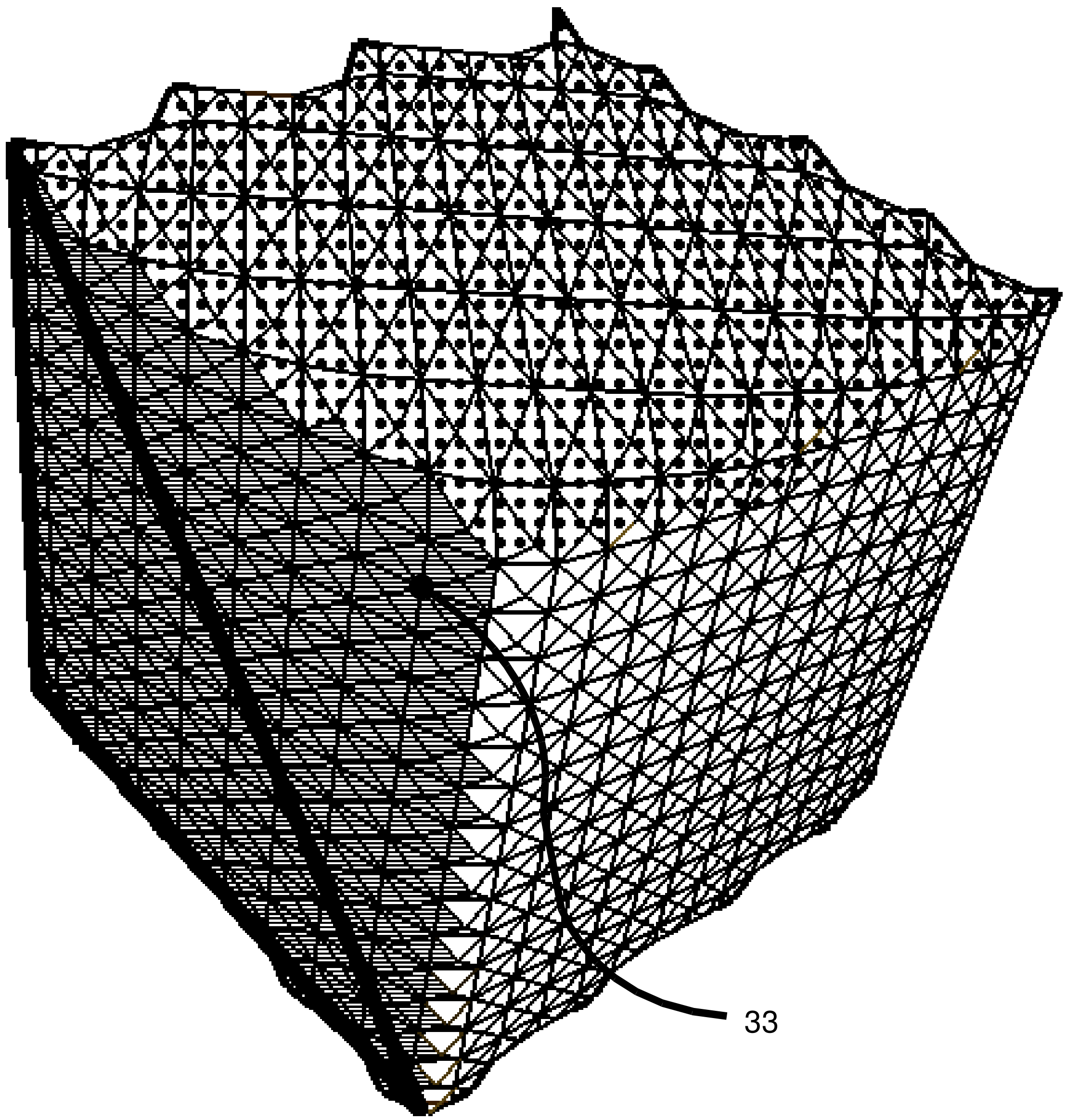

Fig 22.

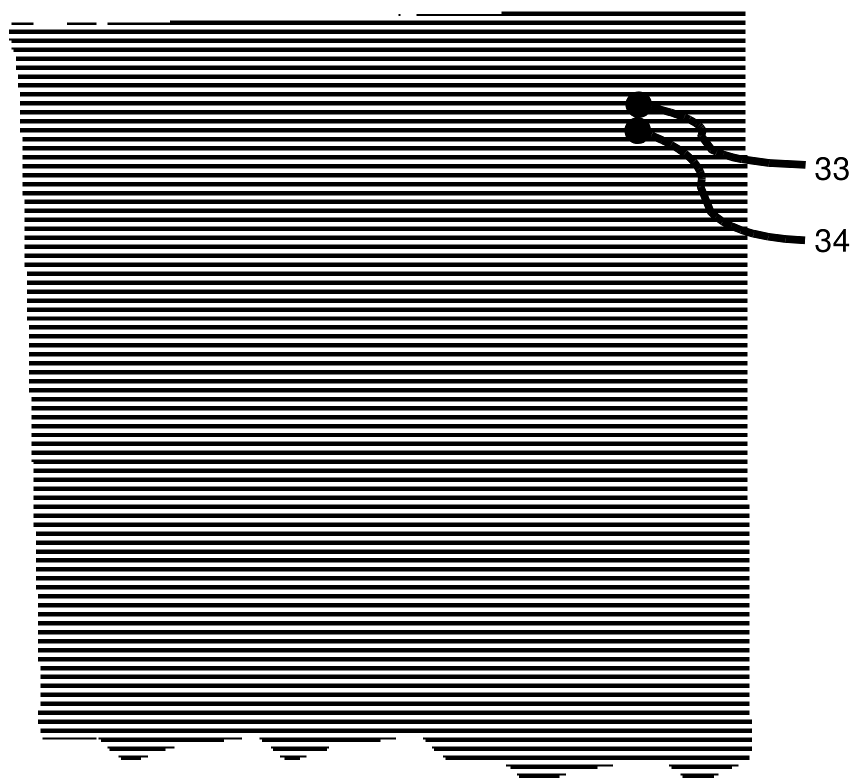

Fig 23.

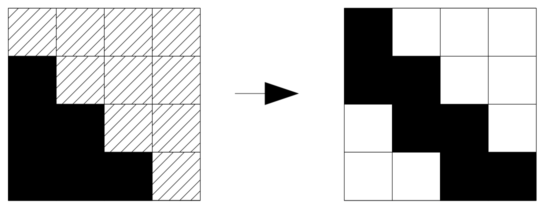

Fig. 24(a)

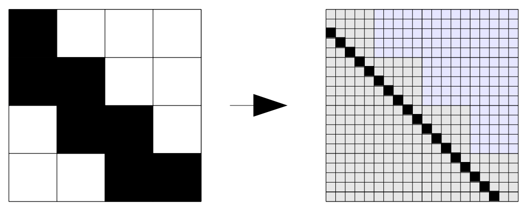

Fig. 24(b)

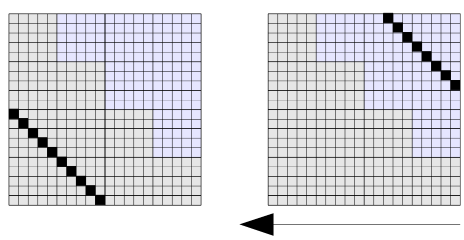

Fig. 24(c)

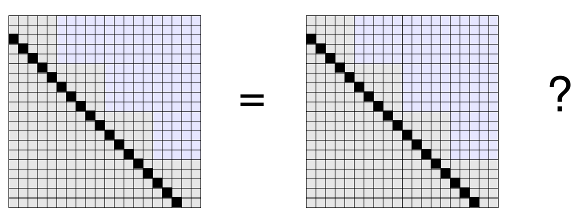

Fig. 24(d)