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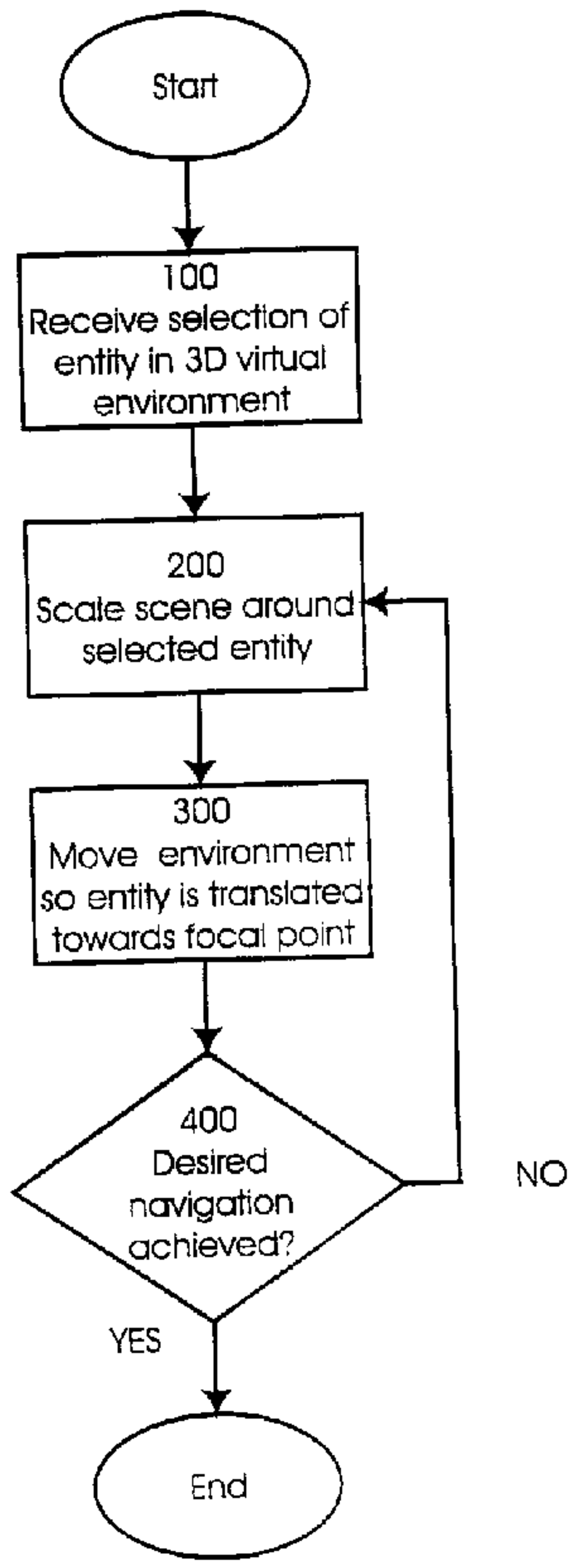
(54) **METHODE ET SYSTEME DE NAVIGATION DANS UN ENVIRONNEMENT VIRTUEL**

(54) **METHOD AND SYSTEM FOR NAVIGATING A VIRTUAL ENVIRONMENT**



(57) A method and system for navigating in a three-dimensional virtual environment is provided. The present invention is particularly suited towards three-dimensional graphs representing computer programs, where nodes represent objects or other programming structures, and arcs in between the nodes represent function calls or other types of relationships between the structures. The collective nodes and arcs represent a specialized type of virtual environment. At least a portion of the virtual environment is displayed on a monitor, the virtual environment portion being represented by a frustum, the frustum having a narrow portion at the front of the monitor and diverging towards the back of the monitor to give the perception of depth to a user. The frustum remains stationary, and has a focal point, usually at the centre of the monitor screen. When a user selects an object displayed on the monitor, the scene on the monitor is scaled by a predetermined amount. In addition, the scene is moved such that the selected object is translated towards the focal point. The scaled and moved scene is then displayed on the monitor. The steps of scaling and moving are repeated until the desired navigation is achieved. Rates of scaling and translating are preferably chosen so that the animation of the navigation is smooth. By making the navigation rapid, a user can be provided with both focus and context when viewing a three-dimensional graph. Other navigational features can be included, such as automatic selection of the entity, or rotation of the virtual environment about the focal point.

ABSTRACT

A method and system for navigating in a three-dimensional virtual environment is provided. The present invention is particularly suited towards three-dimensional graphs representing computer programs, where nodes represent objects or other programming structures, and arcs in between the nodes represent function calls or other types of relationships between the structures. The collective nodes and arcs represent a specialized type of virtual environment. At least a portion of the virtual environment is displayed on a monitor, the virtual environment portion being represented by a frustum, the frustum having a narrow portion at the front of the monitor and diverging towards the back of the monitor to give the perception of depth to a user. The frustum remains stationary, and has a focal point, usually at the centre of the monitor screen. When a user selects an object displayed on the monitor, the scene on the monitor is scaled by a predetermined amount. In addition, the scene is moved such that the selected object is translated towards the focal point. The scaled and moved scene is then displayed on the monitor. The steps of scaling and moving are repeated until the desired navigation is achieved. Rates of scaling and translating are preferably chosen so that the animation of the navigation is smooth. By making the navigation rapid, a user can be provided with both focus and context when viewing a three-dimensional graph. Other navigational features can be included, such as automatic selection of the entity, or rotation of the virtual environment about the focal point.

METHOD AND SYSTEM FOR NAVIGATING A VIRTUAL ENVIRONMENT

Field of the Invention

The present invention relates generally to interactive computer graphics and more particularly relates to a system and method for viewing objects using a computer by navigating through a three-dimensional virtual environment.

Background of the Invention

One way to visually represent information structures is in a three-dimensional virtual environment comprising a network of nodes and arcs, technically called a graph. (As known to those of skill in the art, arcs can also be referred to as edges and/or links.) It is known to use graphs to represent computer programs, where the nodes represent entities such as procedures, modules, or objects in an object-oriented computer program, while the arcs represent relationships between the entities, such as method-usage, function-calls or inheritance. Prior-art graphs include entity-relationship diagrams used in database modelling, Myers diagrams used to represent module relationships in software, call graphs showing calling relationships between procedures, inheritance graphs showing the pattern of inheritance in object-oriented code, and data-flow diagrams used in systems modelling. The shape and the colour of the nodes and arcs can be altered to represent different properties and/or attributes of those entities and relationships.

One problem with prior art graphs is that they do not scale easily. For example, once some limit of scaling is reached, the graph or diagram becomes a tangled, incomprehensible web. One solution to this problem is to modularize the graph and create subsidiary graphs on different pages. More recent experimental systems use interactive graphics to help the scaling problem.

In general terms, it can be difficult to display a large graph in a fashion that allows a viewer to focus on the detail of a small-structure while simultaneously comprehending the overall context of the small-structure within the large graph. In an attempt to overcome problems with focus and context, prior art graphs incorporate techniques such as distortion, elision, and multiple windowing.

Distortion gives more visual space to designated points of interest, and decreases the space given to those objects distal from the points of interests. The basic concept of distortion techniques is to spatially expand what is currently interesting at the expense of what is not, thus providing both focus and context. Elision involves hiding parts of the structure or virtual environment until they are needed. This is typically achieved by collapsing a node that contains a sub-graph into a single node. One known elision technique is the intelligent zoom system as discussed in L. Bartram, R. Ovans, J. Dill, M. Dyck, A. Ho & W.S. Havens (1994) "Contextual assistance in user interfaces to complex, time critical systems: the intelligent zoom.", *Proceedings Graphics Interfaces '94*, Morgan Kauffmann, Paolo Alto, pp. 216-224.

In addition, multiple windows can be used where one window shows a large-scale overview while one or more additional windows show expanded details on a small-scale. One problem with multiple windows is that it can be difficult to see where the zoomed-details belong in the overview window.

The foregoing techniques are typically used in two-dimensional graphs. However, another technique involves representing the information on a three-dimensional graph, possibly incorporating one or more of the foregoing techniques. Three-dimensional graphs provide focus and context through the operation of linear perspective. Generally, more detail can be seen in objects shown in the foreground than object shown in the background. Perspective and depth can also be created by overlap, cast-shadows, motion, stereoscopic viewing and other types of depth cues as is known to those of skill in the art. By changing the viewpoint and the foreground, the focus can be changed. However, only a small part of the context information is typically visible, and the part that is visible can be somewhat arbitrary and unrelated to the current focus. Accordingly, the layout of the graph can be critical to provide a suitable context. However, assuming the layout is suitable, it is necessary to provide tools to allow a user to navigate through the virtual environment.

In three-dimensional environments, certain navigational techniques are loosely referred to as zooming. These include, for example, changing a camera's focal length by moving the camera toward an object and/or scaling the object. The result in all cases is that part of the scene occupies a larger viewing area of the viewing window. Zooming typically refers to any technique which results in this effect regardless of the actual operation used. Zooming can give the viewer the ability to rapidly zoom into and out of objects in the virtual environment, which means that although focus and context are not simultaneously available, the close temporal relationship therebetween can allow the user to cognitively integrate the information.

It is believed that larger structures can be better understood in three-dimensions than two-dimensions. However, the need for high-speed graphics processors, effective rendering operations, effective graphical-user-interfaces and the like have heretofore limited the utility of three-dimensional graphs. With the advent of faster graphics processors, there is now a need for more effective rendering operations and/or graphical-user-interfaces in order to improve the utility of interactive three-dimensional graphs.

In particular, there is a need for improved navigational techniques in three dimensional virtual environments. While prior art systems and methods do provide navigational tools, such as zooming, translation and rotation, it can be awkward for a user to effectively select a particular object for viewing, and utilize the provided navigational tools to effectively examine the object. For example, during zooming operations it is possible that the selected object will become too large, too quickly, and accordingly the user will lose sight of the object. Similarly, problems can occur to during translation and rotation, such that the selected object becomes lost to the user attempting to navigate through the three-dimensional virtual environment. Awkward fumbling between menus, keystrokes and/or mouse clicks to effect a series of operations can further hamper effective navigation.

Summary of the Invention

It is therefore an object of the present invention to provide a novel system and method for navigating through a three-dimensional virtual environment which obviates or mitigates at least one of the disadvantages of the prior art.

A method and system for navigating a three-dimensional virtual environment is provided. The present invention is particularly suited towards three-dimensional graphs representing computer programs, where nodes represent objects or other programming structures, and arcs in-between the nodes represent function calls or other types of relationships between the structures. At least a portion of the virtual environment is viewable on a monitor, the viewable portion being represented by a frustum which diverges to give the perception of depth to a user. The frustum remains stationary, and a focal point is defined therein, while the virtual environment can be scaled, moved and/or rotated in relation to the focal point.

In one embodiment, a user first selects an object displayed on the monitor. Next, the scene on the monitor is scaled by a predetermined amount. In addition, the scene is moved such that the selected object is translated towards the focal point. The scaled and moved scene is then displayed on the monitor. The steps of scaling and moving are repeated until the desired navigation is achieved. Rates of scaling and translation are preferably chosen so that the animation of the navigation is smooth. By making the navigation rapid, a user can be provided with both focus and context when viewing a three-dimensional graph.

Brief Description of the Drawings

The present invention will now be explained, by way of example only, with reference to certain embodiments and the attached figures, in which:

Figure 1 is a system for navigating a three-dimensional virtual environment in accordance with an embodiment of the invention;

Figure 2 is a block diagram of the processing unit of Figure 1;

Figure 3 is a schematic diagram of a sectional view of a virtual environment and the front of the monitor of Figure 1 displaying a portion of the three-dimensional virtual environment;

Figure 4 is a schematic diagram showing a sectional view of the virtual environment of Figure 3 on another plane, and a perspective view of the viewable frustum of the virtual environment;

Figure 5 is a flow chart of a method for navigating a three-dimensional virtual environment in accordance with another embodiment of the invention;

Figure 6 shows the monitor of Figure 3 wherein the cursor is shown overlapping one of the objects within the virtual environment;

Figure 7 shows the monitor of Figure 6 wherein the selected object has been partially scaled and translated;

Figure 8 shows the frustum of Figure 4 wherein the selected object has been partially scaled and translated as shown in Figure 7;

Figure 9 shows the monitor of Figure 6 wherein the selected object has been scaled and fully translated to the focal point of the monitor;

Figure 10 shows the frustum of Figure 4 wherein the selected object has been scaled and translated as shown in Figure 9;

Figure 11 shows the monitor of Figure 9 wherein the selected object has been further scaled;

Figure 12 shows the monitor of Figure 11 wherein the selected object has been rotated about the focal point; and

Figure 13 shows the frustum of Figure 4 wherein the selected object has been rotated as shown in Figure 12.

Detailed Description of the Invention

Referring now to Figure 1, a system for navigating a three-dimensional virtual environment is indicated generally at 20. In a present embodiment, system 20 is a computer 22 having a processing unit 24 that generates user-output to one or more user-output devices, which in a present embodiment includes a monitor 26. Monitor 26 can be a cathode-ray tube, an electroluminescent display, an active matrix display and/or any other user-output display device, as will occur to those of skill in the art. Processing unit 24 receives user-input from user-input devices which in a present embodiment include a keyboard 28 and a pointing-device or mouse 30. Processing unit 24 can optionally be connected to a persistent storage device which in a present embodiment is a hard-disc drive 32.

Referring now to Figure 2, processing unit 24 houses a motherboard 32 that includes a microprocessor 34, random access memory 36 and a video output card 38. Video output card 38 is connected to monitor 26 and operable to generate electronic signals to monitor 26 that represent a scene or at least a portion of a three-dimensional virtual environment. Processing unit 24 further includes a rendering engine 40, which is operable to perform a variety of known operations, including scaling, movement and rotation operations, that render or generate the scene data received from microprocessor 34 and random access memory 36, and which is used by video output card 38. It will be apparent that rendering engine 40 can be incorporated directly as hardware on motherboard 32 or into any of the other hardware components thereon. In other embodiments of the invention, rendering engine 40 can be simply part of a software program executing on the microprocessor 34.

One suitable configuration of motherboard 32 includes a Pentium III microprocessor 34, one-hundred-and-twenty-eight megabytes of random access memory 36, and any known sixteen-megabyte accelerated graphics port (AGP) video-output card 38 with openGL incorporated therein. The functions of rendering engine 40 can be divided between hardware integral with the AGP video output card 38 and software executing on the Pentium III microprocessor, which is stored on hard-disc 32. Other configurations of motherboard 32 will occur to those of skill in the art.

Referring now to Figure 3, processing unit 24 is operable to present at least a portion of a virtual environment 42 on the screen 26a of monitor 26. Virtual environment 42 is three-dimensional, having an x-axis 47x, a y-axis 47y and a z-axis 47z perpendicular to both x-axis 47x and y-axis 47y. As shown in the attached Figures, virtual environment 42 is represented by an ellipsoid, but it will be understood that other three-dimensional shapes can be used, such as a sphere or a cube. Furthermore, as will occur to those of skill in the art, virtual environment 42 need not be bound by any particular shape. Processing unit 24 is also operable to store a coordinate system using a predetermined scale for each axis. It will be understood that axes 47x, 47y, 47z reside within virtual environment 42, and accompanying coordinate scales need not visually appear on monitor 26. Furthermore, as will be understood from the discussion below, axes 47x, 47y, 47z are movable in relation to monitor 26.

Processing unit 24 is further operable to store one or more objects within virtual environment 42 which can be viewed on monitor 26. In a present embodiment two objects 50, 52 within virtual environment 42 are shown on screen 26a. A third object 53 resides within virtual environment 42, stored within random access memory 36 and/or hard-drive 32, but is not visible on monitor 26. It will be apparent that other objects within virtual environment 42 can be stored within random access memory 36 and/or hard disc 32, without actually being presented on monitor 26. While objects 50, 52 and 53 are cubic, it will be apparent that they can be any type of entity having any shape, colour or form, as desired.

In a preferred embodiment of the invention, objects 50, 52, 53 represent nodes of a graph which can be interconnected with arcs. (The arcs are not shown in the attached Figures). As is known to those of skill in the art, in a three-dimensional virtual environment such arcs can be individual lines or three-dimensional tubes. In the preferred embodiment, such a graph is representative of a computer program, where the nodes represent entities such as procedures, modules, or objects in an object-oriented computer program, while the arcs represent relationships between the entities, such as method usage, function calls or inheritance. In other embodiments the graph can represent databases or other data structures. Further discussion on such graphs can be found in Franck, G. and Ware C., 1994 "Representing Nodes and Arcs in Three-Dimensional Networks", *Proceedings of the IEEE Conference on Visual Languages*, St. Louis, October, p. 189-190. Other graphic representations are within the scope of the invention.

Processing unit 24 is further operable to present a cursor 54 on screen 26a. Cursor 54 is movable on screen 26a, based on user-input received from a user-input device such as mouse 30.

Referring now to Figure 4, processing unit 24 determines which portions of virtual environment 42 to present on monitor 26 by modelling the scene or viewable portion of virtual environment 42 as a frustum 54. While in a present embodiment frustum 54 is a truncated pyramid, frustum 54 can be a truncated cone or other structure, depending on the shape of screen 26a. Frustum 54 represents the perceived field-of-view for a user 56 of system 20 looking at the screen 26a of monitor 26, having a near clipping plane 54a and a far clipping plane 54b. Frustum 54 also includes top, bottom, left and right clipping planes. The volume of frustum 54 represents the scene or portion of virtual environment 42 displayed on screen 26a. In a present embodiment, screen 26a is located approximately one third of the distance from near clipping plane 54a to far clipping plane 54b, but can be located at other positions within frustum 54. As shown in Figure 4, the corners of screen 26a coincide with the corners of frustum 54. It will be apparent that where the scene or the portion of viewing environment 42 is displayed in a window on screen 26a, then the corners of the window coincide with the corners of frustum 54. As seen in Figure 4, objects 50, 52 are within frustum 54 and thus visible to user 56, while object 53 is outside frustum 54, and thus, not visible to user 56. As shown in Figures 3 and 4, frustum 54 has its own set of axes 57x, 57y, 57z which remain fixed within frustum 54. As will be explained in greater detail below, processing unit 24 is operable to scale, move or rotate the scene or portion of virtual environment 42 within frustum 54 in relation to axes 57x, 57y, 57z in order to effect navigation through virtual environment 42. Thus, while axes 47x, 47y, 47z of virtual environment 42 are scalable, movable and/or rotatable in relation to frustum 54, axes 57x, 57y, 57z of frustum 54 remain fixed. In a present embodiment axes 57x, 57y are defined on the surface of monitor 26 and the origin of axes 57x, 57y, 57z resides at the centre of monitor 26.

The origin of axes 57x, 57y, 57z is defined as a focal point 58. In general, focal point 58 resides between near clipping plane 54a and far clipping plane 54b, but need not coincide with screen 26a. Further, while in the present embodiment focal point 58 is in the centre of screen 26a, it will be understood that focal point 58 can be located in other positions within frustum 54.

Processing unit 24 is operable to store the locations of objects 50, 52 and 53 within virtual environment 42 and to present at least a portion of virtual environment 42 within frustum 54.

Virtual environment 42 can be navigated as frustum 34 remains static throughout the navigation. Navigation functions can include translation, scaling and rotation. When performing a translation, virtual environment 42 is shifted or moved to different locations within frustum 54. During scaling, virtual environment 42 is enlarged or reduced to different sizes, allowing user 56 to discern different levels of detail of objects within frustum 54. Further, objects within frustum 54 can be rotated about either one or more of the axes 57x, 57y, 57z at focal point 58. During rotation, virtual environment 42 is rotated about focal point 58.

In a present embodiment of the invention, processing unit 24 is operable to receive a selection of one of the objects within the virtual environment and perform a series of scaling operations that changes the size of virtual environment 42 in conjunction with a series of movement operations on virtual environment 42 so that the selected object translates towards the focal point. The operations are preferably performed at a rate which makes the entire process appear smoothly animated. It is also presently preferred that the rate of translations decelerate as the selected object approaches the focal point. The operations can be discontinued when the selected object appears at the focal point, or a user-input is received instructing cessation of the operations.

A method for navigating virtual environment 42 will now be discussed with reference to Figure 5. At step 100 a selection of an entity in a three-dimensional virtual environment is received. In a present embodiment that utilizes the foregoing system 20, user 56 moves mouse 30 to provide a user-input to processing unit 24, which responds by moving cursor 54 in accordance with the movements of mouse 30. Referring now to Figure 6, cursor 54 is shown overlapping with object 50, and a dashed line indicates the path taken by cursor 54 during movement. Next, a user provides a second user-input, preferably by depressing and holding one of the buttons on mouse 30. The combination of the location of cursor 54 and the depression of the mouse button is received by processing unit 24 as a selection of object 50. It is presently preferred that, regardless of where cursor 54 overlaps object 50 when the mouse button is depressed, the centre of object 50, as defined within the coordinates system of virtual environment 42, will be received as the selection. Other means of selecting object 50, or another entity, will occur to those of skill in the art.

Referring again to Figure 5, at step 200 the scene surrounding the selected entity is scaled. In a present embodiment, virtual environment 42 is increased in scale in all three dimensions by a predefined multiple, so that the scene surrounding the selected entity increases in size. In a presently preferred embodiment, where system 20 is operable to display twenty frames per second, virtual environment 42 is increased in scale by about five percent. Thus, where system 20 displays a different number of frames per second, the scene is increased at a rate-of-scaling of about one-hundred-and-sixty-five percent per second.

While a predefined multiple based on a rate-of-scaling of about one-hundred-and-sixty-five percent per second is presently preferred, it is believed that the rate-of-scaling can be from about fifty percent per second to about four-hundred percent per second. It is further believed that another acceptable range for the rate-of-scaling can be from about one-hundred-and-forty percent/second to about one-hundred-and-eighty-five percent per second. More preferably, the rate-of-scaling is in the range of from about one-hundred-and-fifty percent per second to about one-hundred-and-seventy-five percent per second. Generally, it will be understood any rate-of-scaling can be chosen, but a rate-of-scaling which produces smooth animation is more generally preferred.

In one embodiment of the invention, step 200 is implemented on system 20 by scaling the entire scene surrounding focal point 58, and then moving the scene so that the overall effect is to scale the scene surrounding the selected entity. Other methods of performing scaling operations will occur to those of skill in the art, and are within the scope of the invention.

It will thus be apparent that step 200 is essentially a three-dimensional scaling operation, which is rendered and displayed in two dimensions on monitor 26. In a present embodiment of the invention, the scaled scene is not displayed on monitor 26 at this step, but it will be understood that the scaled scene could be displayed at this point.

Next, at step 300, the scene is moved so that the selected entity is translated towards the focal point. In a present embodiment, this is accomplished by translating virtual environment 42 so that the selected entity is translated towards the focal point. It is also preferred that the path of the translation is linear, calculated along a straight line between the selected entity and the focal point. It is also preferred that the rate of translation should decelerate as the selected entity approaches the focal point so that the selected entity reaches the focal point in about one second.

While in a present embodiment the rate-of-deceleration is chosen so that the selected entity reaches the focal point in about one second, it is believed that the rate of deceleration can be chosen so that the selected entity reaches the focal point in a range of from about 0.25 seconds to about 4.0 seconds. It is also believed that the rate of deceleration can be chosen so that the selected entity reaches the focal point in a range of from about 0.5 seconds to about 2.0 seconds. More preferably, the rate of deceleration can be chosen so that the selected entity reaches the focal point in a range of from about 0.75 seconds to about 1.5 seconds.

Another suitable movement operation is to move virtual environment 42 so that the selected entity moves at one given velocity until it stops at the focal point.

Another suitable movement operation is to move virtual environment 42 so that the selected entity is translated by a predetermined ratio of the distance ("ratio") from the selected entity to focal point 58. In this operation, the selected entity never actually reaches focal point 58, but approaches it. Using this movement operation, the selected entity is preferably translated by a distance of about ten percent of the overall distance between the selected entity and focal point 58, based on a frame-rate of twenty frames per second.

While a ratio of about ten percent is presently preferred, (based on a frame-rate of twenty frames per second) it is believed that the ratio can be from about two percent to about twenty percent. It is also believed that the ratio can be from about five percent to about fifteen percent. More preferably, the ratio of translation can be from about nine percent to about eleven percent. It will be understood that these ranges can vary depending on the frame-rate, and in general, the ratio will be chosen based on the frame-rate so that the translations appear smoothly animated.

Other suitable movement operations will occur to those of skill in the art, and are within the scope of the invention.

It is presently preferred that the results of steps 200 and 300 are then rendered and displayed on monitor 26.

At step 400, it is determined whether the desired navigation has been achieved. In a present embodiment, processing unit 24 examines a user-input, such as whether the button of mouse 30 has been released, in order to make this determination. If the required user-input has not been received, (for example, the button on mouse 30 has not been released) then processing unit 24 determines that the desired level of navigation has not been achieved, and the method returns to steps 200 and 300, where the scene is scaled and translated according to the previous description of those steps. If the predetermined user-input has been received, (for example, the button on mouse 30 has been released) then processing unit 24 determines that the desired level of navigation has been achieved and the method of the present embodiment ends.

For example, if the button on mouse 30 is released before object 50 is translated to focal point 58 then object 50 will appear on monitor 26 as somewhat enlarged and translated towards focal point 58, as shown in Figures 7 and 8. Because of the navigation, only a portion of object 52 remains visible on monitor 26. Further, as best seen in Figure 8, virtual environment 42 has increased in scale, and has shifted so that object 50 is closer to focal point 58 which has remained fixed.

If, however, the button on mouse 30 is released when object 50 reaches focal point 58, then object 50 will appear on the centre of monitor 26 in an enlarged form, as shown in Figures 9 and 10. Due to the navigation, object 52 no longer appears on monitor 26 as it is outside frustum 54.

If the button on mouse 30 continues to be depressed when object 50 reaches focal point 58, then object 50 continues to increase in scale, but no further translations occur, as shown in Figure 11. Alternatively, user 56 can provide another user-input which instructs processing unit 24 to decrease the scale of object 50. By increasing and decreasing the scale of object 50, user 56 can obtain focus and context in close temporal relationship, allowing user 56 to cognitively absorb the information.

In another embodiment of the invention, navigation, (i.e. further scaling) ceases once the selected object reaches focal point 58.

In another embodiment of the invention, step 100 can be used to select, either automatically or manually, an object within virtual environment that is not visible in the frustum. For example, a user can be provided with a menu selection which allows the user to select an object within the virtual environment 42 that is not shown in the frustum 54 (e.g. object 53) Next, prior to step 200, virtual environment 42 is descaled (i.e. decreased in scale) until the selected object becomes visible in frustum 54. The remainder of the method can then be performed as previously described.

The present embodiment can be desirable where virtual environment 42 is a three-dimensional graph containing a plurality of nodes and arcs representing objects and their relationships, respectively, of a computer program. Where the user is viewing one object that relates to a second object that is not visible, the user can be provided with a menu selection allowing him to automatically select the second related object. As previously described, the scene can then descale until the second object becomes visible, and then the method can continue at step 200, as described until the second object is moved to the focal point of the frustum, and scaled accordingly.

In another embodiment of the invention, once the desired level of navigation has been achieved, user 54 can rotate and/or shift object 50 about the one or more of axes 57x, 57y, 57z. For example, as shown in Figures 12 and 13, object 50 is rotated on its centre about axes 57y and 57z. Where object 50 represents an element or object of a computer program in a three-dimensional graph, it can be rotated until a face bearing information relevant to the object is viewable in a direction normal to monitor 26. The rotation can be performed automatically once object 50 reaches focal point 58 or it can performed based on a user-input provided to processor 24.

While the embodiments discussed herein are directed to particular implementations of the present invention, it will be apparent that the sub-sets and variations to these embodiments are within the scope of the invention. For example, the present invention can be implemented in a stereoscopic system, having a three-dimensional viewing apparatus such as a head-mounted stereoscopic viewing device, as will occur to those of skill in the art. In addition, step 100 can be accomplished using either manual or automatic techniques, while steps 200 and300 need not be performed in any particular order, and/or can be performed in parallel. Further, other types of computers, user-input devices, processing units etc. can be used, as will occur to those of skill in the art. It will be further apparent that the foregoing embodiments can be modified to allow a user to decrease the scale of the selected object once it is positioned at the focal point. Further, by allowing a user to rapidly increase and/or decrease the scale of the selected object, the user can be provided with both focus and context.

Furthermore, while a variety of rates and methods of scaling and translations can be used, it will be understood that any rate and method can be used, and in particular rates and methods which display smooth animation during the scaling and/or translation of the selected object, and/or which result in the deceleration of translations and/or scaling as the object approaches the focal point.

It will be further apparent that the teachings of the present invention can be directed to a variety of software and animation applications, including CAD/CAM, film, video games, three dimensional geographical information systems etc.

The foregoing embodiments can, of course, be combined to provide additional functionality, and/or can be incorporated as features into a larger software application and/or method that offer other features to a user.

The present invention can be suitable for providing a means to automatically navigate a virtual environment, by allowing a user to select an entity that is not visible within the frustum using a predefined criteria, such as a user-defined search or based on a relationship between the non-visible entity and a visible entity. Once the non-visible entity is selected, it can be brought to the focal point by descaling until it appears in the frustum, and then successively scaling and translating the entity until it is positioned at the focal point.

The present invention provides a novel method and system for navigating virtual environments, for use in the viewing and/or examination of objects in three-dimensions. The present invention is believed to be particularly suitable for use in navigating three-dimensional graphs containing a plurality of nodes and arcs, where nodes represent objects or similar computer language components, and arcs represent function calls, method calls, inheritances and/or other types of relationships between objects. The navigation technique is believed to provide functionality to interactive three-dimensional graphs which model computer programs, and allow such graphs to be used in place of two-dimensional graphs. The navigation technique allows a user to select an object with a single input that smoothly brings the object to a focal point for the user based on a single manual input, or through some automated criteria that selects the object. The central focal point is fixed, allowing the virtual environment can be scaled, translated or rotated in relation to the focal point and thus allowing a user to readily navigate through the virtual environment. Focus and context is provided by allowing the user to rotate and/or rapidly increase and/or decrease the scale of the selected object once it has been translated to the focal point.

We claim:

1. A method for navigating a three-dimensional virtual environment containing a plurality of nodes interconnected by at least one arc, said nodes representing entities in an information structure, said at least one arc representing a relationship between said entities, at least a portion of said virtual environment being displayed in a scene, said method comprising the steps of:

receiving a selection of an entity within said virtual environment;

scaling said scene about a focal point;

moving said scene in a direction such that said entity is translated towards said focal point; and

displaying said scene.

2. The method according to claim 1 further comprising the steps of repeating said scaling and moving until a desired level of navigation has been achieved.

3. The method according to claim 2 further comprising the steps of rotating said scene about said focal point.

4. The method according to claim 1 wherein said scaling is an increase based on a multiple determined by a predetermined rate-of-scaling based and a given frame-rate.

5. The method according to claim 4 wherein said predefined rate-of-scaling is about one-hundred-and-sixty-five percent per second.

6. The method according to claim 4 wherein said predefined rate-of-scaling is from about fifty percent per second to about four-hundred percent per second.

7. The method according to claim 1 wherein said translation is along a line between said selected entity and said focal point.

8. The method according to claim 2 wherein said translation occurs at a rate-of-deceleration such that said selected entity reaches the focal point in about one second.

9. The method according to claim 2 wherein said translation occurs at a rate-of-deceleration such that said selected entity reaches the focal point in a range of from about 0.25 seconds to about 4.0 seconds.

10. The method according to claim 1 wherein said selected is displayed in said scene.

11. The method according to claim 1 wherein said selected entity not visible in said scene and said step of receiving said selection is based on an operation that determines said selected entity has a relationship with a displayed entity of interest to a user.

12. A system for navigating a three-dimensional virtual environment containing one or more entities comprising:

a processing unit having a microprocessor, random access memory, a video output card and a rendering engine, said processing unit being operable to store said three-dimensional virtual environment;

a user-output device connected to said processing unit, said processing unit being operable to model said portion as a frustum and present said frustum on said user-output device, said user-output device being operable to present said frustum as a viewable scene to a user, said frustum having a focal point;

a user-input device connected to said processing unit, said user-input device being operable to allow said user to select an entity presented in said scene;

said processing unit being operable to perform at least one scaling operation scaling said scene about said focal point and to perform at least one movement operation that shifts said scene in a direction such that said selected entity is translated towards said focal point; and

said processing unit being further operable to present said scaled and moved scene to said user-output device.

13. The system according to claim 10 wherein said user-input device is a mouse and said processing unit is operable to display a cursor on said user-output device in response to movements of said mouse; said processing unit being further operable to select said entity via placement of said cursor over said entity and depressing a button on said mouse.

14. The system according to claim 10 wherein said processing unit continues to scale and move said scene until said selected entity is translated to said focal point.

15. The system according to claim 10 further comprising a second user-output device connected to said processing unit, said processing unit being further operable to present said scene as a stereoscopic image on said user-output devices.

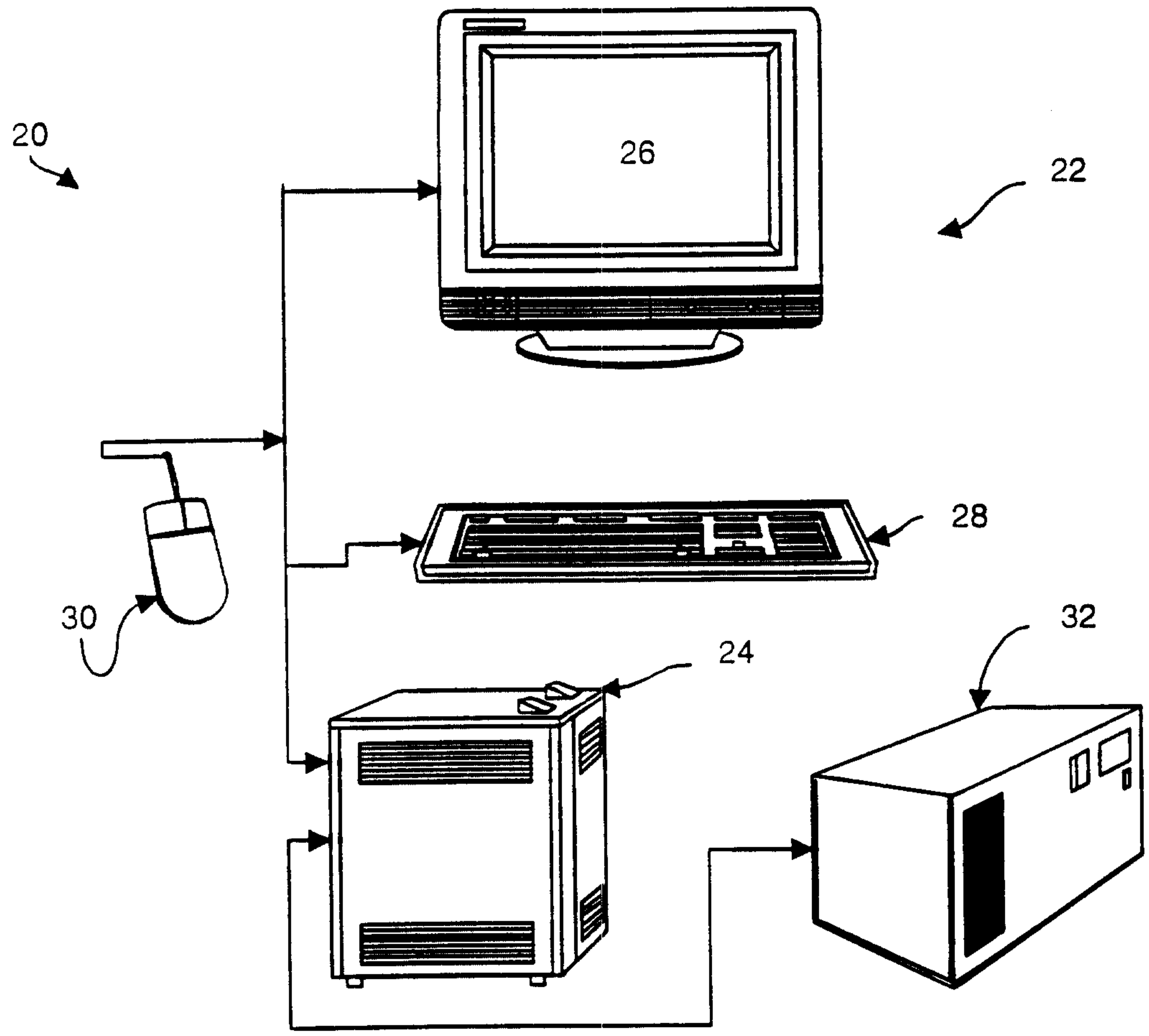


Fig.1

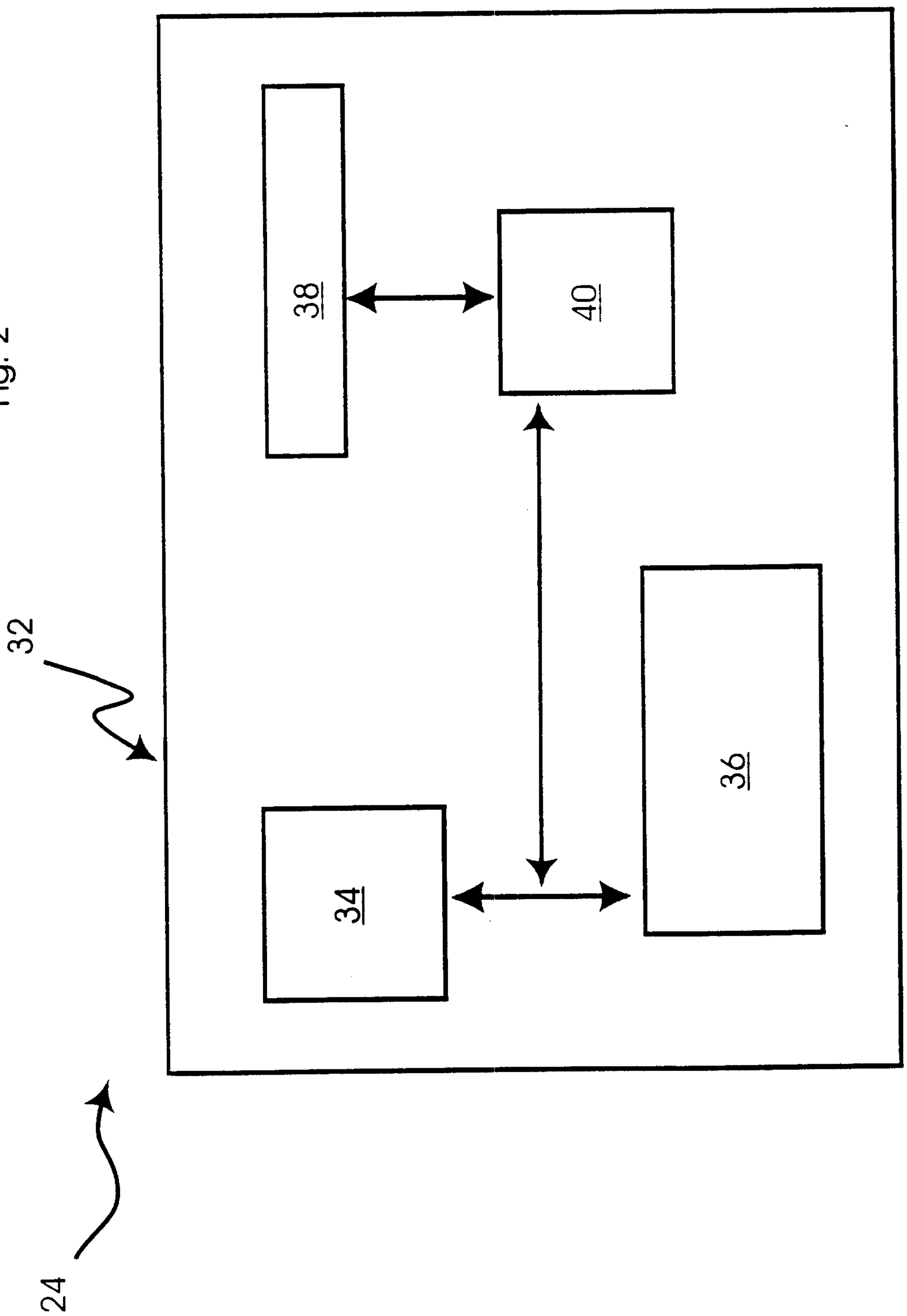


Fig. 2

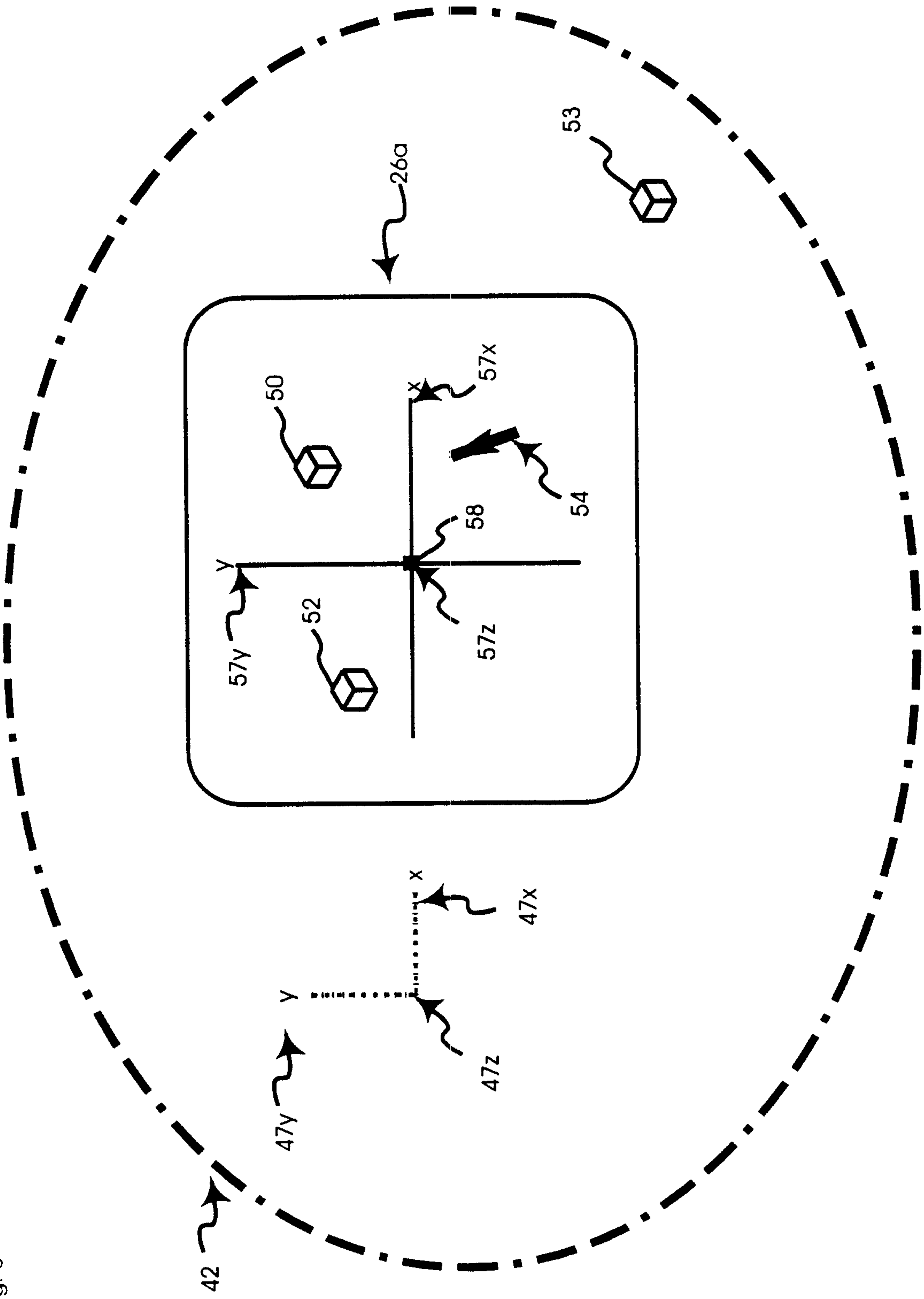


Fig. 3

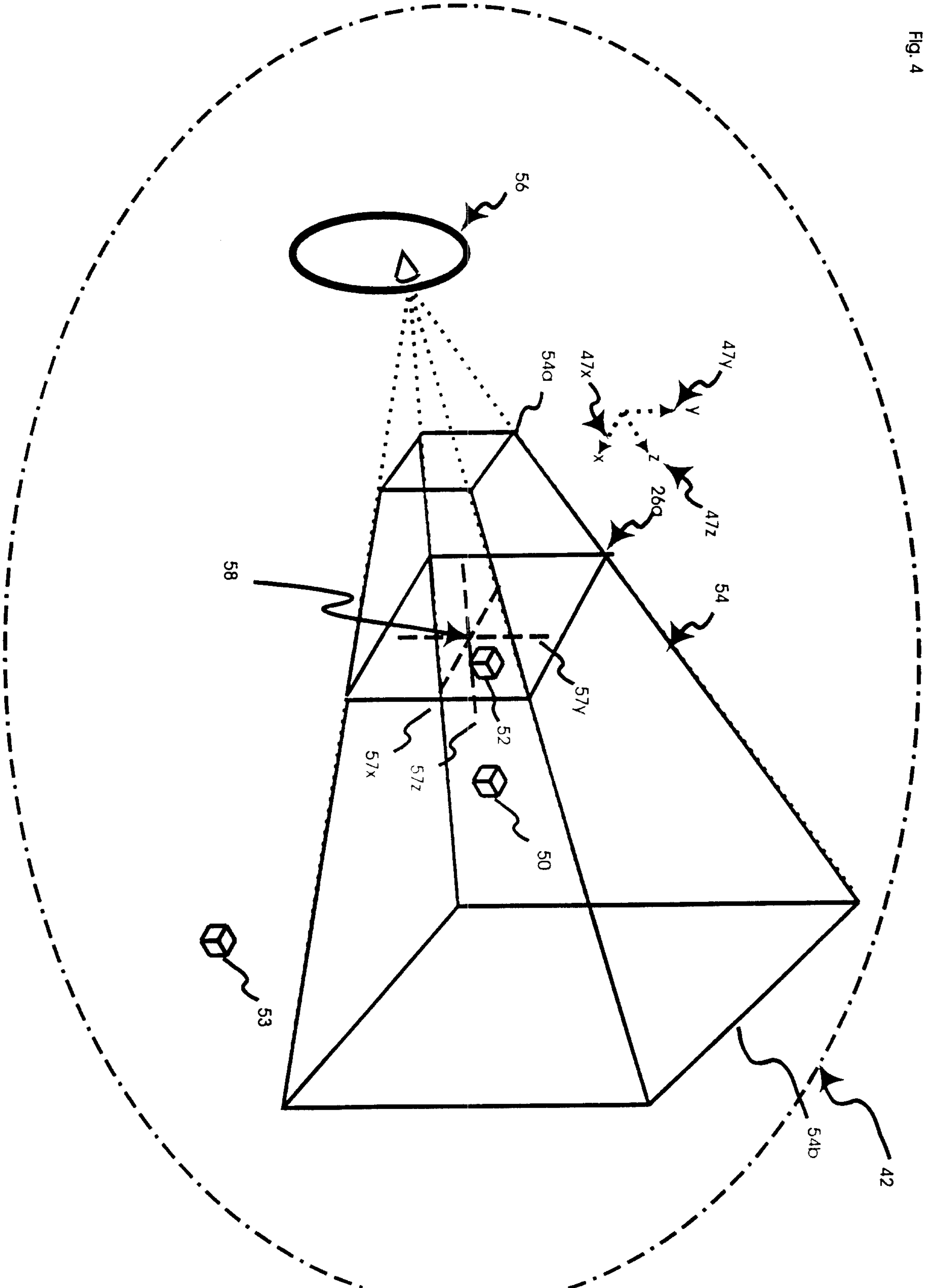
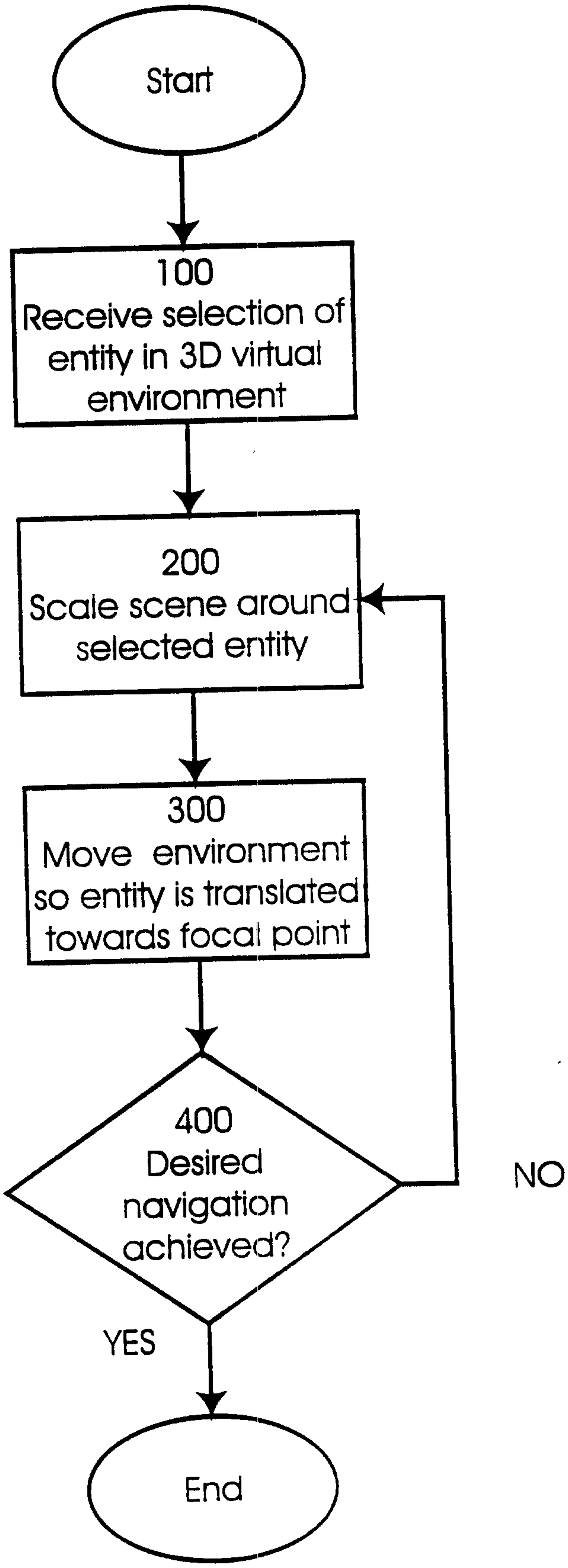


Fig. 4

Fig. 5


Start
100
Receive selection of entity in 3D virtual environment
200
Scale scene around selected entity
300
Move environment so entity is translated towards focal point
400
Desired navigation achieved?
NO
YES
End

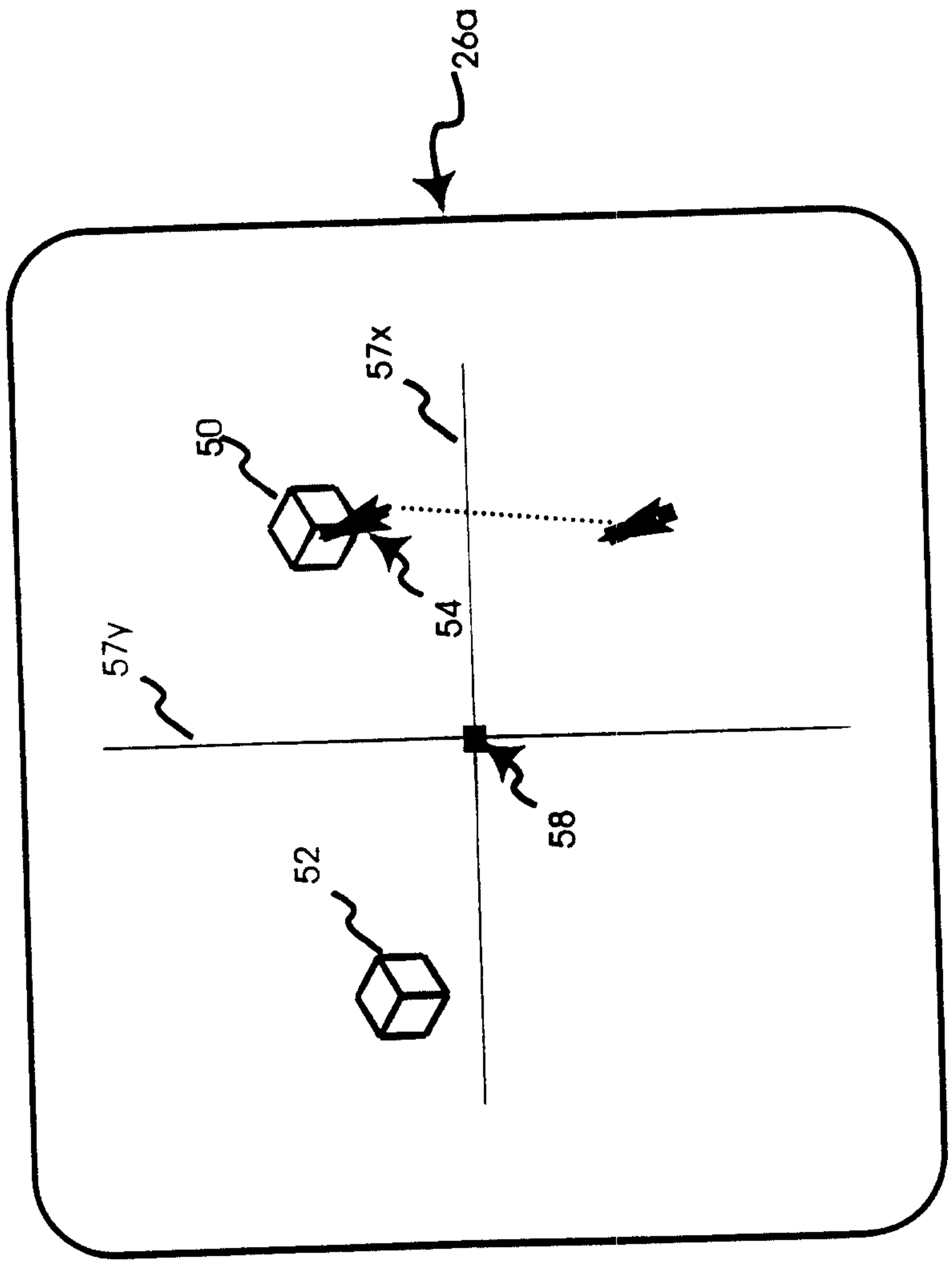


Fig. 6

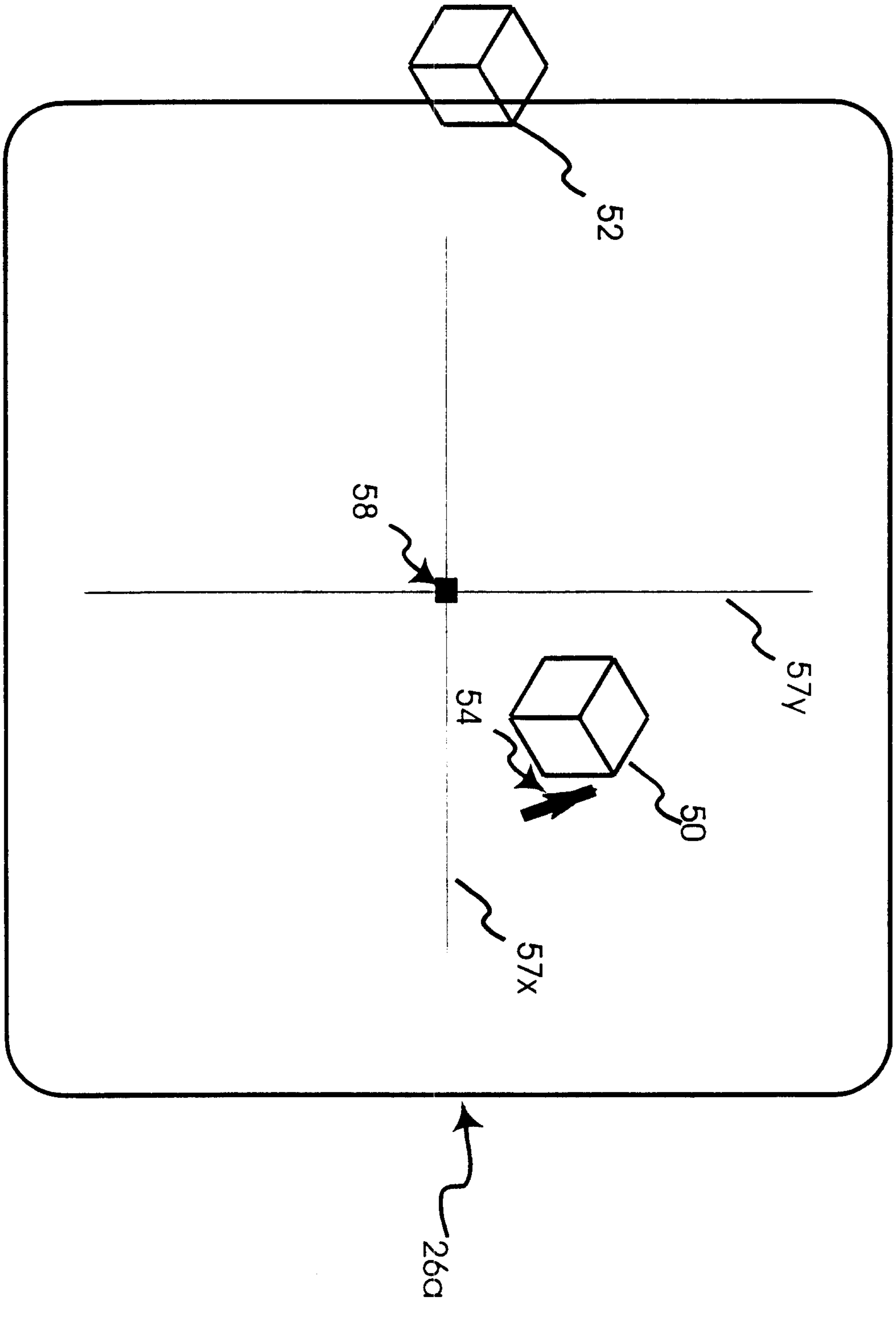


Fig. 7

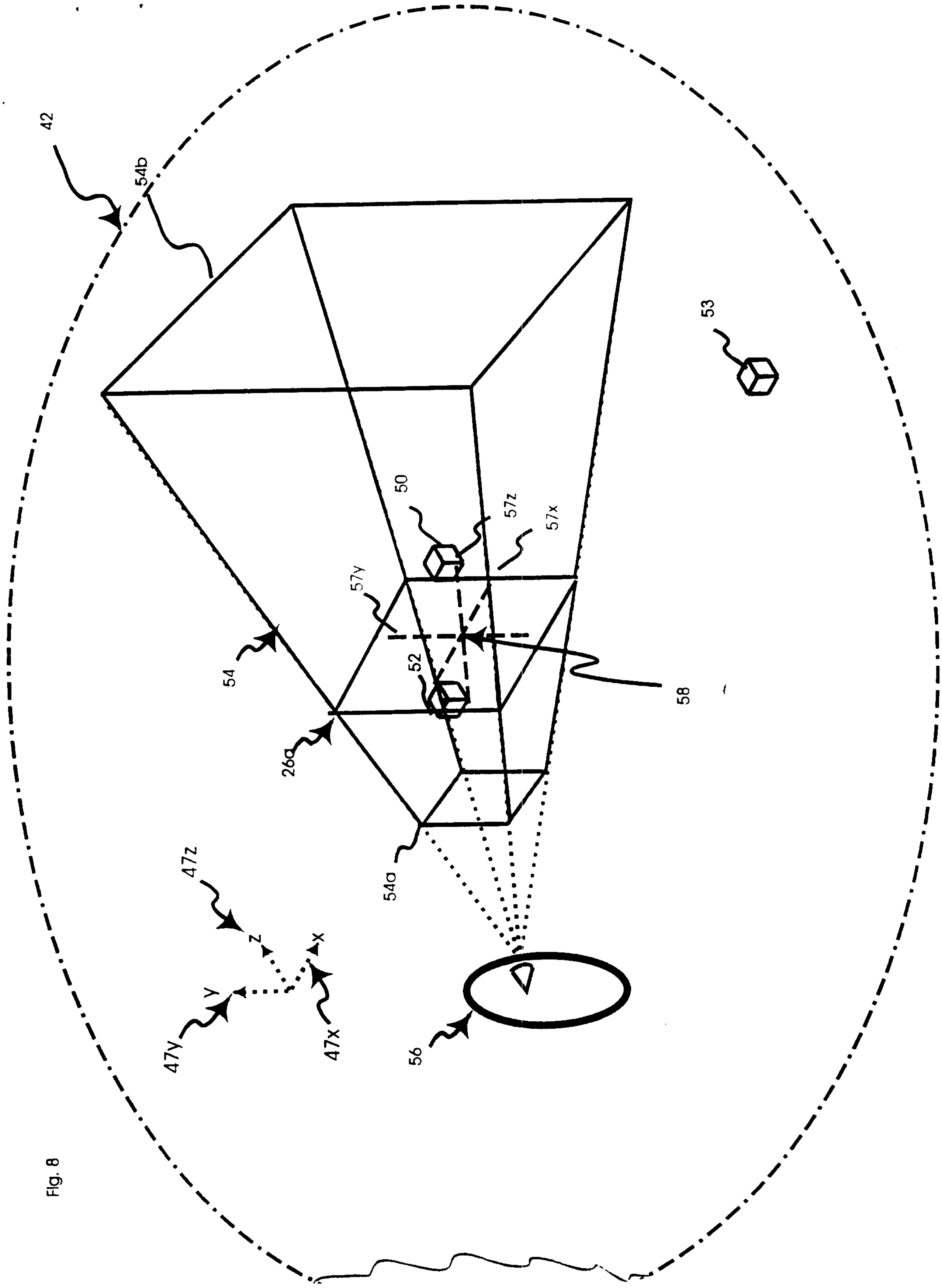
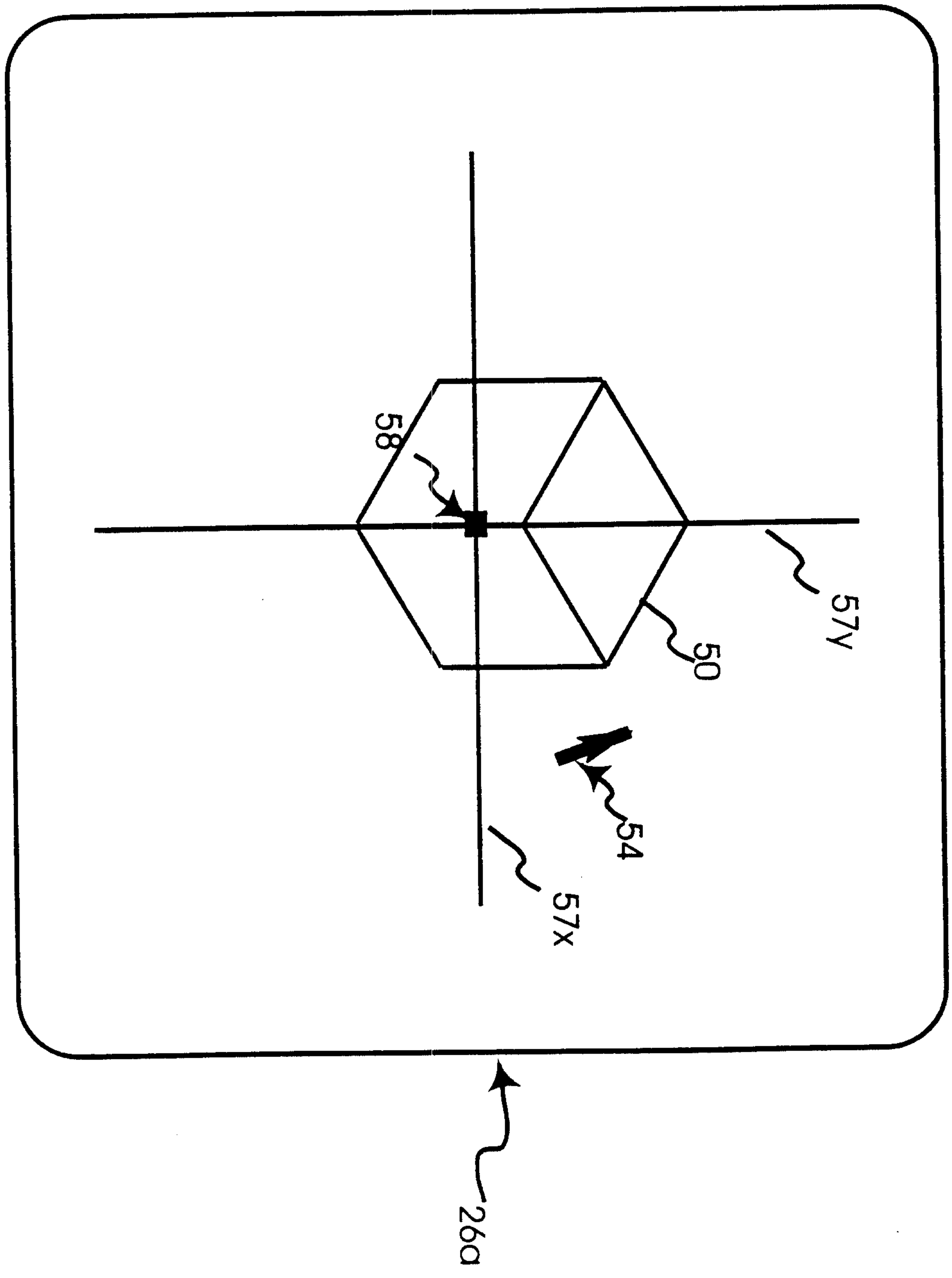


Fig. 8

Fig. 9



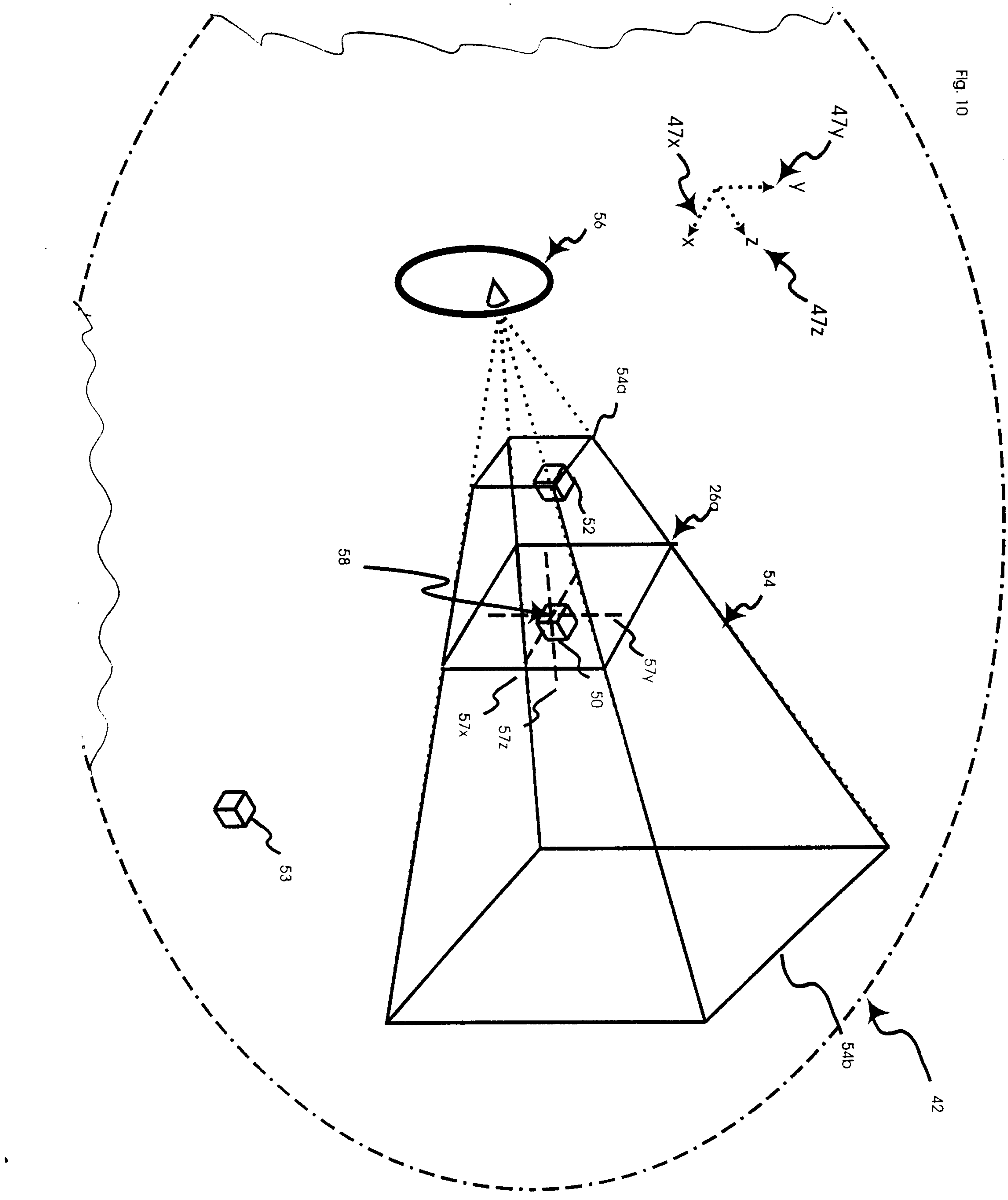


Fig. 10

Fig. 11

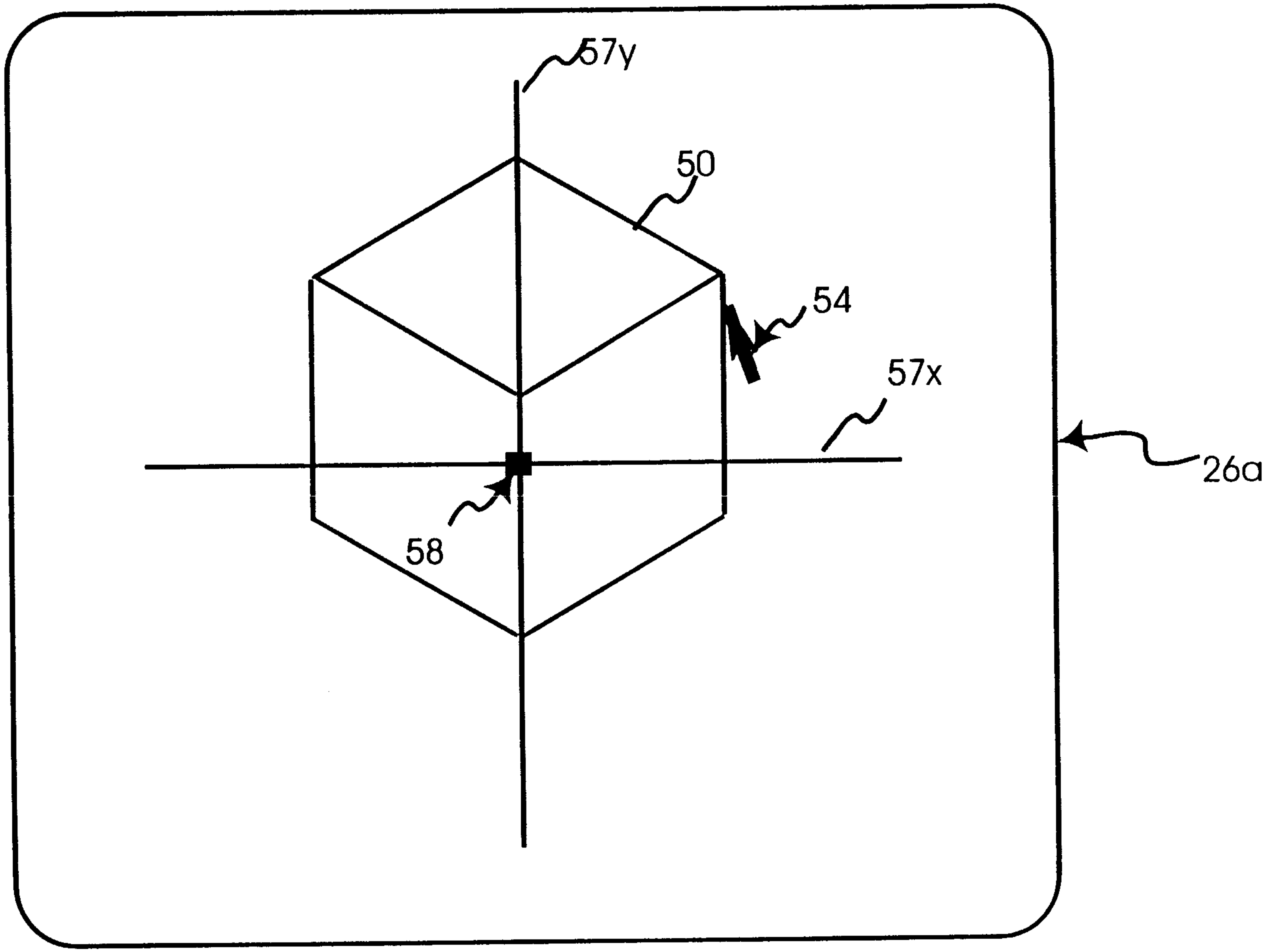
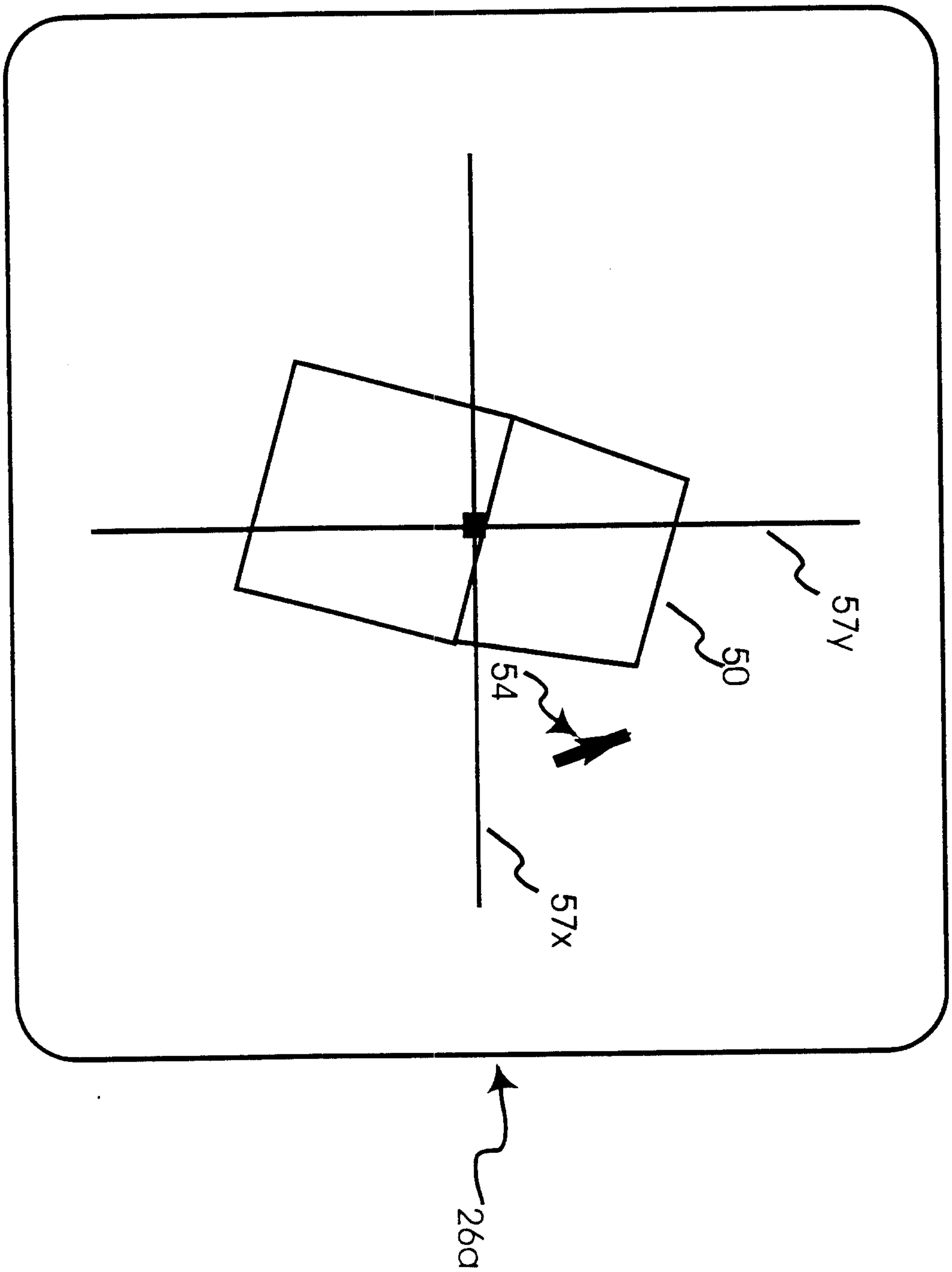


Fig. 12



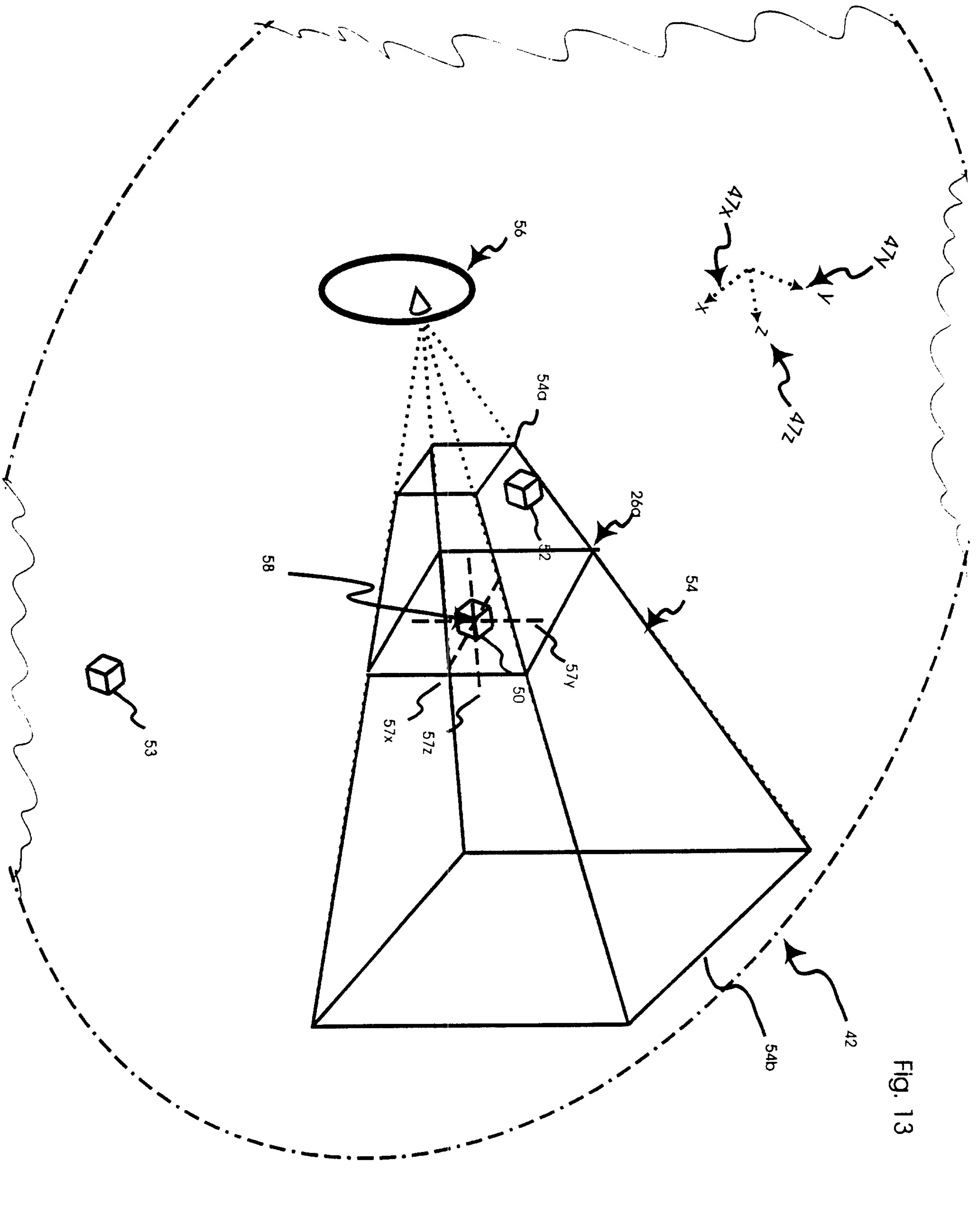
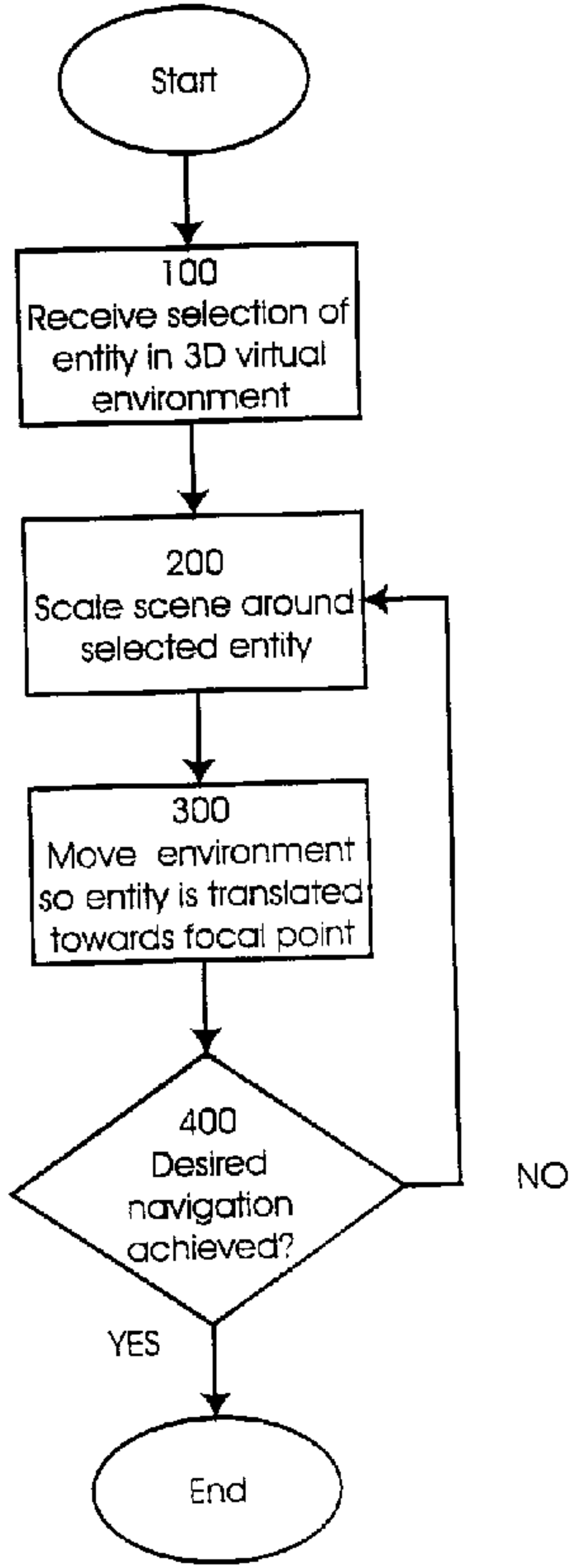


Fig. 13


Start
100
Receive selection of entity in 3D virtual environment
200
Scale scene around selected entity
300
Move environment so entity is translated towards focal point
400
Desired navigation achieved?
NO
YES
End