

COMPACT REACH-IN DISPLAY SYSTEM FOR TWO-HANDED USER INTERACTION WITH VIRTUAL OBJECTS

FIELD OF INVENTION

This invention relates to the field of user interfaces with computers, and particularly to 'Virtual Reality' systems where the sensory space of the user is brought into correspondence with the numerically defined space of the computer.

BACKGROUND OF THE INVENTION

1. Nomenclature and Definition of Terms

In the following description, "virtual image" is used in the sense standard in optics; an image visible to the eye and perceived as being at a certain location, but (unlike the "real image" formed in a camera) for which no relevant light rays pass through that location. In contrast, a "virtual object" is used to mean an entity whose geometry is defined within a computer, which is so displayed by computer graphics as to appear to be at a particular physical location, and whose position and/or properties can be modified by user activity at or near that location. The term "natural work volume" is used to mean the region easily reached by the hands of a seated user whose arms are supported by a table, and convenient for the eyes: approximately (less for a smaller user) within a height of 30cm from the table, 50cm wide, and between 15cm and 50cm from the eyes.

2. Description of the Related Art

The currently most common way for a computer user to interact with a three-dimensional dataset in the computer (whether this be a medical or seismic scan of a volume, a representation of the surface of a skull or vehicle or mountain, *etc.*, *etc.*) is to display it as a three-dimensional picture on the computer monitor, but to control it through the two-dimensional motions of a mouse on the desk surface. Since this cannot simultaneously and independently modify the three point-position variables of depth in the screen, height on the screen and left-right placement, let alone the three orientation variables corresponding to rotation about the three standard axes, every change of position becomes a painful task in indirect management. Other systems use three-dimensional position sensors (with or without report of rotation), still with the controlling hand at a different place from where the controlled object is seen. When an effort is made to give the user consistent position information, with reports from hand and eye agreeing as they do with real objects, this is 'Virtual Reality', where the user functions in a space shared with the computer.

Virtual Reality is often implemented using a head-mounted display, but issues of calibration and speed currently make this an unsatisfactory environment for sustained,

careful work. We are concerned here with systems in which the user interacts with a fixed 3D display system. In such a system there is a means of delivering distinct images to the left and right eyes; this may be by placing the images on two monitors (or areas of one monitor) and using mirrors to place them appropriately in front of the eyes; or the left and right views may be alternated—over time, or over rows of pixels—on one monitor, using polarization and polarizing filters to determine what reaches each eye.

Where this involves looking directly at the monitor, co-location of the handheld sensor and of the visually perceived position of the objects that it controls require that the hand and sensor be placed between the user's eyes and the display. This allows the hand to block the user's view of displayed objects whose intended position is nearer the user's eyes, rendering the perceived 3D relationships inconsistent. It is therefore better for the user to see an image of the display screen in a reflecting surface, which can hide the hand(s) and sensor(s); the hand-held tool is visually represented within the display as a graphical object, so that normal graphics produce a consistent view of what objects are nearer and further. The image should appear within the user's natural work volume, preferably with support for the hand and arm to reduce fatigue.

A number of such systems have been proposed, in the patent and open literatures. The earliest is in a paper by Schmandt [1982]; an identical configuration (still without arm support) is included in a patent by Deering [1993]. Several papers by Serra, Poston *et al.* report work on a similar configuration, as does Blackwell *et al.* [1995]. All involve a downward-facing monitor supported above the user's head height by a substantial frame, with a reflecting surface that is either horizontal or sloping upward in the direction forward of the user. The result is a wide, high system that requires considerable desk or laboratory space, and does not allow the user access to the monitor for normal desktop-computer purposes. (Its reflected image is more conveniently placed, but upside down; software specialized to this environment adjusts for this, but standard software becomes unusable.)

The invention here disclosed, in contrast, is constructed around a monitor in the normal position (and hence usable both for 3D interaction and for routine editing, etc.), with movable structure between screen and user that adds little to the desk area used. Position sensors and (optionally) force-feedback interaction tools are integrated with the display.

SUMMARY OF THE INVENTION

The invention is a system which slopes a reflecting surface downward away from the user, rather than upward. A screen in a standard position—upright or near it—creates a reflected stereo image in the region of maximum user dexterity. Following earlier systems, a six-degree-of-freedom position sensor (optionally supplying force) in each hand controls a virtual tool, that appears in the reflected image to be where the sensor is held, and interacts with the other displayed objects in ways controlled by application software using code supplied with the system.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic side view of the relative positions of the real display screen, the mirror, the frame supporting the mirror and the fixed elements of the sensing system, the optional robot arm applying force to a hand-held sensor, real and virtual light rays between the user's eye and the real and virtual (reflected) display screen, the apparent positions of a virtual tool and a virtual object for a user looking at the real or virtual screen, and the filters (different for the two eyes) which enable a stereo pair of images to be delivered to the user's eyes.

Figure 2 shows a three-dimensional view of the same physical structures, omitting the real and virtual images.

DETAILED DESCRIPTION OF THE INVENTION

The reach-in display system incorporates screen (1) in an upright position (that is, in the normal attitude range for desktop computers), capable of stereo display under control of computer graphics hardware. Mounted in front of (1), in such a position that either (a) the user can look over it and see the screen in the usual way, or (b) the mounting can be swivelled out of the way, is a light frame (2). Held in each of the user's hands is a position-sensing device (3). The location and orientation of (3) relative to a fixed reference device or devices (4) can be deduced from controlled signals emitted by, and/or signals received by, (3) or (4) or both; each device (3) carries (5) one or more buttons (which report "pressed" or "unpressed" states and transitions between these) or scaled input devices (which report user-controlled values in a continuous range). The coupling between (3) and (4) may be through one detecting emissions or reflections from the other, or by a mechanical connection (6), which may detect force applied by the user and may transmit force felt by the user. (In implementations where position determination is based on camera observation of (3), emission of energy detected by (3), or detection of energy emitted by (3), there may be several of the fixed units (4). Where the linkage is mechanical, a single attachment point per position sensor is sufficient. In a hybrid system using mechanical linkage for one hand only, in particular to deliver force, an emission-detection system supporting the sensor used in the other hand can also determine the base point of the mechanical system, which need not therefore be rigidly linked to the screen in one permanent position.) The frame (2) supports a mirror (7) sloping downward from the user, so that the user can see within the natural work volume a displayed stereo image in the virtual image (8) of the screen (1). (The two-point attachment of the frame and mirror in Figure 1 is for clarity; other support arrangements, and methods of permitting the structure to be rotated out of the way, are obvious to one skilled in the art. The attitude of the mirror is important, but it can be held there in many ways.) A surface sloped like a drafting table, with or without a central hole that allows the hands and the sensors (3) to move below its main surface, may be added for better support of forearms and wrists. Filters (9) control which screen images are visible to which eye, so that software can present the appropriate view to each eye to generate in the brain a stereoscopic combined image, whose elements have perceived depth. The filters (9) may be mounted on the

frame, or worn by the user as glasses. (Optionally the head may be tracked for better correspondence between the user's eye positions and the viewpoints for which the left and right view are rendered; but if the rendering delay is long relative to head movement speed, this option is counter-productive.) The position reference devices (4) may be mounted on the frame (2), directly on the monitor, or otherwise rigidly linked to the monitor. Software performs the relative position deduction, allowing a virtual object called a "tool" (10) to appear to the user in the display (7) at the location corresponding to the physical position of (3), by creating in the real screen a stereo image (11) at the apparent position shown. An overall control loop allows an application program in the computer (12) to determine when (10) is to interact with a virtual object (13) generated or managed by the application program (for example, when (10) is close to (13) and a button (5) is clicked or held down), upon which the program modifies the position of the object, the relative position of its parts, the properties logically assigned to it (linkage to other objects, stiffness, toxicity, ore concentration, or whatever the application requires), or the way that all or part of it is displayed, according to the needs of the application and the choices made by the user.



CLAIMS

1. The rigid placement of a downward-sloping reflecting surface in front of an upright computer-generated stereo display, to produce a stereo view with a virtual screen centred in the user's natural work volume.
2. The same, where the surface is partially reflecting, so that the computer-generated display is superimposed on objects physically present.
3. The same, where the display requires passive or computer-synchronized filters (mounted on the system or on the user's head) that control which eye receives which view.
4. The same, with support for wrists, forearms and elbows.
5. The same, with emitters (mounted rigidly with respect to the display) of energy ultrasound or electromagnetic, which can be detected by sensors on a device in each or either hand, and permit computation of the position and orientation of the device.
6. The same, with rigidly mounted cameras observing the position of a device in each or either hand, with image analysis software to compute the position and orientation of the device.
7. The same, with emitters of energy ultrasound or electromagnetic mounted on a device in each or either hand, and fixed sensors of these emissions that permit computation of the position and orientation of the device.
8. The same, where one or more cameras are mounted on a device in each or either hand, and standard objects easily recognizable by software are rigidly mounted, so that the position and orientation of the device can be computed from the camera views.
9. The same, where the device in each or either hand is attached to a robot arm from whose joint angles the device position is computed and reported to the computer.
10. The same, where the robot arm detects forces applied by the user, and/or delivers computer-selected forces to the device in the user's hand.
11. The same as (5-9), where the handheld device carries buttons, or rotating or sliding attachments, by moving which the user can signal to the computer.
12. The same as (5-9), where the computer-generated display includes an image of a tool at the position and orientation currently reported for the device in each or either hand.