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(54) Title: METHOD AND APPARATUS FOR CONTROLLING THE MOVEMENT OF A VIRTUAL BODY

(57) Abstract

A virtual body modelling apparatus and method are described, in which a user's body is modelled in a virtual environment and animated to follow physical movements of the user. Stores (30, 32) hold data defining the virtual environment as well as features of the virtual body representation, including sequences of virtual body motions (for example a walking sequence for the legs of the virtual body) which sequences are initiated in response to one or more predetermined physical movements by the user, and animated by a display generator (28) providing images of the virtual environment to the user. Various forms of feedback to the user are provided, including force feedback where the user's physical movements are constrained in dependence on conditions within the virtual environment, visual feedback where the user's viewpoint of the virtual world is modified as a sequence of body motions is executed, and audio feedback (62) such as the sound of footsteps triggered at predetermined points in the sequence of motions.
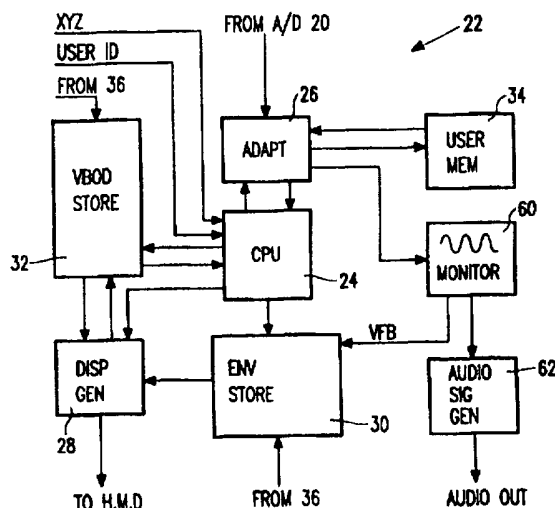
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DESCRIPTION

Method and apparatus for controlling the movement
of a virtual body

5   The present invention relates to a method and apparatus for controlling the movement of a virtual body, where the virtual body is a computer-based model that represents the human, or other, form in a computer-generated virtual environment.

10   The form taken by the virtual environment will depend on the intended use of the system and may, for example, comprise the interior of a building for an architectural modelling application, or urban or surreal landscapes for games or other applications, around which environment the virtual body controlled by the user is moved. In the following, the term "virtual environment" will be used
15   for such virtual landscapes or situations: the term "physical environment" will be used to denote the 'real-world' surroundings of the user, for example a room in which the user contacts the various hardware devices, such as a head-mounted display (HMD), which provide the interface to the virtual environment. The terms "virtual body" and "physical body" should be construed accordingly.

20   One example of a control device in the form of a haptic glove is described in International Patent Application WO92/18925 (W. Industries). Within the virtual environment (viewed for example via HMD) the users hand appears as a cursor which undergoes changes corresponding with movement and flexure of the users hand. Contact between the cursor and objects within
25   the virtual environment is simulated by inflating cushion portions of the glove to give a sensation of touch. Whilst the haptic glove is useful for techniques such as hands-on molecular modelling, within a virtual world where the object is to provide a sense of visual realism for the user, the changeable cursor (and the lack of the rest of a body) can detract from the users feeling of immersion.
30   A far more complex system, for generating and processing synthetic real-time environments is described in International Patent Application

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WO95/11479 (Redmond Productions). In the system described, the user is placed in a closed physical environment within which all the interaction occurs. On first use, a detailed virtual body for the user is built up, the process making use of detailed position sensing means within the physical environment to form a 'wire-frame' model of the users body. Onto the wire frame, the virtual body is built up to a high density image with shading and hidden surface removal using a library of stored male and female body parts of all shapes and ages. In order to provide stimuli to the user (in addition to stereo imaging and audio through an HMD), the closed chamber includes a number of interaction apparatuses including a variable resistance treadmill, tactile output devices (pixel-addressed banks of rods which can be pushed out to form shapes or surface textures) and a "cybercycle" vehicle simulator.

Whilst this latter system may provide the user with a high degree of immersive realism, the processing power required to generate and animate the virtual body in addition to generating the virtual environment is extremely high.

It is therefore an object of the present invention to provide a system for modelling a virtual body within a virtual environment, and controlling the movements of the virtual body in response to user body movement, which system is relatively simple to implement whilst providing acceptable (or better) levels of realism.

It is a further object of the present invention to provide, in such a system, easily implementable mechanisms for supplying feedback from the virtual environment to a user.

In accordance with the present invention there is provided a virtual body modelling apparatus operable to generate and animate under user direction a representation of a body in a virtual environment, the apparatus comprising: a first data store, holding data defining the virtual environment; a second data store, holding data related to features of the virtual body representation; user motion detection means; and processing means arranged to generate a

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representation of the virtual environment based on data from the first data store, to generate the body representation within the virtual environment based on data from the second data store, and to periodically modify the generated body representation in response to signals received from the user motion detection means; characterised in that the second data store holds data defining at least one sequence of body motions, and the processor is arranged to call said sequence data and modify the generated body representation such as to follow the sequence of motions on detection of one or more predetermined signals from the user motion detection means.

By the use of pre-stored sequences of body motions (for example a walking sequence for the legs or a waving sequence for an arm) the need to monitor user movements and update the generated image of the virtual body to exactly follow the users execution of these movements is greatly reduced. Different speed sequences may be provided for a given body motion, or means may be provided to control the speed at which a sequence is reproduced.

The apparatus may suitably include means operable to generate feedback to the user to enhance the realism, with the feedback being generated in relation to the following of the sequence of motions, and at one or more predetermined points in the sequence. Such feedback may take a number of forms, including force feedback where means may be arranged to provide controllably variable resistance to movement of the users physical body, such as to simulate difficult conditions in the virtual environment. Another possible form of feedback is audio feedback (for example the user hearing the sound of his/her footsteps in the virtual world) with the apparatus including audio signal generation means and the feedback comprising an audio sequence generated at a predetermined point or points during the sequence of motions. A still further form of feedback is visual feedback which may be provided where the user is presented with the image of the virtual environment from a first viewpoint, and the generated representation of the virtual environment is modified to change the viewpoint in synchronism with the following of the sequence of motions.

As will be described hereinafter in terms of an exemplary embodiment, the motion detection means may comprise a restraint coupled to a rotatable shaft and attachable to a users limb, with movement of the restraint by the user producing rotation of the shaft and the user motion being derived from the angular deflection of the shaft. With such an arrangement, force feedback may be provided in the form of an electro-magnetic coil or the like to generate a torque opposing rotation of the shaft.

Also in accordance with the present invention there is provided a method for user-directed animation of a computer-generated representation of a body in a virtual environment, comprising the steps of: determining an initial position for the virtual body within the environment, rendering an image of the body within the environment and presenting it to a user; monitoring movement of the user in a physical environment and translating said movement into movement of the virtual body relative to the virtual environment; and periodically updating the rendered and presented image; characterised in that at least one pre-stored sequence of body motions is provided, and the generated body representation is modified such as to follow the sequence of motions on detection of one or a predetermined sequence of physical motions by the user. The rate of modification of the generated body representation may suitably be determined by a filtered (for example time averaged) value for speed of user movement, such as to result in a smooth movement of the virtual body, unaffected by short hesitations or the like on the part of the user.

Further features and advantages of the present invention will become apparent from reading of the following description of preferred embodiments of the invention, by way of example only, and with reference to the accompanying drawings, in which:

Figure 1 is a plan view of a foot axial motion measurement device:

Figure 2 represents a first data processor arrangement for translation of direct measurement to virtual body motion;

Figure 3 represents an alternative data processor arrangement for the

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translation of indirect measurement to virtual body motion; and

Figure 4 is an alternative configuration of foot axial motion measurement device enabled to provide force feedback to the user.

5   The following description is specifically concerned with modelling and controlling the legs of a virtual humanoid body that a user or participant in a virtual world may control, with the mechanism for control of the leg movements of the virtual body being directed by measured movement of the users legs. As will be readily appreciated, many of the techniques described may also be
10   used for controlling movement of the arms and head of a virtual body.

The arrangement for measuring the movement of the human legs is via an apparatus which translates the current physical position of at least one point on the users legs into a measurement appropriate for input to a data processor. A first embodiment of such an apparatus is shown in Figure 1 and comprises
15   an arrangement of footrests 10 pivotally connected to opposite ends of an arm 12, which arm is connected to a perpendicular central shaft 14, such that the left and right footrests may be rotated about an axis along the shaft 14. Stops 16 limit the extent of rotation and the degree of rotation of the shaft 14 around its axis is measured by means of a potentiometer 18 which provides a variation
20   in current or voltage with rotation that then may be passed via an appropriate analogue-to-digital (A/D) converter 20 providing a digital signal representative of the deflection for input to a data processor 22. Other inputs to the processor 22 may be provided for input from mass storage 36 (e.g. CD-ROM), additional user positioning data (XYZ), and identification codes (USER ID).

25   As will be understood, other angular position sensing means may be used in preference to the potentiometer to generate a deflection signal for supply to the data processor. It will also be recognised that, whereas the above system of measurement gives a single value at each measured instant for both the left and right legs, the position of each leg might be measured
30   independently.

Once this measurement relative to the human leg positions has been

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made, it must next be translated into a walking motion of the virtual body. The translation is carried out by the data processor 22 which, as shown in Figure 2, is based around a central processor unit (CPU) 24 which receives the digitised rotational measurement from the A/D converter 20 (Fig.1), optionally via an adaptive mechanism 26 to be described. Generation of the virtual environment is handled by a display generator stage 28 under direction of the CPU 24 and using data from an environment data store 30. This data store 30 may be of limited size (to allow fast access) holding only the data describing the area of the environment where the virtual body is currently situated: as required, this data store 30 may be updated from mass store 36 (Fig.1).

The current user position and orientation in respect of the virtual world may optionally be based on external inputs XYZ from position sensors monitoring user movement or, in a simpler implementation, the height of the user viewpoint within the virtual environment may be substantially fixed, with the horizontal location and orientation for the virtual body being determined relative to a set starting position purely on the basis of the input from the rotation sensor 18 of Figure 1.

A first method for simulation of the walking motion of the legs is to use a mathematical model of walking human legs (held in a store VBOD 32 of the data processor 22) from which the CPU 24 derives the actual position and orientation of each of the joints of the virtual leg within the virtual environment from the position of the users foot or leg (based on the rotary measurement) within the physical environment. For example, with the apparatus of Figure 1, the feet (and hence the ankle joints) follow a constrained path. The mathematical model may suitably specify movements in relation to an origin point (the location of which may be specified from input XYZ) such as the centre of the pelvis. There may be some rotation of the hip joints about the origin point specified or allowed for in the model and the movement of the legs is defined by the relative positions of the hip and ankle joints, the lengths of the upper and lower leg, and the maximum permitted range of relative movement of the parts about the joints in two or three dimensions.

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From the determined relative positions of the leg components, the display generator 28 generates a representation of the legs as they appear in the virtual environment, suitably on the basis of additional data from the VBOD store 32 specifying the appearance of the individual components.

An alternative method uses a stored sequence held in the VBOD store 32 (instead of the mathematical model) which sequence is composed of a set of frames of possible leg positions for display within the virtual environment by the display generator 28. When cycled through, the sequence of frames give the appearance of a walking motion. A number of such sequences might be held in the VBOD store 32, representing various walking speeds, with the CPU 24 selecting which is to be used on the basis of the input from the apparatus of Figure 1. Alternatively, where a single sequence is held, the display generator 28 may be controlled to selectively drop frames to give the appearance of something walking faster, or selectively repeat frames for slower walking. Interpolation between frames to give a smoother walking action may also be provided where the display generator has the capability.

A first method for achieving the translation between physical measurements such as the output from the potentiometer 18 of Figure 1 and action in the virtual world is to directly map the measured or derived position of the human legs onto a representation of the virtual human legs, which may be chosen via either of the two methods described above - that is to say deriving the current virtual leg model from a mathematical model, or choosing the most appropriate leg model from a pre-stored set or sequence of such models. A possible problem with this approach lies in the action of individual users when exposed to the measurements: some will make strong walking motions, whilst others will make weak shuffling motions, and some may stop for short periods of time. This can translate into an erratic appearance to the walking motion of the virtual body.

In order to improve this approach, adaptive mechanism 26 is included at the positional measurement input to the CPU 24 as shown in Figure 2. This mechanism adapts on the fly to the measurement apparatus output, to translate

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the users erratic, variable measurements into a steady walking motion. Any of a number of adaptive mechanisms, such as adaptive filters and neural networks, may be used. In operation, the physical movement corresponding to putting a particular foot on the ground may be used as a key, with the generated or modelled sequence of virtual leg motions taking its timing from the key - regardless of what irregular motions the user legs may make between keys. Certain irregularities or features of a particular users walking action (for example whether the user has a limp or takes relatively short steps) may suitably be learnt by the adaptive mechanism 26 and these adaptive mechanism settings (what it has learned about the current user) may be stored in a user memory 34, and recalled when the CPU 24 determines from a USER ID signal that that particular user has access to the system once again.

An alternative to the above technique is an indirect approach as shown in Figure 3: those features performing the same function as in Figure 2 are identified by the same reference numeral and will not be described again. Here the input from the user measurement device of Figure 1 is passed to an arithmetic stage 40 which derives measures of speed and acceleration based on the input users walking motion. These are then translated via some pre-specified relationships into a speed for the walking virtual body. This speed of the virtual body is then passed via the CPU 24 to the display generator 28 where it is used to determine movement of the user viewpoint within the virtual environment, and also to calculate the positions of the legs for the virtual body. In the case of the above-described technique using a number of pre-stored sequences of animations representing a walking motion, the calculated speed from stage 40 is used to determine the offset into a look-up table 42 that indicates which sequence should be used at the current speed, with the derivations of the leg position from CPU 24 determining the state of the walking process. It may also be desirable to have the adaptive mechanism 26 in place in this system, as for the direct approach described above.

In order to enhance the user-perceived realism of the virtual environment in which the user is walking, force feedback may be provided to the user. The

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purpose of the force feedback is to make it harder or easier for the user to move in the physical environment. For example, where leg movements are being measured, a mechanism may be provided which can act against, or inhibit, the users physical leg movements. Such feedback would be useful to give the impression of tiring or weakening, or of walking over a more demanding environment or uphill.

An example means of providing force feedback to a users legs, with reference to a modified version of the mechanical measurement system described with reference to Figure 1, is shown in Figure 4. The data processor 22 running the simulation controls a variable current source 46. The shaft 14 on which the measurement device is mounted also comprises the rotor of an electromagnetic device 48, arranged such that when a current is supplied to the device 48 from the current source 46, it requires a greater force to rotate the shaft 14 around its axis. Thus the data processor 22 may vary the current to provide a greater or lesser degree of inhibition to the users physical walking motion.

The arrangement of Figure 4 also enables the user to adopt a more natural walking style than that of Figure 1, with the footrests 10 constrained to run along respective parallel paths by loop portions 50 descending from each footrest through a respective slot 52 in a horizontal platform 54. The underside of each footrest 10 may be provided with rollers, or low friction materials may be used for the sole of the footrests 10 and the upper surface of the platform 54. The lower part of each loop portion 50 receives a respective end of the arm 12, with the pivot axis of the arm (the axis of shaft 14) being set midway between the slots 52 and halfway along their length.

By use of elongate loop portions 50, together with straps 56 across the top of each footrest 10, the user may lift his/her feet whilst executing the walking motion, rather than being required to adopt the 'skiing' technique required by the apparatus of Figure 1. As will be recognised, the arrangement of Figure 4 will exaggerate (in terms of the output signal) the usual tendency for the foot to be moving fastest midway through a stride: this exaggeration

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may suitably be compensated for by the CPU or adaptive mechanism of the data processor 22.

Returning to Figure 2, as a means of enhancing the perceived realism, the viewpoint of the user (when it coincides with a view seen from the virtual walking character) may be modulated in relation to the walking action. A simple means to implement this is for the adaptive mechanism 26 to evaluate a sine function based on averaged or key user inputs (as described above), with the amplitude of the sine function being a measure of the state of the walking motion, and the measure being periodic with relation to a footstep. This sine function is supplied to a monitor stage 60 and a proportion of the value of the sine function from the monitor stage is then added to the viewpoint and direction via the environment data store 30 as shown (signal VFB) or via the CPU 24, to give the appearance of up/down/sideways movement of the field of view as is experienced when walking in the real world. The sine function (or other means of providing a suitable periodic measurement suitable for input to the viewpoint/direction) may instead be stored in a look-up table and indexed at key points in the users movement cycle, rather than being locally generated.

Another form of feedback supported is audio cues to provide an additional sense of immersion and feedback to the user. In order to generate the sound of footsteps for example, an event driven approach may be used. Here a footstep sound is generated by audio signal generator 62. The sound is triggered twice during each cycle through a walking motion (once for each foot): this corresponds to once per cycle for the sine wave from monitor circuit 60 on the basis of which the viewpoint is changed. In the system described here, a measurement of the human walking motion may be used not only to initiate a number of different techniques for rendering of the users virtual limbs in the virtual environment, but also to trigger and direct force, visual and audio feedback to the user.

From reading the present disclosure, other modifications and variations will be apparent to persons skilled in the art. Such modifications and variations may involve other features which are already known in the art and which may

be used instead of or in addition to features already described herein. Although claims have been formulated in this application to particular combinations of features, it should be understood that the scope of the disclosure of the present application also includes any novel feature or combination of features disclosed

5   herein either explicitly or implicitly, whether or not relating to the same invention as presently claimed in any claim and whether or not it mitigates any or all of the same technical problems as does the presently claimed invention. The applicants hereby give notice that new claims may be formulated to such features and/or combinations of such features during prosecution of the present

10   application or of any further application derived therefrom.

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CLAIMS

1.   Virtual body modelling apparatus operable to generate and animate under user direction a representation of a body in a virtual environment, the apparatus comprising:

a first data store, holding data defining the virtual environment;

a second data store, holding data related to features of the virtual body representation;

user motion detection means; and

processing means arranged to generate a representation of the virtual environment based on data from the first data store, to generate the body representation within the virtual environment based on data from the second data store, and to periodically modify the generated body representation in response to signals received from the user motion detection means;

characterised in that the second data store holds data defining at least one sequence of body motions, and the processor is arranged to call said sequence data and modify the generated body representation such as to follow the sequence of motions on detection of one or more predetermined signals from the user motion detection means.

2.   Apparatus as claimed in Claim 1, further comprising means operable to generate feedback to the user, said feedback being generated in relation to the following of the sequence of motions, and at one or more predetermined points in the sequence.

3.   Apparatus as claimed in Claim 2, further comprising force feedback means arranged to provide controllably variable resistance to movement of the users physical body.

4.   Apparatus as claimed in Claim 2, including audio signal generation means, wherein the feedback is an audio sequence generated at a

predetermined point or points during the sequence of motions.

5.   Apparatus as claimed in Claim 1, wherein the user is presented with the image of the virtual environment from a first viewpoint, said generated representation of the virtual environment being modified to change the viewpoint in synchronism with the following of the sequence of motions.

6.   Apparatus as claimed in Claim 1, wherein the motion detection means comprise a restraint coupled to a rotatable shaft and attachable to a users limb, wherein movement of the restraint by the user produces rotation of the shaft and the user motion is derived from the angular deflection of the shaft.

7.   Apparatus as claimed in Claim 6, further including force feedback means operable to generate a torque opposing rotation of the shaft.

8.   Apparatus as claimed in Claim 1, wherein the second data store holds data defining a plurality of sequences of body motions in respective areas of a look-up table, the processing means is configured to derive a speed value from the input from the user motion detection means, and said speed value is used to index the look-up table.

9.   A method for user-directed animation of a computer-generated representation of a body in a virtual environment, comprising the steps of:
    determining an initial position for the virtual body within the environment, rendering an image of the body within the environment and presenting it to a user;
    monitoring movement of the user in a physical environment and translating said movement into movement of the virtual body relative to the virtual environment; and
   periodically updating the rendered and presented image;

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characterised in that at least one pre-stored sequence of body motions is provided, and the generated body representation is modified such as to follow the sequence of motions on detection of one or a predetermined sequence of physical motions by the user.

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10.   A method as claimed in Claim 9, wherein the rate of modification of the generated body representation is determined by a filtered value for speed of user movement.
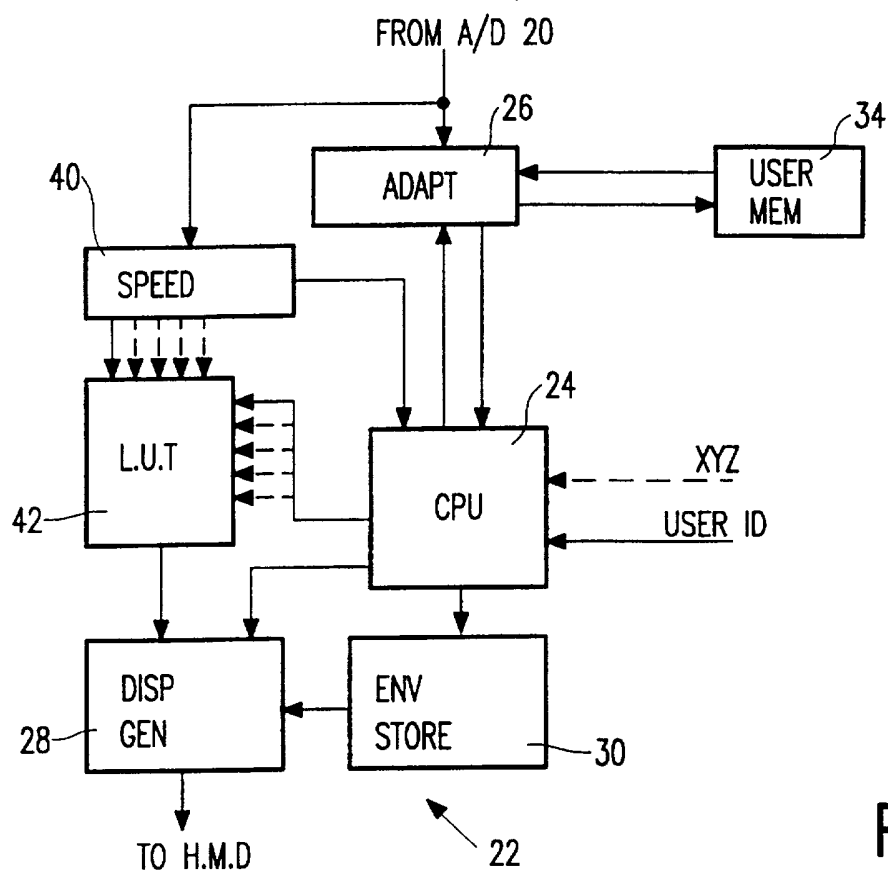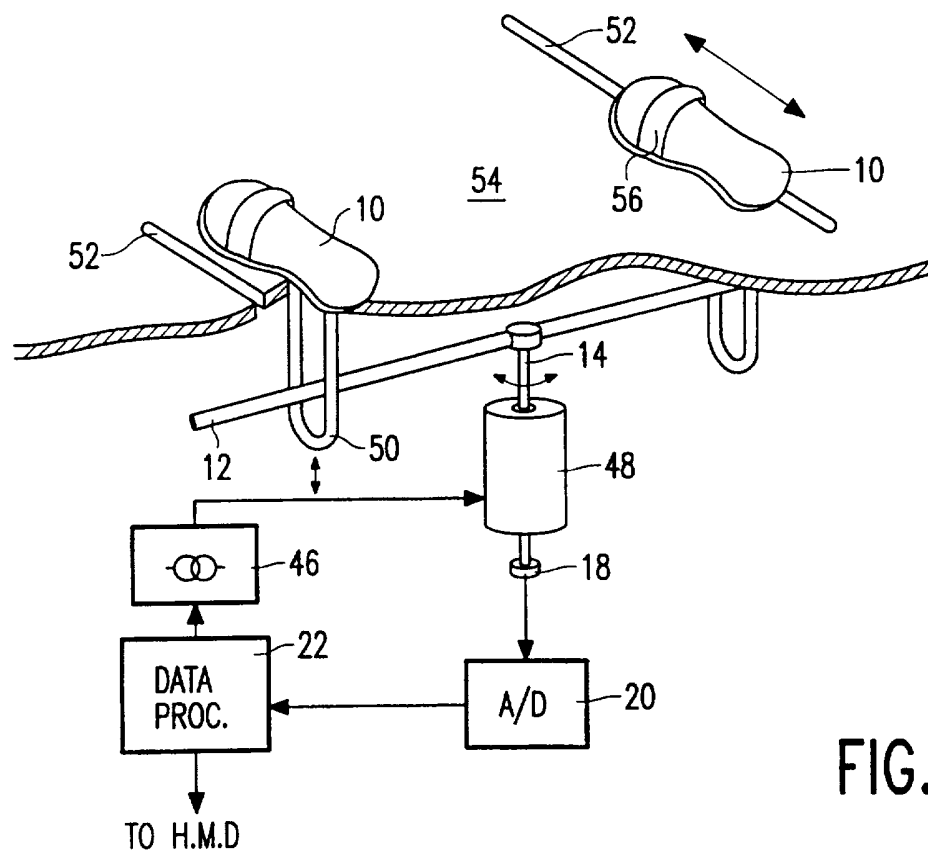
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FIG. 1
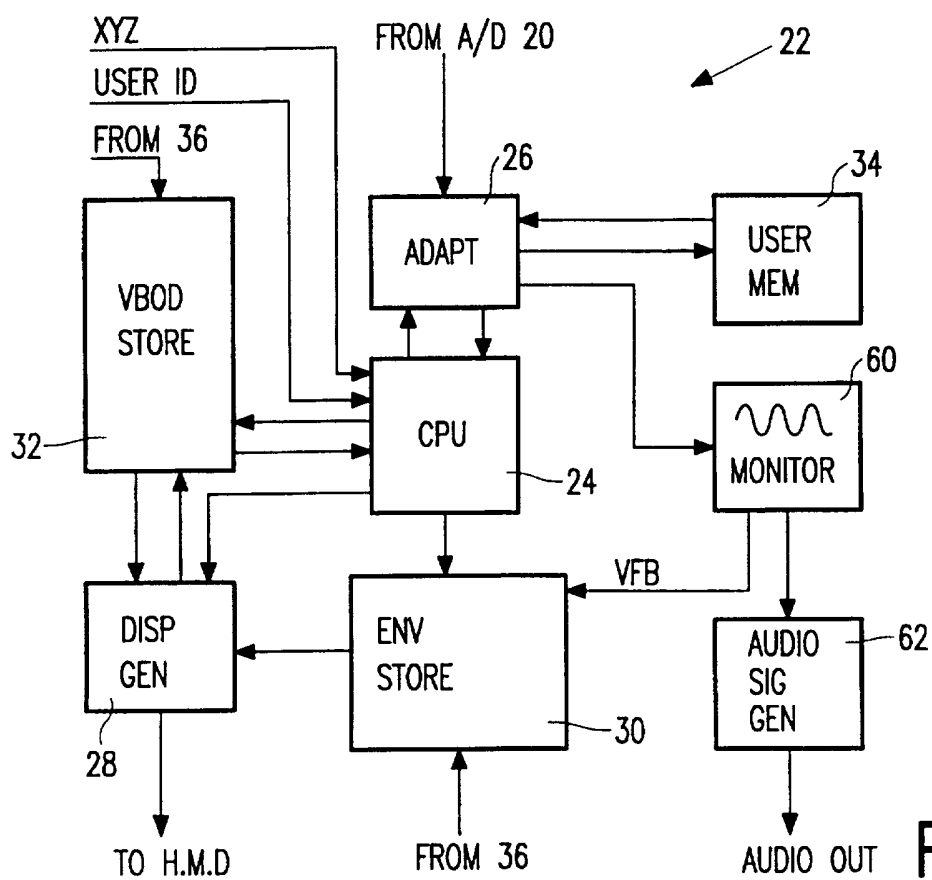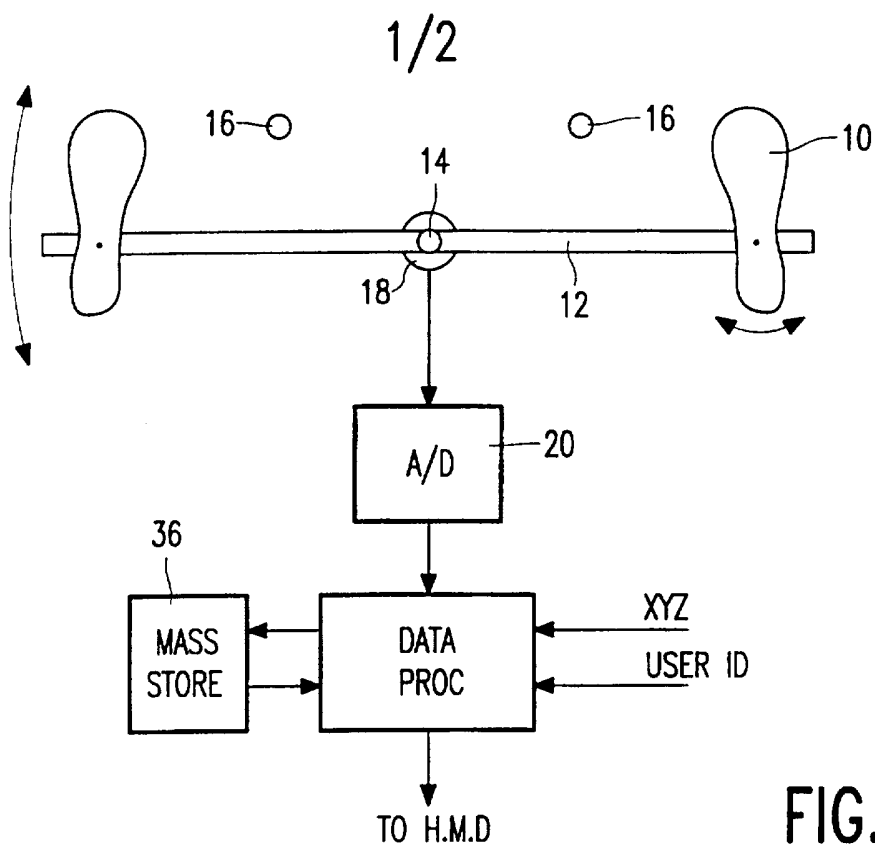
FIG. 2

FIG. 3

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB 96/01225

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G06F 3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	WO 9508793 A1 (VIRTUAL UNIVERSE CORPORATION), 30 March 1995 (30.03.95), page 2, line 12 - page 3, line 16; page 4, line 31 - page 5, line 22; page 12, line 7 - line 27 --	1,2,4,5,9
A	US 5255211 A (SCOTT REDMOND), 19 October 1993 (19.10.93), column 2, line 61 - column 4, line 23 --	1-10

X	Further documents are listed in the continuation of Box C.	X	See patent family annex.

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10 March 1997	13 -03- 1997

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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB 96/01225

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5389865 A (CHARLES J. JACOBUS ET AL), 14 February 1995 (14.02.95), column 2, line 26 - column 3, line 22 -- --------	1-10

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