7.2 Self-Motion Interfaces

Self-motion interfaces are defined as those cases where the user moves himself through a VE, as opposed to being passively moved in some type of vehicle. Currently the illusion of self-motion through a VE is supported by generating visual displays that represent some concept of “flying” when the user points a finger or some type of wand in the direction he wishes to travel. Undoubtedly, there are many types of application for which such interaction is ideal, but flying through an environment may well give a different perspective and less detailed knowledge of the environment than that which can be acquired by walking through it. In particular, locomotion is needed to acquire accurate information about surface characteristics such as resilience, slope, and texture. It is also essential for time-related information, in those cases where visibility is limited in some fashion, or when a user is required to exert the types of energy he would in performing actions in the physical world. These differences will be critical when VEs are used in applications such as special operation forces mission rehearsals.

7.2.1 Commercial Products

The interface mechanisms commonly used to control VE flying are the whole hand input and pointing devices discussed in Section 5.1 and Section 5.2; these are not mentioned further here. Likewise, exercise systems that link conventional exercise equipment with the 2-D presentation of scenery on a CRT are not considered representative of VE systems and also excluded. Instead, this section discusses a range of novel types of interface devices (such as gyroscopes, hang gliders, and interactive motion platforms) that only recently have become commercially available and that provide kinesthetic motion feedback.

Human gyroscopes allow a user to rotate his body axis freely in 6 DOFs and are available from Aerotrim USA, Inc., Orbotron, Inc., RPI Entertainment, and StrayLight Corporation. With appropriate position tracking of body movements, these devices allow other interface displays to be coordinated with the user’s movement. Virtual Images’ CyberPak allows the user to turn freely in any horizontal direction while he controls his rate of forward or backward motion through a hand-held controller. A hang glider is available from Dreamality Technologies, Inc. and Trailcraft Manufacturing Ltd. This device allows a representation of gliding through a VE, with the direction of motion controlled by the user turning his body and pushing on some type of bar. Information on a second hang glider, marketed by CyberEvent Group, Inc., was not available. A motion platform manufacturer, Denne Development Ltd. (DDL) has developed products that offer new ways of full-body interaction. By making the motion platform itself responsive to changes in the user’s center of gravity, and providing information on these changes to the VE system, these interactive platforms also allow coordination with other interface displays. The final product discussed is a very different type of interactive motion base system developed by RPI Entertainment. The characteristics of these various products are summarized in Table 18.

Table 18. Characteristics of Commercially Available Self-Motion Products

Product	Vendor	Device Type	Range of Motion	Additional Provided Interface Equipment	Price
Aerotrim	Aerotrim USA, Inc.	Gyroscope	360° pitch, roll, yaw	None	$7,995
CyberPak	Virtual Images, Inc.	Revolving backpack	360° horizontal	HMD, head tracker, 3-D localized sound display	$31,500
CyberTron	StrayLight Corporation	Gyroscope	360° pitch, roll, yaw	HMD, head tracker, sound display	$54,000
DreamGlider	Dreamality Technologies, Inc. and Trailcraft Manufacturing Ltd.	Hang glider	~60° horizontal	HMD, sound display	$26,700
Orbotron	Orbotron, Inc.	Gyroscope	360° pitch, roll, yaw	None	$10,000
X-otron VR	Orbotron, Inc.	Gyroscope	360° pitch, roll, yaw	HMD, head or ring tracker, 3-D localized sound display, hand controllers	$27,000[a]
Supertron	Orbotron, Inc.	Gyroscope (2-man)	360° pitch, roll, yaw	None	$14,500
PemRAM 3 Axis Motion Base	Denne Developments, Ltd.	Interactive motion platform	42° pitch, 40° roll, 360mm heave	None	$27,000
PemRAM 6 Axis Motion Base	Denne Developments, Ltd.	Interactive motion platform	40° pitch, 40° roll, 50° yaw, 0.4m heave, 0.4m sway, 0.45m surge	None	$50,000
SimuPod	RPI Entertainment	Rotational	360° pitch, roll, yaw	Visual display (various), 3-D localized sound display, hand controllers, "rumble and thump" generators	From $30,000
SimuSled	RPI Entertainment	Forward tilting motion platform	100-360° pitch, 10-45° roll, (optional 360° yaw, shift motion axis)	Visual display (various), voice recognition, 3-D localized sound display, hand controllers, "rumble and thump" generators	$14,000

a. The motorized, interactive version starts at $35,000.

7.2.1.1 Aerotrim

Aerotrim USA, Inc. developed their patented gyroscope motion platform, Aerotrim, for use as an exercise machine, although it has since been used for a variety of purposes ranging from aiding pilots to overcome airsickness and disorientation to therapeutic treatment for neurological disorders. It has also been used by Sportsland America and others as a means of user navigation in VEs.

The Aerotrim is a free-standing gyroscope that allows the user to control whole body orientation in any direction. A photograph and some specification details are given in Figure 103. The Aerotrim base price is $7,995.

Specification	
Floor Space	9.5 ft diameter circle
Device Height	9.5 ft
User Range of Motion	360° pitch, roll, yaw
Device Weight	750 lb
Max. Payload	275 lb
User Size	3.5 to 6.5 ft

Photo courtesy of Aerotrim USA, Inc.

Figure 103. Aerotrim

7.2.1.2 CyberPak

CyberPak from Virtual Images, Inc. is another interface system designed to allow a user to navigate through a VE. The user stands on a stationary platform, positioned against a NASA-like space pack, and holds a hand grip and control buttons attached to the pack via arm structures. He is free to turn in any horizontal direction and controls forward and backward motion through the VE by pushing or pulling on the hand grip. The system is controlled by a Pentium PC with a Division image generator. A choice of HMDs is available, supported by head tracking. CyberPak also includes 3-D binaural sound spacing for its audio interface. Figure 104 provides some specification details.

Specification	
Floor Space	6 x 9 ft
Device Height	7 ft
User Range of Motion	360° horiz
Device Weight	~400 lb
Max. Payload	> 1,000 lb
User Size	19 in width

Figure 104. CyberPak

The system primarily is intended for use in entertainment applications and comes with a TV monitor for external audience viewing and one game (additional games will shortly be added). Virtual Images, Inc. also see CyberPak being used in diverse applications ranging from training to therapy for fear of heights. Currently only supporting individual users, a networking capability is expected to become available in Spring ‘96. The price for CyberPak starts at $31,500.

7.2.1.3 CyberTron

The CyberTron system, developed by StrayLight Corporation, provides a VE interface that combines visual (using a Liquid Image HMD) and auditory feedback with user motion. Motion is supported by a gyroscope motion platform, chiefly used so that the user can simulate flying through a VE. A Polhemus Isotrak II is used for head tracking so that user movements can be monitored and used in the generation of visual displays. A photograph of the CyberTron and further details are given in Figure 105.

Specification	
Floor Space	80 sq ft
Device Height	8.5 ft
User Range of Motion	360° pitch, roll, yaw
Device Weight	750 lb
Max. Payload	~300 lb
User Size	Up to 6.25 ft

Photo courtesy of StrayLight Corporation

Figure 105. CyberTron

StrayLight Corporation has developed three standard games for use with CyberTron, including one game that allows competitive play between users in up to four networked CyberTron systems. CyberTron, including HMD, tracker, and one game is priced at $54,000.

7.2.1.4 DreamGlider

The DreamGlider system from Dreamality Technologies, Inc. and Trailcraft Manufacturing Ltd. provides the experience of hang gliding through a VE. It comprises a trapeze support system that provides the sensation of vertical motion to the user, who rests in a supporting sling and controls the direction of the glider by forces he exerts on a control bar. The system runs on a Pentium-based PC, augmented with a Synthetic Images Reality Blazer image generation board and an Advanced Gravis Ultrasound card. Currently, it uses a modified Virtual I/O HMD, although Dreamality Technologies in collaboration with Forte Technologies is developing their own HMD that is expected to be introduced later in ‘96. A photograph and some specification details for the system are given in Figure 106. The price for a single DreamGlider system, including one hang gliding game, is $26,000.

Currently, three special effects are being developed to augment the VE experience. The first of these is a smell capability, expected to allow the release of up to four different scents as

Specification	
Floor Space	7 x 8ft
Device Height	7 ft
User Range of Motion	Side-to-side, forward-back, and sway movements typical in hand gliding
Device Weight	500 lb
Max. Payload	325 lb
User Size	N/A

Photo courtesy of Dreamality Technologies, Inc. and Trailcraft Manufacturing, Ltd.

Figure 106. DreamGlider

a user flies through certain areas in the VE. The second effect will be the addition of a hydraulic servo motor capable of raising and lowering the DreamGlider device to provide the sensation of lift. Finally, fans will be included to generate the sensation of a breeze.

Originally designed as an entertainment system, the DreamGlider system is being upgraded for use as a hang gliding trainer. The current system starts the hang gliding experience with the user stepping off a cliff. For training applications, the user needs to be able to run down a hill and then take off and the companies are investigating how a treadmill can be integrated with the DreamGlider device to introduce this capability.

7.2.1.5 Orbotron, X-otron VR, and Supertron

Orbotron, Inc. market a series of human gyroscope motion devices. The initial product, also called Orbotron, is not motorized and allows free motion in pitch, roll, and yaw dimensions for a single user. Initially designed as an workout machine, the Orbitron was quickly used for entertainment applications. With the VE option, called the X-otron VR, it includes an Optics 1 HMD capable of either 2-D or 3-D optics, with either head tracking, or user tracking based on the position of the gyroscope rings. The VE system also includes localized 3-D sound generation and supports dual joysticks with a total of eighteen programmable buttons for user input. Further details for the X-otron VR are given in Figure 107. The price of the Orbitron is $10,000, and the X-otron costs $27,000.

Specification	
Floor Space	10 x 10 ft
Device Height	9 ft 8 in
User Range of Motion	360° pitch, roll, yaw
Device Weight	1,670 lb
Max. Payload	300 lb
User Size	4 to 6.16 ft or 4 to 6.33 ft

Figure 107. X-otron VR

Specification	
Floor Space	114 sq ft
Device Height	11 ft
User Range of Motion	360° pitch, roll, yaw
Device Weight	1,950 lb
Max. Payload	300 lb
User Size	4 to 6.16 ft or 4 to 6.33 ft

Figure 108. Supertron

The more recently introduced Supertron differs from the Orbitron in allowing free motion for two users simultaneously. This device was designed for either entertainment or research applications. Currently available as a stand-alone device, priced at $14,500, a Supertron VE option is expected to become available by the end of 1996. Further details for the Supertron are given in Figure 108.

A motorized single-man gyroscope that can be controlled by a computer, or an analog input from some other source, is also available. Designed as an entertainment device, this product supports VE applications with the same HMD, sound display, and joysticks as the Orbitron, and both head tracking and ring tracking are supported. In appearance similar to the Orbitron, the motorized single-man gyroscope differs in requiring 12 x 12 feet area of floor space. Its price starts at $35,000. A two-man version of the motorized gyroscope is expected to become available in Fall '96.

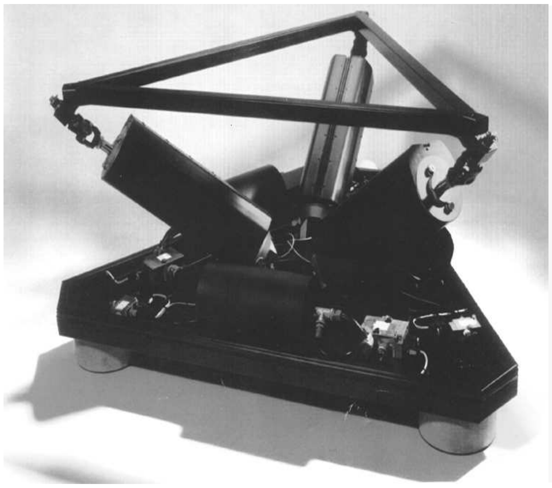
Wheelchair versions of both the Orbitron and the single-man motorized gyroscope are available. These are suitable for use by paraplegics or quadriplegics.

7.2.1.6 PemRAM Motion Bases

Denne Developments, Ltd. (DDL) market new motion platforms based on their patented Precision electromagnetic RAM (PemRAM) actuators. In these electromagnetic rams the space under the pistons is filled with air at a pressure sufficient to support the deadweight of the payload. The pressurized part of the ram is connected to a small reservoir and isolated from the main air supply so that it forms a long-stroke gas spring. This counterbalance system enables the motion base to stay where it is, effectively in neutral equilibrium, and the dynamic motion is provided by impulsive forces from the electromagnetic actuators. The force actuator generates forces that are felt as acceleration cues by the user. By effectively eliminating gravity from the equations of the motion, the actuators have a low power requirements, typically one tenth of that required for hydraulic systems. The high bandwidth of the system allows quick and precise control of the forces generated, including vibrations exceeding 30 Hz.

A feature that makes the new PemRAM motion bases potentially very useful for VEs is their ability to automatically react to user movements. Since the currents flowing in the actuators are continuously monitored, it is possible to identify changes in the center of gravity of the platform, that is, identify the movements of the user and allow this to be taken into consideration in interactively controlling the motion base and any other VE interface displays. When the user leans in any direction, the actuators automatically adjust to compensate for the shift in the center of mass, holding the position of the motion base constant.

Two PemRAM motion bases are currently available, a three axis and a six axis system. Via an electronic control unit, these motion bases provide a serial computer interface. Further details are given in Figure 109 and Figure 110. The prices are approximately $27,000 and $50,000 for the three axis and six axis motion bases, respectively.



	Specification		
Base	1.5 m equilateral triangle		
Weight	240 Kg		
Payload	300 Kg nominal, 500 Kg maximum		
Loading Height	590 mm		
Capsule Interface	Mounting triangle on 620 mm radius pitch circle		
Performance:	Displ.	Velocity	Accn.
Heave	±180 mm	0.5 m/sec	0.5 g
Pitch	-24°+18°	35°/sec	3330°/sec^2
Roll	±20°	40°/sec	330°/sec^2

Photo courtesy of Denne Developments, Ltd.

Figure 109. PemRAM 3 Axis Motion Base

	Specification		
Base	1.5 m circle		
Weight	380 Kg		
Payload	600 Kg nominal, 1000 Kg maximum		
Loading Height	0.6 m		
Capsule Interface	Mounting triangle on 0.7 m radius pitch circle		
Performance:	Displ.	Velocity	Accn.
Heave	±-0.2 m	0.5 m/sec	0.5 g
Pitch	±20°	35°/sec	3330°/sec^2
Roll	±20°	40°/sec	330°/sec^2
Yaw	±25°	40°/sec	330°/sec^2
Surge	+0.25m, - 0.2m	0.5 m/sec	0.5 g
Sway	±0.2 m	0.5 m./sec	0.5 g

Figure 110. PemRAM 6 Axis Motion Base

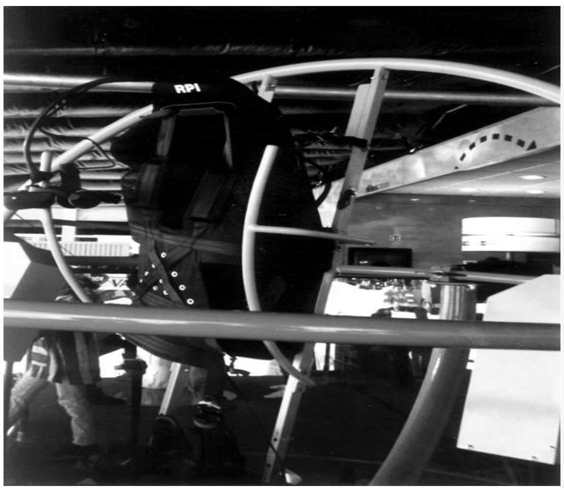
Photo courtesy of Denne Developments, Ltd.

Figure 111. PemRAM Surfing Demonstration System

The interactive capability of the PemRAM motion bases has been demonstrated in a number of entertainment applications, including one for surfing (see Figure 111) and another for flying through an aerial obstacle course. These applications have used a flat screen rather than an HMD because of the disparity between the high update rate for PemRAM motion cues (ideally 100 Hz) and that typical for commercially-available HMDs. Also, the demonstrators have found that users able to maintain a connection with the real world through their peripheral vision fail to experience the disorientation that has occasionally been reported when peripheral vision is not provided. Additionally, for safety reasons, these demonstrations have surrounded the user with a hand rail mounted on a platform.

7.2.1.7 SimuPod

RPI Entertainment's SimuPod is a rotational motion-based product with a V-brace configuration linear actuator. It allows a full 360° movement for pitch, roll, and yaw, supporting any rotational body effect. Motion can result from the movements of the user's body, or be generated by a PC-based motion control system. Rumble and thump effects are produced using bass speakers and vibration transducers attached to the user's backpack. A variety of RPI developed visual displays are available for use with the SimuPod, including HMDs, projection, pull-up head-coupled, and lean-in head-coupled displays, and 3-D localized sound is available. For user input, hand controllers can be attached to the device frame. The SimuPod is available in wireless mode, where no cables are attached to the user. A photograph of the SimuPod and further details are given in Figure 112.



Specification	
Floor Space	12 x 11 ft
Device Height	10 ft
User Range of Motion	360°
Device Weight	1900 lb

Figure 112. SimuPod

The SimuPod is primarily intended for the entertainment industry, and over 44 licensable rides and games are available. However, the product is available to developers of other types of VE applications. It is built and customized to order allowing, for example, restrictions on user size and weight to be adjusted to meet client needs. The price for SimuPod ranges from $30,000 to $350,000.

7.2.1.8 SimuSled

Another RPI Entertainment product is the SimuSled. The user starts by standing up and then falls forward or backward, allowing simulation of flying, skydiving, gliding, and sledding, or any similar activities. The basic product includes a motion platform capable of 100° pitch and 10° roll motions, though these can be increased to 360° pitch and 45° roll. An optional 360° yaw and a fourth motion axis, described as shift, can be added. The SimuSled includes a voice input channel to accept user spoken commands. As with other RPI Entertainment products, a range of visual displays, 3-D localized sound, and special effects are available and the device is network capable.

As before, this product is primarily intended for the entertainment industry, and many games are available, but it can also be purchased for use in other types of applications. It is built and customized to order, with an approximate price of $14,000 for a single sled, depending on configuration.

7.2.2 Current Research and Development

Until recently, research into self-motion interfaces was exclusively the province of universities. Over the past few years, the DoD has started to support research in this area, leading to the involvement of some private companies. While the DoD is focused on providing support for dismounted infantry actions in the military's Distributed Interactive Simulation (DIS) network, it is likely that the bulk of the research products will be applicable to the more general, non-military VE self-motion applications. Unlike the university work, however, much of the DoD-sponsored work is short-term; for example, the Small Business Innovation Research (SBIR) efforts discussed below are all required to be completed within a six month interval. Whether the DoD will continue to support research in this area is unknown.

7.2.2.1 Computer Graphics Systems Development Corporation

Researchers at CGSD are investigating the development of a Locomotion Simulator for Three-Dimensional Virtual Space. The goal is to produce a 3-D generalization of a treadmill, called an OmniTrek, that will enable walking and running in virtual space without actually traveling more than four feet from a nominal position. This device is intended to support turning to any direction and simulation of climbing or descending stairs, or travelling across variable terrain. It is designed to be used safely without a tether or harness.

The OmniTrek is a computer-controlled robotic apparatus about ten feet in diameter. The top surface of the device is co-planar with a raised floor. The raised floor is about four feet above the primary floor upon which the device sits. The walking surface has no holes or gaps, and is flat except when climbing or descending. Simulation of some soil types, such as sandy soil, is possible. The device is designed to output the position and velocity of the user, and in most cases the position of the user's feet and head. The most difficult aspects of the design relate to the safety of the device, to ensure that the user will not easily lose balance in ordinary operation and that, in any case, a fall would not result in a serious injury. The general approach is to use three levels of safety: software that controls the device to prevent injury, hardware detectors that stop motion if a foot is in a potentially dangerous place, and design details that will push the user out of the way if all else fails. The virtual reality imaging system used with the OmniTrek must have low latency and generally would include graphic imagery of the body of the user. The preferred computer interface will be dedicated Ethernet.

The OmniTrek is the subject of a SBIR feasibility and design study sponsored by the US Army Simulation Training and Instrumentation Command (STRICOM). The design and the study are currently nearing completion, and demonstrations of certain of the control aspects (control laws, tracking problems, and motor sizing) have been made in the context of a one-directional device. If the feasibility and design study is successful, the researchers hope to develop a working prototype system that would include imagery for the virtual environment.

7.2.2.2 Cybernet Systems Corporation

In another effort sponsored by STRICOM through a SBIR contract, Cybernet Systems Corporation is developing a prototype full body kinesthetic display to simulate locomotion for dismounted troops under virtual training and exercise scenarios. The design is referred to as the foot haptic approach because it begins by providing a full six axis motion platform for each foot of the soldier. To this base design, kneeling boards are added to support rolling, kneeling, and prone postures. A vertical feature presentation mechanism allows pushing realistic walls, windows, doors, and high vertical obstacle features.

Commercially, the system will be applicable to a variety of motion-based training and play scenarios. It can be the basis of systems for indoor track and field training, and training in eye-hand-body coordination sports such as tennis, baseball, and golf. The system can be incorporated into training VE systems for civilian safety and police personnel. Finally, it can be used in VE-based rehabilitation systems.

7.2.2.3 Institute for Simulation and Training

Dr. Jim Parsons at the Visual Systems Laboratory of the Institute for Simulation and Training (affiliated with the University for Central Florida) is developing a treadmill-based locomotion system. The treadmill being used is of a type used by cardiologists in assessing patients' medical conditions. It has been modified in several ways. The motor was removed to increase the safety of the device for users wearing HMDs and, to increase ease of user movement, the plywood foundation under the belt was replaced with a specially made material-handling conveyor. User motion is detected via proximity switches mounted on each edge of the treadmill and the user signals turns to the left or right using buttons mounted on the treadmill handles. A photograph of the device is shown in Figure 113.

Figure 113. IST Treadmill Locomotion Device

The signals from the treadmill to the Silicon Graphics machine that generates the VE visual scenes are transmitted via a modified Microsoft Mouse: the signals from the directional buttons on the treadmill are wired into the mouse buttons, and the signals from the proximity switches drive relays that simulate the roller ball of the mouse. The serial mouse input is then translated to provide the proper granularity for the VE, allowing the rate of user motion to adjust the visual display.

This treadmill locomotion device is being used by the Army Research Institute in a series of experiments that are investigating the effectiveness of the VE training for outdoor navigation skills. Current work with the interface system is focusing on providing the ability to monitor finer granularity of user motion.

7.2.2.4 Sarcos Research Corporation

Sarcos performed some of the earliest work in linking the individual combatant to VEs. Initial work in the Individual Portal into Virtual Reality (IPORT) series was conducted under contract for Army Research Laboratory (ARL) to build a UNIPORT motion platform. This device (shown in Figure 114) allows the user to direct his movement through a VE by turning the seat to change his direction and adjust speed of motion by the rate of pedaling; the visual scenes generated are tied to these motions. An important feature of the UNIPORT is that it allows the physical exertion imposed by moving through the VE to be adjusted based on such characteristics as the type of motion being simulated (walking, crawling, running), the terrain surface, and the load the soldier is expected to be carrying. The UNIPORT provided the first linkage of physical exertion into the VE and the first integration of dismounted infantry in the Distributed Interactive Simulation network. When linked into military simulations conducted on the DIS, the UNIPORT's capability to require appropriate action-related physical exertion provides for soldier decision-making under conditions of risk.

Photo Courtesy of Sarcos Research Corporation

Figure 114. UNIPORT

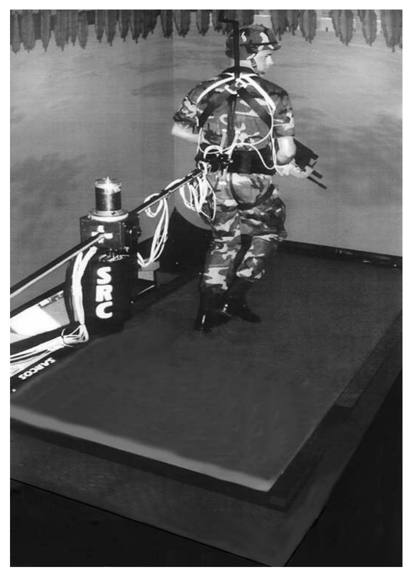


Photo Courtesy of Sarcos Research Corporation

Figure 115. TREADPORT

Building on this initial work and an analysis of infantry movements and combat actions, SARCOS completed a functional requirements description for linking Dismounted Infantry to VEs, and the Systems Architecture is in final draft. This work was sponsored by ARPA in support of the Army's Dismounted Infantry Battlespace BattleLab (DIBBL).

SARCOS' second development in the IPORT series, the TREADPORT, allows the soldier to move naturally within the VE. A tether and control system keep the soldier essentially centered on the flat treadmill-like surface of the TREADPORT and the VE is adjusted responsively to his movements. It has a natural user interface allowing walking/running/crawling and a full range of postures—kneeling, sitting, prone, etc. A photograph of the TREADPORT is shown in Figure 115. This work was sponsored by ARPA and STRICOM in support of the DIB-BL.

Nearing completion is the Individual Soldier Mobility Simulator (ISMS) being developed for the ARL. This motion platform (shown in Figure 116) was developed as a high fidelity terrain interactive system including feedback for mud, rocks, stairways, and navigational obstacles. The system will support testing of new soldier equipment in a laboratory environment representative of field conditions. It features scenario-based energy expenditure and high fidelity foot-motion tracking.

All SARCOS motion platforms will work with Polhemus or the SARCOS SENSUIT for motion capture. The SENSUIT allows direct, interactive, real-time control of an icon in a virtual world. It is a clear and responsive icon-wise to the hand and arm signals required for dismounted infantry combatant operations. Compared to the Polhemus, SARCOS states that the SENSUIT is free-ranging, features greater accuracy and speed in measuring joint angles directly, provides better resistance to sensor drift, has the capability to measure many more degrees of freedom, does not require inverse kinematic computations, and is insensitive to metals or other interference in its environment.

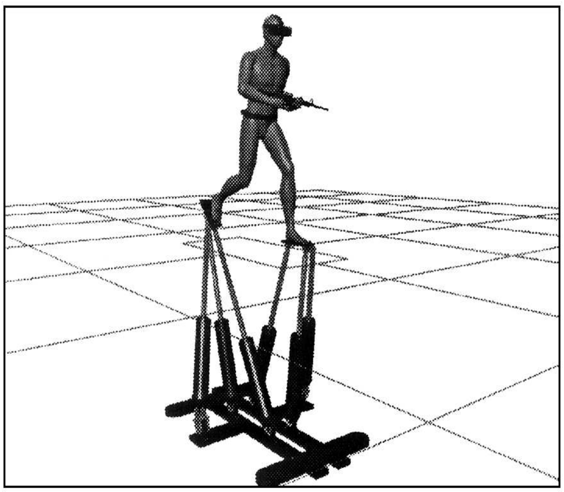
7.2.2.5 Systran Corporation

In the final SBIR I effort being sponsored by STRICOM, Systran Corporation also is completing a feasibility study for a locomotion simulator to support training of dismounted infantry in the DIS environment. This work has centered on the development of a design for a simulator called LocoSim.

Photo Courtesy of Sarcos Research Corporation

Figure 116. Individual Soldier Mobility Simulator

In the simplest terms, LocoSIM employs DDL's PemRAM actuators (see Section 7.2.1.6) to move boot plates to various positions within an operating envelope defined by the granularity of the micro-terrain being traversed. The user still moves as usual in walking, running, or crawling (based on foot movements only) over different terrain, or ascending or descending stairs. His leg and foot actions initiate actuator displacements that, via the connection of linkages and size of displacements, result in the displacement and angular orientation of each boot plate. A pivot plate attached to the forward end of the boot plate allows the user to change the direction of his motion and provides a limited rolling capability while in a prone position. Each boot plate is individually controlled, with the front and back being driven separately to allow matching the characteristics of human gait. An additional actuator is used to provide a side-step capability. A leg/foot sensor suite (including force, displacement, and rotary sensors) is mounted on an exoskeleton, itself mounted on the boot plate, to provide input on user movements. The LocoSim itself is intended to be placed below floor level, underneath a gap in the floor, such that the boot plates are positioned horizontally with the floor. A sketch of the device is shown in Figure 117, while Figure 118 shows a more detailed view of the boot plate and sensor mechanism. As designed, each boot plate exhibits a DOF for each of the longitudinal, height, pitch, roll, and transverse axes. Freedom for the yaw axis is simulated via force-feedback from the boot plate and leg/foot sensor system. (DOFs in the roll and transverse directions are not expected to be supported in the initial LocoSim implementation).



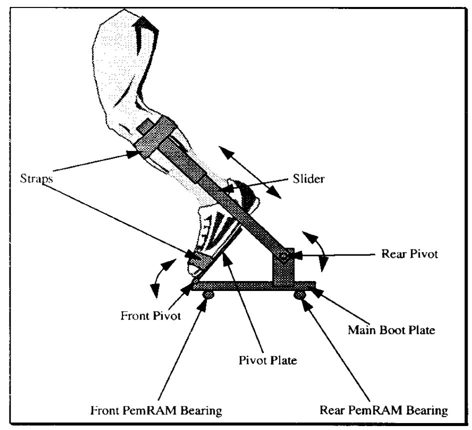


Figure 118. LocoSim Boot Attachments

The overall LocoSim design includes the requirements for the LocoSim control system, intended to interface with the DIVE VE supported by the Army Research Laboratory, and a high level functional software design.

7.2.2.6 University College London, UK

Researchers at the University College London and the London Parallel Applications Center propose a paradigm of body-centered interaction as an alternative to traditional mouse and menu interaction schemes for user interaction with VEs. In accordance with this paradigm, Dr. Mel Slater's group has developed the Virtual Treadmill system. With this system, a participant can walk normally within the range of the tracking device. For moving over larger distances, the participant employs gestures similar to walking, in effect, walking in place. These gestures are identified by pattern analysis of head tracking data using neural nets. In addition to walking, the Virtual Treadmill allows a participant to walk up steps by detecting an object collision of the participant with a virtual bottom step, and then subsequent walking moves the participant up the steps. Walking down steps is initiated by identifying when the participant steps over the top step. Climbing and descending virtual ladders is supported in a similar manner, with the participant's hand elevated over his head to signal going up the ladder, and hand positioned lower than his head to signal descending the ladder.

This body-centered paradigm is assumed to help participants identify with the representation of their body in the VE, that is, their virtual body, and so increase their sense of presence. In an experiment to test this hypothesis, the researchers compared two different navigation schemes with respect to their effect on the reported sense of presence (Slater, 1994). Sixteen subjects were selected, half of whom used a 3-D mouse for navigation, and the other half used the Virtual Treadmill. The experimental task was to pick up an object, take it into a room, and set it on a particular chair. The chair was positioned so that a subject had to cross a 20-foot deep chasm to reach it, by either following a wide ledge around the room or going directly across the chasm. In all cases, the participant saw a virtual body as self representation, or at least those parts of the body that would normally be visible given the current direction of gaze. The main finding of the experiment, as reported by Slater, was that while a higher association with the virtual body gave a higher presence score for the Virtual Treadmill participants, there was no such correlation for the 3-D mouse users.

Current research by the group is largely concerned with multi-participant VEs where the participants may be at different physical, remote locations and the shared virtual world distributed over a wide-area network. Such a system is already linking the Universities of London, Nottingham, and Lancaster. In this case, not only is there a relationship of individual participants to their own bodies, but recognition of and interaction with the other participants. At the present time, this system uses body-centered interactions, based on head and hand tracking data, to allow gestural movements to be translated into 3-D geometrical, virtual structures. The next phase of development will include the integration of the Virtual Treadmill into the system.

Future plans with respect to the Virtual Treadmill include modifying the system to recognize different walking speeds.

7.2.2.7 University of Tsukuba, Japan

For several years, Dr. Hiroo Iwata at the University of Tsukuba, Institute of Engineering Mechanics, has led researchers in the development of a Haptic Walkthrough Simulator. As the name suggests, the device is primarily intended to support walkthroughs of building and urban space designs.

The user of this device wears a pair of modified roller skates that are equipped with four castors to permit him to move in any direction. Each skate has a rubber break pad attached at the front that generates frictional force on the rear foot as the user walks. Optical encoders are used to measure the length of the user’s step and any turning angle so that body position and orientation can be calculated. A mechanical tracker is used for monitoring the position and orientation of the head. These data are then used to correlate the visual display, provided by a HMD, with movement of both feet and head. A metal hoop positioned around the user’s waist limits his forward or backward motion so that the user remains in the same place. A photograph of the device is given in Figure 119.

The complete system uses two PCs: one with a graphics accelerator for image generation, and a second for supervising the motion tracking of feet and head. To provide manual input to the VE, an input device such as the Haptic Master (see Section 6.2.2.5) can be mounted on the steel hoop. The walkthrough simulator can also be used in conjunction with a motion platform to support the simulation of movement across an uneven surface.

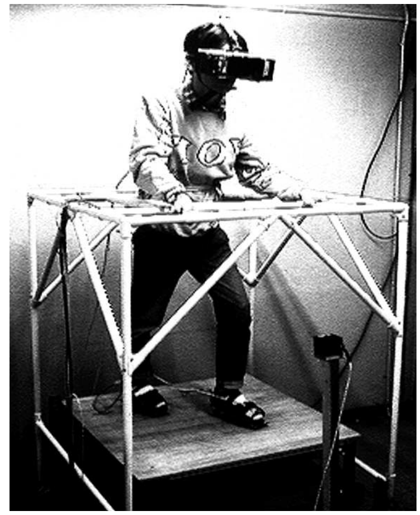


Figure 119. Haptic Simulator

The researchers have used the walkthrough simulator in two experiments that examined the potential benefit of being able to simulate walking through a VE, as opposed to the current mode of flying via hand gestures. Specifically, these experiments looked at how walking and flying compare with respect to distance estimation (Iwata and Matsuda, 1992). In each case, three subjects were asked to follow a given path through a VE until they reached a marked goal. For the first experiment, six straight line paths were used and, after completing each, the subjects were asked to simply mark the position of the goal on a prepared worksheet. The second experiment used six paths in the shape of a four-sided figure and, after each completion, the subjects were asked to sketch the shape of the path so that the estimated distances could be measured. In both experiments, distances greater than ten feet were always overestimated, and lesser distances were frequently underestimated. However, the distance estimates given after walking a path were closer to the true distances than those given after flying the path.

Research has just started on improving a virtual staircase display. The original virtual staircase display used strings to pull a user's feet, but this approach led to problems in body stability. Researchers are now investigating the use of a 3 DOF motion platform to implement a virtual staircase display.

Future plans for the walkthrough simulator will include applying the simulator in the study of human behavior in emergency situations; in particular, it will be used in a refuge simulator for fire accidents.