7.3 Passive Motion Interfaces

Passive motion interfaces will continue to play a large role in training simulators and entertainment applications, and visual displays and motion platforms will continue to be used as the primary means of supporting the illusion of movement. As stated earlier in this report, the traditional types of motion platforms used in simulators represent a mature and well-defined technology area that is not addressed in this report. Similarly, the traditional type of cabin simulator is not discussed in detail, save to mention that the application of VE interface technology to cabin simulators is relatively new, and the development of virtual cabin simulators will allow more general-purpose simulators to be built, and support the rapid prototyping of simulator designs. Working towards this end, Boeing Computer Services (see Section 6.2.3.1) and CGSD Corporation (see Section 6.2.3.2) are both investigating the development of a virtual cockpit instrument panel. Researchers at the Air Force Institute of Technology are developing a virtual cockpit using an HMD for display of both out-of-the-window images and the cockpit itself. In its Fusion Interfaces for Tactical Environments (FITE) Laboratory, Armstrong Laboratory is taking an augmented reality approach to the research and development of advanced pilot interfaces for the F-16. Here the pilot sits in a F-16 cockpit shell and is presented with both virtual and non-virtual visual and auditory displays. None of these effort incorporate actual motion cues, but rely on visual scenes to induce a sense of passive motion.

There is a new type of product on the market that offers a lower cost approach to providing passive motion cues. These products, typically based on the military's G-seats, limit the provision of kinesthetic cues to those that can be presented through a chair.

7.3.1 Commercial Products

The set of motion chairs currently on the market are predominantly intended for use in VE entertainment applications. Five such products are considered here. The characteristics of these products are summarized in Table 19, and then each is described in more detail below.

7.3.1.1 Cyber Air Base

From ViRtogo, Inc., the Cyber Air Base is a pneumatically powered 6 DOF motion chair. In its current form the motion is driven by either VHS, laser disc, or broadcast sources. The visual display is provided by Kaiser Electro-Optics Inc.'s VIM 500 HRpv and supported by head tracking. RS-485, RS-232, and four extra programmable analog and digital control pins allow for customization with special interface devices, such as a steering wheel or pedals. Special effects such as a "rumble and thump" generator are available as options. A photograph of the Cyber Air Base is given in Figure 120. The standard single

Photo courtesy of ViRtogo, Inc.

Figure 120. Cyber Air Base

Table 19. Characteristics of Commercially Available Passive-Motion Products

Product	Vendor	Source of Motion	Range of Motion	Additional Provided Equipment	Price
Cyber Air Base	ViRtogo, Inc.	Pneumatic reservoirs	26-29° pitch, 26-29° roll, 26-29° yaw	HMD, head tracker, optional rumble and thump generator	$19,999
Cyberchair	RPI Entertainment	2-3 axis motion base	20-360° pitch, 30-360° roll (optional yaw movement)	Visual display (various), 3-D localized sound display, hand controllers, rumble and thump generator, air stream generator	$14,000
CyberMotion Seat	CineMotion International plc	Pneumatic reservoirs	18°pitch, 18° roll, 125 mm heave	LCD flat panel display, sound display, hand controller, rumble and thump generators	$55,000 (for 2-seat unit)
IntelliSeat	Torus Systems, Inc.	Pneumatic cushions	Not applicable	Controlled seatbelt, heated/cooled air streams, 12 scents	$850
SIM245	Jessler Enterprises, Inc.	Brushless electric motors	45° pitch, 45° roll	HMD, hand controllers, rumble and thump generators	From $19,000

seat is priced at $19,999. A double seat version is also available with either a projector and screen or two VIM HMDs. A 4-6 seater version is being developed for release in the fourth quarter of 1996.

An interactive version of the Cyber Air Base is under development and expected to be released in the middle of 1996. The motion for this version of the chair is computer-controlled, and the user is provided with a programmable joystick for giving input commands.

7.3.1.2 Cyberchair

RPI Entertainment markets the Cyberchair. While primarily intended for the entertainment industry, this product is available to developers of other types of VE applications. The overall design of the chair is based on a flight seat mounted on a RPI Entertainment developed motion platform. For the standard model, the motion platform provides 20° pitch and 30° roll, though these can be increased to a full 360° as a special option. A three axis design is available to provide yaw movement. Rumble and thump effects are produced using bass speakers and vibration transducers. A variety of RPI Entertainment or OEM developed visual displays are available for use with the chair, including HMDs, projection, pull-up head-coupled, and lean-in head-coupled displays. The basic user input devices, mounted on a chair arm, are a joystick and a trackball. Various special effects can be provided, for example, air streams can be used to provide the sensation of a wind. A photograph of the Cyberchair is presented in Figure 121.

Figure 121. Cyberchair

With respect to game support, over forty-four licensable games are available. Cyberchairs can be networked via a standard telephone interface to allow multiple users to share the same experiences. The price of a single Cyberchair is approximately $14,000, depending on the configuration. For quantities of over three hundred, the price ranges from $3,000 to $62,000.

7.3.1.3 CyberMotion Interactive Motion Seat

The CyberMotion interactive attraction marketed by CineMotion plc includes two individual interactive seats incorporating a pneumatic motion control system that offers a simulation industry standard 3 DOFs. The motion system is self-contained, and located under the seat. It provides up to 18° of pitch and roll, and 125 mm of heave (lift).

Each CineMotion seat comes with a multi-function joystick coordinating both the motion system and the PC CD-ROM interactive game. The game is displayed and played in conjunction with a 12.1 inch LCD flat screen. Additionally, the motion system is connected with an audio control system that allows audio signals to automatically generate vibration and conjunction with a 12.1 inch LCD flat screen. Additionally, the motion system is connected with an audio control system that allows audio signals to automatically generate vibration and shock effects. The system is controlled by a PC, and up to eight systems can be networked together. A photograph of the CyberMotion chair is given in Figure 122.

Marketed as a two seat module complete with individual coin operated mechanisms, and with the first CD-ROM interactive game included, the CyberMotion systems costs $55,000. (The company makes no provision for providing the air compressor used in the pneumatic motion system, but will do so on request.)

Photo courtesy of CineMotion International plc

Figure 122. CyberMotion Interactive Motion Seat

CineMotion also markets the AirRide Passive Motion seat.

During 1997, CineMotion will be announcing further gameplay products in the sitting and standing positions, again using their internationally patented pneumatic motion system. Research developments also are underway for a low-cost motion seat for use in the home market.

7.3.1.4 IntelliSeat

Photo courtesy of Torus Systems, Inc.

Figure 123. IntelliSeat

The IntelliSeat, developed and marketed by Torus Systems, Inc., was designed as an alternative to hydraulic or electromagnetic motion systems. Instead, this system uses six individual pneumatic reservoirs placed in the seat and back cushions of the chair to provide the illusion of motion. The seat belt is controlled to give additional motion cues by tightening or loosening to indicate forward or reverse-direction accelerations. A panic button is provided that a user can push to immediately stop the chair's response to all computer-generated motion commands. A photograph of the IntelliSeat is provided in Figure 123.

The IntelliSeat system supports two non-motion sensory cues. The first of these, called TorusBreeze, is achieved by using micro fans to blow air streams that are strategically directed to "buffet" a user's ears and face. Small heating and cooling units can change the temperate of the air streams. The second non-motion sensory cue provides odors and is called Toruscent. Here a total of twelve scents, six in each chair arm, are stored in solid form and dispersed using the TorusBreeze. A proprietary activation system triggers the scent units to open and close so as to deliver a very faint essence chosen to enhance the VE imagery. An additional sensory modality is planned for release in summer 1996. Called TorusMist, this subsystem will use a atomizer contained in the chair arm to spray small amounts of water on the user. The intent here is to make the user cool, rather than wet; providing a sensory cue for actions such as moving through bushes after a rainfall. The basic IntelliSeat is available for $850.

Another version of the seat, called IntelliSeat340, is exclusively intended for use with Torus Systems Inc.'s Toruscope 360 special venue motion picture format system.

7.3.1.5 SIM245

Jesler Enterprises, Inc.'s SIM245 is another motion chair. This chair is powered by brushless electric motors, providing 45° pitch and 45° roll. Two user controls are mounted on the chair, these are a joystick with a dual fire switch and a turbo throttle with auxiliary button. The head mount provides support for the i-glasses,VFX1, CyberMaxx, VIM, or FS5 HMDs. Rumble and thump effects are provided by means of a 10 inch sub woofer and a sound amplifier. The system is controlled by a Pentium 90 MHz computer with a 16-bit sound card. A photograph of the SIM245 is shown in Figure 124.

Photo courtesy of Jesler Enterprises, Inc.

Figure 124. SIM245

The price for the SIM245 depends on the HMD selected and ranges, for a single unit, from $19,000 to $24,000. This includes one game, with additional games available at $1,500 each.

7.3.2 Current Research and Development

Two efforts investigating the development and use of motion seats have been identified and are discussed below.

7.3.2.1 Denne Developments Limited

Under contract to the British Government, Denne Developments, Ltd. (DDL) is developing a G-seat, called the CyberSeat. G-seats are intended to overcome the limitation of motion platforms for supplying sustained acceleration forces by simulating motion through the application of pressure to the skin. As a low cost alternative to the traditional pneumatic actuators currently used in G-seats, DDL will use their patented PemRAM technology (see Section 7.3.2.1) to provide sustained forces through the cushions on the back and seat of a specially designed chair. Since this approach does not require large body movements to simulate user motion, it is expected to avoid the difficulties that heavy headsets can cause when used with conventional motion platforms.

A prototype CyberSeat is expected to be completed by late 1996, with a commercial product released in 1997/98.

7.3.2.2 Flogiston Corporation

Under a SBIR Phase II grant from NASA, Flogiston Corporation is developing a personal motion platform (PMP) that will be used for training astronauts in EVA procedures. The PMP will provide visual and auditory interfaces, in addition to a motion interface to a VE. The major element of the PMP is the Flogiston Chair, a reclining device developed under previous NASA funding that supports the body in a neutral posture. This chair is mounted on one of two motion platforms: a 3 DOF platform that uses electromagnetic ram actuators, or a 6 DOF platform driven by pneumatic actuators. The visual interface, attached to the chair, will employ a device that provides a high resolution image and supports peripheral vision. The auditory system will consist of off-the-ear headphones, providing 3-D localization of sound, and moving mass vibrators positioned on the chair and the motion base. Together, these two types of auditory interfaces will be capable of providing frequency signals ranging from 0 to 20 kHz. The user controls movement through the VE by means of 6 DOF pucks, mounted on the chair to lie under each hand. A photograph of the current PMP is provided in Figure 125.

Supporting software will allow integration of the PMP with VE systems on Unix and NT Windows machine environments. It will include a generic behavioral model capable of interpreting user input and mapping simulation-generated motion, auditory, and visual cues to the appropriate stimuli.

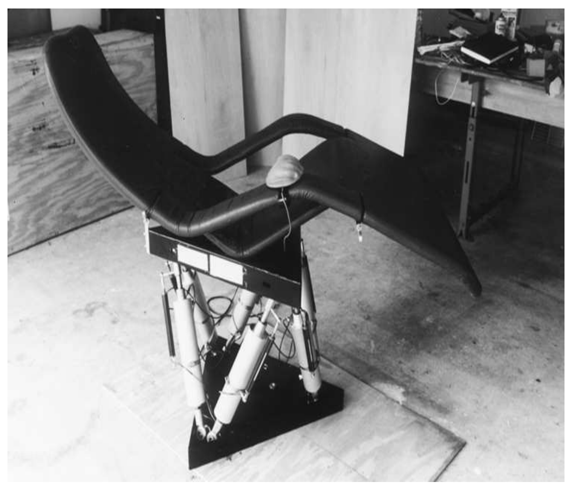

Photo courtesy of Flogiston Corporation

Figure 125. Personal Motion Platform (PMP)

The current work is centered around refining and extending an initial PMP developed under an earlier SBIR Phase I grant. This work entails developing new software for the motion platform, in particular, developing a new motion control algorithm and drivers for different motion platforms. Tests of the PMP are being conducted that include refining PMP motion cuing based on the stress levels induced by particular motion platform movements. Future work is expected to include the development of a haptic feedback device to replace the current 6 DOF hand controller.

In addition to delivering the PMP to NASA, Flogiston will market a commercial version of the system called the Flostation. This product is expected to come to market in late 1996.

7.4 Summary and Expectations

Flying by means of some hand-held control device will always be a common method of representing movement through a VE. It is a low-cost approach, one that is not physically taxing on the user, and suitable for many types of applications. While some gyroscope devices are commercially available and are being used in entertainment applications, studies on the effects of frequent or prolonged use of these devices on the user are needed. Nonetheless, the use of gyroscopes, hang gliders, and probably similar devices yet to appear, also is expected to continue. In addition to entertainment applications, such motion interfaces are likely to see limited use in specialized types of applications, such as those dealing with space or underwater environments. The potential role of interactive motion platforms has not been fully investigated as yet and, again, there are human factors and safety issues to be addressed. It is believed, however, that this type of responsive motion platform is going to see wide use, in both traditional motion platform application interfaces and in innovative ways.

To date, research into interfaces that allow some type of active user locomotion, albeit restricted, has seen little progress. Six prototype interfaces systems have been identified, three developed by Sarcos Research Corporation, and one each by the Institute for Simulation and Training, University College London (UK), and the University of Tsukuba (Japan). Each group of researchers has taken a different approach using, for example, a unicycle, treadmill, walking in place, and modified roller skates. In addition, STRICOM is sponsoring the design of three new prototypes, one of which is expected to be selected for further development. One of these designs employs a 3-D treadmill and the other two are based on the concept of movable foot plates. It is worth pointing out that all the current approaches to active locomotion, except one, are mechanical in nature. While each approach limits user movements in varying degrees, there are inherent differences in the way the mechanical and non-mechanical approaches limit and facilitate user movement. For example, technology advances in tracking and recognizing body movements, and in tracking range, will allow the current non-mechanical moving in place approach to be expanded to allow a wide range of user movement, but by itself will never support conditions of varying surface conditions or obstacles. Mechanical approaches, on the other hand, limit the user to a restricted set of movements and those movements may only approximate real motions. However, some mechanical approaches are capable of simulating a variety of surfaces, including such obstacles as stairs.

It is expected that research and development on locomotion interfaces will continue. Probably this work will be funded largely by the DoD to meet particular training requirements, but it should result in spin-offs applicable for non-DoD applications. While some advanced prototypes may see trial use in specific applications during the next five years, such systems are not expected to come into practical use within this timeframe. As advanced prototypes are developed, researchers will need to investigate many issues, such as the importance of fidelity to normal human motion for particular applications, and human factors concerns.

As discussed in the introduction to this section, traditional cabin simulators are a well developed field that has been excluded from consideration. As a result, the material presented for passive motion interfaces focuses exclusively on motion chairs: five commercial products and two being developed in research efforts. The majority of these devices provide inertial displays in which body mass is moved, using electromagnetic or pneumatic actuators to provide motion in 3 to 6 DOFs. The two motion chairs that use a non-inertial approach both provide pressure through the seat and back chair cushions to induce the sensation of motion (the IntelliSeat uses pneumatic actuators and the CyberSeat uses PemRAM electromagnetic actuators). With one exception, the Personal Motion Platform, all current motion chairs are primarily intended for entertainment applications and most of the commercial systems provide special effects such as breezes blowing across a user and scents. There are no major technical challenges in this area. Further products are likely to come to market in the next few years and the only significant issue is one of matching device capabilities, and price, to application needs.