Optimizing the Rehabilitation Potential of a Treadmill Interfaced to the Virtual World

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CHI 2007, April 28 – May 3, 2007, San Jose, USA
ACM 1-xxxxxxxxxxxxxxxxx.

Abstract
In this position paper we describe the development of a treadmill interfaced to a Virtual Reality environment for rehabilitation, and discuss the need for systematic optimization of such exertion interfaces.

Keywords
Virtual Reality, rehabilitation, treadmill, exertion interface, optimization

ACM Classification Keywords
H5.2. [Information interfaces and presentation (e.g., HCI)]: User interfaces---Input devices and strategies (e.g., mouse, touchscreen)

Introduction
The potential of exertion interfaces in the gaming industry has, in recent years, been recognized and commercially exploited (Reebok Cyberrider, GameRunner), but there is a dearth of research into the optimization of the interaction between these novel interfaces and the gaming experience to derive the maximum benefit, whether for fitness, weight loss or rehabilitation.

Virtual Reality and Rehabilitation
An ongoing challenge for therapists is the need to engage and motivate patients to actively participate in their rehabilitation. VR displays, as a tool of rehabilitation, have been demonstrated to help engage patients [5] and also improve movement [3]. Boian, Burdea, Deutsch and Winter [1] noted that most individuals do not fully recover their walking ability

after stroke and proposed a system of training using Virtual Reality to enrich the rehabilitation environment. In addition, Hoffman [2] demonstrated that pain responses in the human brain can be significantly reduced using Virtual Reality as a distraction. If this pain-reducing phenomenon can be combined with an interface which is optimized for rehabilitation, patients may be able to engage in therapy at a higher level, leading to increased long-term gains in function and mobility.

Current trends

Previously, the main use of treadmills with VR was non-interfaced, e.g. a treadmill placed in front of a video screen allowing viewing of distracting or motivating content whilst walking or running on a treadmill. More recent developments have seen exertion tools such as treadmills and bicycles linked directly to the computer as a joystick / mouse substitute, allowing expenditure of significant physical effort during the gaming experience (e.g. Reebok Cyberrider, Gamerunner). However, although it is generally accepted that such interfaces are likely to promote fitness and weight loss when used by those used to more sedentary interactions with the computer, there has been little systematic evaluation of the benefits of these interfaces.

In addition, although rehabilitation researchers are aware of the potential of exertion interfaces to enhance rehabilitation, again there is a lack of data available for the design and optimization of both the interface and environment in order to derive the maximum benefit.

Preliminary investigations

The authors are currently researching the optimization of a treadmill interfaced directly to Virtual Rehabilitation environments, allowing direct manipulation of the software to engage with the rehabilitation process, enhancing the rehabilitation possibilities of this “exertion interface”.

Interface

The prototype (non-motorised) treadmill uses a photoelectric sensor to detect movement of the flywheel. The output from this sensor is routed through a measurement and automation peripheral (LabJack U12) which is then interfaced to the USB port of the computer. A C++ program processes the count and timestamp (in ms) from the sensor input. The readings are averaged over the preceding second to smooth the transitions from one speed to another.

Environment

Rehabilitation environments are modelled in 3D Studio Max and loaded into WorldToolKit. The treadmill input is used to drive the movement of the viewpoint through the model, giving the illusion of walking in the VR environment.

Software control

Intermediary software, written in VisualStudio (C++), can be used to optimize the exertion benefits of the interface.

For example, early work by the authors demonstrated that if a subject walking on a treadmill is presented with a video (.avi) of a virtual walkway which is moving slowly with respect to the speed of the treadmill, the subject will subconsciously increase the walking speed, suggesting that manipulating the speed of movement through the virtual world may increase the exertion afforded by the interface without the subjects being consciously aware of having increased the physical effort [4]. Current studies are underway to systematically investigate the effect of software “gain” (gearing) of this interface to establish the optimum gain mis-match required to induce maximum walking effort on the treadmill.

Summary

Although exertion interfaces are currently being developed and used in a variety of applications, there is

a need for more systematic evaluation of the interaction between the interface, the software and the user, to enable optimization of such interfaces for use in gaming, exercise and rehabilitation. Discussion and collaboration between Exertion Interface researchers from a variety of disciplines would offer opportunities to share ideas, challenges and solutions, and to collectively explore future directions which might be taken to fully exploit the health benefits of the Virtual World.

Acknowledgements

Thanks to Andrew Farrar, Benoit Furdygiel and Luc Charlet for their technical assistance in building the treadmill interface.

Citations

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