Virtual Swimming: a new VR locomotion interface

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ABSTRACT
Swimming afloat in water, as a locomotion interface for virtual reality, is an unfamiliar paradigm. We outline the first step to virtual swimming in the Swimming Across the Pacific (SAP) project and suggest its potential applications. The SAP system primarily consists of the swimming apparatus and the virtual ocean environment. The apparatus, a large box frame mounted with pulleys and cords, suspends the swimmer in a prone position via a hang-gliding harness. The accompanying graphic system renders sky, sea waves, ocean floor and a virtual swimmer. The virtual swimmer mimics the user’s swimming movements by processing sensor data, while the head-mounted display supplies the virtual view. Preliminary user testing suggests the system is capable of providing realistic swimming sensations, and that it has great potential as a general purpose navigation system in immersive environments.

Keywords
Virtual reality, swimming, locomotion interface, navigation

INTRODUCTION
Locomotion interfaces, as Hollerbach *et al* [1] defines them, are “energy-extractive interfaces to virtual environments” and they “fill needs that are not met by conventional position-tracking approaches or whole-body motion platforms”. Their development is particularly supported by researchers in VR such as Durlach and Mavor [2] because with them come many unforeseen applications. Although our initial motivation for developing a swimming locomotion interface is from a performance art work (Swimming Across the Pacific) that requires virtual swimming, such interface can have many potential applications.

For example, a swimming locomotion interface could replace a positioning device, such as a mouse, as a navigation system for “liquid-like” data spaces. “Swimming” through data spaces could offer different perspectives on how we view and manipulate data.

SYSTEM DESCRIPTIONS
Our current design, mainly comprised of a swimming apparatus and a virtual ocean environment, is linked using Polhemus Fastrack sensors, a head-mounted display and a tcl/tk calibration interface.

The Swimming Apparatus

The swimming apparatus (Figure 1) is an 8ft x 8ft x 8ft wooden box frame with horizontal beams on top and bottom. By running static cords through the pulleys mounted on the beams and attaching the cords to the harness with carabiners, the user is supported at the shoulders and the hip in a prone position.

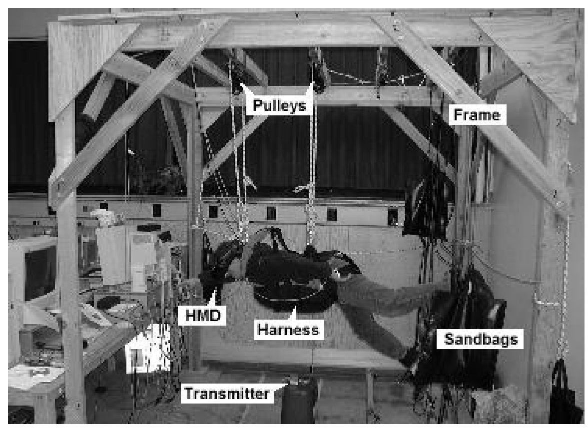

Figure 1: A profile view of the swimming apparatus

The rope-pulley system for the legs is designed to conform to the preferred swimming style of the performance artist, in this case, the front crawl and butterfly stroke. With these strokes, only the vertical kicking motions are considered. For each ankle, we run 5mm static cords through two high ball bearings mounted on one of the top beams and two on the bottom. This forms a rectangle where the diagonally opposite pulleys are connected with additional cords for stability. Between the inner pair of the top and bottom pulleys, there is an ankle brace for securing the swimmer’s leg in place. Between the outer pair of top-bottom pulleys, the static cords hold a sandbag which counter-weights the swimmer’s leg so that only resistance is provided during kicking. Bungee cords connecting the inner pair of pulleys further help restore the kicking energy, adding buoyancy.

Currently, there are no mechanisms designed for the arms. Considering that fast swimming depends more on effective streamlining of the swimmer's body in water than on rapid strokes, the arms are left free, to allow smooth movements.

The Virtual Ocean Environment

The graphic system (Figure 2), implemented in OpenGL, comprises a sky hemisphere, a sea surface plane, an ocean floor plane and a virtual avatar. The sky hemisphere is texture-mapped with clouds, the sea surface is textured-mapped with wave patterns and the ocean floor plane is textured-mapped with marine creatures. Both planes have fog and caustic effects and their textures are animated to move past the virtual swimmer making it appear as if the virtual avatar is swimming forward. The animation speed depends largely on the movements of the swimmer.

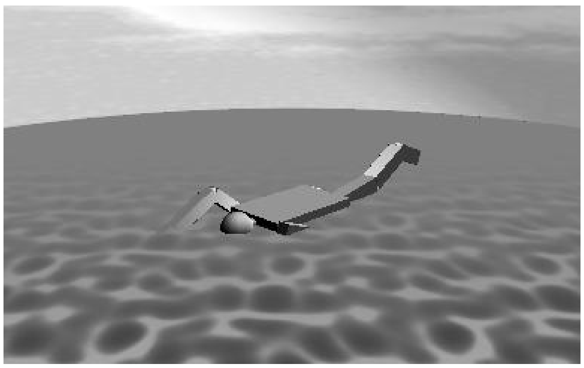

Figure 2: An aerial view of the SAP virtual environment

Synchronizing the Real World and the Virtual World

A head-mounted display enables the swimmer to see the virtual view, while a tcl/tk interface provides real-virtual world calibration, and Polhemus Fastrack sensors approximate the movements of the avatar. Because we were limited to only four sensors, we fixed a number of would-be sensor positions and assigned sensors to positions of the swimmer's body that best let us approximate swimming movement through inverse kinematics. In our setup, we have a sensor for tracking the head; the orientation of this sensor determines how we adjust the camera to up-date the view. We have a sensor at each of the swimmer's wrists, and the arm movements are predicted using vectors formed by approximated shoulder and elbow positions. The last sensor is attached to the right leg. The movement of the left leg is predicted from the right, depending on whether the swimmer does the butterfly or the front crawl. Once we acquire more sensors, we can conceivably place sensors on the swimmer's torso, elbows and knees to produce better results.

USER TESTING

Informal user testing on engineering and computer science graduate students, SAP performance artists, researchers and volunteers, shows that most people feel like they are swimming when suspended in the apparatus. The head-mounted display mal-functioned due to hardware incompatibility during preliminary user testing; nevertheless, the subjects could see the virtual environment via a CRT monitor and experience SAP. Responses to the mechanics of the apparatus are also positive. People like the resistance and buoyancy of the rope-pulley systems that simulate the kicking-in-water feeling. However, the graphic system could be more sophisticated in generating realistic 3-D water effects, landmarks and marine creatures, making the swimming experience more engaging and the navigation more entertaining.

POTENTIAL APPLICATIONS

Our swimming apparatus moves in virtual water, but it could be used more generally to move in data spaces that use liquid as a metaphor. Operations such as arm strokes, kicking, paddling and diving gain new meaning when used to navigate various data spaces, such as a financial data, molecular models, 3-D artwork, DNA strands and body cavities. For example, medical students could swim through a framework of blood vessels to investigate human anatomy. Similarly, economists could swim through stock exchange statistics to get a sense of the state of the market.

This leads to the interesting concept of using one's whole body instead of a mouse as a navigation device. The effect can dramatically heighten the users' sense of scale, distance meaning, and even self-awareness. In addition, users have a more intimate experience when exploring the data space. Expending energy at a body scale may allow a person to understand how objects relate to each other in a body scale frame-of-reference. A swimming locomotion interface therefore provides a novel way to explore data spaces.

SUMMARY AND FUTURE WORK

Swimming Across the Pacific introduces surface swimming as a new locomotion interface. It has potential for navigating 3D spaces using a water metaphor. We outline the first iteration of the swimming locomotion design that can be improved by the addition of audio, gustatory, olfactory and haptic devices to further engage the senses. The next stage of SAP is to improve on the current design through better graphics and a better designed harness for additional comfort, easy attachment and removal of sensors. Taking a different approach to navigation, a locomotion interface such as swimming can provide a thought-provoking perspective on information exploration.

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