Haptic Collaboration: Biomedical Engineering Meets Digital Design

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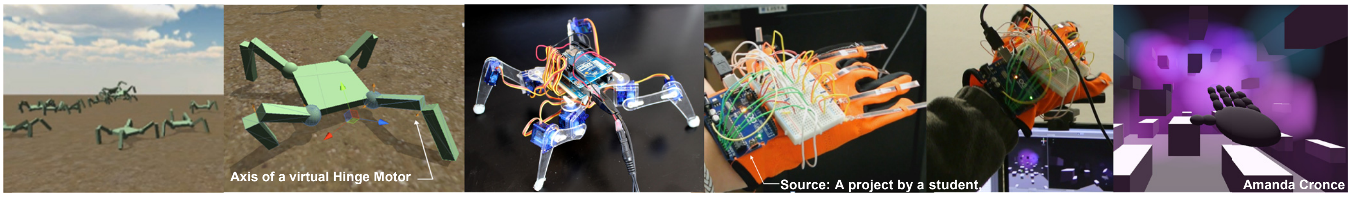

Figure 1: *Series of digital design projects interfacing physical prototypes with virtual game environments. A quadruped robot (right). A haptic glove (left).*

1. Introduction

This talk presents results of ongoing research and educational collaboration between the School of Art + Design (SoA+D) and the Department of Biomedical Engineering (BME) at New Jersey Institute of Technology. This collaboration began when researchers from BME became aware of a series of projects by digital design students from SoA+D producing virtual games that interface with fabricated physical design prototypes with microcontrollers through the use of the Unity 3D game engine as an application hub to connect the virtual and real worlds. The BME researchers had developed a novel admittance-controlled haptic robotic exoskeleton for assisting the upper extremity motions of people with stroke and cerebral palsy and were seeking to integrate it with an engaging and challenging virtual environment that can retain a user's interest. The result is a user-controlled haptic manipulator that allows individuals with neurological impairment to be therapeutically assisted by the exoskeleton (BME) while haptically interacting with virtual objects in a 3-D animated environment (SoA+D). The talk also introduces a new cross-disciplinary educational approach employing expertise of both academic units.

2. Our Approach

The SoA+D has developed a course for designers to create real-time interaction between physical prototypes and a digital application environment for games and simulation using readily available commodity hardware, including Arduino microcontrollers and Kinect sensors, and Unity 3D game engine software, with its computational physics. The course resulted in projects, such as 1) a haptic glove that allows a user to interact with virtual objects while returning a haptic sensation through vibrations of motors at the user's fingertips, and 2) a quadruped robot that can learn its own gait cycle virtually using the physics engine while physically testing motions. Unity and Arduino can be interfaced using the Transmission Control Protocol (TCP), which allows for implementation of GPU-accelerated computational physics, which is sufficiently fast to simulate user interaction with game objects and controls the physical prototype to provide a sense of virtual touch. While Unity animation operates at the computer screen refresh rate (~100 fps), its physics can operate at a higher frequency required for proper haptic perception.

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3. Unity 3D: A Collaboration Hub

The versatility, usability, and adaptability of Unity have been proven as we have developed interfaces between Unity and MATLAB, which is the current primary means for BME researchers to control their haptic robots using TCP. Unity also serves as a collaboration hub between the BME and SoA+D due to its speed and accuracy for computational physics and compatibilities with various CAD model formats in common use among digital designers. This allows designers to provide original game logic with animated high-quality models using its real-time rendering capabilities without compromising accuracy and speed that are required by engineers. Unity's graphics capability is also compatible with immersive commercial stereo vision glasses and projection systems that can enhance the therapeutic effects.

4. Serious Games: Haptic Collaboration

Our approach couples the BME-developed exoskeleton with the SoA+D capacity to employ the graphics and the physics engines of game development systems to provide therapeutic effects of gaming using stereoscopic glasses and motion tracking systems in addition to the sense of touch to be provided by the exoskeleton. The BME's prototype supports 6 degrees of freedom plus a finger/thumb grip, which matches the flexibility of the human arm and surpasses any other admittance-controlled system of this type including the MIT Manus (only 3 haptic-degree-of-freedom with no haptic grasp). Admittance control allows the user to input a force and translates that force into motion, and the user will feel resistance in the robot when the virtual arm makes contact with the objects. Digital designers have started producing visually enhanced serious games for the system, and now the research collaboration has developed into a new cross-disciplinary educational platform. The talk will present and demonstrate the most recent results.

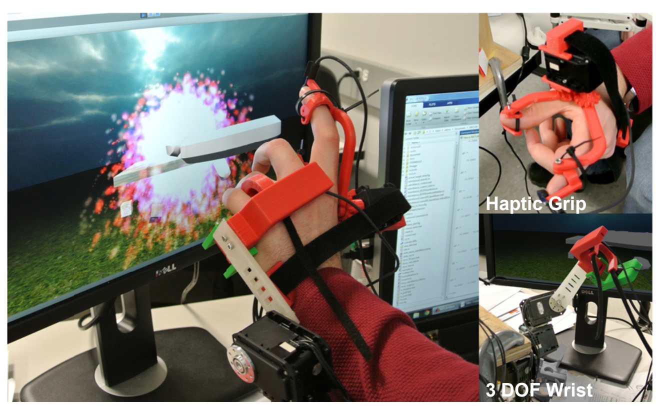

Figure 2: *An exoskeleton with admittance-controlled 3-degrees-of-freedom wrist and a finger/thumb grip haptically interacting with virtual objects in a 3-D animated environment.*