Human sensory augmentation

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Introduction

Humans have an inherent desire to push their limits and the boundaries of what they can do. Robotic and mechanical devices have been developed to augment a person's performance and allow them to gain a competitive advantage. For example, think about the controversy regarding blade prosthetics that could provide certain athletes with a possible advantage. Another means to improve human function is through sensory augmentation, essentially allowing someone to improve the functioning of one of their senses. Our balance sense, in particular, can be directly targeted using small electrical currents applied behind the ears to improve our sense of balance and motion. Indeed, these small currents activate the vestibular system in the inner ear and help humans detect head motion, thus providing information needed for navigation and balance. Recently, we have established a computational model of how electrical currents result in a given perception of virtual motion that has a clear mechanical equivalent. We need to test the predictions from this model to determine the exact motions (linear and angular) and the timing of the motions elicited by electrical currents applied behind the ears. The knowledge created by the proposed apparatus could also prove useful for immersion in virtual reality and gaming environments.

Problem

To understand the motion induced by electrical vestibular stimuli, we need to test volunteers with their head in different orientations with respect to gravity while we apply controlled motions in 6DoF (3D linear and 3D angular). We currently have a 6DoF Stewart mechanism in the lab (Fig. 1) but we need to expand its capabilities to address the objectives of this project. First, we need to build a device that will allow us to position volunteers in different orientations with respect to gravity (i.e. multi-axis positioning device; see Fig. 2). Second, we need to expose human volunteers to constant velocity stimuli to assess how the brain processes vestibular information. This will require installing also a rotary motor on top of the current Stewart mechanism. We currently have a functioning system to provide rotation with an axis orthogonal to the plane of the Stewart mechanism's top plate.

Our proposal is for the creation of a unique device to test vestibular function in order to develop methods to augment sensory function in humans. The device will include a large rotary motor with a multi-axis positioning device to be mounted on top of our current Stewart mechanism. This project will also require control of the actuator(s) with National Instruments hardware and software (preferably LabVIEW).

Fig. 1. Stewart mechanism similar to the one available for this project

Fig. 2. Example of a multi-axis positioning device.

Expected Outcomes

At the completion of the project, a technical report detailing a production-ready model of the multi-axis rotary device is expected. Students are expected to review previous designs, formulate new designs, perform failure mode analysis, compare the performance of various designs and source the required hardware and required manufacturing.

Resources available

Supervisory: Drs. Wu and Blouin will supervise the student team. Bi-weekly meetings will be organized to guide the development of the multi-axis rotary device.

Students are expected to perform most of their work using SolidWorks. They will have access to preliminary designs for the device.

Requirements

1) The functionality of the device is the most essential aspect. We need to control the orientation of the volunteers and velocity of the rotation. Students will need to design locking mechanisms to safely actuate human participants in different orientations. The angular position should be adjustable in at least 5deg increments with the centre of rotation located within a participant's head (positioning device) and angular velocities up to 30 RPM (rotation orthogonal to the Stewart mechanism's top plate) would be desirable.
2) Considerations for the ability to install recording and stimulation equipment in the chair where human volunteers will be tested for up to 5mins at constant angular velocity are important.
3) The weight, size and stiffness of the multi-axis rotary device should be taken into consideration. It will be installed on top of our current Stewart mechanism and the space in the lab is limited. Consideration should be made to keep volunteers as close as possible to the platform of the Stewart mechanism, ensure their head is at the centre of rotation and minimize vibrations.
4) Minimizing electrical noise is also essential through the use of good wiring practice (e.g., shielding and braiding), grounding, and potentially being able to distance any noise generating components (amplifiers etc.) from the volunteers. We will be using this device while performing electrophysiology in humans and therefore electrical noise from the device will create contaminate our neural signals.
5) Cost is moderately important.
6) Aesthetics is of minimal importance.