DESIGN OF SENSORY AUGMENTATION SYSTEM FOR POSTURAL CONTROL REHABILITATION

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INTRODUCTION

In activities of daily living (ADL), postural control plays a significant role for people with neurological impairments. Jeka et al. [1] have shown that light touch (contact force less than 1N) of fingers on fixed surfaces contributes to postural control during quiet standing and walking. By virtue of this additional sensory information from skin stretch feedback, people with neurological impairments may reduce their body sway in ADL, which can ultimately lead to improved quality of life.

In recent years, Verite et al. developed a sensory augmentation system for postural control while quiet standing [2]. However, this system is not portable because this system requires force plate and fixed structure of actuators, which in turn limit the usability of device in daily living and have less availability in ADL. Therefore, portability was one of the main concerns in our study. The objectives of this study are to i) design a portable sensory augmentation system for postural control, and ii) estimate the feasibility of our system in postural control application.

METHODS

Fig. 1 shows a schematic diagram of our sensory augmentation system and Fig. 2 shows a fabricated system. Using the gradient descent algorithm [3], the pitch angle in subject's anterior-posterior direction is calculated from the data of inertia measurement unit (IMU) (MPU-9150, InvenSense Inc., San Jose, CA) which is attached at the center of mass (COM) of a subject. Contactor's angular velocity is defined to be proportional to angular deviation of pitch angle from a reference angle. A reference angle is defined as a pitch angle when a subject is standing upright. When a subject tilts forward, the contactor rotates in clockwise direction and vice versa. The contactor is operated by a DC motor (Faulhaber, Germany). An embedded control

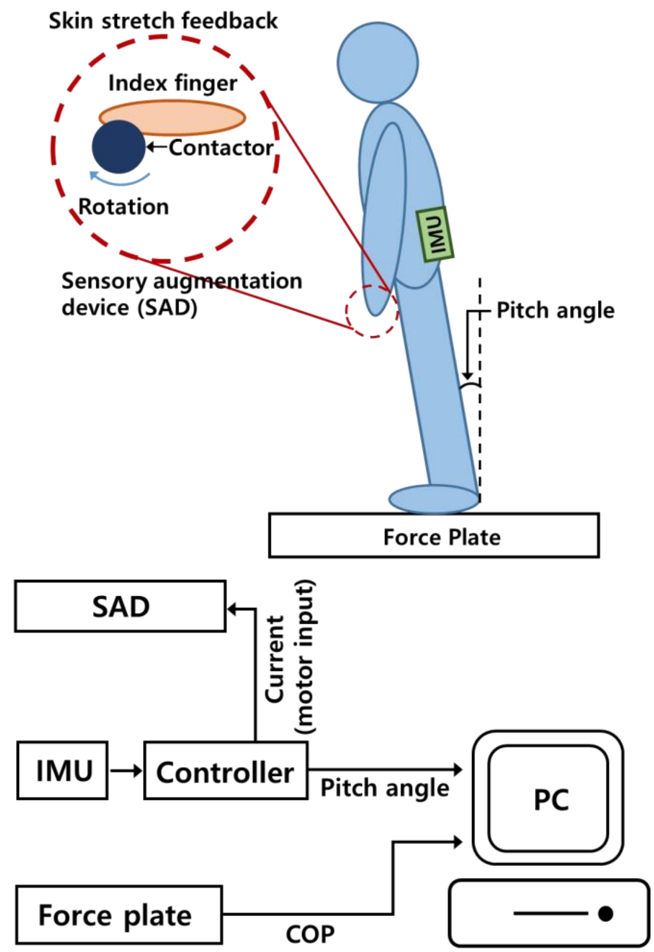

Figure 1: Schematic diagram of sensory augmentation system.

unit (myRIO, National Instruments, Austin, TX) takes the pitch angle of a subject from the IMU as an input, calculates the desired angular velocity, and controls the DC motor so that the contactor will maintain the desired angular velocity. A PID feedback control and an encoder were used to robustly maintain angular velocity of the contactor to a desired value.

The skin stretch is triggered at the index fingertip pad since the distribution of mechanoreceptors sensitive to skin stretch on the hand is concentrated

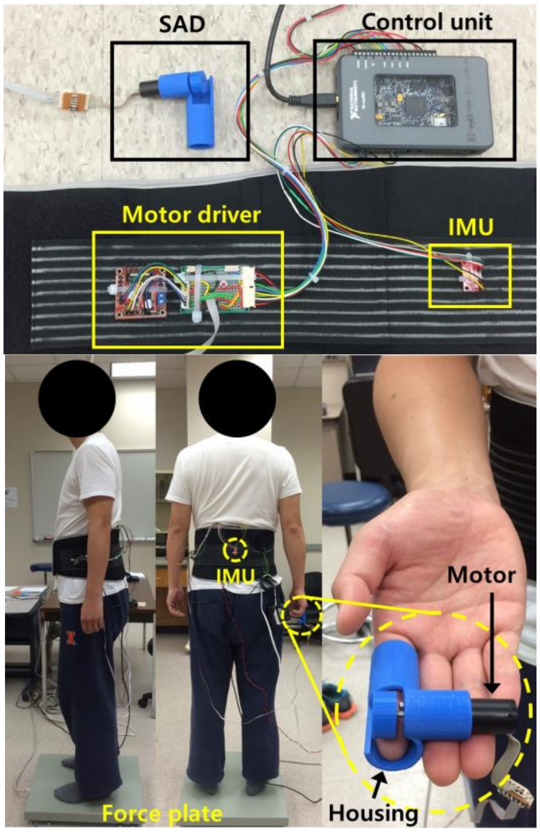

Figure 2: Fabricated sensory augmentation system.

at the index fingertip pad [4]. The DC motor is mounted at the housing of sensory augmentation device (SAD) where subject's index finger is inserted. Several contactors and housings with different size were fabricated using the 3D printer (Replicator 2X, Makerbot, Brooklyn, NY) to accommodate various finger sizes of subjects.

Besides the portable system of SAD and IMU, a force plate (OR6, AMTI, Watertown, MA) and a data acquisition system (DAQ) (USB-6002, National Instruments, Austin, TX) with a PC were prepared to collect center of pressure (COP) and pitch angle data. These data will be used to evaluate the efficacy of the SAD system. The IMU, embedded control unit, and a motor driver are enclosed in a waist belt so that subjects can easily wear the system (Fig. 2). Sampling rates of SAD, IMU and DAQ system were 2kHz, 500Hz, and 1kHz, respectively.

RESULTS AND DISCUSSION

Fig. 3 shows the relationship between contactor's angular velocity and pitch angle. As expected, contactor's angular velocity tracked the desired

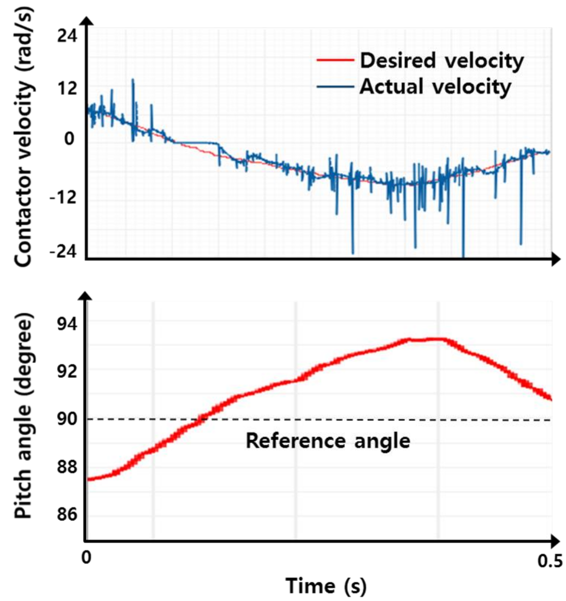

Figure 3: Relationship between contactor's angular velocity and pitch angle of subject.

angular velocity determined by body postural sway (pitch angle). Note that the reference angle was set to 90°.

CONCLUSIONS AND FUTURE WORK

A sensory augmentation system for postural control rehabilitation was developed using skin stretch feedback. This portable system consists of SAD, embedded control unit, motor driver, and IMU. To test the efficacy of the system, a force plate and DAQ was additionally used. By virtue of this device, subjects would receive skin stretch feedback, which may contribute to the reduction of body sway. Currently, only pitch angle was used to determine the motor velocity input. However, time derivative of pitch angle can also be used. Furthermore, battery should be used as a power source for portability. These studies will be included in future work. The efficacy of SAD system will be evaluated by examining the effect of augmented sensation at the fingertip due to SAD on quiet standing balance for various sensory modalities

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