

Design Approach on Human-diminishing Devices Considered through Development of Hemiplegic Gait Simulation Device

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Abstract— This position paper proposes a design approach for a "human diminishing device" to generate much more realistic experience of being the physically challenged, such as hemiplegic patients, in comparison to existing simulation suits, and refers to significance of the "human diminishing device" to let an able-bodied person rediscover its ability "covered" in daily life and exploit the ability more actively.

Keywords- *Simulation suit, Hemiplegic gait, Illusory kinesthesia, Reflex action, Tendon vibration*

I. HUMAN-DIMINISHING TOOLS

A human enhancing technology is defined as a technique that drives natural body to much stronger body through use of advanced technology, or a technique to make "inability" into "ability". On the other hand, there are technologies that go in opposite direction, that is, turning normal body down to much weaker body, or making "ability" into "inability". Authors refer such techniques as a "human diminishing technology" in this paper. Figure 1 illustrates position of "human enhancing technology" area and that of "human diminishing technology" area in a map.

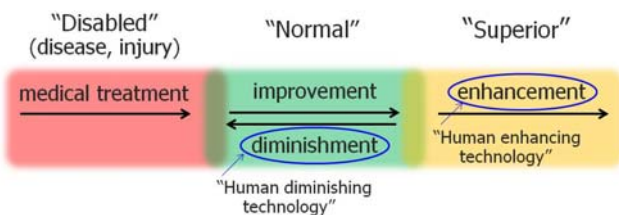


Figure 1. Position of "human enhancing technology" area and that of "human diminishing technology" area

The well-known tool that diminishes perceptive and motor ability temporarily and non-invasively is a hemiplegia simulation suit [1]. It consists of jacket and physical restraint for upper and lower limbs. An able-bodied person wearing the simulation suit would experience difficulty in walking and moving limbs and can simulate hemiplegic-related difficulty in moving joint.

This position paper proposes a design approach for a "human diminishing device" to produce much more realistic experience of being hemiplegic patients in comparison to an existing "human diminishing tool", and

refers to significance of the "human diminishing device" from a perspective of human enhancement.

II. DESIGN OF HEMIPLEGIC GAIT SIMULATION

Authors have researched to develop a hemiplegic gait simulation device in order to generate more realistic experience of hemiplegic gait by focusing on embodied clues. When we take each step while walking, we can, consciously or not, exploit many varieties of clues integrated from cognitive and motor functions such as touching the ground with foot, seeing toward walking direction, or adjusting standing posture. Moreover, for instance, touching the ground provides us important clues such as friction, pressure, posture and deformation which are integrated subconsciously.

On the other hand, hemiplegia patients suffering from loss of perceptual function, motor function and their coupled functions due to brain damage are often unable to exploit current bodily clues for taking first step because those clues have deficits and are partially distorted. Even when the patients scarcely make a step, the patients would confront a difficulty in taking another step. Hemiplegia patients always struggle with negative progression of not being able to generate, exploit, nor pay attention to appropriate information for a continuous gait, and they experience mental conflict between intentions that he/she wants to walk and inconvenient body which doesn't move as he/she intends to. Such phenomena let patients lament over, "I don't understand how to move my legs." and "My leg moves automatically against my will." Those experiences that hemiplegia patients have are undoubtedly different from the experiences that the existing simulation suit will generate, which is only an imitation of an appearance that hemiplegia patients shows such like flexion of the elbow and extension of the leg on the paralyzed side by just attaching restraint. This remarkable fact indicates that design approach for advanced simulation device should be based not on appearance but on mechanism itself that results in such appearance, in order to generate much more realistic experience. Therefore authors propose a design approach for simulation device that many varieties of embodied clues should not be generated, exploited, nor paid attention by able-bodied subject with the simulation device.

III. FEATURE OF THE HEMIPLEGIC GAIT SIMULATION DEVICE

Authors have researched to design and develop a hemiplegic gait simulation device based on an approach mentioned above [2]. This section describes how to apply that approach to the design and feature of the simulation device. The idea of the simulation device is to cause embodied clues to be not exploited in appropriate way for keeping on walking by making difference between “posture and physical movement of actual lower limb” and those of “perceived lower limb”. To do so, authors focused on four phenomena influencing posture and movement: 1. illusory kinesthesia, 2. reflex action, 3. preventing adaptation to stimulation, 4. providing fluctuating load around threshold.

Firstly, an illusory kinesthesia, phenomena that a subject feels as if its limb were moving even when the limb is still, is applied to make a difference between physical movement of left leg and one of perceived left leg. The motor illusion is generated based on tendon vibration method by providing appropriate vibratory stimulation onto specific tendons [3]

Secondly, a reflex action is applied to let the left leg automatically move independently from a subject's intention. This could be achieved from the same technique as generating the illusion.

Thirdly, intensity and its timing of a vibratory stimulation for motor illusion and reflex are controlled by an experimenter for a subject not to adapt to the stimulation.

Lastly, a subject's knee and ankle are moved subtly around threshold that a subject scarcely perceives, in order to make more difference between posture of physical left leg and one of perceived left leg. Additionally this manipulation can also change intensity of motor illusion.

By integrating these four phenomena and by adjusting each degree of influence, our hemiplegic gait simulation device generates much more realistic experience than existing simulation suit. Figure 2 illustrates a rendering of the hemiplegic gait simulation device based on this idea. The vibrators for generating motor illusion and reflex, and actuators for adjusting the degree of motor illusion by moving the limb and for providing subtle load are attached on left knee and ankle. Several sensors are

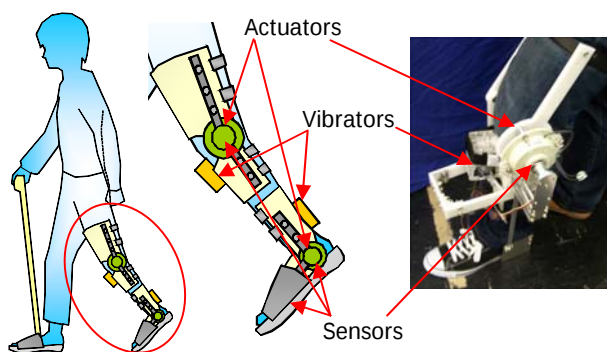


Figure 2. A hemiplegic gait simulation device

installed around both joints and soles of both feet for measuring posture and gait cycle, and for adjusting load. Authors have developed the device as illustrated in Figure 2 and attempted several trials. Preliminary results indicated that able-bodied subjects experienced tonic extension of left leg that is similar to hemiplegia patients often experience which set forth capability of our proposed design approach.

IV. SIGNIFICANCE OF HUMAN-DIMINISHING DEVICES

This position paper has been describing human diminishing technology for experiencing inability such as hemiplegic simulation suit, and design approach for advanced simulation device generating much more realistic experience. Final section illustrates significance of the "human diminishing device" from perspective of human enhancement.

Objective of utilizing simulation suits and devices is mainly for a practical education to understand the situation of hemiplegia patient, as well as to demonstrate patient's situations to draw public interest, and many researches on its effects have been conducted so far [4]. Furthermore, when an able-bodied person equips with simulation device, he/she would find themselves easily maintaining body balance by moving upper limbs as a substitute of lower, temporally paralyzed, limbs, and also would find which parts of lower limb and how such parts cannot move smoothly as he/she intends to by comparing with normal walking without the device. And this kind of compensatory and coordinated actions encourages us to focus on our abilities and capabilities that are hidden in daily life. Thus diminishing device for simulation of weaker people would not only allow us to explore their situations that may lead to understanding of them and solution to improve their environments, but also for an able-bodied person to rediscover its ability "covered" in daily life and by letting the person exploit the ability more actively and finely, which is as significant as an enhancing device.

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