2015 IEEE World Haptics Conference (WHC)
Northwestern University
June 22–26, 2015. Evanston, Il, USA

Inducing Elbow Joint Flexion by Shear Deformation of Arm Skin

Kotaro Shikata, Yasutoshi Makino, and Hiroyuki Shinoda, *The University of Tokyo*

***Abstract*—We present a new wearable device for inducing involuntary elbow joint flexion and extension by stretching the skin surfaces of an upper arm and a forearm. The device can teach proper motions to users through haptics. In previous studies, rotational motion of forearm was achieved by applying normal or shear deformation to the skin. Our proposed system can instruct bending motions of limbs and can be used along with the previous rotating induction device. We report that users can recognize bend/extend direction with more than 80 % accuracy with our device.**

I. Introduction

Under current information technologies, it is difficult to teach detailed body motions to other people through visual and auditory senses. For example, it is hard to tell how to ride a bicycle with words, even when you yourself are a good rider. A factor of the difficulty is the translation of the teacher's words or visual information to the rider's motion. The translation by the learner is tiring and unreliable, and the time lag for translation makes teachers' instructions ineffective in real-time motions.

Our research goal is to achieve direct intuitive motion instructions via haptic as if an instructor teaches golf swing motion by grabbing leaner's hand. This purpose can be achieved some previous technologies including exoskeletal actuators [1, 2] and electric stimulus for contracting muscles [3]. In this paper we show a novel haptic device which makes users bend/extend their elbow by giving tangential force to an upper arm and a forearm. This technology is suitable to realize a light-weight and easily-wearable motion teaching device.

Usage of reflex is one of the solutions to make users body move involuntarily via haptic stimulus. A phenomenon inducing human motion with haptic stimulation called "Hanger-Reflex" was first introduced on Japanese television programs. The first academic research on it was [4], to our knowledge. When one wraps a wire hanger around their head, then their neck rotates involuntarily. Nakamura et al. developed a wrist twisting device inducing rotational reflex on forearm with pressuring two opposite points on wrist by linear actuators. They measured force thresholds that users can perceive rotating directions [5]. Shikata et al. also tried to induce reflex phenomenon at body parts. They found that shear force can also promote rotational reflex on forearm [6].

Based on these previous studies, the rotational motion of limbs could be possible via haptic stimulus. Therefore bend/extension motions are then desired to induce arbitrary motions of limbs. In this paper, we show that a tangential force given to user's upper arm and forearm (shown in Figure 1 (a)) induces involuntary bend/extend motions of their elbow joints. By using our device, we observed some subjects moved their elbow involuntarily, though not all subjects were induced the motions at the current stage. The individual differences of effectiveness of the system was supposed to be the individual variations of perception. In this paper, we report one evidence, as our first step, that the proposed system can teach bend/extend directions intuitively to users with more than 80 % accuracy.

The elbow bending system can be applied to rehabilitation in medical fields. The device does not gives excessive physical overload, which may injure user's joints. The potential application of our device includes sports, as a learning support system of pitching, batting, or golfing.

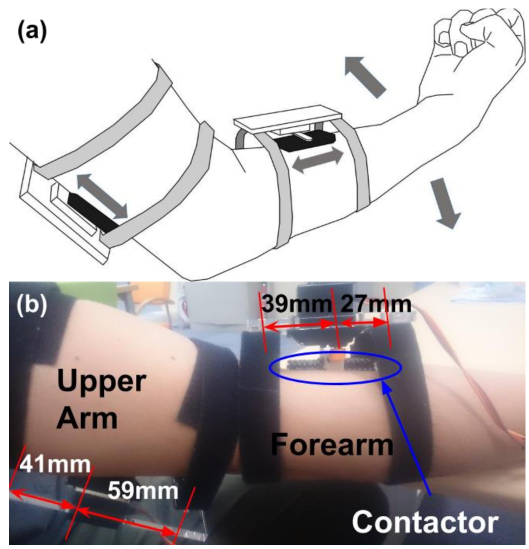


Figure 1. Attachment of proposed system.

II. Proposed Device

We tried to investigate whether bend/extend motion also can be induced by haptic stimulus as well as rotational motions. At first, we stretched skin surface with our hand to know the possible area which induces bend/extend motion of an elbow joint. Then we found stimulating front side area of forearm close to elbow joint and back side area of upper arm close to it could induce bend/extend motion as shown in Figure 1 (a).

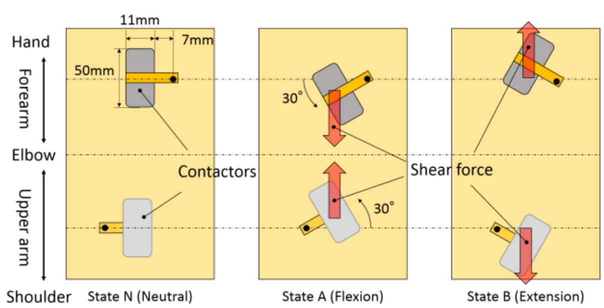
Based on this insight, we made a prototype. Figure 1 (b) shows how to attach the devices to the arm. One device unit is made of a servo motor (GWSMICRO/2BBMG/J), a contactor which sticks to the skin softly with a rubber sheet, and an acrylic plates with a Velcro band to fix them onto an arm. One device is set on a front side of a forearm close to elbow joint, and the other one is set on the back side of an upper arm.

III. EXPERIMENTS

We investigated whether users could be induced to bend/ extend their elbow joint by our proposed device. Figure 1 (b) shows typical situation of how the device was attached to users. In this experiment, examinees sat down and put their right elbow on a desk. The device was set on their right arm.

There were 3 states for experiments as shown in Figure 2. Two of them were used for stimulation (state A and B) and the rest one is used as neutral (state N). Every stimulus starts from N state. The bending stimulus corresponded to the transition of two states from N to A, while the extending one corresponded to from N to B. The transition duration from N to each stimulus was 0.5 second. We conducted 80 trials (40 bending and 40 extending stimuli in random order) to each examinee. As for the neutral state, we asked examinees to bend their right arm about 30 degrees compared with fully extended state. After the each stimulus, examinees had to choose perceived direction: bend or extend without seeing the actuators' motion, by clicking mouse with their left hand. Six examinees: 5 male and 1 female, mean age 23 years old, took part in the experiment.

Figure 3 shows the results. The overall average accuracy of 6 examinees was 81.5%. The resulting correct rate is high enough to conclude that the stimuli we prepared were evaluated as we expected. Some examinees actually bent/extended their elbow joint when the device stimulated their skin. However, this result does not mean that our device induces involuntary action of elbow joint, but only demonstrates that people can tell the differences of motion direction.



.Figure 2. Diagram of stimuli which are seen from the front side of arm.

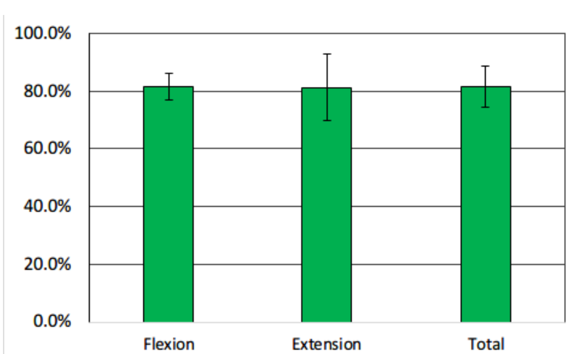


Figure 3. Percentage of correct answers of each evaluation.

IV. DISCUSSIONS

In this paper, we found the appropriate stimulus points experimentally. The procedure to find the optimal spots systematically for arbitrary users is left as our future work.

For considering the optimal spot, anatomical insights have to be taken into consideration. In Hanger Reflex, the stimulated points are clearly different from the neck muscle or tendon positions. In our system, the relative position of arm muscles might be important since they are closely positioned. There are two representative muscles on upper arm and forearm [7]. A brachiordial muscle is on the front of forearm, and a triceps brachii muscle is on the back of upper arm. When elbow joint bends, a brachiordial muscle contracts, and a triceps brachii muscle extends. The skin surface stretches similar to the state A. In contrast, they act opposite manner when elbow joint extends. The skin surface stretches similar to the state B.

The above correspondence suggests some direct link between skin stimulation and muscle response. In that case, the mechanisms to induce joint actions might differ from the previously examined methods like the hanger-reflex. Clarifying the relationships between the stimuli and the muscle is one of our future works.

V. CONCLUSIONS

In this paper, we proposed a wearable device that deforms arm skin laterally to induce elbow joint motion. Our experiments showed that the device could instruct bending/extending directions with its accuracy of 81.5%. In the experiment, some examinees involuntarily moved their elbow to our intended direction. However in the current stage, our device could not make all examinees move their elbows. To find an optimal stimulating points is one of our important future works.

ACKNOWLEDGEMENTS

This work was partly supported by MEXT KAKENHI Grant-in-Aid for Young Scientists (A) 15H05315.

REFERENCES

[1] Pratt, J. E., Krupp, B. T., Morse, C. J., and Collins, S. H. "The RoboKnee: an exoskeleton for enhancing strength and endurance during walking." Robotics and Automation, 2004. Proceedings. ICRA'04. 2004 IEEE International Conference on. Vol. 3. pp. 2430-2435, IEEE, 2004.

[2] T. Hayashi, H. Kawamoto, and Y. Sankai, "Control method of robot suit HAL working as operator's muscle using biological and dynamical information." Intelligent Robots and Systems, 2005.

[3] E. Tamaki, T. Miyaki, and J. Rekimoto. "PossessedHand: techniques for controlling human hands using electrical muscles stimuli." Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM, pp. 543-552, 2011.

[4] R. Matsue, M. Sato, Y. Hashimoto, and H. Kajimoto, ""Hanger reflex": A reflex motion of a head by temporal pressure for wearable interface." SICE Annual Conference, pp.1463-1467, IEEE, 2008.

[5] T. Nakamura, N. Nishimura, M. Sato, and H. Kajimoto, "A Wrist-Twisting Force Display Using the Hanger Reflex," Annual Conference of VRSJ, pp.519-522, 2014. (Japanese)

[6] K. Shikata, S. Tabata, K. Odani, K. Saito, Y. Makino, and H. Shinoda, "Forearm Rotation Control by Applying Shear Deformation." Annual Conference of VRSJ, pp.84-85, 2014. (Japanese)

[7] Joseph, E. Muscolino, "The Muscular System Manual: The Skeletal Muscles of the Human Body" Third edition, Mosby, 2009.