2021 年度　永守財団　研究助成　研究報告書

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1．研究題目

Development of Haptics Display that Simulate Liquid Material Properties using Electromagnet (電磁石を用いて液体の物性を再現したハプティクスディスプレイの開発)

2．研究目的

This proposal aims for development of a handheld and light weight **virtual reality (VR) controller** consists of robotic soft actuator (presented previously), and **programmable viscosity material controlled with electromagnetic**. Unlike the previous VR controller presented in the FY2020 proposal, this research aims to <u>integrate the tactual perception of liquid material properties (e.g., viscosity)</u> together with the shape haptics information. By integrating the knowledge in Human Perception and material control, create the computational model that take the relationship between electromagnetic and perceived viscosity, the controller could allow user (VR player) to perceive various haptic stimulations in addition to the shape of complex objects but also the weight-shifting and material properties. As shown in Figure 1, this proposal will contribute on the previous work (*Nagamori Award 2020*) by carrying the VR controller with shape and texture manipulation

Figure 1 Proposed VR controller that can simulate the different viscosity perception (blue) in addition to the programmable soft actuator (green)

and adding the viscosity perceptual programmable with electromagnetic. I will **utilize the ferromagnetic material** that could control its viscosity properties with magnetic field for manipulating virtual viscosity. Therefore, this proposal would **broaden the range of application with the proposed VR controller** such as for virtual laboratory in which the students could learn the virtual chemistry classes or for the medical training to enhance the telepresence system in which the remote participant could feel the same experience as the local users. To summarize, this proposal will contribute to the following area: 1) novel VR controller to enhance both perceived shape and texture with enclosed liquid material properties by combining the soft actuator and electromagnetic, 2) a computational model that considering the relationship between haptic rendering (e.g., shape, texture, and viscosity) using digital fabrication technique.

3. 研究内容及び成果

This research is investigating how the different magnetic field generated from the electromagnet could modify the viscosity perception of virtual object. At the begin of this project, I have created a prototype device to generate the viscosity perception through ferromagnetic material (Figure 2). The device included the servo motors that balance the ferromagnetic position, the lifting and rotating function that allows the system to generate the throw and lean action of the fluid material. The electromagnet is attached on the balancing plate and the ferromagnetic tray is placing on the top of the electromagnet. In addition, the gyro sensor is attached on the basement of the device to measure the rotation angle. The preliminary experiment has been conducted to confirm the placement and initial position of the device. A perceptual study has been conducted with 5 participants to collect the haptic perception and the prototype response. However, as mentioned in the follow up document, the participants report that the device is too big to handle, and the response is a little bit slows so that it is effects how they could perceive the haptic information of the virtual contents.

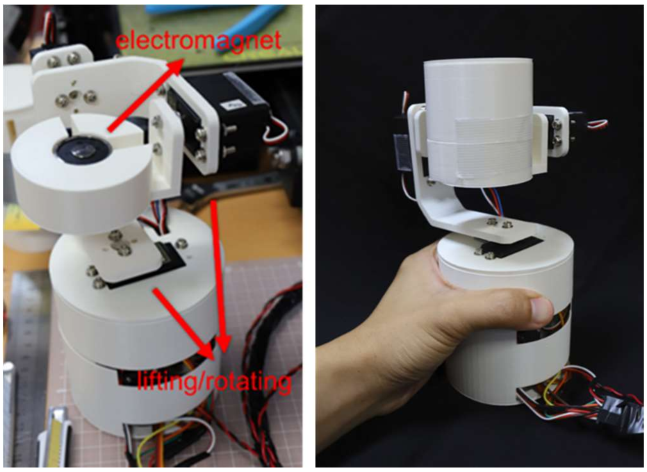

Figure 2 First prototype of the device embedded with electromagnet.

Solving the issues on size and haptic response, I have redesigned the device and replaced the parts of hardware (e.g., the step motors, and microcontroller) (Figure 3). The new device increased the haptic response through the speed of step motor. I have conducted an additional experiment to confirm the haptic response with 5 participants that newly recruited to evaluate the device. The participants are randomly interacting with the previous and current version of the devices. After that, they are asked to compare the performance of the devices in the following conditions; (1) ease of use, (2) fatigue, (3) accuracy, (4) response of haptic perception through 7-points Likert scale. As the results, all participants are rated the device easier to use when compare with the previous version

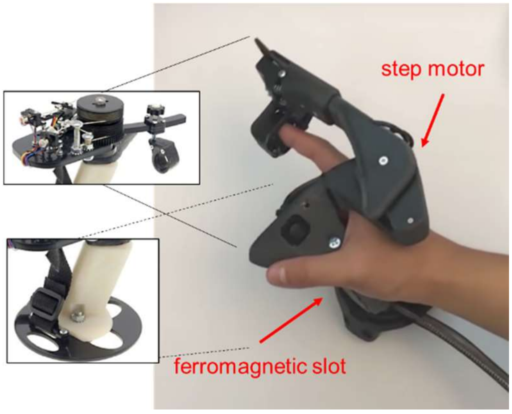

Figure 3 Final design for haptic viscosity device (using ferromagnetic slot).

(average 5.9 from 7). They also rated the fatigue was reduced compared to the previous version (average 5.5 from 7), and also the response of haptic perception and accuracy are increased (average 6.2).

Prior confirmed the usability of the new device, I have investigated the characteristic of ferromagnetic in response to the electromagnet. While my vision is to explore the wide range of haptic perception that allows mapped various of materials. However, in the current setting, my application is the chemical laboratory in which the haptic perceptions can be ranged between water (i.e., less viscosity) to honey (i.e., high viscosity). Since the nature of ferromagnetic has a viscosity closed to the water, without any manipulation my hypothesis is that its simulate the viscosity of water. Then, when we manipulated the viscosity of ferromagnet by charging the electromagnet with 3Hz (i.e., given 5V of power at 3 cycles/second), my hypothesis is that its can simulate the viscosity of honey. To confirm this hypothesis, I have conducted the haptic perception experiments (remark that in the current experiment, I did not provide the visual feedback) in which the participants are compared the haptic perception simulated with ferromagnetic under the decided parameters, and the actual haptic of water and honey.

4. 今後の研究の見通し

First, the results of the current research progress is plan to submit as a conference paper to IEEE World Haptics (WHC) 2023 and the research progress included the user study is plan to submit as a short transaction paper on IEEE Transactions on Haptics. Furthermore, the current results are also planning to submit at the domestic conference on informatics (情報処理学会) that allows for discussion regarding the future direction of this study.

Second, the experiment that conduct in the current research does not occur the visual stimulus. The visual stimulus could affect how the participants perceived the viscosity from the haptic simulation device. For example, by adding the visual stimulus of material with different viscosity corresponding to the viscosity simulated from the haptic device, it could enhance the viscosity parameters. Therefore, in the next step, I would like to conduct the experiment to explore the effects of visual stimulus in addition to the haptic stimulation.

Finally, the main aim of this study is to integrate this device with the previous shape simulation device (i.e., presented in 2020 final report). Therefore, in the next step, I would like to integrate the viscosity simulation device with the previous shape manipulation device, which could add both functions to simulate virtual information through VR devices.

5. 助成研究による主な発表論文，著書名

学術論文（査読付）

1. Santawat Thanyadit, Parinya Punpongsanon, Thammathip Piumsomboon, and Ting-Chuen Pong. XR-LIVE: Enhancing Asynchronous Shared-Space Demonstrations with Spatial-temporal Assistive Toolsets for Effective Learning in Immersive Virtual Laboratories. Proceedings of the ACM on Human-Computer Interaction (In Proceedings of the ACM Conference on Computer-Supported Cooperative Work & Social Computing 2022) 6, CSCW 1, Article 136, April 2022.

国際会議（査読付）

2. Parinya Punpongsanon. Exploring on Haptics Viscosity Perception through Liquid Magnetic Control. IEEE World Haptics 2023. (Preparation)