Research of Visual Haptics for Remote Machine Manipulation via Brain Signal Evaluation toward Robot Implementation

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ABSTRACT

A remote machine operation system is being developed to reduce migrant labor from developing countries to developed countries. The focus is on simplifying the operation interface by utilizing human cognitive characteristics. This paper will introduce visual haptics technology that transmits force haptics of remote machines with video images.

1 Introduction

In 2013 at some village in Indonesia where is no electric power, I met a fisherman who said, "I am already HAPPY enough" [1][2]. He told me how happy he is to live with his friends and family in a familiar land where he can be himself. Remote machine is a technology that can provide this HAPPY for all people (Fig. 1).

The social implementation of remote machine system requires not only machine technology and communication technology, but also the establishment of methods for understanding and evaluating the cognitive characteristics of "humans" and their application to systems. This paper outlines the remote machine system technology that the authors have been working on. In section 2, our prosed visual haptics technology is described [3][4][5][6]. In section 3, the other technology which contributes to make remote machine operation being easy to use is introduced [7][8][9]. In section 4, the contribution of this paper and our information [10] to demonstrate our remote machine technology are summarized.

Fig. 1 HAPPY for ALL

2 Visual Haptics to Feel “Haptics” with “Eyes”

It is important to develop a remote machine manipulation technology with a simple and intuitive human interface that can be easily used by anyone.

2.1 Proposed Visual Haptics [3][4][5][6]

Methods of physically transmitting haptic information requires an operator to wear massive devices. We propose a new visual haptics system that superimposes haptic information visually on the contact point.

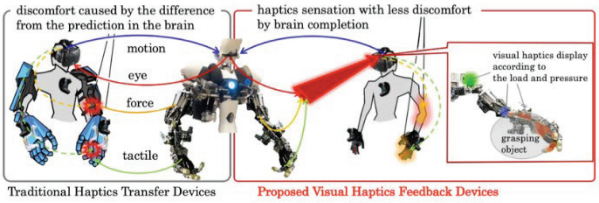

Fig. 2 Comparison of haptics feedback device between existing and proposal

2.2 Method

In order to demonstrate the effectiveness, a new method of brain signal analysis is established as shown in Fig. 3 [3] and applied for evaluation of operability on remote machine manipulation with proposed visual haptics in real spaces [4]. To compare feedback modalities for haptic transmission, a simple device was constructed as shown in Fig. 4. The equipment can be operated by a subject motion. The gap between the grippers is controlled by a dedicated control interface, as shown in Fig. 4(b). The operator can obtain haptic sensations when the robot arm grasps the object with one of three feedback modalities: sound, vibration, and light. A speaker and vibration motor are attached to the gripper control interface worn by the operator, as shown in Fig. 4 (b), and the LED is attached to the tip of the robot gripper, as shown in Fig. 4 (c). A pressure sensor is attached to the tip of the gripper; when the pressure exceeds a threshold value, the speaker, vibration motor,

or LED is activated. For subjective evaluation, the subjects were interviewed and asked to answer a questionnaire after each session. The questionnaire asked the subjects to score each feedback modality from 0 to 100 (the higher the score the better). For each session, two kinds of data were collected with timestamps for later analysis: from the pressure sensor mounted on the gripper and the 32-channel EEG array sensor mounted on the subject.

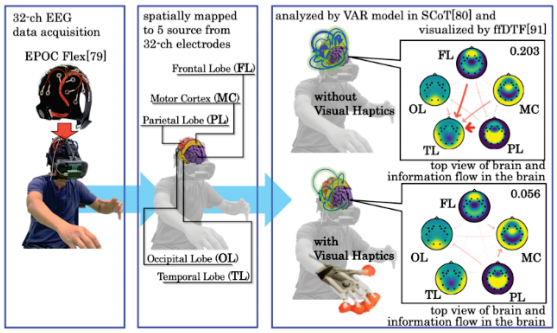

Fig. 3 Procedure of brain signal analysis

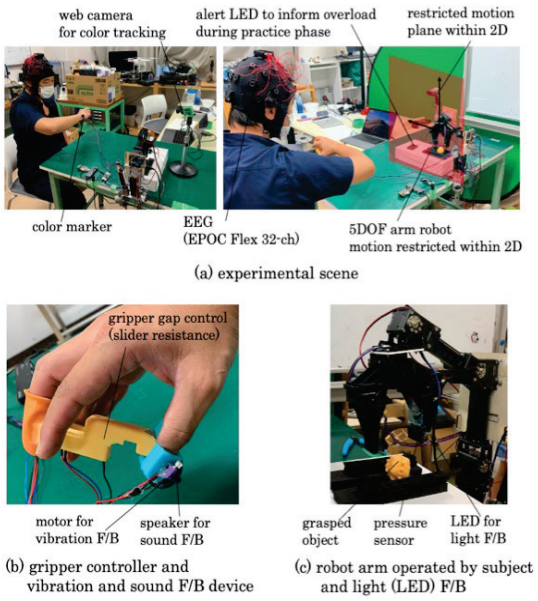

Fig. 4 Evaluation equipment for three feedback modalities

2.3 Results

Seven subjects were participated in this evaluation test. Two of the subjects were excluded from the evaluation because their EEG measurement results deviated from the whiteness test and they did not understand the contents of the task instructions sufficiently. The collected data of three sessions of five subjects are separated correctly into each case from the recorded time stamps, and the following data analysis is conducted. The visual feedback modality was found to be most effective at reducing the grasping force by 24.1% without increasing the amount of information flow in the brain as shown in Fig. 5. A positive correlation was identified between the subjective assessment and the reduction of information flow in the brain, which indicates the usefulness of the EEG measurements as shown in Fig. 6.

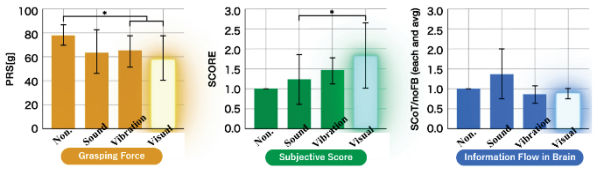

Fig. 5 Results of grasping force, subjective score, and information flow in brain

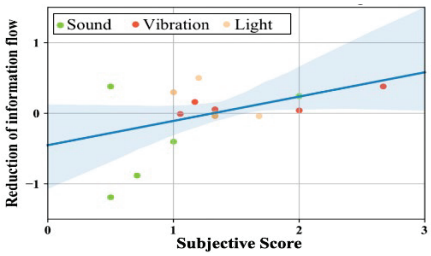

Fig. 6 Subjective score and reduction of information flow in the brain for the three modalities

3 Toward Social Implementation

Although, haptics feedback is important element to achieve social implementation of remote machine system, there are a lot of the other elements to resolve technically. In this section, three our developed elements are introduced.

3.1 Human Eye Display to Reproduce “Eyes”

It is known that human vision functions differently in central and peripheral vision. The developed system named “Human Eye Display” provides natural images and reduces communication bandwidth by presenting images that match the work scene and the communication situation. For example, during manipulation, the central field of view is stereoscopic with high resolution, while the peripheral field of view is flat with low-resolution black and white images. During movement, the size of the central field of view is reduced and the resolution of the peripheral field of view is increased as the speed increases. Moreover, the attention field could be zoomed up and the motion gain between the operator motion and the robot motion are tuned automatically.

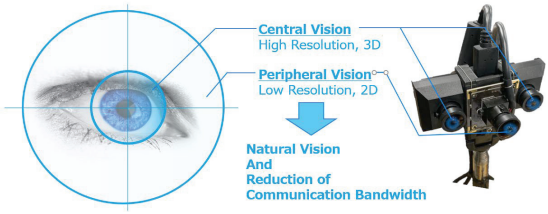

Fig. 7 Function of human eye and prototyped camera

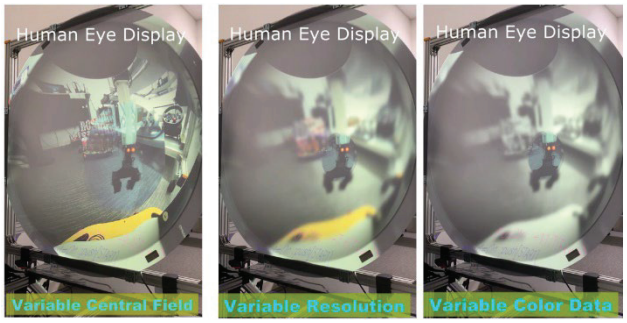

Fig. 8 Human eye display with adaptive control of central and peripheral vision

3.2 Remote Machine Grows with the Operator [7][8]

With the evolution from human operation to automatic operation, it is expected that one operator will be able to operate multiple remote machines as shown in Fig. 9, or that remote machines will be fully automated. In the field of mobility, automatic driving technology can be applied, and its realization is expected to be near. The authors have confirmed that the application of modular neural networks enables automatic operation from human remote operation data and can flexibly respond to route changes [7]. We are working on the development of automation technology via task segmentation to respond flexibly to changes in remote work tasks as shown in Fig. 10 [8].

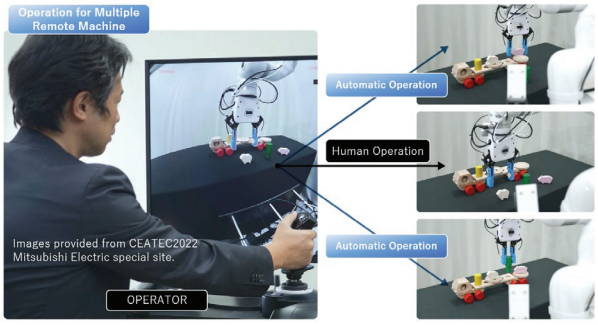

Fig. 9 Multiple remote machine operation owing to automatic technology

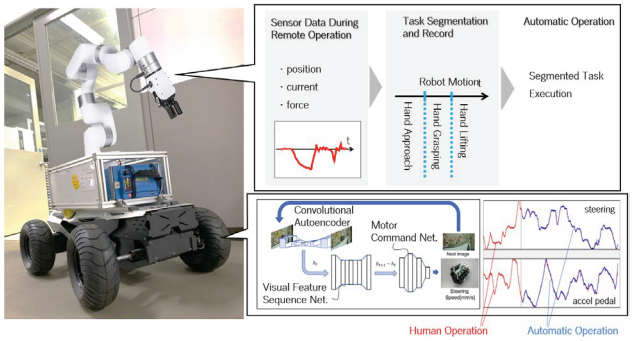

Fig. 10 Automation through learning of human operation data

3.3 Remote Communication [9][10]

When extending the application of remote machine manipulation, a communication function with people around the remote machine is necessary. In communication, not only verbal communication but also non-verbal communication is known to be important. As a remote machine that combines remote manipulation and remote communication, we propose “Augmented Avatar” in which each function is designed separately and then integrated (Fig. 11). The baseline of this proposal was selected as a FINALIST in the international contest XPRIZE/AVATAR [9][10] and is considered to have received a certain level of recognition.

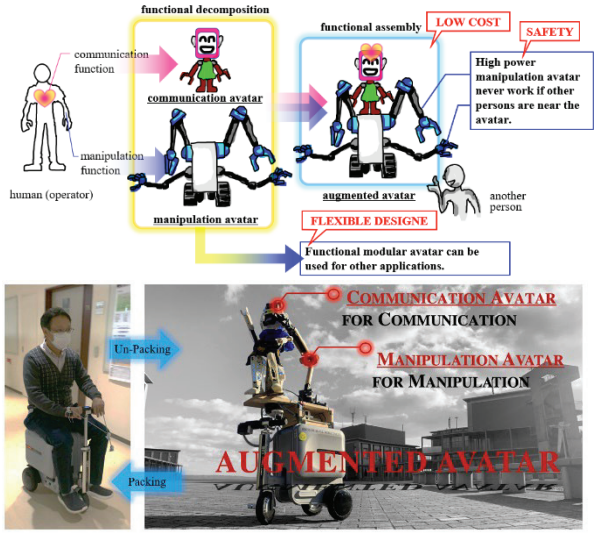

Fig. 11 Manipulation x Communication Remote Fusion: Augmented Avatar (XPRIZE/AVATAR FINALIST)

4 Conclusion [11]

Haptic feedback is an important element for remote machine manipulation. We previously proposed a method for visually superimposing haptic information on a contact point with an object and confirmed its effectiveness through EEG measurements. To the best of our knowledge, there has been little in the literature on using EEG measurements as an objective and quantitative evaluation of methods for remote machine operability. We comprehensively evaluated the operability of three feedback modalities in terms of the grasping force and cognitive load for an object-grasping task with an actual robot arm. The visual feedback modality was found to be most effective at reducing the grasping force by 24.1% without increasing the amount of information flow in the brain. A positive correlation was identified between the subjective assessment and the reduction of information flow in the brain, which indicates the usefulness of the EEG measurements. Based on these results, the proposed visual haptic feedback is expected to contribute to the development of a highly

operable remote machine without the need for a highly complex and expensive interface.

The other three our developed elements were introduced. Firstly, “Human Eye Display” has a big potential because it can display natural videos even if near future communication bandwidth still limit especially for uploading data. Secondly, Automation technology using data set during human operation also has a good approach for the situation in which full automated system can’t be developed or realized because of too complicated task, too drastic environment, or poor sensor. This kind of approach never be required to guarantee complete automation because a human operator can compensate the lack of robot performance by remote operation. Finally, we proposed augmented avatar, prototyped, and demonstrated the effectiveness through worldwide competition named XPRIZE/AVATAR.

Social implementation of remote machine system is still not easy and there is a lot of barriers. On the other hand, the expectation and potential are so huge. We had the opportunity to co-create an experience of remote machine operation technology at METoA Ginza for both adults and children from March 2022 to January 2023 as shown in Fig. 12 [11] The system is still prototype and the function is just grasp and move light weight object, but a lot of visitors had a enjoy time. This experience made us known that there is a lot of way to contribute the better world.

Through the experience of operating the machine from the machine camera and the EEG measurement research, we once again realized the depth of human cognitive ability and its potential development. The remote opportunity manipulation technology is not limited to the expansion of space and the body, but can be sublimated to the expansion of the mind through the sharing of different cultures and values, and even to a sense of oneness with animals, nature, the earth, and the universe.

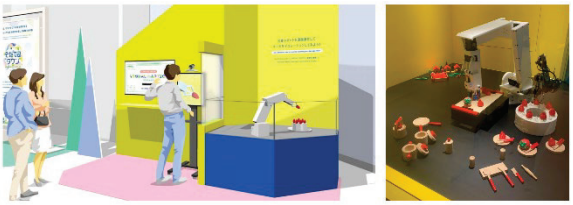

Fig. 12 Experience equipment at METoA Ginza

Fig. 13 Expansion of the "mind" and a sense of oneness with the earth and universe

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