Presenting the sensation of flying with flapping virtual wings independent of the limbs

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Fig. 1: Flying with flapping virtual wings independent of the limbs

***Abstract*— Since ancient times, people have longed to fly in the sky. Actual flying involves risks and costs, but using a VR device makes it easy to experience flight. In this research, we propose a method of presenting the sensation of flying with flapping virtual wings independent of the limbs, such as a flying lizard. Unlike studies that presents the sensation of flapping wings by moving the arms, new applications that use the limbs during the flight experience can be expected by flying without moving the limbs. In this paper, we proposed a method of presenting the sensation of manipulating the wings without using the limbs and a method of transmitting the force acting on the wing to humans. We conducted experiments using these methods and obtained subjective evaluations. From the experiment, it was confirmed that the operation by static muscle contraction is also effective for operationing wings. It was also shown that the haptics presentation using EMS has a higher overall evaluation. Finally, we obtained the result that the body image expansion of the virtual wing which proposed in this study is possible.**

I. INTRODUCTION

Since ancient times, people have longed to fly in the sky. Until today, we have had a flight experience by using vehicles such as airplanes and hang gliders. However, actual flying involves risks such as crashes, costs such as fuel, and the skill to operate the equipment. By using Virtual Reality (VR) system, those risks and costs can be avoided, and makes it easy to experience flight.

Fig. 1 shows how they flying with flapping virtual wings independent of the limbs. In this research, we propose a method of presenting the sensation of flying with flapping virtual wings independent of the limbs as a reature with wings growing from the back of a human, as shown in Figure 1, using a VR system.

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A. Background and purpose of the research

Many studies have been conducted to give a sensation of ”floating” of ”flying” using VR devices. Research on the sensation of falling generated by visual stimuli and a proposal for a flight experience device using a body assistance mechanism are examples.

Regarding research that gives a sensation of ”flying with flapping”, research has been conducted on a device that allows the user to board a large control device and experience a bird in flight. [1] This method has disadvantages such as the need for a large scale device and the limitation of limbs movement.

In addition, there are still few studies on giving the sensation of flying with flapping one’s wings. In general, studies on giving the sensation of flying by becoming a bird have been conducted, and studies on giving the sensation of flying by becoming a creature with wings independent of its limbs, such as a flying lizard, have not yet been focused on.

In this research, we propose a method to present the sensation of flying with flapping wings bymanipulating the wings that grow from the back without using limbs movements. By not using limbs movements, it is possible to use hands and feet during the VR flight experience, such as throwing an object while flying, whick is expected to expand the range of the VR flight experience.

II. EXPANSION OF BODY IMAGE

In this research, two elements are important: to make humans feel ”wings” that do not originally exist (existence), and to present the sensation of ”flying with flapping with one’s wings” (movement). In order to present these sensations, we focus on the expantion of the body image.

A. Body image

Humans have the ability to perceive their own body shape, which is called body image. It allows us to ditinguish between ourselves and others.

Besides, there are two concepts that are closely related to the body image: sence of self-ownership and self-agency. Sence of self-ownership is the sensation or experience that one’s own body parts belongs to one’s own body. Sence of self-agency is the sensation or experience that one is performing and action by oneself and that one is in control of the body parts.

The sense of self-ownership and self-agency are closely related to the formation of the body image. Therefore, it is considerd that the following elements in this research can be satisfied by flying with a virtual wings body image, that is by expanding the body image and operating.

- To make humans feel ”wings” that do not originally exist (Sense of self-ownership)
- To present the sensation of ”flying with flapping with one’s wings” (Sense of self-agency)

B. Body image expantion

The body image may change dynamically to parts other than the self. This is called body image expantion. An example of body image expansion is to treat a tool (for example, a tennis rackaet or a baseball bat) held in the hand as if it were a part of one’s own body without being aware of its shape, and hit the ball back.

Body image expansion can be broadly categorized into two types: one is sensory remapping, such as the Rubber Hand Illusion (RHI), and the other is the dynamic expansion of the boy image during tool use mentioned above (Embodiment of tools).

C. Rubber Hand Illusion

The Rubber Hand Illusion is the illusion that we feel the rubber hand as if it were our own hand. It is an illusion phenomenon in which a person perceives a haptics stimulus on a rubber hand after gibing a synchronized haptics stimulus to a real hand hidden from field of vision and a rubber hand in front of the eyes for about 2 to 20 minutes. One of the characteristics of RHI-based body image expansion is that the original body part and the remapped part cannnot coexist.

D. Embodiment of tools

There is a neurophysiological study on the embodiment of tools using Japanese macaque monkeys that showed the expansion of body image by tool use. By observing the activity of bimodal nuerons with hand somatosensory receptors and visual receptors near the hand in the parietal cortex of Japanese macaque monkeys during tool use, and showed that the monkey’s body image extendetd to the tip of the tool.

E. Body image expantion approach

In this research, we focus on the body image expantion to tools (embodiment of tools).

It is known that tele-robots and avatars, which have similar degrees of freedom and dynamics to humans, can be recognized as part of the body by perfectly synchronizing their body movements, such as the generation of the sensation of being transported, as in the RHI, or the embodiment of tools.

It has also beeen shown that the temporal coincidence of sensory information (such as visual and haptics) is highly important in the generation of the RHI. Therefore, the temporal coincidence of sensory information is considerd to be important also in the embodiment of tools. On the other hand, spatial coincidence is considered to be flexible, and there are cases where the subject responds as if the subject had struck his or her hand when hitting the rubber hand with RHI occurring.

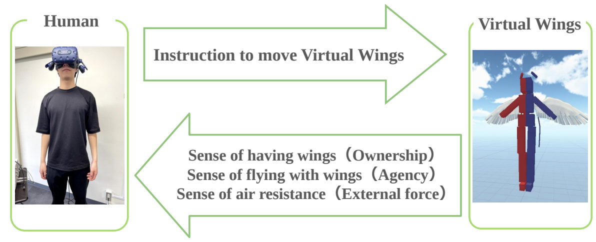


Fig. 2: Method of body image expansion

As described above, body image expantion (embodiment of tools) can be expected by integratin multiple senses and matching the sensory information presented in time. In this study , we try to expand the body image as shown in Fig. 2. We attempted to integrate multiple senses by giving a instruction to move the wing from the human to the wing, and transmitting the sense of having wings, the sense of flying with wings, and the sense of air resistance. From the above, we present the sensation of flying with flapping virtual wings independent of the limbs.

III. HOW TO PRESENT WINGS INDEPENDENT OF LIMBS

A. Information transmission from humans to virtual wings

First, we describe a method of giving instruction from a human to virtual wings to move the wings. There are several methods of presenting information from a human to a system in a VR space, such as using a controller, gestures, or biological signals. Since the purpose of this study is to control the wings with something other than the limbs, we use biological signals that can be measured without limbs movement, instead of controllers that mainly use the hands or gesture that require limbs movement. In addition, the virtual wings is controlled by EMGs, which are easy to obtain numarical values among biological signals.

B. Information transmission from virtual wings to humans

Next, we describe a method of providing information from the virtual wings to a human. The five senses can ve mentioned as senses that work on humans. Among them, visual and haptics senses are often used as the information that works on humans in body image expantion. This indicates that the integration of visual and haptics senses is effective in body image expansion. In this research, we present information from virtual wings using both visual and haptics senses.

1) Presentation of visual information: The visual presentation is performed by outputting images created by PC software (Unity) to a visual display as shown in Fig. 3. The output image shows it is moving in the air and wings growning from one’s back.

We use an illusion called vection (self-induced self-motion sensation) to present the appearance of movement in the

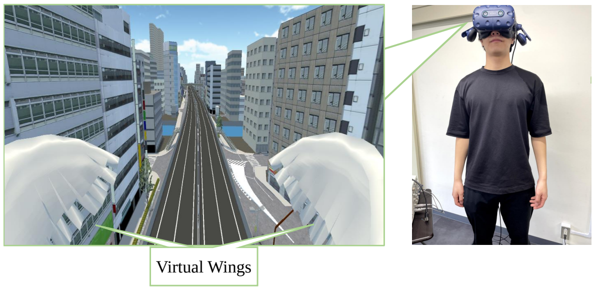


Fig. 3: Presentation of visual information by using the virtual environment

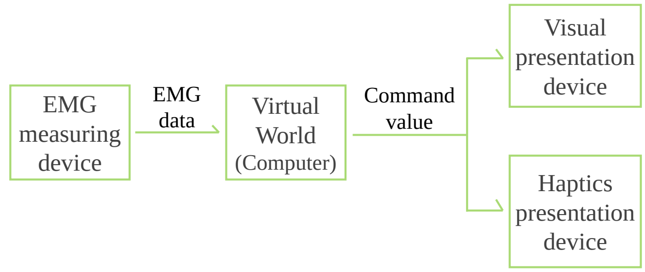


Fig. 4: Experimental environment system

air. Vection is the illusion that a body moves in a direction opposite to the direction of motion of the stimulus when a uniform motion stimulus is presented over most of the visual field.

As for the presenting growing wings from the back, when the user looks back, one can see the part of the wings growing from the back. Furthermore, when the wings are flapped, the appearance of expanding and closing the wings in the field of view is presented.

2) Presentation of haptics information: In haptics presentation, by presenting the haptics sensation at the root of the wings, the sense of having wings, the sense of flying with wings, the sense of air resistance are presented. This encourages the expansion of the body image through the presentation of haptis sensations to a certain area, similar to the expansion of the body image to the tip of a stick held by the hand in the embodiment of tools.

Besides, we also prepare two haptics displays: one using vibration and the other using electrical stimulation.

Haptics display using vibration presents vibration by an eccentric motor. Haptics display using elecal stimulation is called EMS (Electro Myo Stimulation) is a method of stimulating muscle contraction by applying electrical stimulation to muscles and motor nerves to simulate haptics sensation.

In this research, haptics sensation is generated by muscle contraction using EMS equipment, and information from the wings is presented.

IV. SUBJECTIVE EVALUATION EXPERIMENT OF BODY IMAGE EXPANTION USING THE PROPOSED METHOD

Using the proposed method of body image expansion, we examine the methods of manipulation and presentation, the position of manipulation and presentation, and evaluate each combination.

A. Exprimental environment for subjective evaluation

We describe the experimental environment for the subjective evaluation experiment. As shown in Fig. 4, we use a system that sends the values measured by the electromyography device to the software (Unity) on the terminal, and operates the visual and haptics presentation devices from Unity.

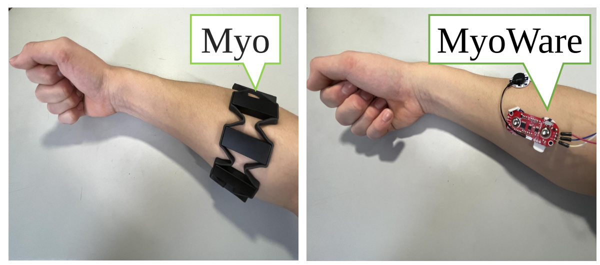


Fig. 5: EMG devices (Left: Myo, Right: MyoWare)

First, two EMG measuring devices, Myo (Thalmic Labs, Fig. 5. left) and MyoWare (Advancer Technologies, Fig. 5. right) , are prepared to compare manipulation by gesture and force.

Next, for haptics display, we prepare haptics presentation devices using vibration and EMS. The vibration function of Myo is used for vibration haptics presentation, and the Omron HV-F122 (Fig. 6) , a low-frequency treatment device, is used for EMS haptivs display.

Then, for the visual presentation device, two types of visual presentation will be prepared, one using an LCD monitor and the other using a Head Mounted Display (HMD) , in order to compare the third-person perspective and the first-person perspective. The LCD monitor is GW2765HT (BenQ), and the HMD is Quest from Meta. The virtual wings

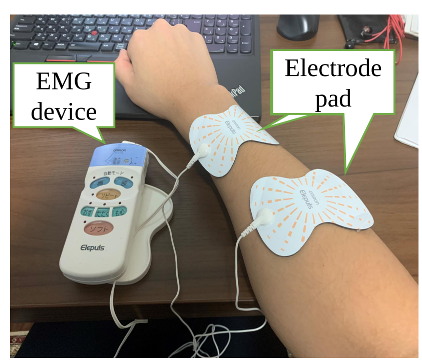


Fig. 6: EMG device (Omron HV-F122)

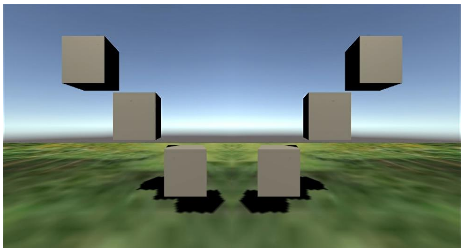


Fig. 7: Virtual Wings skeleton

TABLE I: Comparison items

Comparison item	Wings operation	Haptics display	Visual display
Wings operation	Gesture/Strengthen	Vibration	TPP
Haptics display	Strengthen	Vibration/EMS	TPP
Visual display	Strengthen	EMS	TPP/FPP

used for visual presentation is shown in Fig. 7.

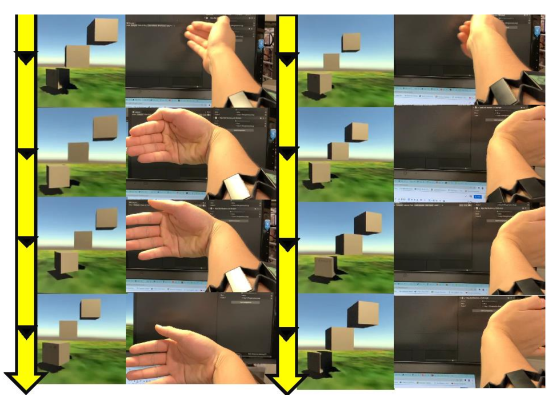
B. *Examination of operation and presentation methods*

Table 1 shows the comparison items, where FPP is First Person Perspective and TPP is Third Person Perspective.

1) Comparison of wings operation methods: First, we compare the manipulation methods of the wings. Manipulation methods using EMG can be classified in to gesture (dynamic muscle contraction [2]), which are movements accompained by joint movements, and manipulation by force or static muscle contraction, which does not involve joint movements.

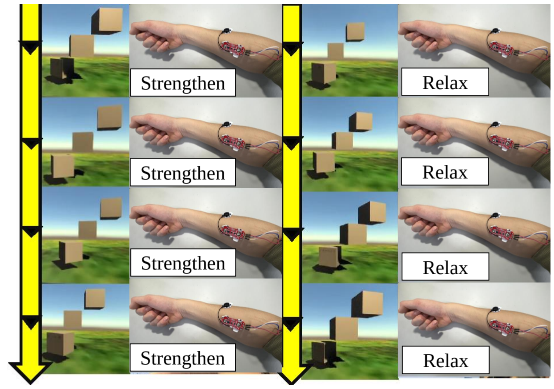
Fixing the conditions of haptics and visual presentation and comparing manipulation by gesture and force (Table 1).

When Myo is used as the myoelectric measurement device (manipulated by gesture), the virtual wings is designed so that when the wrist is bent inward, the wings also flaps inward, and when the wrist is opened outward, the wings also opens outward, as shown in Fig. 8. The haptics sensation is presented in such a way that the Myo attached to the forearm vibrates in time with the inward flapping of the wings.



(a) Wings move inward (b) Wings move outward

Fig. 8: Manipulation of virtual wings skeleton using Myo



(a) Wings move inward (b) Wings move outward

Fig. 9: Manipulation of virtual wings skeleton using MyoWare

In the case of using MyoWare (manipulation by force), the wings are designed to close when forces is applied and to open when relaxed, as shown in Fig. 9 The haptics presentation is made by vibrating Myo attached to the arm when the wings flap inward. MyoWare measures the forearm, chest, and shoulder as the measurement sites, where the forceful motion is easy.

As a result of the verification, we confirmed that it is possible to operate the virtual wings using force as well as gestures, which is a common method of operating VR applications, as intended by the pilot.

2) Comparison of haptics presentation methods: Next, we compare the haptics presentation methods using vibration and EMS.

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Fig. 10: Inductance of oscillation winding on amorphous magnetic core versus DC bias magnetic field

IX. CONCLUSIONS

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APPENDIX

Appendixes should appear before the acknowledgment.

ACKNOWLEDGMENT

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REFERENCES

[1] Max Rheiner. Birdly an attempt to fly. In *ACM SIGGRAPH 2014 Emerging Technologies*, pages 1–1. 2014.

[2] Howard G Thistle, Helen J Hislop, Mary Moffroid, and EW Lowman. Isokinetic contraction: a new concept of resistive exercise. *Archives of Physical Medicine and Rehabilitation*, 48(6):279–282, 1967.