# A Virtual Reality System for Occupational Therapy with Hand Motion Capture and Force Feedback

## A Pilot Study of System Configuration

Kouki Nagamune[1(✉)], Yosuke Uozumi[1], and Yoshitada Sakai[2]

[1] Graduate School of Engineering, University of Fukui, Fukui, Japan
nagamune@u-fukui.ac.jp
[2] Graduate School of Medicine, Kobe University, Kobe, Japan

**Abstract.** This study proposes a virtual reality system for occupational therapy with hand motion capture and force feedback. Force feedback is realized by using a vibration motor. In the experiment, the proposed system was applied for three health males. The results with force feedback were close to the setting distance more than the results without force feedback. As a future work, actual working task used in clinical situation should be applied to this system.

**Keywords:** Virtual reality · Occupational therapy · Force feedback

## 1 Introduction

Japan is facing to high aged society. Japanese government estimates 4.7 million people who has dementia in 2025 [1]. On the other hand, the number of occupational therapist is only 57 thousands in 2011 [2]. This number cannot be rapidly increased due to the falling birth rate. Therefore, decreasing the task of occupational therapist is essential for the future. This problem is not limited to Japan. Other developed countries also have similar situation.

Occupational therapy is useful for treatment of patient with dementia which is derived from some diseases such as Parkinson's disease [3]. In occupational therapy, an examiner (occupational therapist) assigns a motion task based on standard procedure to a patient. The motion task aims to recover the motor function of the patient. Usually, the motion task requires that the examiner should explain the motion task and measure the operational time to finish the motion task. If this operation can be realized with a computer instead of the examiner, it can support to decrease the daily work of the occupational therapist. The difference between conventional and proposed occupational therapy is shown in Fig. 1.

In the past two decades, virtual reality technology has been researched to apply for rehabilitation [4]. Some studies [5, 6] have been reported that a virtual realty can be applied to the occupational therapy. The studies employed only motion capture device for virtual reality. Most of studies are focusing on motion of the body. However, it is difficult


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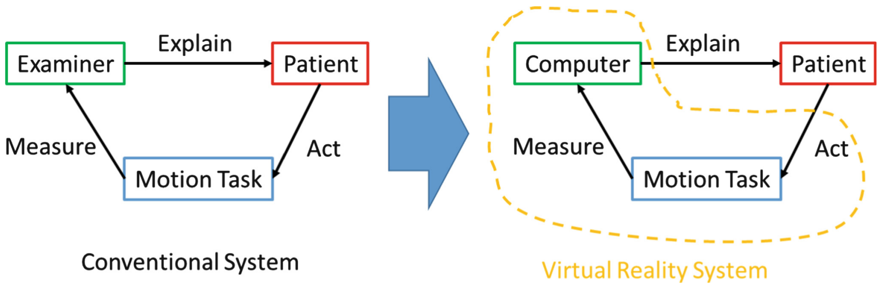



**Fig. 1.** Virtual reality system for occupational therapy

for patients to do actions such as taking objects, because visual feedback provides a little information for recognizing the condition relating the body and objects in the virtual space. Kelly et al. proposed a new system which employed a mechatronic-virtual system to train human motor control [7]. The mechatronic virtual system is realized by using air pressure to make a force. However, the air pressure system needs air pump which is comparatively large size. In addition, an air tube possibly interferes motion of the subjects due to the tension of the air tube, when the air fulfils in the air tube.

The purpose of this study is to develop a system which provides a force feedback such as touching feelings to subjects by using a vibration motor. The reasons to use the vibration motor are easy feasibility and light weight.

## 2 Method

The basic concept of the proposed system is shown in Fig. 2. In the general virtual reality, a subject acts to object. Then the change as the result is projected through visual sense. In this case, it is difficult to recognize the relationship between the body and objects where the a part of body is placed in front of the objects along visual line.

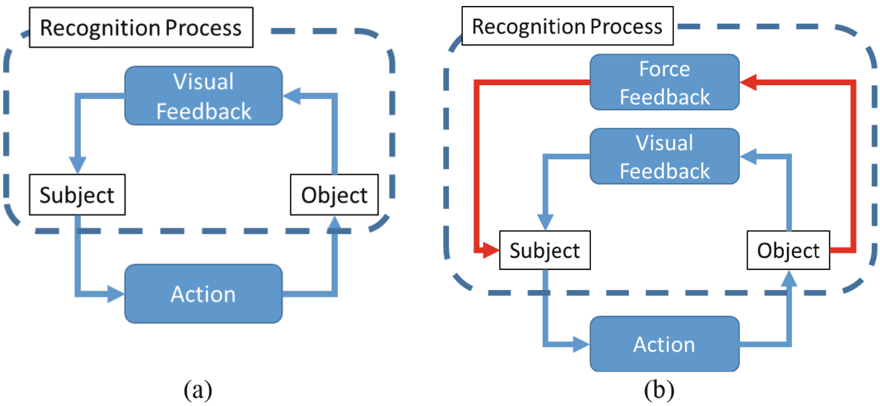



**Fig. 2.** Basic concepts of (a) general and (b) proposed virtual reality

Obstacles often exist in the field of view. To overcome this problem, the proposed system provides additionally force feedback to the fingers of the subject.

The proposed system consists of motion capture (LM-C01, Leap Motion), digital/analog convertor (USB-3114, Measurement Computing) and vibration motor (LBV10B-009, NIDEC COPAL Corporation). The specification of the motion capture is tabulated in Table 1. The motion capture has an image sensor, and can obtain information of points of each joints and endpoints of the fingers in real-time. The coordinate system of virtual space is determined by the motion capture (Fig. 3). This study focuses on only tips of the thumb and index finger.

**Table 1.** The specification of the motion capture

| Precision | 0.01 (mm) |
|---|---|
| Sampling rate | 200 (frames per sec) |
| View angle | 150 (degrees) |
| The number of detectable fingers | 10 (fingers) |
| Connection | USB cable |

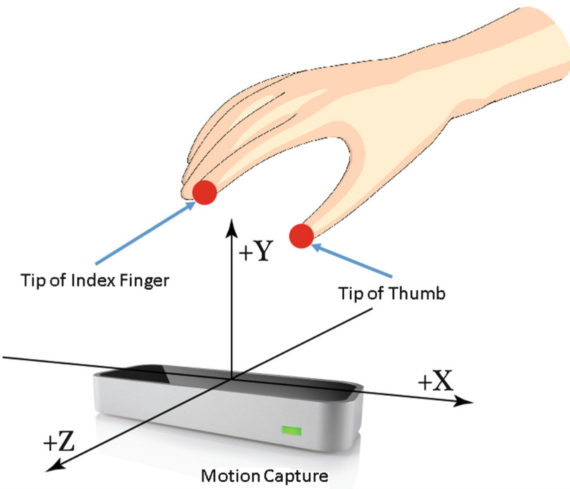



**Fig. 3.** Coordinate system

This study employed vibration motor to provide a force which can impress a virtual object on subjects (Fig. 4). In the virtual space, the vibration motor is activated when the finger touches the virtual object. The vibration power depends on the dent degree of the finger to the virtual object. When the finger pinches with large distortion of the virtual object, the vibration motor strongly shakes. The vibration motors attach to the fingers by thumbstall (Fig. 5). The thumbstall has three types (small, medium, large) for size, because the finger diameter has variation from person to person. The proper size was choosen by the subject.

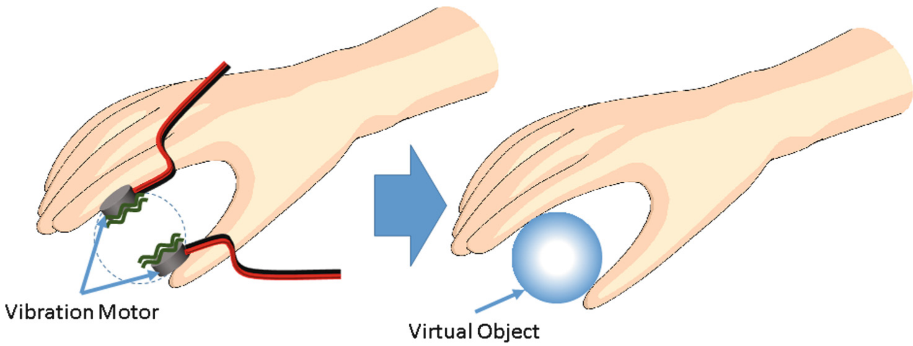



**Fig. 4.** Virtual object with vibration motor

This study used a cubic shape with 30 mm edge and a spherical shape with 30 mm diameter as virtual objects. The virtual object is set to be directry above the motion capture. We developed a software to display the virtual space and control the vibration motors. The software is monitoring the position of the finger tip. When the finger tip is recognized inside the virtual object, the vibration motor is activated with the digital/analog convertor. The vibration power depends on the distance from the boundary of the virtual object to the finger tip.

In the experiment, an examiner measures the length between tips of thumb and index finger, when a subject judges to pinch the virtual object. In the virtual space, only the virtual object and tips of fingers are displayed (Fig. 6). This system consciously shows only tips of fingers. If the virtual fingers are displayed, the virtual object is hidden under the fingers. In the case, it must be harder to recognize the pinching condition to subjects.

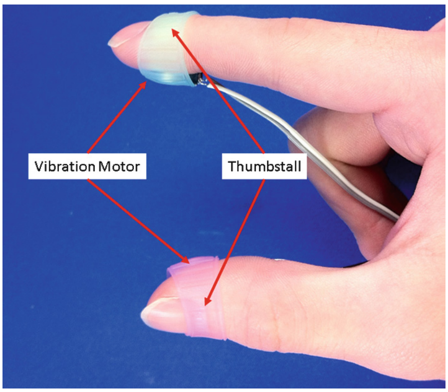



**Fig. 5.** Setting of vibration motor

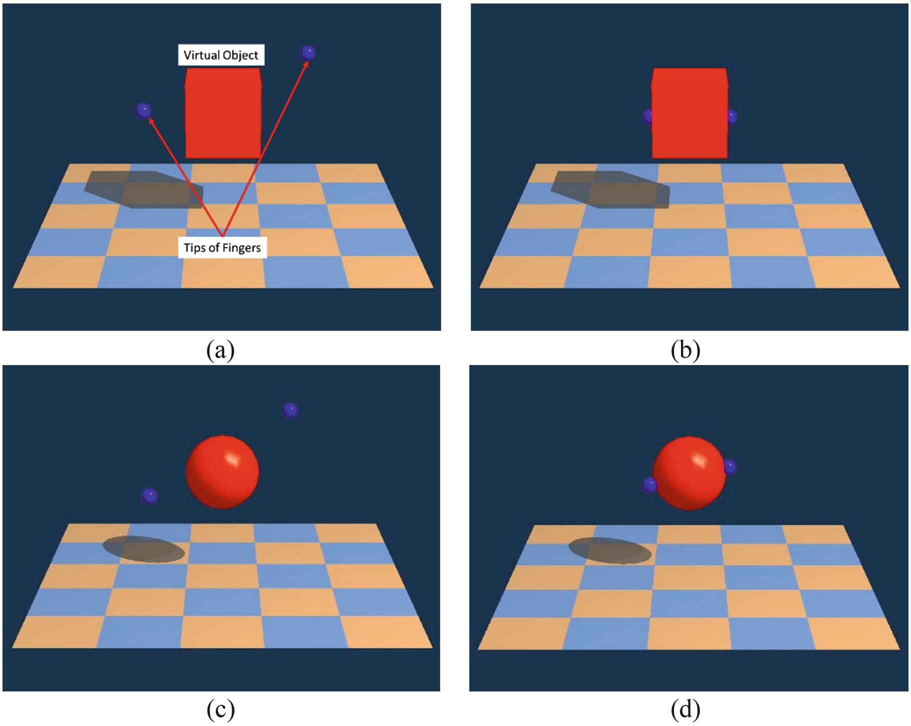


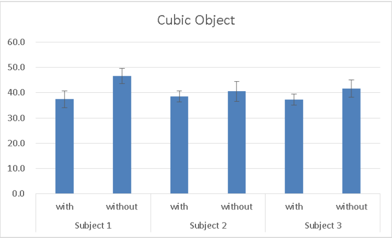

**Fig. 6.** Pinching conditions of (a) off and (b) on in case of cubic object and (c) off and (d) on in case of spherical object.

## 3 Experiments

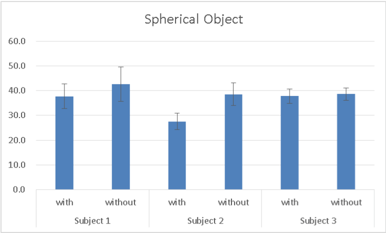
Subjects are three healthy males (age: 22–38 years old) who has no injury about upper limbs. All subjects performed five trials with dominant hand (all subjects are right hand). The virtual target was cubic and spherical objects. First, they performed without force feedback. Second, they performed with force feedback. After each trial, the real distance between fingers was measured by a caliper.

## 4 Results

Results in case of cubic and spherical objects are shown in Fig. 7. The vertical axis indicates the pinching distance where the unit is mm. The results show that pinching distance with force feedback is close to the setting one (30 mm) more than without force feedback. The pinching errors with and without force feedback were 7.7 mm and 12.9 mm in case of cubic object, respectively. As same way, the pinching errors with and without feedback were 4.3 mm and 9.9 mm in case of spherical object, respectively. However, most results indicated higher distance than setting one.




(a)




(b)

**Fig. 7.** Experimental results of (a) cubic and (b) shperical objects

## 5 Discussions

The result show the force feed back system is effective to pinch with accuracy. In addition, subjectives felt easily a virtual object from their finger. When they have no force feedback, the judgement depends on only visual feedback. Subjects have no confidence to pinch some objects with only visual feedback. From these results, we think force feedback is important information to do motion task for patients.

This study includes mechanical limitations. The vibration motor was attached by using thumbstall due to easy making process. However, it is difficult to be worn, even though the subject is healthy person. Therefore, it might be better to embed the vibration motor to a glove. In addition, the glove requires shorter time to wear than the thumbstall. This study focused on only two fingers (thumb and index finger), so the experiment was limited about pinch motion. To measure real pinching motion, the vibration motor should be attached to all the fingers.

As the other limitation, the distances between tips of the fingers were manually measured with a caliper. It possibly includes manual error due to the accuracy. This is reasonable approach to measure the distances. As previously mentioned, we think virtual system gives importance to have touching feeling for the subjects more than accuracy.

## 6 Conclusion

This study proposed a virtual reality system for occupational therapy with hand motion capture and force feedback. Force feedback was realized by using a vibration motor. In the experiment, the results with force feedback were close to the setting distance more than the results without force feedback. As a future work, actual working task used in clinical situation should be applied to this system.

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