A Proposal of Remote Rehabilitation System for Cerebrovascular Patients Combined with Video Call Center

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***Abstract*— Japan's low birthrate and rapidly aging population are causing medical expenses to take up ever more of the national budget. As the result, rehabilitation therapy is being shifted from hospital-care to home-care. We thus propose a remote rehabilitation system combined with a video call center to make up for the shortage of rehabilitation therapy done by visiting physiotherapists. In this paper, we focus on cerebrovascular patients and adopt MS-KINECT for home usage to measure strain of the upper body. Measuring tools and expression formats of measured data are also introduced.**

Keywords- rehabilitation; remote rehabilitation; motion capture; KINECT; video call center

I. INTRODUCTION

Japan's low birthrate and rapidly aging population are causing medical expenses to take up ever more of the national budget. To suppress this increase in medical expenses, medical treatments, including rehabilitation, are being shifted from hospital-care to home-care. The amount of rehabilitation therapy in a home done by a visiting physiotherapist is limited by law and is insufficient for patients to recover completely. We thus propose a remote rehabilitation system combined with a video call center to make up for the shortage of rehabilitation done by visiting physiotherapists.

Sixty-two percent of rehabilitation patients suffer from cerebrovascular diseases [1]. These diseases also have the longest rehabilitation term as shown in Figure 1 [1]. Therefore, we focus on cerebrovascular patients in the first part of our research.

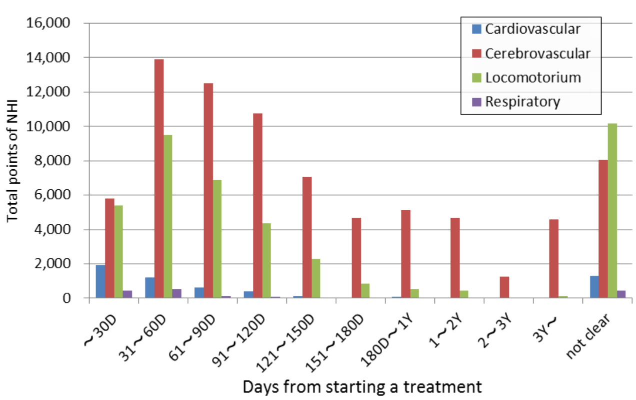

Figure 1. Total points of the national healthcare insurance (NHI) according to the duration of feeding period from treatment start date in Japan

In case of cerebrovascular disease, most patients have paralysis on one side of the body, and their bodies lean and twist to the paralysis side. Also, because of unusual muscle strain, their hands and feet become stiff. In some cases, muscles of the upper body go into convulsions.

In case of a hand or foot, a joint angle is easy to measure with a protractor. However, a joint angle of a body is very difficult to measure with a protractor, because the joint angle combines the lead and the twist. A motion monitoring system, Vicon [2], that uses multiple video cameras, has been introduced to big hospitals and rehabilitation centers. Unfortunately, it is too expensive for a small facility to introduce. As a matter of course, it is impossible to adopt for a remote rehabilitation system, because the remote rehabilitation system is used personally.

It is very difficult for patients to continue the self-rehabilitation at home, so our system has two features to help them continue:

- A patient can check data to see the effect of rehabilitation.
- A call center operator guides patients through the therapy and encourages them with images and conversation through the Internet.

We believe that patients should see practical data showing them getting better and hear a person's voice to improve their morale and to motivate them to continue rehabilitation.

After introducing related works in Section 2, we describe the concepts and features of the remote rehabilitation system in Section 3. Expression formats of the ante-flection, lean, and twist of the body are explained in Section 4. Measuring applications for the ante-flection, lean, and twist of the body are described in Section 5 and evaluated in Section 6. The key points are summarized in Section 7.

II. RELATED WORK

In this section, we introduce existing remote rehabilitaion systems, tools for measuring the strain of upper body, and MS-KINECT usage applications adopted in rehabilitation.

A. Remote rehabilitaion systems

Traditionally, remote rehabilitation has been administered between a therapist and a patient through a video conference system or video phones, without using measuring and monitoring tools [3]. In accordance with evolution of remote monitoring tools, robotics and virtual reality technologies, they are combined with video conference system. Holden et al. applied virtual reality technologies to their telerehabilitation system [4]. Carignan reported rehabilitation system for which robotics was applied including remote rehabilitation [5]. Bradley et al. reported investigations of the design, control and implementation of a form of the intelligent exoskeleton, web-based strategies and robotics for remote rehabilitation [5]. In these researches, therapists directly guide or coach patients through their systems. Therefore, existing remote rehabilitation systems can shorten convey time for a visiting therapist. However, these systems are insufficient to make up for the shortage of therapists.

B. Measurement tools for the strain of upper body

Vicon is one of the most famous companies in the motion capture industry. They can measure complex motions of joints in a body [2]. Vicon's system needs plural specialized video cameras, and know-how is needed to measure motions of joints. Thus, this system is too expensive for a small rehabilitation center or an individual to purchase and operate. Akimoto et al. developed a measurement tool for scoliosis [7]. It uses MS-KINECT to measure undulations on a body. This tool can express measurement data with an image, a graph, and numerical data and store them. Jing Tong et al. developed new scanning technology that can fully scan the body and show VR images of it [8]. It uses three MS-KINECTs. However, they did not account for measuring the lean and twist of a body. Burba et al. applied MS-KINECT to measure breathing rates derived from motions of the chest, and the number of shakes of tapping the knee derived from motions of the knee [9].

C. Applications adopted MS-KINET to rehabilitation

Garrido et al. applied MS-KINECT rehabilitations for patients who have trouble with their sense of balance [10]. They express the lean of the body by an image of the balance scale and show arrows to correct a patient's posture.

There are also many video games for rehabilitation that use MS-KINECT [11], [12], [13].

III. Concept of Remote Rehabilitation System

Our remote rehabilitation system is based on the following ideas:

- Practical data that shows the patients getting better will more effectively encourage them to continue rehabilitation than simply giving them vague information such as "you are a little better than yesterday".
- Hearing a person's voice is likely to cheer patients up.

Additionally, we plan to employee non-professionals as operators instead of physiotherapists to hold down operation costs.

We introduce roles of a physiotherapist and operator, and necessary functions to realize above concepts.

A. Roles of a physiotherapist and operator

Roles of a physiotherapist are as follows:

- Teaching operators how to guide patients through rehabilitation and supervising the operators.
- Deciding and changing therapy programs on the basis of diagnostics data and measured data.

Roles of an operator are as follows:

- Monitoring motions of a patient and measuring joint angles by the measuring tools.
- Coaching a patient in how to move his or her body using the administration tools and therapy contents on the basis of therapy programs.

B. Necessary functions

As shown in Figure 2, this system comprises following components:

- Administration tools: An operator uses these tools to guide patients.
- Measuring tools: An operator uses these tools to measure joint angles.
- Supervising tools: A physiotherapist uses these tools to coach operators. A physiotherapist can monitor how an operator is coaching patients and instruct him or her in therapy with these tools.
- Communication exchange application: This application connects a patient with an operator. This application works on a video conference server.
- Therapy contents: Presentation contents to explain how to train, or training content such as video games for rehabilitation.
- Patient database: Patient data which include profile data, measured data, therapy programs, and coaching video are stored and managed by this database. The access permission policy for this database has to be decided by the management organization of this system.

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The supervising tools and communication exchange application are newly added to introduce operators to the remote monitoring system. However, existing remote rehabilitation systems have also same roles for the other components. As a matter of course, practical functions of these components are different in each system.

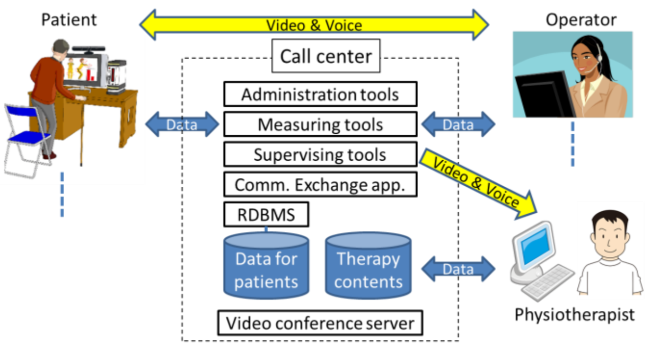


Figure 2. System concept of the remote rehabilitation

IV. EXPRESSION FORMATS

In this paper, strain of the upper body is shown from the ante-flexion, lean, and twists. We describe how to express the ante-flexion, lean, and twist in this section.

A. *Ante-flexion*

In the case of a skeleton model of the pre-packaged program in MS-KINECT, measuring points on the spine are the neck and the navel. However, these points are not sufficient to express the ante-flexion. Therefore, we add three measuring points between the neck and the navel as shown in Figure 3 and measure the depth of each point. We decided to express the ante-flexion as shown in Figure 4.

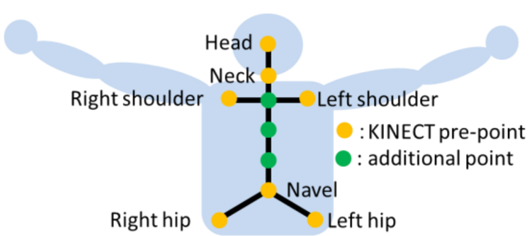


Figure 3. Skeleton model used in this research

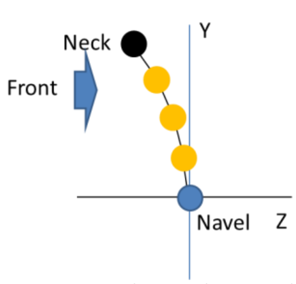
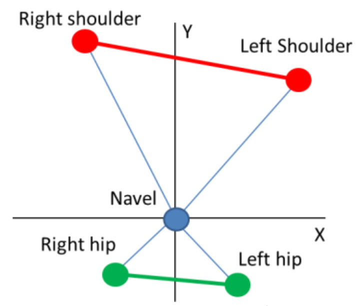


Figure 4. Expression format of the ante-flexion

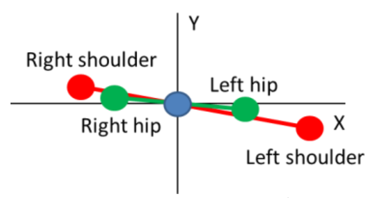
B. *Lean*

We express the lean of the upper body with both a line connecting the right shoulder and the left shoulder and a line connecting the right hip and the left hip from the front view. Two types of front view formats are considered to express the lean of the upper body. One is making a triangle between the right shoulder, left shoulder, and navel, and a triangle between the right hip, left hip, and navel as shown in Figure 5 (a). The other is that both a line connecting both shoulders and a line connecting both hips are plotted on the X-Y plane on which middle points of both lines are plotted on the origin as shown in Figure 5 (b).

We asked 30 people which expression more easily explained the lean of the upper body. Results of answers to this question are shown in Table 1. Most respondents chose the triangle expression format.



(a) Triangle expression format



(b) No triangle expression format

Figure 5. Expression format for the lean of upper body

C. *Twist of upper body*

We express the twist of the upper body with both a line connecting both shoulders and a line connecting both hips from the top view. Two types of top view formats are considered to express the twist of upper body. One is plotting positions of the head and navel in addition to the above mentioned two lines as shown in Figure 6 (a). The other is plotting just the above mentioned two lines on the X-Z plane in which middle points of both lines are plotted on the origin as shown in Figure 6 (b). We asked 30 people which expression more easily explained the twist of the upper body. Results of answers to this question are shown in Table 1. Most students chose the lines-only plotting format. On the other hand, 9 of 14 workers who responded chose the relative position consideration format. Every healthcare worker (3 people) said that positions of lines of the shoulders and the hips relative to the head were important to understand the twist. They all chose Figure 6 (a).

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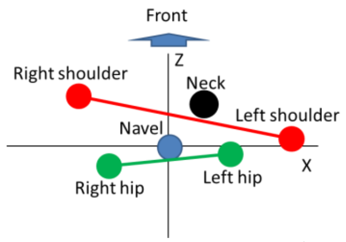
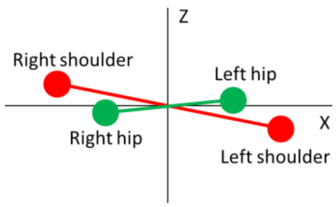


(a) Relative position consideration format



(b) Lines-only plotting format

Figure 6. Expression format for the twist of upper body

TABLE I. RESULTS OF QUESTIONNAIRE ABOUT WHICH EXPRESSION FORMATS ARE EASIER TO UNDERSTAND

		(a)	(b)
Lean	Students	15	1
	Workers	13	1
Twist	Students	0	16
	Workers	9	5

V. MEASURING TOOLS

We developed a tool for measuring the strain of the upper body that will be a component of our remote rehabilitation system. We use MS-KINECT, Kinect for Windows SDK 1.7, and WPF framework in this tool.

A. *Ante-flexion measuring application*

Depth of the neck, the navel, and three points that divide the neck and the navel into four equal parts are measured in this application. The number of measuring points can be increased. An example picture of the display is shown in Figure 7. A video image is shown for a call center operator to easily guide a patient on the upper-right portion of a display. Measured data include error caused by the curve of body and clothes. Therefore we recommend measuring not the front view but the back view as shown in Figure 8.

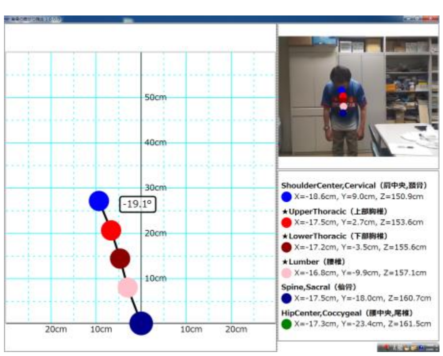


Figure 7. Example of front view measuring the ante-flection

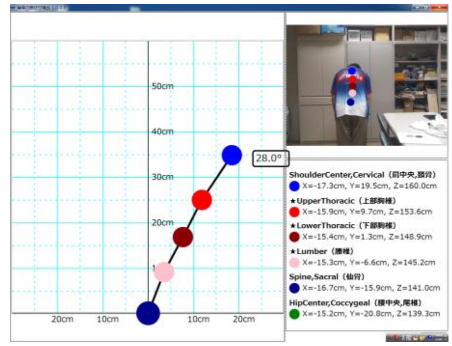


Figure 8. Example of back view measuring the ante-flection

B. *Lean measuring application*

Since most respondents chose the triangle expression format as shown in Table 1, we adopted it. We showed numerical angles between the X axis and the line connecting both shoulders and between the X axis and the line connecting both hips to make practical data easy to understand as shown in Figure 9.

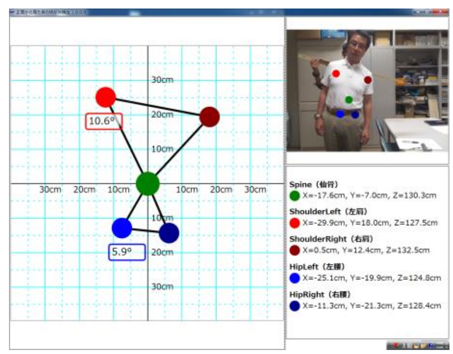
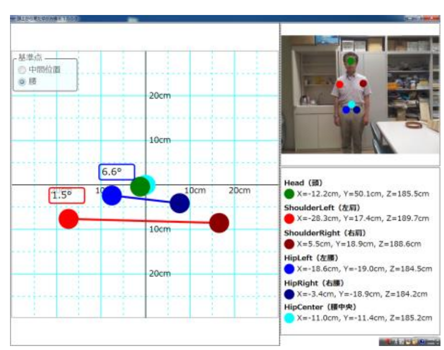


Figure 9. Example of measuring the lean

C. *Twist measuring application*

Since 30% of healthcare workers chose the relative position consideration format and 70% of them chose the lines-only plotting format in Table 1, we designed both of them. We showed numerical angles between the X axis and the line connecting both shoulders and between the X axis and the line connecting both hips to make practical data easy to understand, the same as the lean. Example screenshots are shown in Figure 10.



(a) Example of the relative position consideration format

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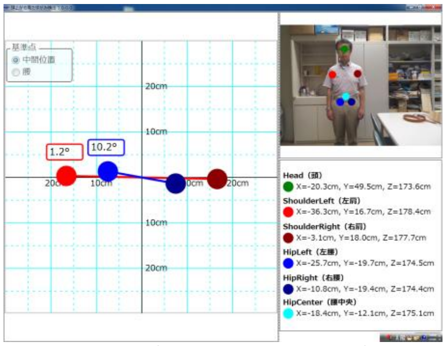


(b) Example of the lines-only plotting format

Figure 10. Example of measuring the twist

VI. EVALUATION OF MEASURED DATA

Since the depth value in MS-KINCT is the shortest distance between the X-Y plane on the depth measuring camera and a measuring point, a tape measure or an acoustic measure is not useful. Hence, we evaluated the angle of the ante-flection, lean, and twist by comparing between values measured by MS-KINECT and by a big protractor (see Figure 11). We fixed a string to a protractor that had a weight at one side for indicating it was the perpendicular to the earth.

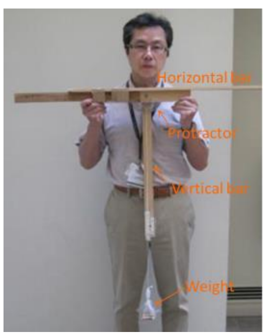


Figure 11. Protractor used in this research

A. *Ante-flexion*

The horizontal bar of the protractor is set on the floor. A rectangular board is fastened to the vertical bar; and an upper body is placed along with the rectangular board to remove influence derived from the curve of the body as shown in Figure 12.

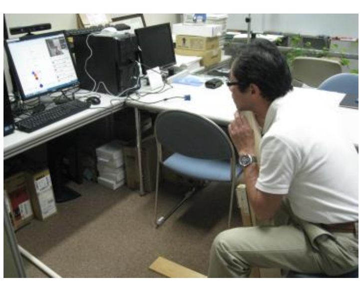


Figure 12. Measuring image of the ante-flection

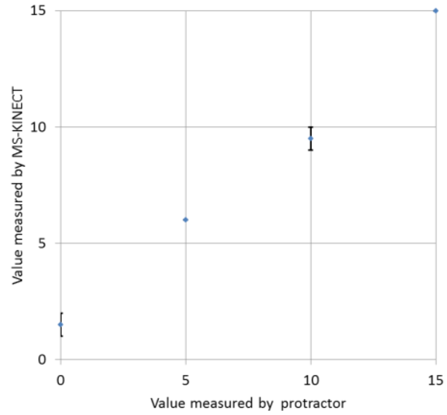


Figure 13. Measured data of the ante-flection

We varied the angle between the horizontal bar and the vertical bar from 0 to 15 degrees. Data measured by the ante-flexion measuring application corresponding to an angle of a protractor is shown in Figure 13. We measured 20 samples. Average and standard deviation data are plotted on the graph. Errors are a few degrees, which would be small enough for practical use.

B. *Lean*

The angle between the X-axis and the line connecting both shoulders was varied from -20, -10, 0, +10, +20 degrees instead of the lean angle. These values were measured by the protractor fitted on both shoulders from the back. We measured the lean of the body by the lean measuring application, and measured data is shown in Figure 14. There are no errors.

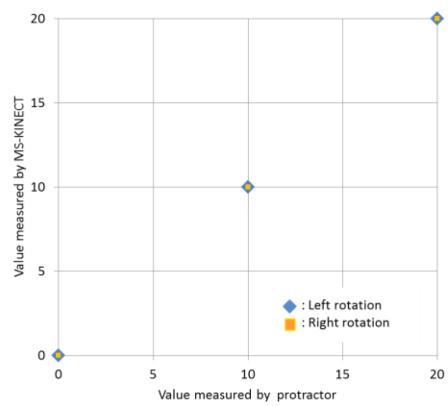


Figure 14. Measured data of an angle between X-axis and a line connecting both shoulders

C. *Twist*

We measured the angle between the X-axis and a line connecting both shoulders from the top view. The horizontal bar of the protractor is fastened to both shoulders, and the vertical bar points to the MS-KINECT to remove the influence derived from the curve of the body as shown in Figure 15. We also measured the line of hips the same as the line of shoulders. Measured data is shown in Figure 16.

Errors for the right rotation in both the shoulders and the hips are very small. However, errors for the left rotation are a few degrees. We are not sure of the reason for this difference.

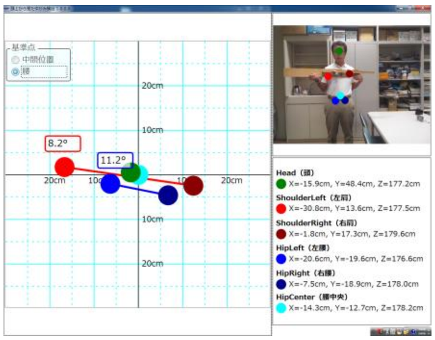
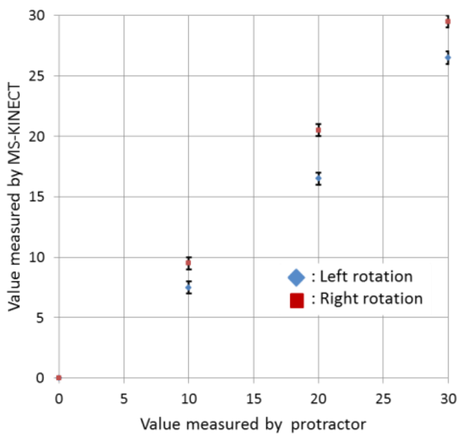
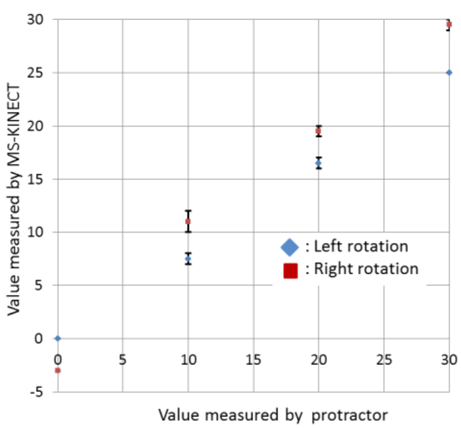


Figure 15. Measuring image of the twist



(a) Measured data for the shoulders



(b) Measured data for the hips

Figure 16. Measured data of the twist

VII. CONCLUSION

We proposed a remote rehabilitation system combined with a video call center to make up for the shortage of rehabilitation therapy done by visiting physiotherapists. We focused on cerebrovascular patients and adopted MS-KINECT for home usage to measure the strain of the upper body. We also proposed to express strain of the upper body by dividing the ante-flexion, lean, and twist and developed an application for measuring them. In the results of evaluating these measuring applications, their measurement errors are sufficiently small.

We are still in process of completing the remote rehabilitation system. The concept that is employing non-professionals as operators instead of physiotherapists to hold down medical expenses is novel. This concept probably would suppress increment of medical expense; and affect institutions of the national healthcare insurance. New business schemes thus have to be created in addition to developing the system to introduce as a service.

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