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 and leading to a shortage of young medical professionals. As a result, rehabilitation therapy is being shifted from hospital-care to home-care. Thus, we 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 to measure strain of the upper body and the Balance Wii Board to measure weight and center of weight for home usage. A remote rehabilitation system is also introduced that includes standing-up and sitting-down therapy content.**

Keywords- rehabilitation; remote rehabilitation; motion capture; KINECT; Balance Wii Board; standing-up and sitting-down therapy; 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 and leading to a shortage of young medical professionals. 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. Thus, we proposed a concept of remote rehabilitation system combined with a video call center to make up for the shortage of rehabilitation done by visiting physiotherapists [1].

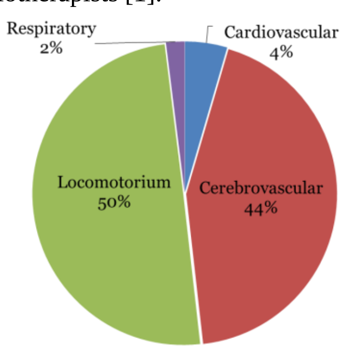


Figure 1. Ratio of disease for rehabilitation

Forty-four percent of rehabilitation patients suffer from cerebrovascular diseases as shown in Figure 1 [2]. These diseases also have the longest rehabilitation term as shown in Figure 2 [2].

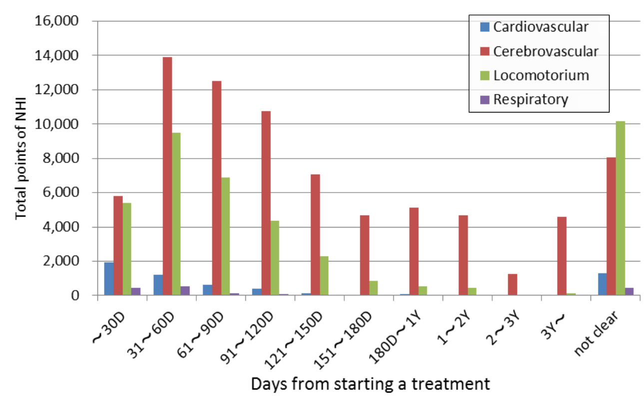


Figure 2. Total points of the national healthcare insurance (NHI) according to the duration of feeding period from treatment start date in Japan

Therefore, we focus on cerebrovascular patients in the first part of our research.

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. Because of these strain of upper body, it is difficult for them to keep the body balance.

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 [3], which 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.

One of the most important types of training for cerebrovascular patients is standing-up and sitting-down training (hereinafter called standing-up training). If patients cannot get up from a bed, they have to continue to stay on the bed and sometimes have bedsores. Therefore, the standing-up training is usually put into practice as the first stage. We develop a standing-up and sitting-down therapy content that utilizes the Nintendo Balance Wii Board. This training content also improves imbalance of the body. Changes of weight and center of weight under the feet and buttocks are necessary to advice patients how to stand up from and sit down on a chair in the standing-up training. Since most pressure-sensitive mats are too expensive for home use, we adopt the Nintendo Balance Wii Board.

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

- 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.

In our proposed remote rehabilitation system, a call center operator guides patients instead of a physiotherapist. Hence, our system has supervising functions for a physiotherapist to coach a call center operator like supervising functions in existing voice call center.

In this paper, we introduce not only concepts of the proposed remote rehabilitation system RRS but also how to design it.

After introducing related works in Section II, we describe the concepts and features of the remote rehabilitation system in Section III. Expression formats of strain of the upper body and change of weight and center of weight are explained in Section IV. Measuring schemes for the ante-flection, lean, and twist of the body are described in Section V. The standing-up training is detailed in Section VI. System designs to realize the above concept and functions are explained in Section VII. The key points are summarized in Section VIII.

II. RELATED WORK

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

A. *Remote rehabilitaion*

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 [4]. 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 tele-rehabilitation system [5]. Carignan reported rehabilitation system for which robotics was applied including remote rehabilitation [6]. 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 [7]. 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 [3]. 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 [8]. 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 [9]. 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 [10].

C. *Therapy contents adopted MS-KINET and Ballance Wii Board to rehabilitation*

Garrido et al. applied MS-KINECT rehabilitations for patients who have trouble with their sense of balance with cerebrovascular disease [11]. 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 [12][13][14].

Fraser Anderson et al. developed a therapy content that combined the Balance Wii Board and a virtual game to improve the sense of balance [15]. This content can measure and record performance of a virtual game and show it to a patient to motivate him or her to continue rehabilitation.

D. *Therapy for standing up by the physiotherapist*

We heard about physiotherapists trained in standing-up and sitting-down therapy, and searched for it on the Internet [16]. The standing-up and sitting-down therapy consists of the following four steps:

Step 1: A patient bends her or his upper body down to shift her or his center of weight to her or his toes and raises her or his buttocks from a chair.

Step 2: The patient streches her or his knees and simultaneously bends her or his upper body up.
Step 3: The patient slightly bends her or his upper body down to shift her or his center of weight to her or his toes from the upright position.
Step 4: The patient sits down on a chair.

This training emphasizes bending her or his upper body up and down to shift her or his center of weight. However, most cerebrovascular patients have paralysis on one side of the body, and their bodies lean and twist to the paralysis side. Imbalance of the upper body will need to be corrected for rehabilitation.

III. CONCEPT OF THE RRS WITH VIDEO CALL CENTER

Our RRS is based on the following ideas:

- Practical data that shows the patients getting better will effectively encourage them to continue rehabilitation, more 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 and compensate for a shortage of physiotherapists.

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 tools*

As shown in Figure 3, this system comprises following components:

- Administration tools: An operator uses these tools to guide patients.
- Measuring tools: An operator uses these tools to measure conditions of a patient including joint angles. Kinds of measuring tool that are kind of sensors are easily added to the RSS as necessary.
- 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 that 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.

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 tools of these components are different in each system.

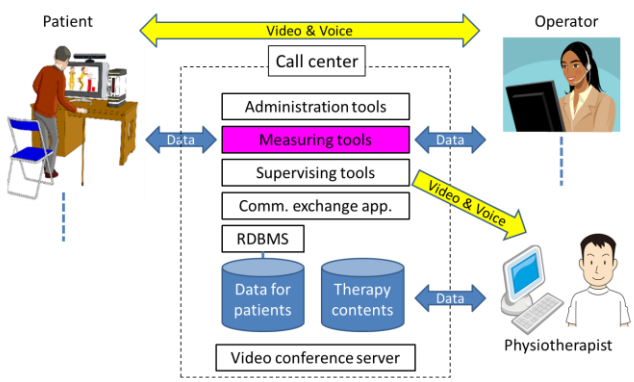


Figure 3. System concept of the remote rehabilitation

IV. EXPRESSION FORMATS OF SENSOR DATA

We design the proposed RRS to be able to easily add as many kinds of sensors as necessary as described in Section III. At present, we think that at least the motion monitoring sensor to measure strain of the upper body and the pressure distribution mat to sense changes of weight and center of weight are needed for rehabilitation of cerebrovascular patients. We choose MS-KINECT as the motion monitoring sensor and Balance Wii Board as the pressure distribution mat for the home use. Both sensors are reasonably enough priced for home use.

In this section, we describe expression formats of strain of the upper body, and changes of load and the center of weight to show operators and physiotherapist in Figure 3.

A. *Strain of the upper body*

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.

1) *Ante-flexion*

In the case of a skeleton model of the pre-packaged program in MS-KINECT v1, measuring points on the spine are the neck and the nave. However, these points are not sufficient to express the ante-flexion. Therefore, we add measuring points between the neck and the navel as shown in Figure 4 and measure the depth of each point. We decided to express the ante-flexion as shown in Figure 5.

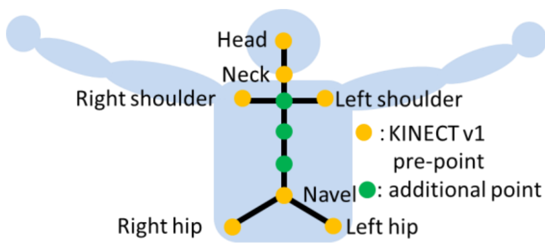


Figure 4. Skeleton model used in this research

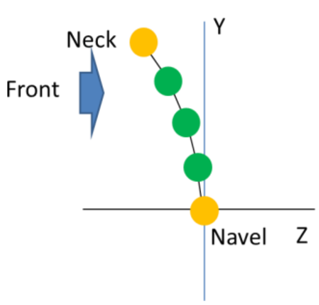
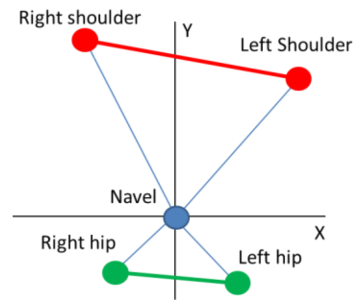


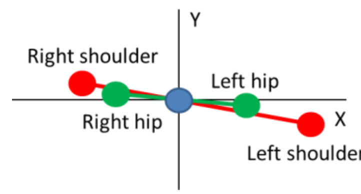
Figure 5. Expression format of the ante-flexion

2) *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 6 (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 6 (b).



(a) Triangle expression format



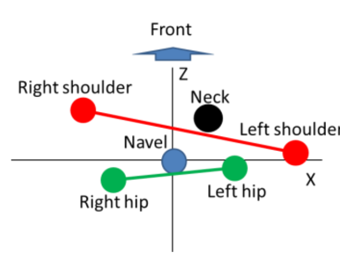
(b) No triangle expression format

Figure 6. Expression format for the lean of upper body

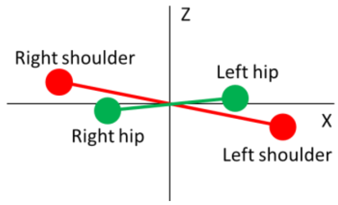
We asked 30 people which expression more easily explained the lean of the upper body. Results of answers to this question are shown in Table I. Most respondents chose the triangle expression format (a).

3) *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 7 (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 7 (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 I. 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 7 (a).



(a) Relative position consideration format



(b) Lines-only plotting format

Figure 7. 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

B. *Changes of weight and the center of weight*

As a result of hearing about the standing-up training content described in Section VII to physiotherapists who work in Yokohama Central Hospital, they requested us to express not illustrations of the body, but visually changes of load and the center of weight such as graph or something.

Since physiotherapists who give us suggestions want to know timings at when they say guides to patients, we express a change of weight as a line graph in accordance with the change of time like Figure 8, and the change of center of weight as not a real-time position or a trace with a solid-line, but the trace with a arrow-line like Figure 9. Lines of feet and buttocks are plotted on a same graph easy to know timing at when they say guides.

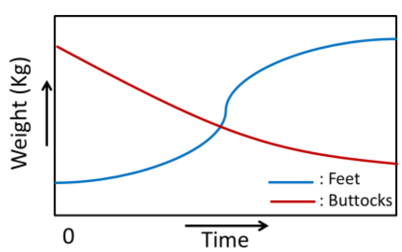


Figure 8. Expression format for change of the weight

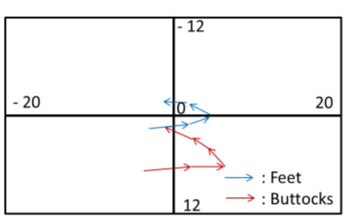


Figure 9. Expression format for change of the center of weight

V. MEASURING FUNCTIONS FOR STRAIN OF UPPER BODY

We developed a tool for measuring the strain of the upper body that will be a component of our remote rehabilitation system.

A. *Measuring application*

1) *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 10. 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 11.

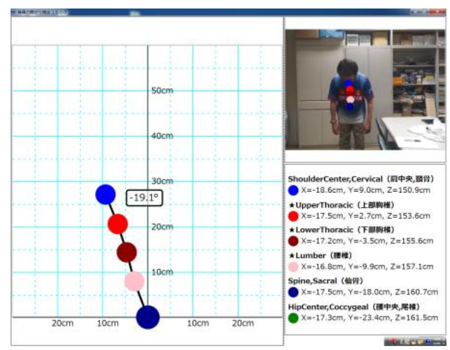


Figure 10. Example of front view measuring the ante-flection

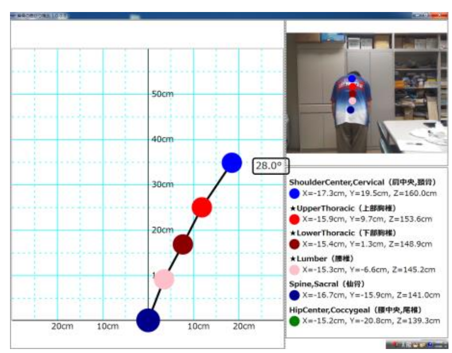


Figure 11. Example of back view measuring the ante-flection

2) *Lean measuring application*

Since most respondents chose the triangle expression format as shown in Table I, 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 12.

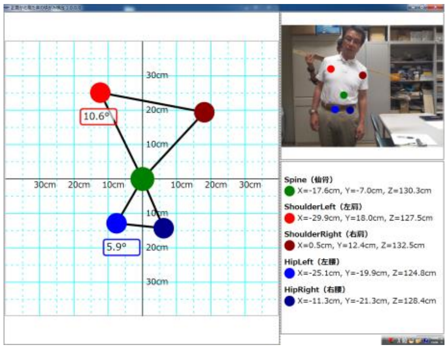
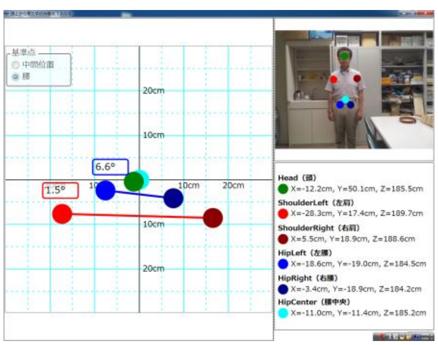


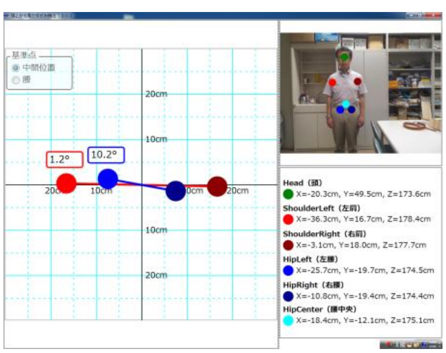
Figure 12. Example of measuring the lean

3) Twist measuring application

Since 30% of respondents (including every healthcare worker) chose the relative position consideration format and 70% of them chose the lines-only plotting format in Table I, 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 13.



(a) Example of the relative position consideration format



(b) Example of the lines-only plotting format

Figure 13. Example of measuring the twist

B. 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 14). We fixed a string to a protractor that had a weight at one side for indicating it was the perpendicular to the earth.

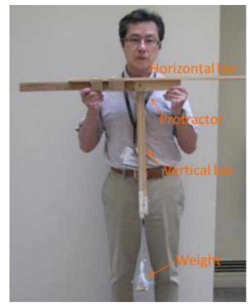


Figure 14. Protractor used in this research

1) 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 15.

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 16. 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.

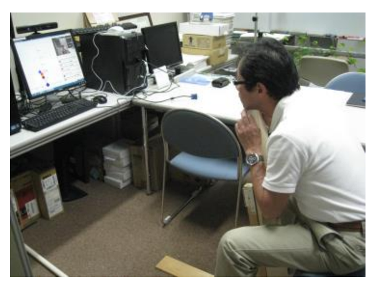


Figure 15. Measuring image of the ante-flection

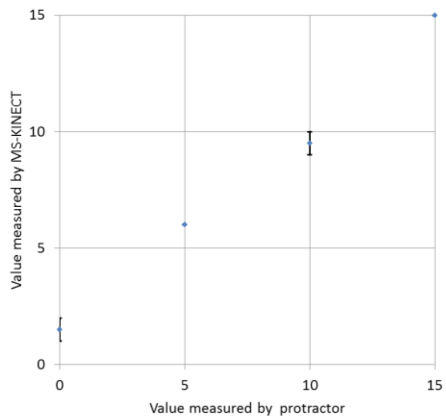


Figure 16. Measured data of the ante-flection

2) 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 17. There are no errors.

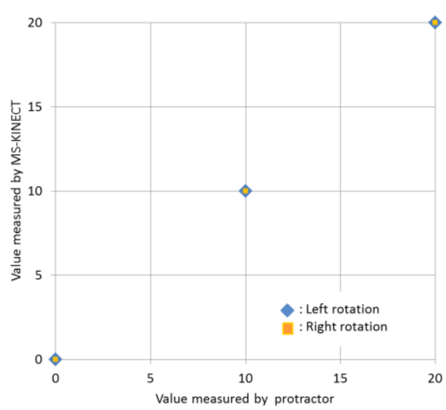


Figure 17. Measured data of an angle between X-axis and a line connecting both shoulders

3) 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 18. We also measured the line of hips the same as the line of shoulders. Measured data is shown in Figure 19. 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.

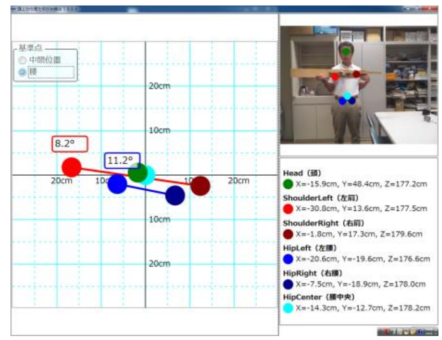
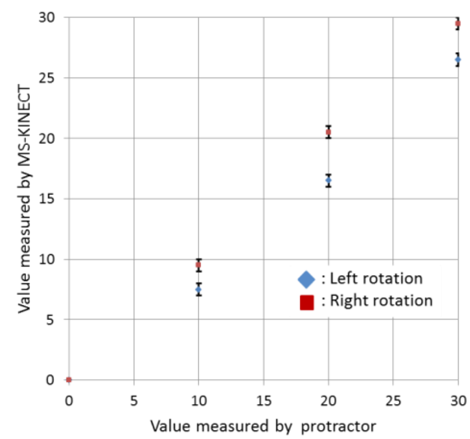
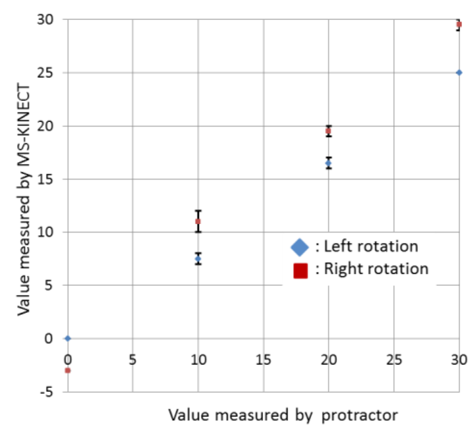


Figure 18. Measuring image of the twist



(a) Measured data for the shoulders



(b) Measured data for the hips

Figure 19. Measured data of the twist

VI. STANDING-UP TRAINING CONTENT

We develop training content for cerebrovascular patients to learn how to stand up from a bed and sit down on it. A chair is used instead of a bed. We designed this content for patients to learn not only with an operator's guidance but also by themselves.

A. System configuration

We use two Balance Wii Boards: the patient puts his or her feet on one and sits on the other as show in Figure 20. Both of them are connected to the patient's PC via Bluetooth. A Balance Wii Board has four load sensors at its four corners and puts out loads at each sensor: total load and the center of load. The scale of the center of load approximately corresponds to its surface size as shown in Figure 21. MS-KINECT is also connected to the patient's PC to monitor a motion of patient.

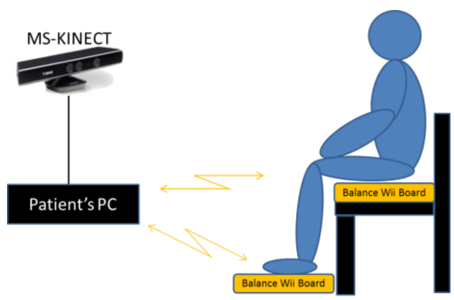


Figure 20. System configuration of the standing-up training content

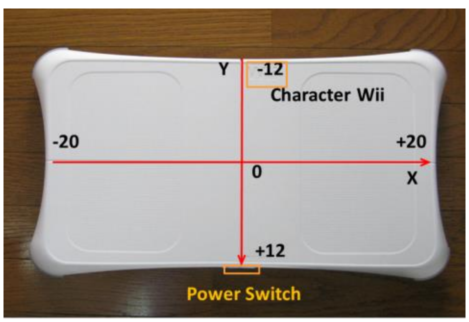


Figure 21. Scale of the balance in the balance Wii Board

B. Training steps

Therapy by a physiotherapist puts emphasis on bending the upper body down and up and shifting center of weight. However, we add correcting strain of the body to learning how to stand up and sit down. Guiding illustrations for each step are shown in Figure 22.

This training content is comprised of the following eight steps;

Step 1: A patient corrects imbalance of her or his upper body. An illustration on a screen leads the patient to correct imbalance of her of his upper body. While the patient leans to the right or left, the training content continues to show a left or right arrow and says "To the left" or "To the right" repeatedly until the center of load under the buttocks is between the decision levels ±TH1 (all TH values are described in the next sub-section.). When the patient maintains balance for 3 seconds, the next training step starts.

The above guidance and decision functions are used for self-learning. In case of guidance by an operator, the operator verbally instructs a patient with not illustrations or written instructions, but a graph of change of the center of weight like Figure 9. This scheme is the same as in the following steps.

Step 2: The patient moves her or his knees forward while continuing sitting on a chair. This step is not in therapy by a physiotherapist. Since it is impossible to stand up while the ankles are further forward than the knees, we add this step. The training content continues to show a forward arrow and say "Go forward" repeatedly until the center of load under the buttocks is shifted over the decision level TH2. When the patient maintains her or his balance for 3 seconds, the next training step starts.

Spep 3: The patient bends her or his upper body down to shift her or his center of weight to her or his toe and raise her or his buttocks from a chair. The training content continues to show a forward arrow and say "bend your body down and raise your buttocks up from the chair" repeatedly until the load under the buttocks is less than the decision level TH3. When the patient maintains this condition for 3 seconds, the next training step starts.

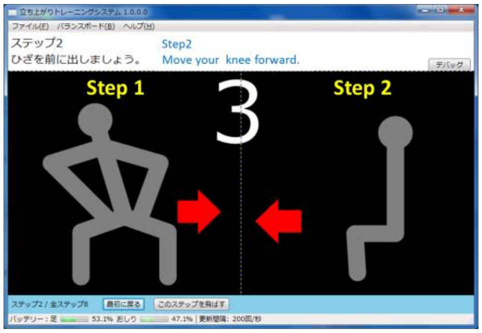
Step 4: The patient stretches her or his knee and simultaneously bends her or his upper body up. The training content says "Please stand up." Since this step does not include a conscious action to learn, it has no illustration.

Step 5: The patient corrects imbalance of the body while standing up. While the patient leans to the right or left, the training content continues to show a left or right arrow and says "To the left" or "To the right" repeatedly until the center of weight under the feet is between the decision levels ±TH4. Vice versa, while the patient leans to left, the training content continues to show a right arrow and say "To the right" repeatedly. When the patient stays upright for 3 seconds, the next training step starts.

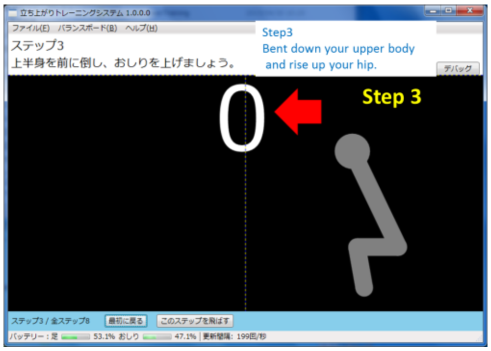
Step 6: The patient slightly bends her or his upper body down to shift the center of weight to her or his toes from the upright position. The training content continues to show a forward arrow and say "Bend your upper body down slightly" repeatedly until a load under the center of weight under the feet shifting over the decision level TH5. The next training step starts as soon as the patient has maintained this condition.

Step 7: The patient sits down on a chair. The training content says "Please sit down." Since this step does not include a conscious action to learn, it has no illustration.

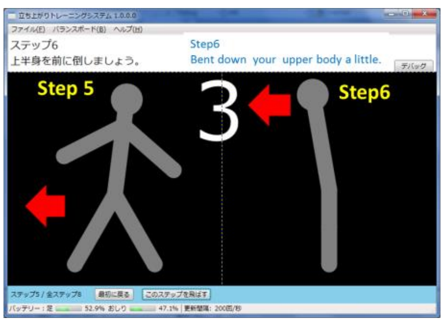
Step 8: The patient bends her or his upper body up and returns to Step 1.



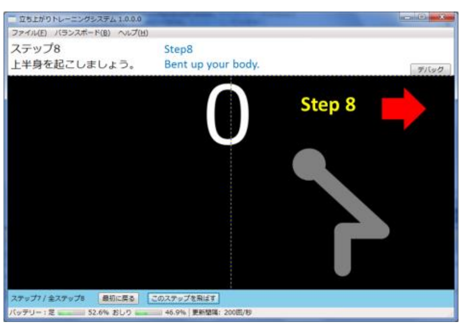
(a) Steps1 & 2



(b) Step 3



(c) Steps 5 & 6



(d) Step 8

Figure 22. Guidance illustrations

C. *Decision levels*

We describe how to decide the decision levels TH1 – TH5 described in the previous sub-section. These decision levels are decided from measurement data. Five able-bodied students did the above eight steps. Changes of loads and center of load under the buttocks and feet were measured for them. We decided the common values for every participant plus the loosen value.

(1) TH1: Since every participant can stand upright and we could not collect data from disabled people, we decide TH1 (center of load) = 3. After collecting data from disabled people, we will reconsider this value.
(2) TH2: When participants move their knees forward, the center of loads under both the buttocks and feet move forward. However, since the change of a center of the buttocks is bigger than that of the feet, we choose the center of the buttocks as shown in Figure 23. Changes of the center of load under the buttocks for every participant are less than -4 on the Y axis, so we decide TH2 = -3 (loosen value = 1).
(3) TH3: Most participants could not perfectly raise their buttocks up from a chair. Since the worst value is 17kg (see Figure 24), we decide TH3 = 20 (loosen value = 3).
(4) TH4: We decide TH4 = 3, the same as TH1. TH4 will have to be reconsidered after data are collected from disabled people.
(5) TH5: Changes of the center of load under the feet for every participant are less than -3 in Y axis as shown in Figure 25. Hence, we decide TH5 = -2 (loosen value = 1).

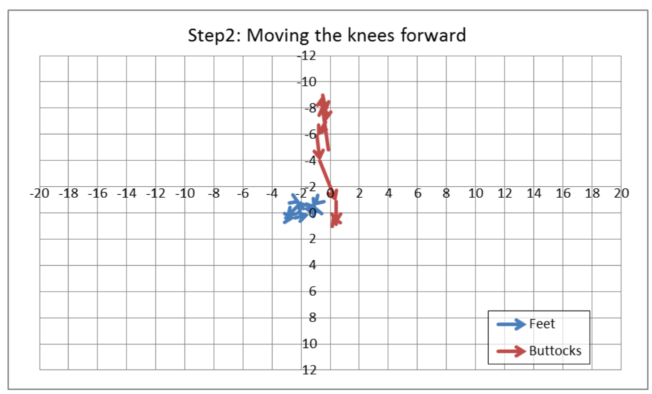


Figure 23. Change of the center of load under the buttocks (red) and feet (blue) when moving the knees forward

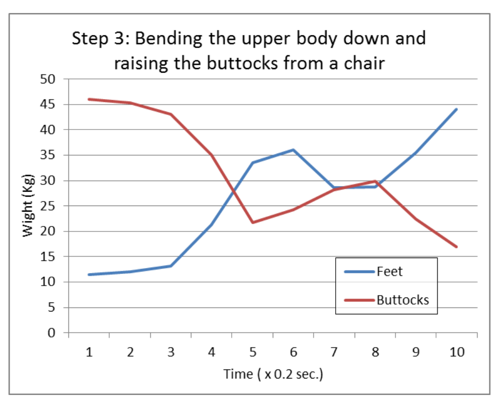


Figure 24. Change of weight under the buttocks (red) and feet (blue) when bending the upper body down and forward

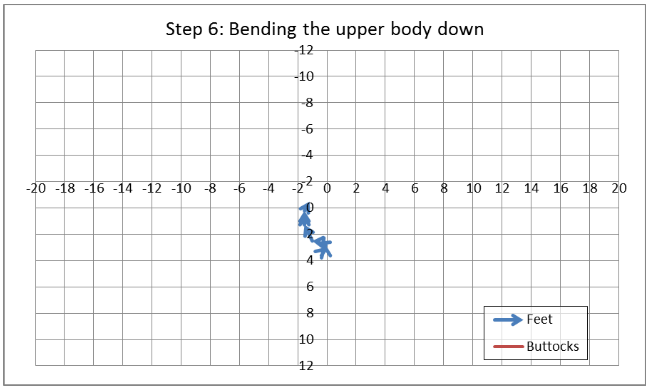


Figure 25. Changes of center of load under the feet

D. Evaluation of decision levels

We did an experiment to verify whether the above decision levels work well. There were six participants. All were able-bodied students who did not participate in the experiment to decide the decision levels. Each participant did steps 1 to 8 for five cycles. Experimental results are shown in Table II. We count 0.5 when a patient does the same step a few times. The recognition rates in steps 2, 6, and 8 are not 100%. We will reconsider these decision levels or schemes.

VII. System Design of the RRS

We have already finished designing a practical remote rehabilitation system, and some of its features have been implemented.

A. Design concepts

This system is comprised of the call center node, a patient's PC, an operator's PC, and a physiotherapist's PC as shown in Figure 3. MS-KINECT is just connected to the RRS introduced in eTELEMED 2015 [1]. However, the advanced RRS is designed for other kinds of sensors to be connected in addition to MS-KINECT. Basically, all sensors work simultaneously to measure a patient's condition in the RSS. Since output data of sensors have to be sent synchronously to the call center, all sensor data are aggregated at the same module.

Basically, we design applications as Web applications to avoid on-site maintenance.

B. Synchronizing scheme between video images and skeleton data

Since video images and skeleton data are independently output from MS-KINECT, both have to be synchronized to enable monitoring at a remote office. Thus, we serialize skeleton data in JSON format and add them to each item of video frame data, which is resized, transferred to the JPEG format, and then transferred to the Base 64 text data at the application on a patient's PC as shown in Figure 26. These data are sent to a Web server in the call center. They are separated again and individually drawn on the canvas of the html monitoring page as shown in Figure 27. Video image data are drawn on a lower layer and skeleton data are drawn in our presentation format on a transparent upper layer as shown in Figure 28. Finally, video and skeleton images formatted in accordance with our proposed method move in synchronization with a Web browser on a physiotherapist's PC as shown in Figures 9-12.

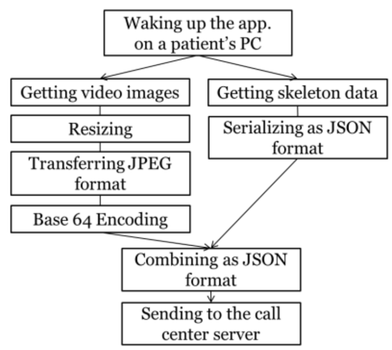


Figure 26. Flow diagram for aggregating video images and skeleton data

TABLE II. Recognition Rate for Motion in Each Step

Participant	Step 1	Step 2	Step3	Step 4	Step5	Step 6	Step 7	Step 8
A	5	4	5	—	5	5	—	5
B	5	5	5	—	5	5	—	5
C	5	4	5	—	5	4	—	4.5
D	5	5	5	—	5	4.5	—	4.5
E	5	5	5	—	5	3.5	—	4
F	5	5	5	—	5	5	—	5
Average	**5.0**	**4.7**	**5.0**	**—**	**5.0**	**4.5**	—	**4.7**
Rate	**100%**	**93%**	**100%**	**—**	**100%**	**90%**	—	**93%**

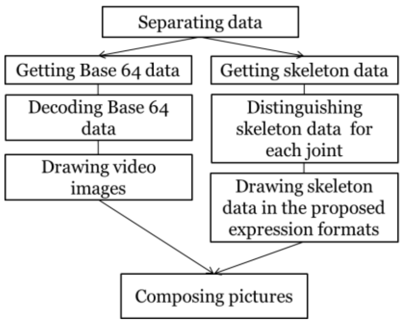


Figure 27. Flow diagram for composing pictures

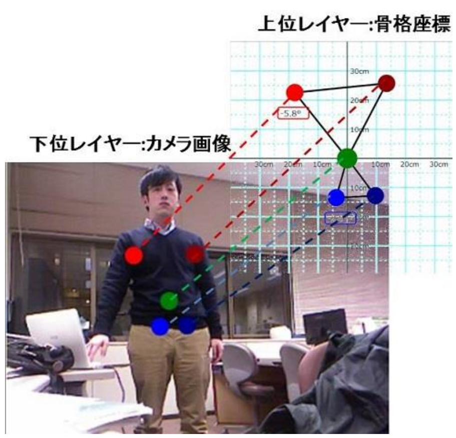


Figure 28. Example of composing video image and skeleton data.

C. *Storing measured data*

An operator monitors the video and skeleton images, change of weight, and change of center of weight, and stores important data for a physiotherapist to understand a patient's condition and reschedule a training plan. After saying to a patient something such as "Let's start measuring", the operator starts by pushing the start button to record monitored data and stops by pushing the stop button. Those data are stored as a temporarily file. The operator usually monitors this file again. If it is fine, the operator pushes the save button to save it as a permanent file. The operator can also store still image data in addition to video data. A physiotherapist can search for these data by using a patient's name, an operator's name, and date and time.

D. *Supervising function*

A physiotherapist needs conversation data between a patient and an operator to supervise an operator. These verbal communication data have to be stored synchronously with measured sensor data. Therefore, these data are recorded on the patient's PC and sent to the call center server together with other sensor data. We adopt the JASON format as the sending data format. Kinds of data sent from a patient's PC to the call center server are KINET video image data, KINECT skeleton data, Balance Wii Board data, an operator's voice, and a patient's voice. If other sensors are added in the future, output data of these sensors will also be sent together with existing data.

E. *Block diagram*

Block diagrams of the call canter node, the patient's PC, the operator's PC, and the physiotherapist's PC are shown in Figure 29.

MS-KINECT and Balance Wii Board are connected to

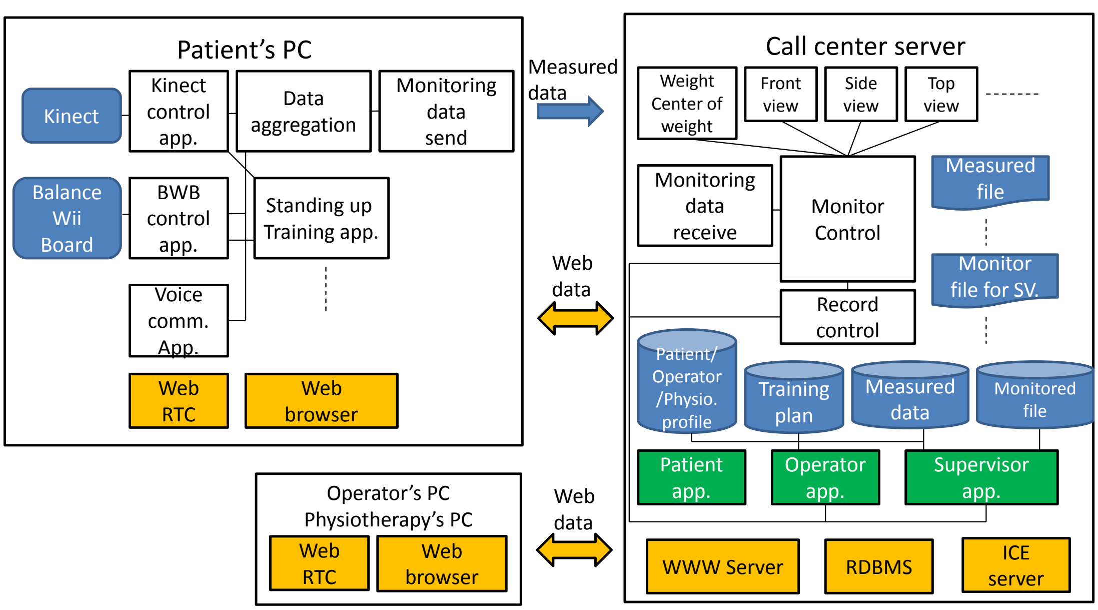


Figure 29. Block diagram of the RRS

the patient's PC. Since Microsoft has released MS-KINECT v2, we developed a remote rehabilitation system with MS-KINECT v2, not v1. Since the skeleton model in MS-KINECT v2 is slightly different from that in MS-KINECT v1, expression formats described in Section IV are modified slightly. Practically, the navel is replaced with the spine-middle, and the shoulder center with the neck.

We design applications as Web applications to make on-site maintenance unnecessary as soon as possible as described in the design concept. However, since we have no technologies to control MS-KINECT v2 and the Balance Wii Board by a Web browser, application programs controlling MS-KINECT v2 and the Balance Wii Board are implemented as native programming code and installed on a patient's PC. The standing-up training application is also developed as native programming code and installed on a patient's PC. Output data of MS-KINECT and Balance Wii Board are aggregated to the data aggregation program and sent to the call center through the monitoring data sending program. Both the data aggregation program and the monitoring data send program are developed as native programming code and installed on a patient's PC. Voice data between a patient and an operator are also aggregated at the data aggregation program. A Web browser is also installed on the patient's PC for presentation of guidance contents and voice communication.

On the other hand, no applications except a Web browser are installed on the operator's PC and the physiotherapist's PC. Coaching applications for an operator and supervising applications for a physiotherapist work on a Web browser as Web applications. A voice communication function is implemented with the Web RTC [17].

The call center server is comprised of many kinds of modules. The monitoring data receiving module receives data sent from a patient's PC. The monitor control module divides received data into each sensor data and draws them as each expression format introduced in Section IV. The record control module stores KINET video image data, KINECT skeleton data, and Balance Wii Board data produced by an operator's operation. These stored files are managed by the database management system. On the other hand, the record control module stores conversation data between a patient and an operator automatically. Patients' profiles and therapy contents are also managed by the database management system. Operators' and physiotherapists' profiles are also stored as database.

This time, a voice communication function is implemented with the Web-RTC and ICE [17].

F. System sequence

This sub-section explains the sequence of using the remote rehabilitation service. As shown in Figure 30, first, operators log in, and then a patient logs in and selects an available operator.

The designated operator selects a training content on the basis of a training menu planned by a physiotherapist. A patient who watches a presented training content follows the presentation by doing the training. The operator monitors and suggests training for the patient and saves video images and skeleton data as necessary. After training, an operator measures the strain of the patient's body.

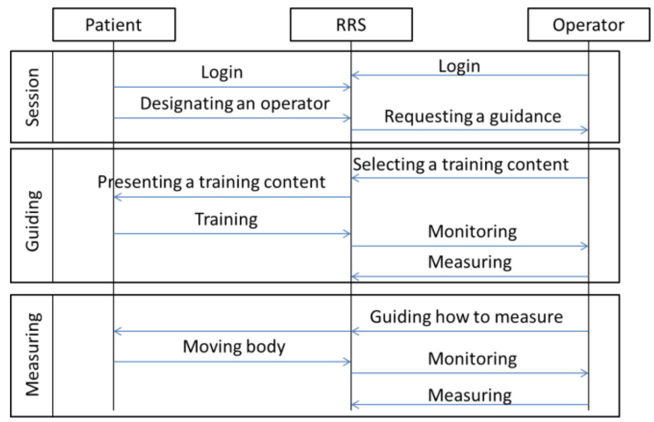


Figure 30. System sequence for using remote rehabilitation service

VIII. 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 expressing 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 the process of completing the remote rehabilitation system. The concept of employing non-professionals as operators instead of physiotherapists to hold down medical expenses is novel. We introduced the standing-up training content that adopts the Nintendo Balance Wii Board and a system configuration that realizes the above concept and introduced functions. The proposed RSS would probably suppress increment of medical expense and affect institutions of the national healthcare insurance. Thus, new business schemes have to be created in addition to developing the system to introduce it as a service.

ACKNOWLEDGEMENTS

Thanks to Mr. Isamu Morohashi and Mr. Hiroki Yamashita, physiotherapists at the Iwate Rehabilitation Center, Ms. Hiroko Shibao and her colleagues, physiotherapists at the Yokohama Chuo Hospital, and Dr. Kouya Sato, physiotherapist at the Better Life Iwate for their useful suggestions to develop the proposed remote rehabilitation system.

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