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Paper:

Development of a Tele-Rehabilitation System Using an Upper Limb Assistive Device

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A tele-rehabilitation system that can achieve remote interaction between a physical therapist (PT) and a patient was developed. Patients need to execute rehabilitation exercises to maintain upper limb function. However, it is difficult for them to travel to hospitals without aid. This system is equipped with a PC and a Kinect sensor at the hospital side (i.e., the PT), and a PC and an upper limb assistive device in the patient's home. The PT displays the motion in front of a Kinect sensor, which identifies the motion. In addition, the device on the home side assists the motion of the patient using the Internet. When the device receives a force higher than the safety value from the patient at any particular point on it, vibrators at the corresponding point on the PT's arm start to vibrate. Thereby, the PT can identify the patient's condition and limitations. The time delays in the transmission of data of device motion and the vibrators were measured and compared. As a result, the PT could identify the patient's condition faster than the motion of the device.

Keywords: tele-rehabilitation, upper-limb assistance, data transmission, Kinect sensor, motion feedback

1. Introduction

Diseases such as stroke, Parkinson's disease, and amyotrophic lateral sclerosis can cause patients' upper limbs to weaken. To improve this scenario, the patient must perform a rehabilitation exercise called range of motion (ROM) exercise. Conventionally, ROM exercise is performed by a physical therapist (PT). However, most rehabilitation centers are located in urban areas. It is difficult for therapists to rehabilitate patients who live in remote areas. A remote interaction between PT and patient must be achieved to address this problem. However, although the PT demonstrates the motion of the arm on a monitor, it is difficult for patients to comprehend the actual motion. Various tele-rehabilitation systems and upper-limb assistive devices have been developed by many researchers.

Rehab-Exos [1] is a five-DOFs upper limb rehabilitation exoskeleton robot based on a modular custom-designed actuation group to achieve upper limb rehabilitation. It can replace a PT to administer rehabilitation exercises. RUPERT [2] is also equipped with five DOFs. It supports the shoulder, elbow, and wrist joints. The target user was stroke patients. A pneumatic McKibben artificial muscle was selected as an actuator. Thereby, the total weight was less than that of the motor-driven devices. Kosaki and Li [3] developed a water-hydraulic exoskeleton. However, this device supports only the elbow joint. ASSIST [4] also uses compressed air and is wearable. This device can assist the elbow and wrist joints. However, the total weight of the two devices must be lifted by the user, which hinders their use by patients. TasKi [5] is also a wearable device for the shoulder and elbow. However, this is a passive type with a spring. InMotion ARM™ [a] is an end-effector-type device that is used for shoulder and elbow evaluation and therapy for stroke, spinal cord injury, multiple sclerosis, Parkinson's disease, and other neurological conditions or injuries. However, this device, the motion-assist arm developed by Kozuka et al. [6], and PLEMO [7] can be moved only in two dimensions. ReoGo-J® [b] is an end-effector-type of device that can achieve three-dimensional motion rehabilitation. Armeo®Power [c] is an arm and hand rehabilitation exoskeleton-type device for early stage patients. It can assist in three-dimensional motion of the arm. By combining game-like software, users can maintain their motivation. However, most of these devices are marginally bulky and difficult to move with. The device developed by Miyawaki [8] is a highly simple and compact device for ADL motion assistance. It can be installed on a wheelchair. However, the movable area is narrow.

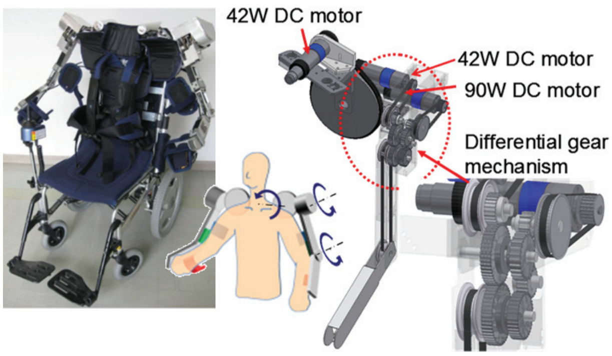


Fig. 1. 3-DOFs upper limb assistive device.

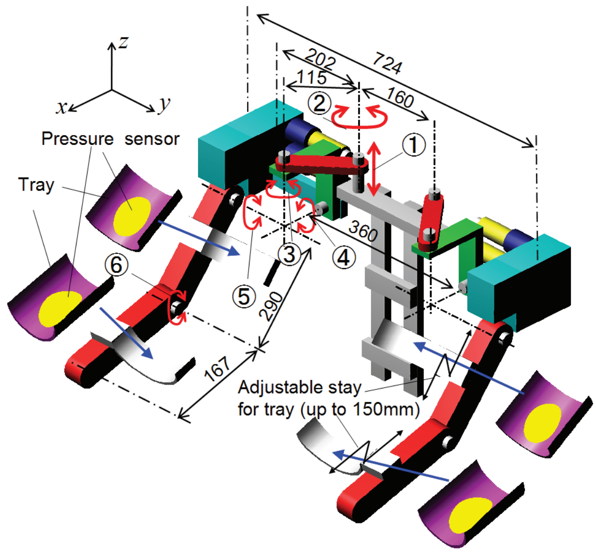


Fig. 2. Device dimensions [10].

If patients want to use these devices, it is necessary to come to hospitals. Orthyo™ is a product developed by AISENS [d]. A PT provides rehabilitation guidance to patients through network communication. The patient's physical condition is conveyed to the PT by an IMU sensor installed on the patient's limb. However, this is not the case for patients who require passive rehabilitation exercises. Xiu et al. developed an at-home wrist rehabilitation system [9]. Through this device the PT operates the device that simulates the patient's wrist in the hospital to transmit the rehabilitation motion remotely to the device that simulated PT's hand in the patient's home for rehabilitation exercise. The system can achieve tele-rehabilitation of passive rehabilitation exercises. However, it cannot be applied to joints with large ranges of motion, such as shoulder or elbow joints.

We developed an upper limb assistive device in our laboratory. It is of an armrest-type and can be installed on a wheelchair [10, 11]. The EMG activity was measured to evaluate the effectiveness of the motion assistance. Thereby, mainly the deltoid muscle (anterior) and biceps brachii muscle could be decreased. Furthermore, from the perspective of cerebral activity, although the users received assistance from the device, better neuro-rehabilitation can be achieved if users input the motion themselves. To expand the usage of this device, we developed a method for ADL motions, which can be assisted by various arbitrary motions using Kinect [12], Kalman filter [13–15], and logistic regression [16].

A tele-rehabilitation system that included vibration feedback was developed by improving this device. The configuration of this new system and comparison results of time delay in mutual communication between the hospital and home sides are presented in this paper.

2. Improved Upper Limb Assistive Device

We had previously developed an upper limb assistive device, as shown in **Figs. 1** and **2**. In general, ROM exercise range has to be decided without pain by feeling "end feel," that means the feeling of the resistance at the end of the limitation of the transitively motion. Of course it has to be in the normal range of human. Human's motion range of each joint and our device range of each joint are shown in **Table 1**, most of the range of the device is smaller than human. The angular velocity of the joint in the transitively motion is usually slowly with feeling the pain of the patient and resistance, on a case-by case basis. This device is equipped with six motors. Each arm has three DOFs: two DOFs for the shoulder joint and one DOF for the elbow joint. All the actuators can be collected at the back of the shoulder by using the differential gear mechanism. There are two trays for the upper arm and fore arm. These can be used as an armrest by placing the user's arm on these. The control system of the device is illustrated in **Fig. 3**. The AD and DA ports are connected to realize the tele-rehabilitation system (this is described later). The user can select the power source according to the usage. The control method of the device for various ADL motions is shown in **Fig. 4**. If the user wishes to raise his/her arm, the Kinect sensor captures his/her motion, and three joint angles of the user are sent to the device. In the device, the adequate values of the three joint angles of the device are calculated from measured human

Table 1. Comparison of each motion angle between human and device [10].

Body part	Axis No.	Motion	Human [deg]	Device [deg]
Shoulder girdle	①	Elevation	20	4
		Depression	10	6
	②	Flexion	20	20
		Extension	20	0
Shoulder	③	External rotation	60	0
		Internal rotation	80	75
	④	Abduction (lateral elevation)	180	45
		Adduction	0	0
	⑤	Flexion (forward elevation)	180	92
		Extension (backward elevation)	50	48
Elbow	⑥	Flexion	145	140
		Extension	5	45

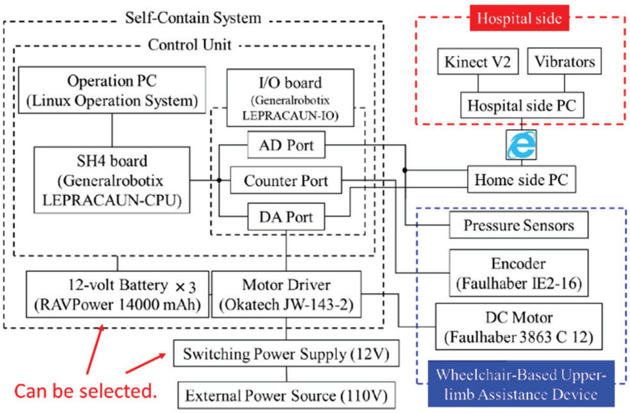


Fig. 3. Control system of upper limb assistive device.

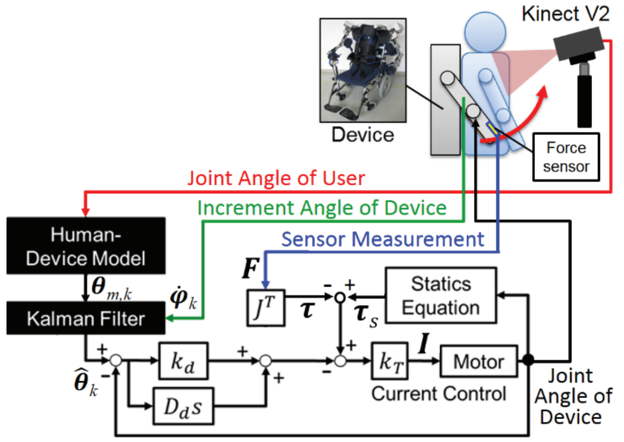


Fig. 4. Control method of the device for various ADL motions.

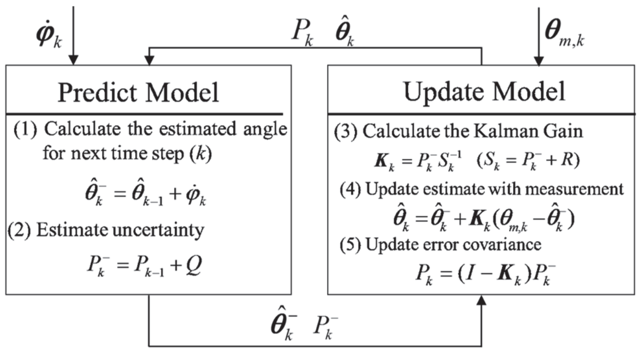


Fig. 5. Block diagram of Kalman filter algorithm of the device.

angles. Then, using the Kalman filter (see **Fig. 5**), the device is controlled to stably and smoothly assist a motion identical to that of the user.

However, the arm length differs across users, and the position of the root of the robot arm is different from that of the shoulder joint. Thereby, the angles of the shoulder and elbow joints are unequal, as shown in **Fig. 6** (left). To assist the motion more precisely, a mechanism model connecting the human arm and robot arm was proposed, as shown in **Fig. 7**. When the user raises his/her arm, the support points B and E in **Fig. 7** are shifted marginally

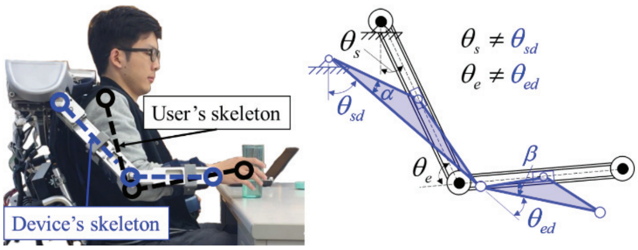


Fig. 6. Comparison between human arm and device arm.

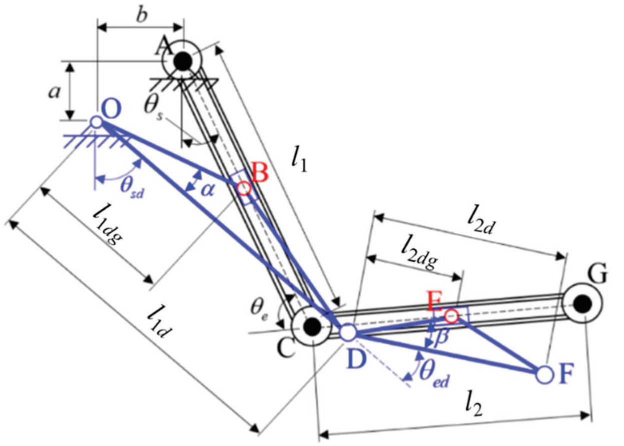


Fig. 7. Mechanism model between human arm and device arm.

to the root of the user's arm. Then, the trays at B and E can be modeled as sliders. From their geometrical relationship, the angles θ_{sd} and θ_{ed} of the robot joints can be determined using the following equations:

$$\theta_{sd} = \sin^{-1}\left(\frac{a\tan\theta_s + b}{\overline{\mathrm{OB}}\sqrt{\tan^2\theta_s + 1}}\right) + \cos^{-1}\left(\frac{1}{\sqrt{\tan^2\theta_s + 1}}\right) - \alpha, \quad (1)$$

$$\theta_{ed} = \sin^{-1}\left(\frac{-cd - e}{\overline{\mathrm{DE}}\sqrt{1-c^2}}\right) + \tan^{-1}\left(\frac{\sin(\theta_{sd}+\beta) - c\cos(\theta_{sd}+\beta)}{\cos(\theta_{sd}+\beta) + c\sin(\theta_{sd}+\beta)}\right), \quad (2)$$

$$c = \tan(\theta_s + \theta_e),$$

$$d = l_1\cos\theta_s - \overline{\mathrm{DE}}\sin(\theta_{sd}+\beta) - l_{1d}\cos\theta_{sd},$$

$$e = -l_1\sin\theta_s - \overline{\mathrm{DE}}\cos(\theta_{sd}+\beta) + l_{1d}\sin\theta_{sd},$$

where θ_s and θ_e are the angles of the human arm, α and β are the angles from the joint to the tray, and l_1 and l_{1d} are the upper arm lengths of the human and robot, respectively. a and b are the displacements of the shoulder joints between the human and robot. This is considered only for two joints: flexion/extension of the shoulder and elbow. The shoulder angle of the adduction/abduction of

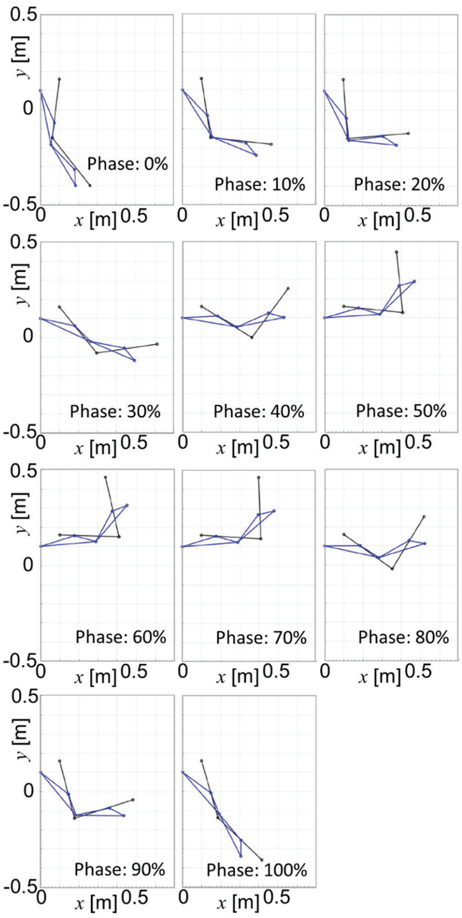


Fig. 8. Motion calculation of human arm and robot arm [12].

Fig. 9. Real motion of human and robot arms [12].

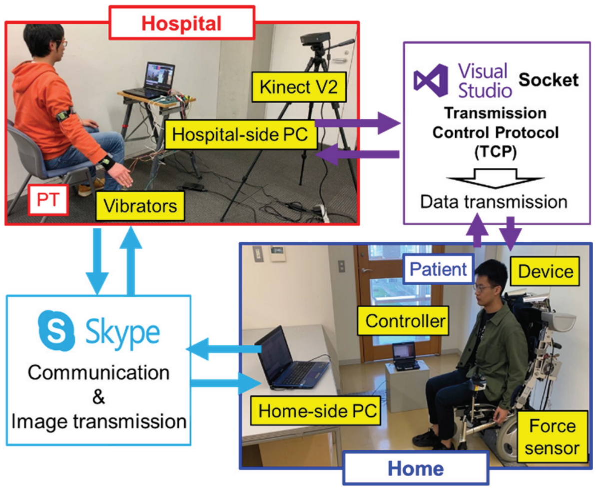


Fig. 10. Configuration of the tele-rehabilitation system.

the robot arm can be assumed to be identical to that of a human. A device control method was developed using these. Moreover, the device was controlled and supported according to an arbitrary motion of the human arm. Furthermore, as an example, the robot arm position according to the drinking motion of the human arm (from the lowest position of the hand (phase: 0%) to the achieving position to the face (phase: 50%)) and placing down of the hand (100%) was calculated as shown in **Fig. 8** [12]. The black line shows the human arm, and the two triangles represent the robot arm of the device. Meanwhile, **Fig. 9** [12] shows the actual assistance motion to take the spectacles off, similar to drinking. These figures verify that the motions of the human and robot arms are different.

3. Tele-Rehabilitation System

3.1. System Configuration

A tele-rehabilitation system for an upper-limb assistive device was proposed to enable a patient to execute rehabilitation. The device was used to achieve tele-rehabilitation for passive exercises and to replace the PT's arm for the device user (patient). **Fig. 10** shows the relationship between the hospital and home sides. The PT in the hospital and the patient in his/her home can communicate and identify the motion by using Skype. The therapy motion was captured based on the angle variation data of the shoulder and elbow joints obtained using the Kinect v2 sensor on the hospital side. The angle data were sent via the Internet as the target angles to drive the upper limb assistive device on the home side. The patient started to move his/her arm similar to the device by simultaneously observing the PT's motion from the Skype monitor. The hospital and home sides exchanged data via the Internet using the transmission control protocol (TCP). In

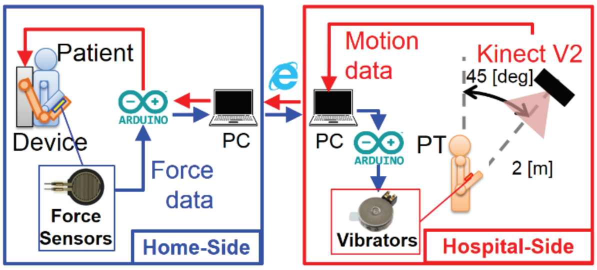


Fig. 11. Sending and feedback data between the hospital side and home side.

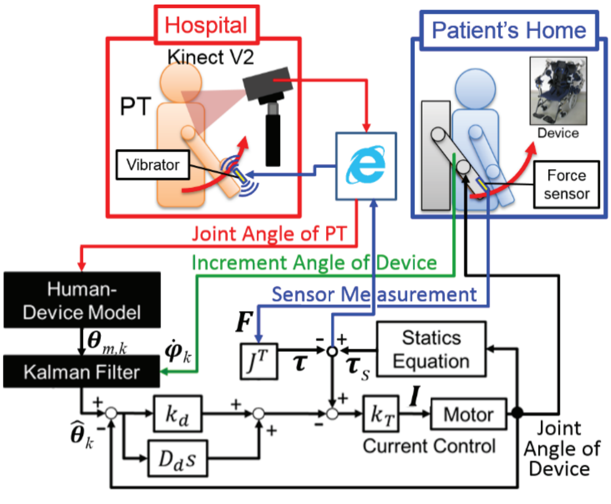


Fig. 12. Control method of device for tele-rehabilitation.

this system, we used the transmission control protocol of the Visual Studio Socket for data transmission. When we wish to connect from the hospital to the home practically, it is necessary to connect different servers. However, in this study, we developed a system in the same local area network (LAN), as a first step to realizing tele-rehabilitation.

In traditional therapy, the PT provides treatment appropriate to the patient's ROM. Therefore, to ensure safety, it is highly important for the PT to accurately identify the patient's condition and the limitations on the variation in the joint angles with meticulously care. Then, to provide feedback regarding the patient's condition to the PT, a multi-directional force perception tray was installed on the device with multiple force sensors, as shown in **Fig. 11**. The torque at each joint was calculated from the measurements of force sensors. When this torque is larger than the safety value (threshold) (the static torque necessary for the human and the robot arm), the PT can perceive vibration in the direction identical to that of the force that the patient exerts on the upper limb assistive device.

3.2. Home-Side Equipment

On the home side, the upper limb assistive device must be installed. To achieve ADL motion assistance (see **Fig. 4**), the control method was modified for tele-rehabilitation, as shown in **Fig. 12**. The Kinect was used

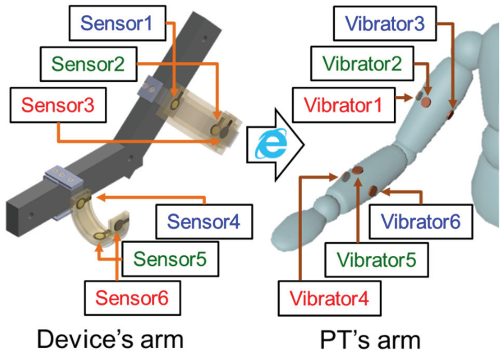


Fig. 13. Layout of the force sensors and vibrators.

for the PT to obtain the target motion via the Internet, rather than rely on the patient. Meanwhile, the difference between τ and τ_s exists. Furthermore, when τ is larger than τ_s, the device outputs and sends the difference value to the PT immediately.

In tele-rehabilitation, the PT can determine the endpoint of the ROM of the joint with the force sensors installed on the upper limb assistive device tray, as shown in **Fig. 13** (left). The three DOFs of the device are on two independent planes. Therefore, a multi-directional perception tray was designed to measure the vertical and horizontal components of the reaction force. These trays for the upper arm and forearm were equipped with three force sensors at the left, right, and bottom, respectively. The arc-shaped design can measure the force in the oblique direction, and the PT can be informed about this direction.

3.3. Hospital-Side Equipment

On the hospital side, the PT must examine the motion of the patient using the device. However, it is difficult to identify the patient's motion only from the monitor. Then, the six vibrators are installed, as shown in **Fig. 13** (right). When the torque values are aberrant as mentioned above, the feedback device should immediately inform the PT to stop the current motion through vibration. Because it is assumed that the robot arm of the device is used instead of the arm of the PT, the positions of the vibrators on the arm of the PT and the force sensors on the device are opposite to each other. **Fig. 14** shows an application example of the four cases of force sensors and vibrators. If the shoulder abduction cannot be continued by the patient, device sensors 3 and 6 receive a force stronger than the static value. Then, PT vibrators 1 and 4 start to vibrate. Meanwhile, if the patient cannot perform shoulder adduction, device sensors 1 and 4 receive the force, and PT vibrators 3 and 6 start to vibrate. When the PT receives the vibration signal, the motion must be stopped immediately for safety. However, this device is difficult to support the extension of the shoulder and elbow, and it is infeasible to identify the abnormal condition of these motions. This device has been used previously for ADL assistance. It is necessary to improve the structure of the trays of the device in future work.

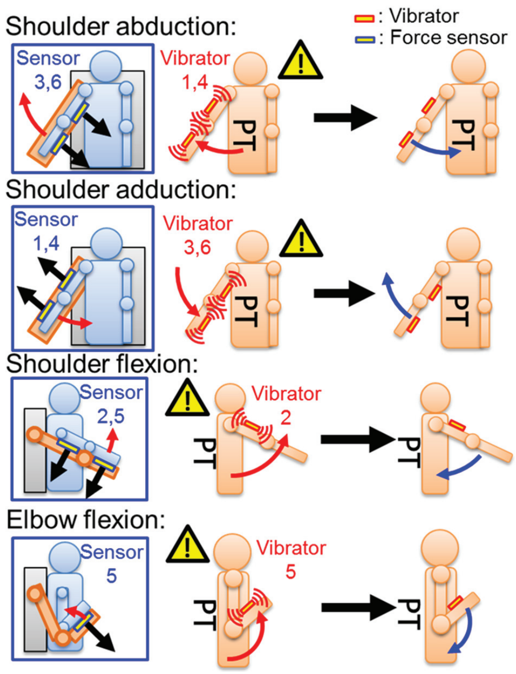


Fig. 14. Relationship between force sensors and vibrators.

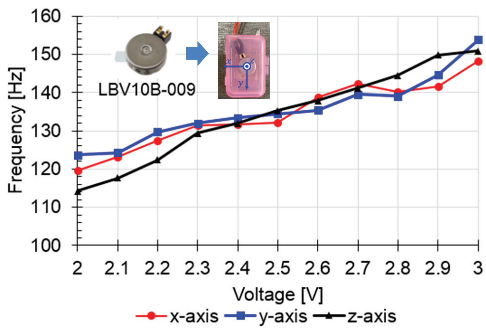


Fig. 15. Relationship between frequency and voltage of the vibrator (LBV10B-009 installed).

Furthermore, the selected vibrator, where LBV10B-009 was installed in the box, can shift the frequency according to the input voltage (see **Fig. 15**). Using this, we designed the input voltage according to the difference in the torque calculated from the force sensors and that obtained based on statics. If the force becomes large, the frequency of the vibrator increases.

This feedback response time is highly important for preventing accidents while using tele-rehabilitation. In the next section, the time delays of the vibration and device motion are discussed.

4. Experiment of Assumed Tele-Rehabilitation

4.1. Experimental Protocol

A measurement experiment of the time delay and joint angle error was carried out to verify the possibility of applying tele-rehabilitation. Two subjects were included, as shown in **Table 2**: Subjects 1 and 2 represented the patient and PT, respectively. These were able-bodied men rather than real patient or PT. Subject 1 was at the Information, Production and Systems Research Center (IPSRC) at Waseda University, which was assumed to be the home of the patient. Meanwhile, Subject 2 was located in the Graduate School of Information, Production, and Systems at Waseda University, which was assumed to be the PT's hospital. They were in the same campus, but each building was different. They communicated through Skype. Subject 2 explained the target motions to Subject 1 prior to the experiment: first, shoulder abduction/adduction by 60°; second, shoulder flexion/extension by 60°; and third, elbow flexion/extension by 120°. We asked Subject 2 to move gradually to arrive at the target angle in 4 s. However, when Subject 2 received the vibration, he had to alter the direction immediately. When Subject 1 perceived certain aberrant motion of the device, he and a third person could stop it. During the experiment, the measured joint angle data from the Kinect and the encoders of the device (which receive information on force from the sensors), and the calculated values of the torque from the sensors and statics were recorded in a PC at each location.

Table 2. Information on subjects.

	Subject 1	Subject 2
Role	Patient	PT
Physical conditions	Healthy	Healthy
Sex	Male	Male
Age	24	25
Weight [kg]	62	75
Height [m]	1.74	1.75

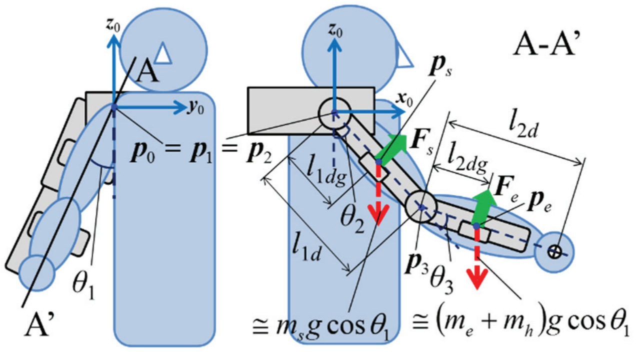


Fig. 16. Simplified model for calculating the measured joint toque and the safety value of the joint torque.

The joint torque was calculated from the data measured with force sensors and using the calculation model shown in **Fig. 16** and Eq. (3). The safety value of the joint torque was calculated using the model shown in **Fig. 16** and Eq. (4). It was difficult to obtain the angle data of Subject 1. The calculation for Subject 1 (patient) was performed utilizing the same model. In addition, the measured torque and safety torque on the device arm were compared.

$$\boldsymbol{\tau} = \begin{Bmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \end{Bmatrix} = \{J_s^{\mathrm{T}} \ \ J_e^{\mathrm{T}}\} \begin{Bmatrix} \boldsymbol{F}_s \\ \boldsymbol{F}_e \end{Bmatrix}, \quad \ldots \ldots \quad (3)$$

$$\boldsymbol{\tau}_s = \begin{Bmatrix} \tau_s 1 \\ \tau_s 2 \\ \tau_s 3 \end{Bmatrix} \cong \{J_s^{\mathrm{T}} \ \ J_e^{\mathrm{T}}\} \begin{Bmatrix} m_s \boldsymbol{g} \\ (m_e + m_h)\boldsymbol{g} \end{Bmatrix}, \quad . \quad (4)$$

$$J_s = \{\boldsymbol{x}_1 \times (\boldsymbol{p}_s - \boldsymbol{p}_1) \ \ \boldsymbol{y}_2 \times (\boldsymbol{p}_s - \boldsymbol{p}_2) \ \ \boldsymbol{0}\} \in \mathrm{R}^{3\times3},$$

$$J_e = \{\boldsymbol{x}_1 \times (\boldsymbol{p}_e - \boldsymbol{p}_1) \ \ \boldsymbol{y}_2 \times (\boldsymbol{p}_e - \boldsymbol{p}_2) \ \ \boldsymbol{y}_3 \times (\boldsymbol{p}_e - \boldsymbol{p}_3)\} \in \mathrm{R}^{3\times3},$$

$$\boldsymbol{F}_s = \{F_{sx} \ \ F_{sy} \ \ F_{sz}\}^{\mathrm{T}}, \quad \boldsymbol{F}_e = \{F_{ex} \ \ F_{ey} \ \ F_{ez}\}^{\mathrm{T}},$$

$$\boldsymbol{g} = \{0 \ \ 0 \ \ -g\}^{\mathrm{T}},$$

where τ is the measured torque calculated from the data of the force sensor, τ_s is the simplified safety torque (see **Fig. 16**), $\boldsymbol{F}_s$ is the measured force at the upper arm tray, $\boldsymbol{F}_e$ is the measured force at the forearm tray, m_s is the mass of the upper arm, m_e is the mass of the forearm, and m_h is the mass of the hand.

4.2. Time Delay of Force Data Transmission and Effectiveness of Vibration Feedback

The measured results are shown in **Fig. 17**. Here, the x-axis represents time, y-axis on the left represents the angle, and y-axis on the right represents the joint torque of the robot arm. The solid black line represents the target angle variation of the robot arm calculated using Eqs. (1) and (2) and was obtained from the arm of Subject 2 (PT) using Kinect. The dotted black line indicates the robot-arm angle measured using the encoders. The solid blue line indicates the joint torque calculated using the data measured by the force sensors. The dotted blue line indicates the safety value of the joint torque. The intersection of the solid blue line and dotted blue line represents the time when the vibration signal was transmitted. The peak point of the solid black line represents the timing of the vibration observed by Subject 2. Subject 2 then identified the difference condition between Subject 1 and the device, and altered the direction of motion. When the solid blue line and dotted blue line intersected again and the solid blue line was under the dotted blue line, the vibration stopped.

Meanwhile, we also carried out an experiment without using the vibrator. The results are shown in **Fig. 18**. Then, the subjects could communicate through Skype. However, information from the force sensors was not obtained.

From the results of **Fig. 17**, the average time delay from the signal transmission to the start of vibration was 0.7 s, and the average angle error was 6.5°. Meanwhile, from the results of **Fig. 18**, the average time delay was 3.0 s, and the average angle error was 22.0°. Apparently, the time delay and angle error reduced because of the use of force sensors and vibrators. Therefore, it is necessary to install the vibration feedback system to ensure safety. When the vibration started, the solid blue line in **Fig. 17(a)** increased. The frequency of the vibrator also increased. Therefore, Subject 2 could clearly determine the condition of Subject 1. Meanwhile, in **Figs. 17(b)** and **(c)**, the maximum difference point was almost identical to the vibration noticed point, then Subject 2 could not perceive the increase in frequency. However, it required time to notice (approximately 0.6–0.9 s), and the robot's torque continued to increase. This could result in a hazardous scenario. Therefore, this system has to be equipped with the vibration function as well as with the automatic stop function by setting the permissible difference value between the measured and safety torques as a

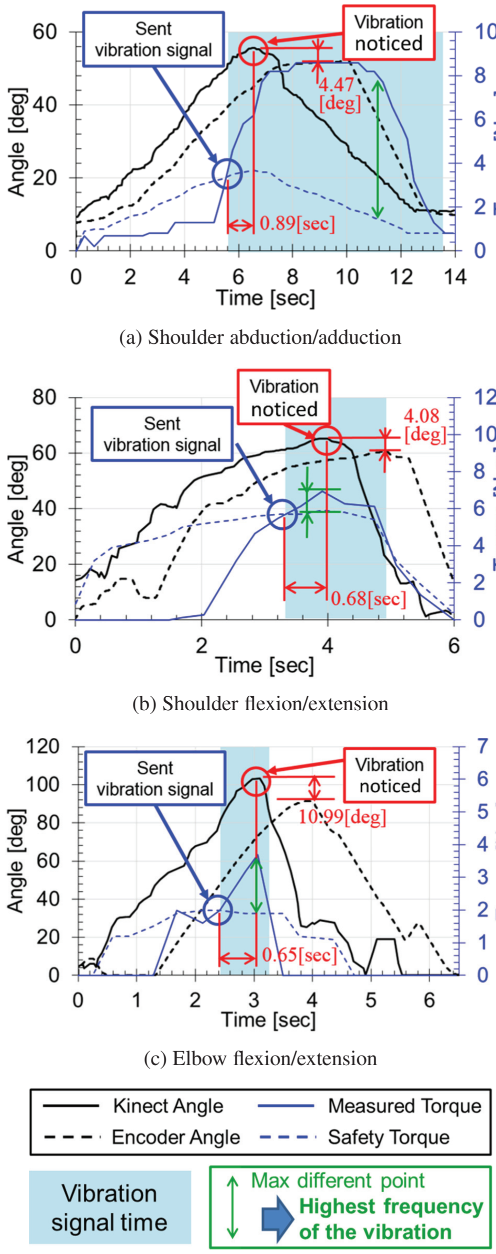
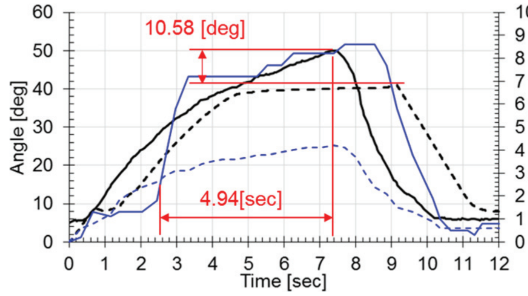
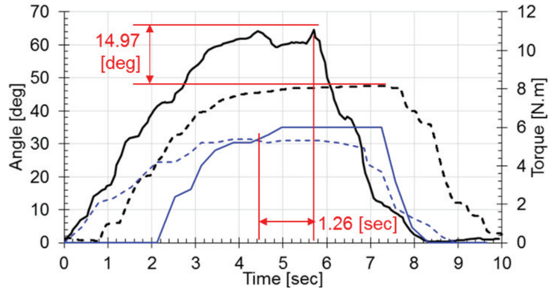


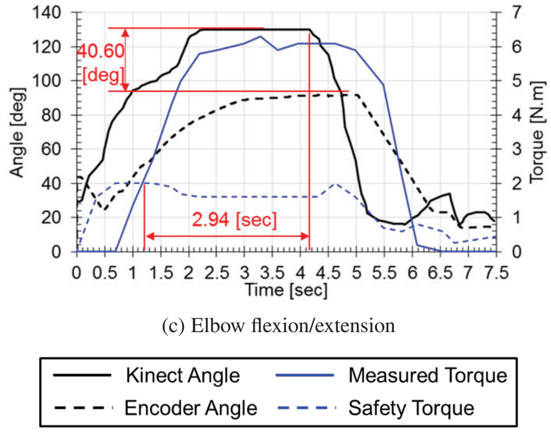
Fig. 17. Evaluation of time delay of the vibration from the signal transmission to the starting, and the angle error of each joint.



(a) Shoulder abduction/adduction



(b) Shoulder flexion/extension



(c) Elbow flexion/extension

Fig. 18. Evaluation of time delay from the intersection to the start time to return the motion (without the vibrators), and the angle error of each joint.

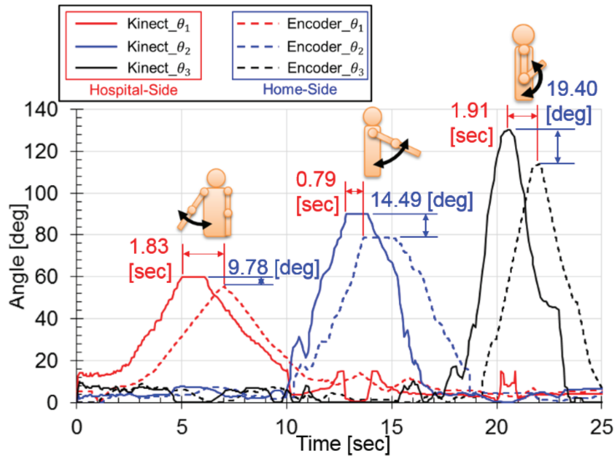


Fig. 19. Time delay of motion transmission and angle error.

threshold.

In general, ROM exercise in rehabilitation has to be performed gradually and cautiously to enable the perception of the patient's pain and the resistance of the target joint while moving. Therefore, the PT must identify these sensitively and continuously. According to the concept of this device, the pain can be identified by communication using Skype, and the resistance can be perceived using the sensor rather than the PT's perception. However, when this system is used practically, it is crucial to ensure communication using Skype and provide the emergency stop function against hazardous cases such as those wherein a sensor does not respond sufficiently or it sends signals with delay.

4.3. Time Delay of Motion Data Transmission

In **Figs. 17** and **18**, it is difficult to evaluate the time delay of the motion data transmission because the rising curve is not sharp. To accurately measure the time delay of the motion, we carried out the experiment wherein the motion time was maintained more stringently. The motion times were raising by 3 s, stopping by 1 s, and returning by 3 s. The motion and target angles were as follows: first, shoulder abduction/adduction by 60°; second, shoulder flexion/extension by 80°; and third, elbow flexion/extension by 120°. The measured results are shown in **Fig. 19**. The solid lines represent the targeted angles calculated by Eqs. (1) and (2) using Kinect measurement data, and the dotted lines represent the angles of the robot arm measured using the encoders. Each measured data point could display a relatively clear triangle shape. The time delay of motion was evaluated from the peak starting points. The average time delay of the motion transmission was 1.5 s. From the previous section, the average time delay of the force data was 0.7 s, which is shorter than that of the motion transmission. From these, Subject 2 could determine the condition faster than the motion of the device, and he could undertake measures for Subject 1. Therefore, to ensure safety, it is necessary for the transmission of vibration signals to Subject 2 (PT) to occur earlier than motion transmission. However, a comparison of the angle errors between **Figs. 17** and **19** reveals that the value increased because the angular velocity of the target motion also increased. This error must also be reduced for an effective utilization of this system for rehabilitation. The time delay and angle error must be reduced. From the result of first step of this system development, the followings are the fundamental rules for the system data transmission:

Delay time:

The signal transmission from the PT to the patient must be faster than the transmission in the opposite direction.

Angle error:

The device motion angle must be smaller than the motion angle of the PT.

5. Conclusions

A tele-rehabilitation system using an upper limb assistive device was developed. This device has a three-DOFs robot arm. We proposed equations for the relationship between human joint angles and robot arm joint angles. Furthermore, a PT in a hospital can display and control the device in the patient's home. The patient's ROM can be measured using force sensors and identified with the vibrators. This feedback system reduced the time delay from 3.0 s to 0.7 s. In addition, the angle error was reduced from 22.0° to 6.5°. The time delay of the motion transmission was 1.5 s, which was larger than that of the force transmission. In this experiment, the PT could determine the condition of the patient earlier than the motion. In future work, the time delay would be reduced. However, this device must continue to transmit vibration signals with minimum delay and earlier than the motion transmission, to ensure safety and more precise rehabilitation.

The following issues of this system need to be addressed in future work:

1. The control system must be improved. Although the Kalman filter is used to estimate the target angle, it is difficult to tune the gain parameters of the angle control. Impedance control would be installed.

2. The evaluation of the safety torque has to be performed as the patient motion by using the Kinect both for PT and patient. Then, the similarity of motion between the PT and patient can be examined.

3. This paper is on the first step of tele-rehabilitation and motion assistance using bilateral data transmission in the same LAN. The final objective is to realize communication by connecting different servers without a time delay and angle error. This would be practically used between the hospital and home of patients.

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