Development of User Intend Understand Module of FSR Sensor Base for Low Cost Rehabilitation Robots

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Summary
In this study an interface that reflects the willingness of rehabilitation patients to devices is proposed to perform intellectual improvements in CPM devices and rehabilitation exercises required devices. The proposed interface is a type of wearable device with a rehabilitation robot. Then, pressures are applied to the interface according to movements of rehabilitation patients and that is to be estimated. It can be used to evaluate the usability of the interface in which the recognition rate is determined by 83.5%. As a result, the interface is a reasonable to estimate the willingness of rehabilitation patients who are employed in this study, even though it does not represent excellent recognition rates compared to other sensors. In addition, the interface shows a high applicability in distributing personal type interface due to its low price.

Key words:
Rehabilitation, active rehabilitation, Rehabilitation Robot, Human Robot Interaction(HRI).

1. Introduction

Physical abnormalities are expressed in different ways and degrade the lives of human beings as the factors of inhibiting everyday life. The physical abnormalities are judged as disability and specific operations and rehabilitation exercises are implemented to recover physical functions [1]. The previous rehabilitation exercises are usually performed as free standing exercises by rehabilitation therapists. However, different methods of rehabilitation exercises are developed and implemented according to developments of medical and engineering technologies. As a result, there are several clinical reports that robot technology based rehabilitation exercises are effective in treating physical abnormalities [2-6]. Based on these clinical effects, studies and developments of rehabilitation devices have largely been conducted in the rehabilitation medicine world based on robot technologies.
Recently the rehabilitation robots are roughly divided into upper and lower limbs and are classified into two different types such as recovering the lost physical functions and replacing the lost functions. Here, the rehabilitation robots for recovering physical functions are usually focused on serious handicapped and hemiplegic patients caused by damages of muscles and nerves [3-5].
In the present conditions, there are few rehabilitation devices for both partially recovered rehabilitation patients and relatively minor rehabilitation patients. CPM (Continuous Passive Movement) devices are usually used for these patients in the present time. CPM devices have been applied to rehabilitation treatments from years ago because it represents effects of activating muscles and nerves through performing monotonic repetitive exercises [7-9]. However, there are no intellectual improvements in CPM devices regarding both the methods of rehabilitation exercises and the reflection of the intentions of rehabilitation patients even though rehabilitation devices have increasingly developed.
Thus, in this study an interface that reflects the intentions of rehabilitation patients to devices is proposed to perform intellectual improvements in CPM devices and rehabilitation exercise required devices.
Interfaces employed in recent rehabilitation devices are presented as joystick types that detect minute body movements focused on the patients who lost physical functions [10-11]. In these interfaces, high cost sensors are used to estimate the weak intent of rehabilitation patients, otherwise it applies simply controlled sensors in order to estimate the intent of patients based on simple manipulations [12-14]. Thus, it is not proper for indicating the intent of rehabilitation patients proposed in this study. It is due to the fact that the patients who recover physical functions and require minor rehabilitation exercises complain of pain in ROM (Range of Motion) or in a certain range even though they can move rehabilitation areas in part. In this study, FSR (Force Sensitive Resistor) sensors were used to propose an interface that can identify the intent of using devices based on simple operations rather than precise controls. Although the functions of FSR sensors show no excellent functions, such as resolution, compared to the pressure sensors, F/T and torque sensors, it is possible to estimate the intent of rehabilitation patients proposed in this study and represents an advantage of applying it as personal interfaces due to its low cost.

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Thus, in this study a low cost rehabilitation system that has active rehabilitation functions in an exoskeleton robot for the patients who recover physical functions and need exercises on specific joints in a case that requires minor rehabilitation exercises is proposed. In addition, although the users presented in the proposed system are able to move rehabilitation points, they are treated by small ROM and are the patients of suffering pain in certain areas. For identifying the intent of rehabilitation patients accurately, it is necessary to determine the intent of using devices based on simple self-intention and easy operations rather than precise controls. Thus, in this study an interface method based on low cost FSR sensors, which allow easy measurements of the external force of users, is proposed. Therefore, a 2DoF type device that performs specific upper limb rehabilitation exercises such as flexion, extension, abduction, and adduction is proposed. Then, a system that proposes an interface of identifying the intent of users and verifies the system is proposed.
This study is organized as follows. The operational principle and requirement in the interface proposed in this study are given in Section 2. The implementation and verification of the proposed method are presented in Section 3. Section 4 concludes the study.

2. Theoretical background

2.1 Method of determining the user intent for low cost rehabilitation devices

The principle of the interface proposed in this study is as follows. As a rehabilitation patient wears a rehabilitation device on an affected part, the part is limited in motions due to the binding caused by the device. After limiting motions in the part, the motions of the patient generate pressures on the bound part along the directions of the motions. Then, the pressures are detected by sensors.
For detecting these motions, there are several studies on estimating pressures and motor torques [4]. In this study, however, the interface proposed in this study aims to apply it low cost devices and uses FSR sensors that are relatively affordable compared to other previous studies. The FSR sensors represent variable resistor values according to the pressures applied to the sensors.
Fig. 1 shows the interface proposed in this study. The interface is fabricated as a band with several FSR sensors and is used at an affected part with a rehabilitation robot (device). As shown in Fig. 2, the conventional rehabilitation robot (device) usually performs the motions of raise/down to the front and side respectively. In addition, the interface presented in Fig. 2 can be applied to lower limbs.

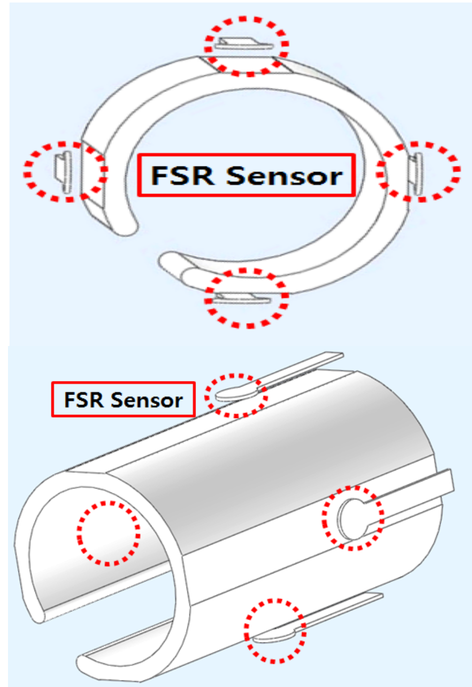

Fig. 1 Conceptual diagram of the interface for determining the user intent

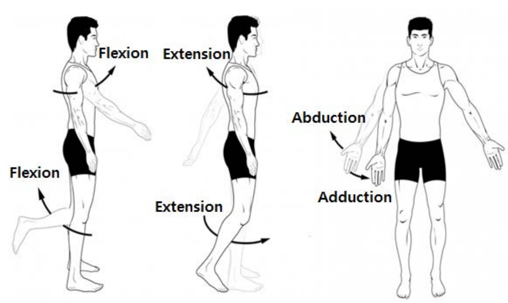

Fig. 2 Ranges of the motions in low cost upper and lower limb rehabilitation devices

2.2 Algorithm for determining user intent

As the interface proposed in this study is used by bonding it to a rehabilitation device, it is difficult to estimate user intent because the initial pressure applied to rehabilitation parts according to users and its force levels are different.Thus, in this study a technique that detects feature points for each user is introduced to determine the initial pressure presented in users and to identify it according to user movements. Eq. (1) shows an exponentially weighted moving average filter equation. (e.g., see Eq. 1).

$$EMA(FSR_{data}, N)_t = \alpha * FSR_{data} + (1-\alpha) * EMA(FSR_{data}, N)_{t-1} \quad (1)$$

Eq. (1) represents the cumulative average of the exponentially weighted moving average filter as a recurrence equation and the weighted average is obtained using the present and previous data as a weighted value (α). By using the data tendency detected in normal times before determining user intent based on this equation, it is determined as a feature point for identifying user intent. The feature point detected in this study is named as NAF (Normal Average Force). Then, the control variables in a rehabilitation device are applied to a direction desired by a user through the changes in FSR sensors based on the NAF of the FSR sensors. As the weight value (α) of NAF is fixed, however, the changes in FSR sensors caused by fluid changes are simultaneously detected in a user intent verification process. Based on the fact, in this study a technique that calculates the weight values, which represent fluid changes, in order to improve recognition rates in user intent based direction identifications. Eq. (2) shows the calculation of fluid weight values (e.g., see Eq. 2)

$$\alpha_p = \frac{FSR_p}{NAF} \text{ , } FSR_{out} = FSR_p \cdot \alpha_j \quad (2)$$

Eq. (2) shows a method that calculates the weight value () varied with real-time through dividing the FSR sensor data () at a corresponding part by NAF. Using this equation, the FSR sensor data is not detected as a simultaneous manner while there are no significant differences between NAF and force in the output of the FSR sensors. Then, as shown in Fig. 3, it allows to applying control variables to a rehabilitation device as the FSR sensor data is the largest value.

3. Implementation and verification

A relatively low price rehabilitation device (robot) was used to verify both the accuracy of the recognition in the proposed method and the algorithm employed in this method. The proposed interface is presented in Fig. 4 and the rehabilitation device used in the verification test is shown in Fig. 5.

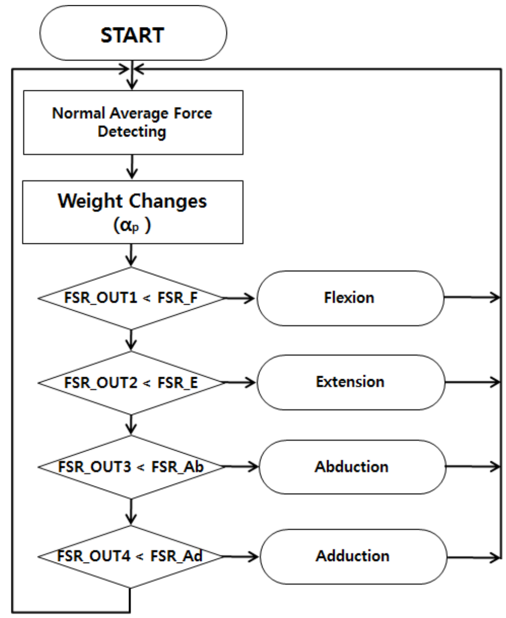

Fig. 3 Direction control flow diagram

Fig. 4 User intent detection interface

Fig. 5 Personal rehabilitation device

3.1 User intent detection interface test and its results

The user intent was detected using a user intent detection module proposed in this study. The detection module performs the motions of the upper limb rehabilitation such as Flexion, Extension, Abduction, and Adduction after installing a rehabilitation robot and wearing the user intent detection module. Then, the results are used to verify the usefulness of the user intent detection module. Fig. 6 represents the data before applying the proposed algorithm based on the user intent detection module.

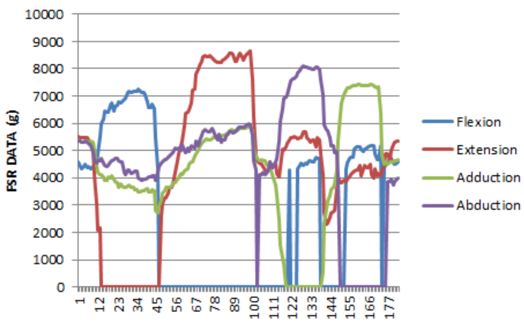

Fig. 6 FSR sensor data of the user intent detection module before applying the proposed algorithm

In the results of applying the user intent detection module, the feature points for each motion were detected. As a result, the possibility of the proposed module was verified. However, it is also verified that a simple user intent detection module shows difficulties in verifying the recognition due to the pressure around the part. The results obtained using the algorithm proposed in this study are presented in Fig. 7.

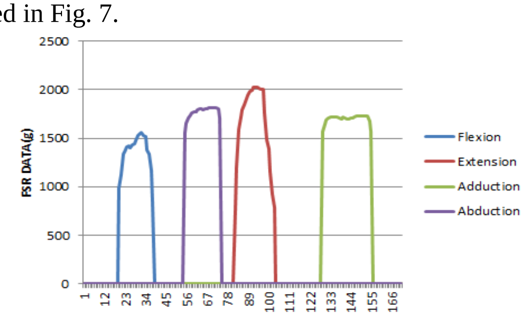

Fig. 7 FSR sensor data of the user intent detection module after applying the proposed algorithm

It is verified that the proposed algorithm shows the FSR sensor data corresponding to each motion. Fig. 8 and Fig. 9 show the FSR sensor data in each motion obtained through extracting the feature points of users as the users try to move.

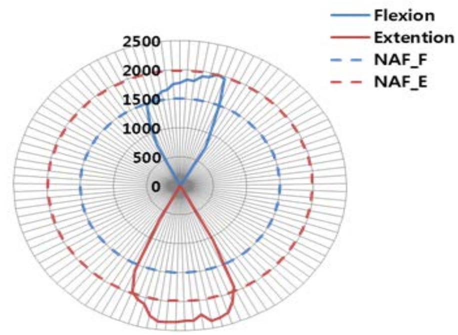

Fig. 8 Interface data in detecting the user intent of Flexion/Extension

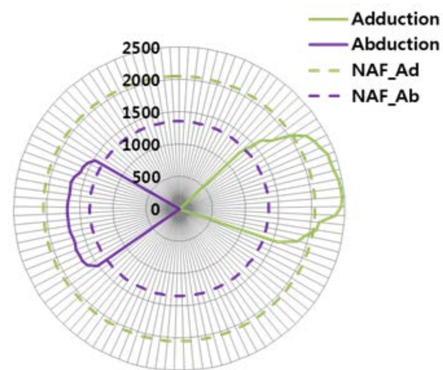

Fig. 9 Interface data in detecting the user intent of Adduction/Abduction

NAFs in each FSR sensor for the motions of Flexion, Extension, Abduction, and Adduction and the accuracy of the user recognition can be measured by the change in FSR sensor data from these four motions as the data is larger than the force of moving the upper limb.

Then, the interface was used to determine the recognition rate of the user intent detection module proposed in this study. The sequence of the motion range was applied to a user through a buzzer every three seconds based on the sequence of motions, Flexion, Extension, Abduction, and Adduction. Table 1 shows the results of the tests, which were implemented a total of 25 times for four subjects.

In the results, the user intent rates in given motions were detected 94, 79, 82, and 79% in Flexion, Extension, Abduction, and Adduction respectively. The average recognition rate was 83.5% without any pre-exercises. Therefore, the recognition rates can be improved through some practices.

Table 1: Results of the user intent detection test

User	Flexion	Extension	Abduction	Adduction	Recognition Rate(%)
1	96%	72%	72%	76%	79.00
2	92%	80%	84%	80%	84.00
3	92%	84%	88%	84%	87.00
4	96%	80%	84%	76%	84.00
Avg.	94.00	79.00	82.00	79.00	83.50

4. Conclusion

In this study an interface method that detects user intent for low cost robots was proposed. The proposed method used low cost force sensors, FSR, for detecting the user intent. The control method for detecting the user intent is implemented based on changes in sensor data compared to NAF after extracting the feature points of initial users. For verifying the proposed method, the recognition rates in the user intent were measured according to the sequence of motions. In the results of the test, the motion of Flexion showed the highest recognition rate of 94%. The Abduction signals were frequently detected in the motion of Extension. Also, the Flexion signals were frequently detected in the motions of Adduction and Abduction. As a result, the average user intent recognition rate in these four motions was determined as 83.5%. Although it is not better than other high price sensors, it is useful to detect the user intent based on the interface proposed in this study. Also, it is considered that the interface is an excellent device due to its low cost and can be used as a personal interface. The method proposed in this study can be used as a control variable in upper and lower limb rehabilitation devices (robots). In addition, as the interface uses low cost force sensors, it allows to presenting a personal interface and to activating rehabilitation treatment robot markets. Furthermore, it can be used to intellectual rehabilitation exercises because the proposed method presents intuitive and easy operations.

Acknowledgments

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