2018 17th International Symposium on Distributed Computing and Applications for Business Engineering and Science

System design of vertical motion support device for upper limb disability

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***Abstract*—Many of patients who have suffered from serious illnesses such as the cerebral infarction and ALS and elderly people have many inconveniences in their daily life. In order to help people with disabilities in the upper limbs to eat, operate computers or paintings, and improve the quality of life of persons with disabilities in the upper limbs, this paper has developed a vertical movement support device for upper limb disabled persons. First of all, the overall structure of the support device was designed and vertical movements were explained. Then, the design and description of the control system were performed. Finally, the user experience proved that the system design of the upper vertical support device was feasible and could be solved，Part of the needs of the upper hand disabled.**

Keywords-Upper limb disabled;support device;vertical movement; control system

I. INTRODUCTION

With the ageing of the population, the elderly are the vulnerable groups of the disease. Among them, the stroke has the characteristics of acute onset and high morbidity rate for the elderly. There are about 2 million new patients and nearly 80% disabled in China every year[1]. This caused an economic burden of 40 billion yuan. Among them, the upper limbs of the person are required to perform more complex exercises than the lower limbs, and the neural control system is more complex and the recovery is slower after injury. After 3 months of concurrent treatment, 55% to 75% of patients have upper limb disorders[2][3]. It is of great significance to improve the upper limb mobility of patients. As mentioned above, the main purpose of this study is to develop a support device, which mainly describes and discusses the mechanical structure system and the control system of the device. Finally, through the user experience, this study demonstrated the feasibility of the upper limb vertical motion support device.

II. SUPPORTING DEVICE FOR VERTICAL MOVEMENT

The whole configuration of the proposed supporting device for vertical movement is shown in Figure1.

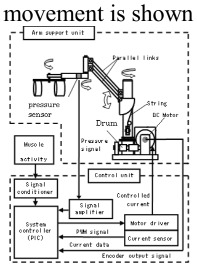

Figure 1. Configuration of the system

This main mechanical device was designed and produced by our lab many years ago, and based on the old machine; we do some changes and improvements on the machine to help us to do the research. Fig.2.1 is the mechanical system configuration and the controller system configuration.

Supporting device is different from spring balancer in power applied method. DC motor rotates a drum to reel a string for rising up parallel links. At the end of the parallel links a horizontal arm is connected. Inside the horizontal arm a force sensor is mounted to measure the assistive force applied to user's arm. On the tip of the horizontal arm a supporting rod is connected. User's arm is fixed on this supporting rod by using two belts. It should be noticed that only the vertical movements of the arm is assisted. Therefore, the assistive device is designed not to restrict horizontal movements. The assistive applies the ability to support their body against the gravity.

The control unit is composed of a system controller, a motor driver, a current sensor, a signal amplifier for force sensor and a signal conditioner for muscle activity sensor. The system controller is configured by using PIC (Peripheral interface controller). The system controller generates PWM (Pulse width modulation) signal to control the DC motor so that the assistive force keeps the desired level. A PC is connected to the system controller and used as an input device to set control parameters or user's body size information.

A. Mechanical system configuration

1) Mechanical configuration of the whole device

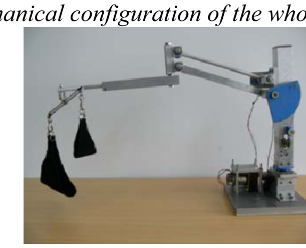

Figure 2. Pictures of supporting device

Figure2. shows the whole mechanical configuration of supporting device for vertical movement.

This device is designed to support vertical movement against the gravity for the upper limb disabled persons.

The main material of the assist device is aluminum alloy, and some the other materials. The total height of the unit is 430mm .And the lengths of parallel links and horizontal link are 250mm and 180mm.Moreover, some

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DOI 10.1109/DCABES.2018.00093

other dimensions are showed in Figure3.

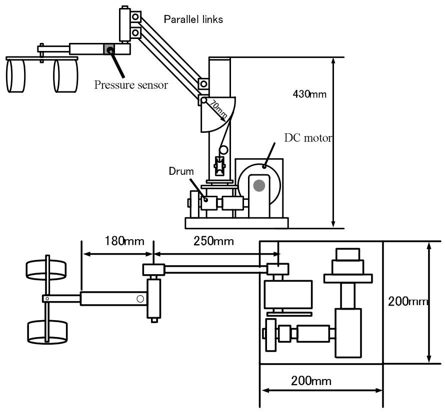

Figure 3. Name of some parts and main dimensions

Learned from the Figure3., the main dimensions of the supporting unit could be known, and deduce the active range of the device. In vertical direction, the highest position is 450mm and the lowest is 65mm. In the two positions, the angle difference is 90°. In addition, there are two bearings in the end of the prop. Based on the lengths of the parallel and horizontal links, the largest radius 600mm's circular motion can be permitted.

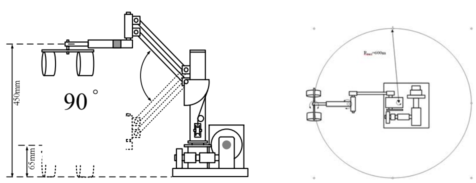

Figure 4. Range of the supporting unit

2) Components of the device

- *DC motor*

The DC motor is produced by servo Japan. DC motor connects drum with coupling and applies the power of the whole mechanical device.

- *Parallel links*

Parallel links rotates with sector part to do the vertical movement and with the sector part the torque transmit to parallel links. Because of the parallel links are adopted, the horizontal link can always keep horizontal direction.

- *Arm supporting part*

This part consists of two parts, horizontal link and supporting rod. Horizontal link is connected with the end of the parallel links and supporting rod is fixed on the horizontal link. In order to get the user's assistive force, pressure sensor is set between the horizontal link and supporting rod part. User's arm is fixed on the supporting rod by two belts.

- *Pressure sensor*

In this research, pressure sensor is used to detect force applied on user's arm. the pressure sensor is mounted inside the horizontal arm to measure the assistive force applied to user and the load value is calculated with the following equations.

Output voltage quantity

$$\text{Calibration coefficient (N/mV/V)} = \frac{\text{Rated Capacity(N)}}{\text{Rated output(mV/V)}}$$

Load value

$$\text{Load} = \frac{\text{Output bridge voltage(mV)}}{\text{Bridge voltage(V)}} \times \text{Calibration coefficient(N/1mV/V)}$$

- *Sensor for muscle activity detection*

In our assistive device an original sensor that detects muscle activity level is employed as a man-machine interface. This sensor is a tactile sensor to detect the level to which the target muscle is stiffened. The level of muscle activity can be estimated from the stiffness information of the target muscle. The sensor is fixed on user's shoulder by using an elastic belt. The user's intention to lift his arm is detected by measuring activity level of a deltoid muscle located on the shoulder that works for eternally rotating shoulder. One advantage of this muscle stiffness sensor is that the muscle activity can be detected even over clothes. These features and advantages of the muscle stiffness sensor contribute to make the assistive device reliable, safe and access friendly. This muscle stiffness sensor is easy to attach and hard to be affected by skin condition, so it can detect muscle activity even on clothes. And for it uses muscle stiffness, it is robust against to noise that transferred through skin.

B. Control system configuration

The control configuration make up of motor controller and motor driver. As the controller, PC and PIC based control are adapted. PC interfaces with the user to set up the target load and notices the present state to user. PIC based controller is used to archive position, speed and current data, and sends PWM signals to motor drive circuit. The motor controller is configured by using PIC. As is shown in Figure5.

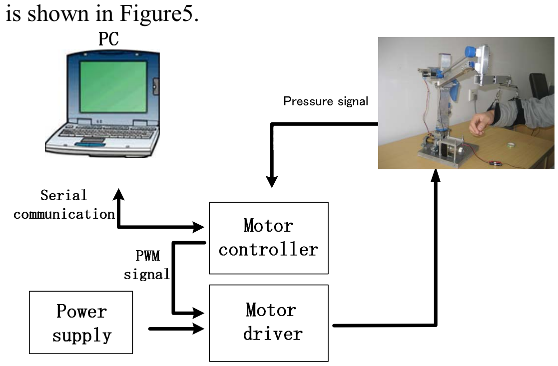

Figure 5. Control system configuration

1) Contents of control system

- *Motor driver*

In this research, a motor driver is developed. In motor driver circuit, two current streams are shown, one is for positive rotation, and the other is for negative rotation. Motor driver has following input-output relation. The motor driver drives the DC motor based on the command signal U_{out} sent from the system controller. U_{out} represents direction of motor rotation and duty ratio of

PWM signal to operate the motor drive circuit. The motor is driven by the rule described below.

Rotation direction:

$$\begin{cases} Positive & (U_{out} \geq 0) \\ Negative & (U_{out} < 0) \end{cases}$$

Duty ratio of PWM signal: $|U_{out}|$

In the motor driver, in order to detect the output, a current sensor is used.

- *Protect circuit*

In motor driver circuit, if the control signals from PIC as the case of short 1 or short 2, will cause short circuit. To solve the problem, in this research, a protect circuit is necessary.

- *motor controller*

To interface with user and to provide safe and effective motions, it is desirable to measure sensor signal like pressure sensor, current sensor, and muscle activity sensor and so on. Figure6. shows the computer screen that is used to set the necessary dates and control the actions of the device.

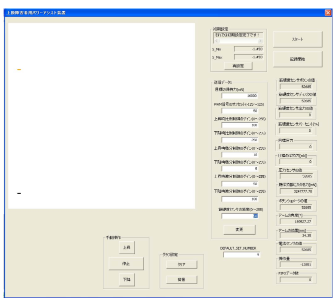

Figure 6. Operating PC screen

From the screen, user's state and some information can be getting, and the dates will be recoded every time. With the program, the device could help the people with upper limb disability better and better.

III. CONCLUSION

In this research, the mechanical device is proposed to help elderly people so that they can keep living an independent life by themselves. The mechanical machine let user to eat, operate computer or draw pictures by itself. The daily actions about upper limb are very important To keep their quality of life and for care workers to care patients or elderly with upper limb disability with less energy.

REFERENCES

[1] Zhang H, Austin H, Buchanan S, et al. Feasibility studies of robot-assisted stroke rehabilitation at clinic and home settings using RUPERT[C]//IEEE International Conference on Rehabil-itation Robotics. Piscataway, USA: IEEE,2011.

[2] Kwakkel G, Wagenaar R C, Twisk J W R, et al. Intensity of leg and arm training after primary middle-cerebral-artery stroke: A randomised trial[J]. Lancet, 1999, 354(9174): 191-196.

[3] Fasoli S E, Krebs H I, Stein J, et al. Effects of robotic therapy on motor impairment and recovery in chronic stroke[J]. Archives of Physical Medicine and Rehabilitation, 2003, 84(4): 477-482.

[4] Charles S K, Krebs H I, Volpe B T, et al. Wrist rehabilita-tion following stroke: Initial clinical results[C]//IEEE Inter-national Conference on Rehabilitation Robotics. Piscataway,USA: IEEE, 2005: 13-16.

[5] Krebs H I, Dipietro L, Levy-Tzedek S, et al. A paradigm shift for rehabilitation robotics[J]. IEEE Engineering in Medicine and Biology agazine, 2008, 27(4): 61-70.

[6] Lum P S, Burgar C G, van der Loos M, et al. Use of the MIME robotic system to retrain multi-joint reaching in post-stroke hemiparesis: Why some movement patterns work better than others[C]//IEEE International Conference on Rehabilita-tion Robotics. Piscataway, USA: IEEE, 2005: 511-514.

[7] Lum P S, Burga C G, Shor P C. Use of the MIME robotic system to retrain multi-joint reaching in post-stroke hemiparesis: Why some movement patterns work better than others[C]//Annual In-ternational Conference of the IEEE Engineering in Medicine and Biology. Piscataway, USA: IEEE, 2003: 1475-1478.

[8] Burgar C G, Lum P S, Shor P C, et al. Development of robots for rehabilitation therapy: The Palo Alto VA/Stanford experi-ence[J]. Journal of Rehabilitation Research and Development,2000, 37(6): 663-673.

[9] Kahn L E, Zygman M L, Rymer W Z, et al. Robot-assisted reaching exercise promotes arm movement recovery in chronic hemiparetic stroke: A randomized controlled pilot study[J].Journal of NeuroEngineering and Rehabilitation, 2006, 3:No.12.

[10] Reinkensmeyer D J, Kahn L E, Averbuch M, et al. Understand-ing and treating arm movement impairment after chronic brain injury: Progress with the ARM guide[J]. Journal of Rehabilita-tion Research and Development, 2000, 37(6): 653-662.

[11] Amirabdollahian F, Gradwell E, Loureiro R, et al. Effects of the GENTLE/S robot mediated therapy on the outcome of up-per limb rehabilitation post-stroke: Analysis of the battle hos-pital data[C]//8th International Conference on Rehabilitation Robotics. 2003: 55-58.

[12] Xu B G, Peng S, Song A G, et al. Robot-aided upper-limb reha-bilitation based on motor imagery EEG[J]. International Journal of Advanced Robotic Systems, 2011, 8(4): 88-97.

[13] Yang Y, Wang L, Tong J, et al. Arm rehabilitation robot impedance control and experimentation[C]//IEEE International Conference on Robotics and Biomimetics. Piscataway, USA:IEEE, 2006: 914-918.

[14] Ju M S, Lin C C K, Lin D H, et al. A rehabilitation robot with force-position hybrid fuzzy controller: Hybrid fuzzy control of rehabilitation robot[J]. IEEE Transactions on Neural Systems and Rehabilitation Engineering, 2005, 13(3): 349-358.

[15] Sugar T G, He J P, Koeneman E J, et al. Design and control of RUPERT: A device for robotic upper extremity repetitive ther-apy[J]. IEEE Transactions on Neural Systems and Rehabilita-tion Engineering, 2007, 15(3): 336-344.

[16] Yu W, Rosen J. A novel linear PID controller for an upper limb exoskeleton[C]//IEEE Conference on Decision and Con-trol. Piscataway, USA: IEEE, 2010: 3548-3553.