

Arm movement support device for rehabilitation

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Abstract: As modern society becomes increasingly more elderly, developing specialized equipment to assist this growing population in everyday tasks becomes more and more important. Here we have developed a passive gravity balanced arm support system. It was designed to assist the arm motion of elderly people with disabilities. The system consists of the joints and the link and the gas springs. This is a very simple and low cost structure. The arm support system constitutes of the support arm that protects the wrist part and the swing arm that protects the elbow. Rather than being done after recovery from paralysis as a functional disorder, rehabilitation that is undertaken by elderly impaired people using the arm balancer is often undertaken with the goal of self-support of active daily living (ADL) at an activity limit level. We evaluate the arm support system for rehabilitation.

Keywords: Biomechanics, Bio-Motion, Human Engineering, Rehabilitation, Training

1. INTRODUCTION

A training machine using robots was developed to provide sufficient momentum safely for patients with hemiplegia following a cerebral stroke. Today, robots are used extensively for rehabilitation. Advantages of using robots for rehabilitation include sufficient strength against training performed by an occupational therapist, excellent repetition features, and realization of constant and regular movements. However, problem areas impeding robot applications to the clinical field include that the devices are too large and expensive [1],[2], and that applicable standards and exercise programs have not been established yet, and that training will be difficult for patients with remarkable spasticity and contracture. Setbacks and abandonment of therapy caused by a lack of patient motivation when rehabilitation is protracted are described as problems related to overall rehabilitation. Particularly for decreased upper limb function attributable to cerebrovascular disorder, functional recovery is difficult and maintenance of the status quo through continued rehabilitation plays an important role. When functional recovery is not promising, maintaining motivation for rehabilitation becomes difficult. In this study, we have developed a passive gravity balanced arm support system for rehabilitation.

2. CONCEPT OF ARM MOVEMENT SUPPORT DEVICE FOR REHABILITATION

Field assessment results for the arm movement support device show that for increased functions and extension of the market of the device, mere application as welfare and nursing care equipment is insufficient, and that modification for use in rehabilitation is

necessary. During initial development, the arm movement support device was intended for arm movement assistance only. Other applications were not available. Brainstorming discussions (creative group thinking) were held with healthcare professionals (orthopedic specialists, rehabilitation specialists, occupational therapists, physical therapists) and engineering-related professionals (equipment development vendors, equipment raters) to explore ways to improve this equipment.

Major improvements derived from the brainstorming method are described below.

- ① The equipment has freedom of movement and can perform three-dimensional movements, but we recommend limiting the degrees of freedom for therapy of patients and for inducing movements. Particularly for severely disabled people, it is necessary to limit the degrees of freedom in a similar manner as is done for a brace.
- ② With movement, after horizontal direction movements are acquired, up/down direction movements are started. For example, linear movements can be done merely using a slide mechanism. Alternatively, two-dimensional movement is realized by combining straight lines (image of drawing drafter).
- ③ Means for limiting rotational movements using a stopper are needed.
- ④ A table-mounted type of device, with a wide movement range, is easier to use than a device used from a seat or chair.
- ⑤ Wheelchair-mounted type devices conserve space and are advantageous.
- ⑥ Features of the equipment are its compact design and low cost. Therefore, current configurations

using gas springs, etc., are appropriate. Electric motor driven types are large and expensive and are therefore not suitable to be used conveniently in clinical applications.

- ⑦ If means for measuring movements of the arm using sensor are added, then a widened movement range after training can be confirmed.
- ⑧ Accuracy in the order of centimeters is sufficient for fingertip measurements by the sensor.

Based on the observations described above, we constructed a system, as shown in Figure 1, corresponding to rehabilitative movements. For use in training, the mechanical portion of the arm movement support device should be modified as presented in ①–⑥ and a means for quantitative assessment of training movements as shown in ⑦ and ⑧ should be added. Using this system, arm movements are measured using sensor signals and accumulation of the movement range of the arm enables qualitative assessment of therapy.

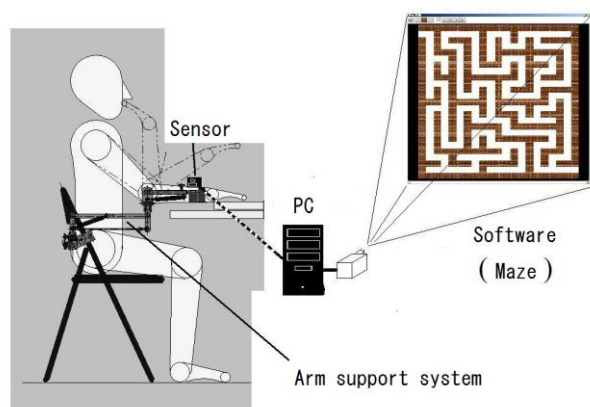


Fig. 1 Concept of the arm support system for rehabilitation

3. MECHANISM OF ARM MOVEMENT SUPPORT DEVICE

The "Arm-Balancer"^{[3],[4]} supports three-dimensional operation. Arm actions over a wide area are possible. The "Arm-Balancer" consists of the joints and the link and the gas springs. This is a very simple structure. Figure 2 shows the constitution of the "Arm-Balancer".

Figure 3 portrays the arm balancer produced for trial purposes. Right hand parts and left hand parts are used commonly with front and rear of the parts. Ball bearings are used at each rotating portion to obtain smooth movements, thereby improving the ease of operability. Next, parts of the arm movement support device with improvements from the brainstorming suggestions are shown. Although the arm balancer developed exclusively for this welfare and nursing care equipment has many degrees of freedom and can perform

three-dimensional movements, improvements ①–③ were incorporated for patient to limit its degrees of freedom to induce their movements. Particularly for severely disabled people, the degrees of freedom should be limited similarly as for brace. The degrees of freedom of rotational movement of the arm balancer and each movable component were limited by a stopper so that the device can be used for training of specific repeated movements. Figure 4 portrays the stopper used to limit up/down movements and rotational movements. A one-touch stopper that limits up/down movements was provided to both a swing arm and a support arm to be used as the mechanism to limit movements. A stopper for rotation was mounted on a rotating mechanism of the swing arm to regulate the rotation angle. Improvement ④ was used to strengthen rigidity of the mounting component with respect to the desk to support stable movements. The improvement shown in ⑤ is an optional function in which a sliding rail is mounted on the armrest portion of the wheelchair to be used also from the wheelchair. As shown in improvement ⑥, basic concepts followed the preceding features of compact design and competitive prices using a gas spring.

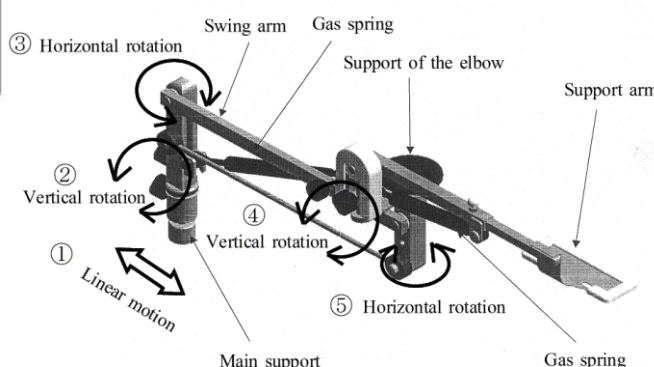


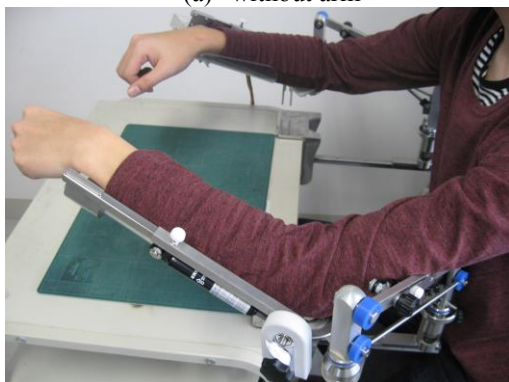
Fig. 2 Composition of the Arm-Balancer

Table 1 Specification of the arm balancer

Item	Specification
Motion of joint	Hip joint
	① Linear motion 480mm
	Shoulder joint
	② Vertical rotation +30°~-5°
	③ Horizontal rotation ±360°~±30°
Elbow joint	④ Vertical rotation +60°~-30°
	⑤ Horizontal rotation +100°~-30°
Actuator	Gas spring
Width/Hight	350mm/225mm
Support Weight	10N(arm) /5N(wrist)
Weight	20N

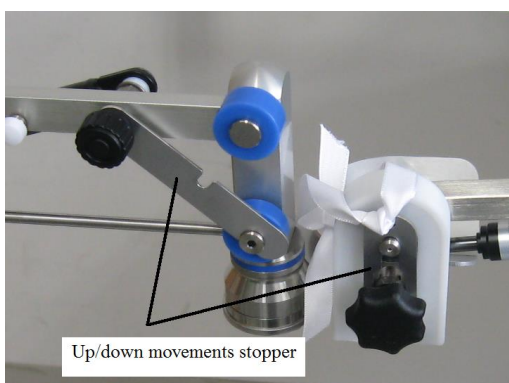


(a) without arm

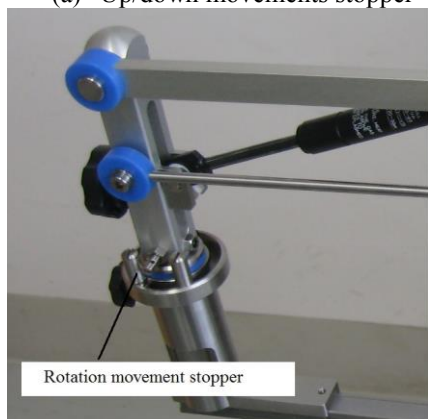


(b) with arms

Fig.3 The arm support system for training



(a) Up/down movements stopper



(b) Rotational movement stopper

Fig.4 Stopper mechanism

The sensor which I used three-dimensional mouse function (Air Mouse FILCO) using the gyro. This sensor measures angular velocity by a gyro. The sensor measure the value as movement of the PC mouse cursor. The sensor and the PC are performed wireless connection of by Bluetooth. We made the measurement software using Microsoft Visual C++ and DX library. This measurement software estimated movement distance of the arm as the distance that moved of the mouse cursor.

4. ASSESSMENT EXPERIMENTS

The trial-produced sensor was fixed to the arm movement support device, as shown in Figure 5. After the sensor is fixed, the sensor and personal computer are connected without wires based on Bluetooth. The sensor will be recognized on the personal computer as a mouse.

In the assessment experiment, the sensor is moved respectively in the X-direction and Y-direction by 10 cm, 20 cm, and 30 cm. Distances measured using the measurement software we developed were checked. Each distance was measured 10 times. Figure 6 shows software algorithm. Then the average of numerical figures was assessed. The X-direction and Y-direction on the display of personal computer are defined as shown in Figure 7. In this experiment, measurement errors between sensor movement distance and distance measured by the measurement software are checked.

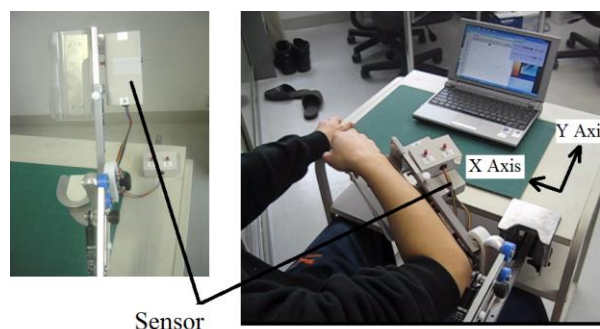


Fig.5 The arm support system with sensor

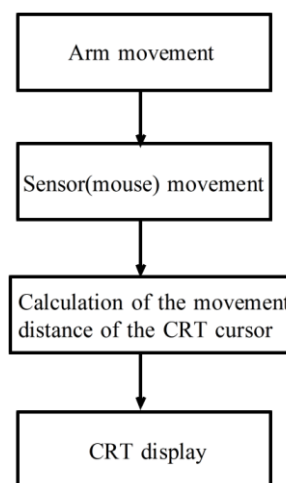


Fig.6 Software algorithm

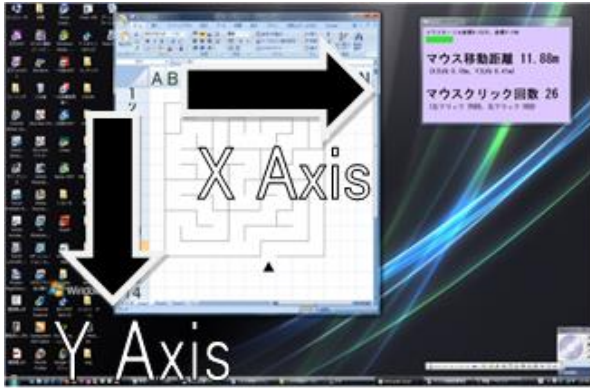


Fig.7 An axis of coordinates

Figure 8 presents measurement results for the X-direction on different size displays (22 inch, 21.5 inch, 15 inch). Figure 8 presents results of measurement in the Y-axis direction on a different size display. Figure 7 shows that, as for average of the measurement in X-axis direction, the longer the actual movement distance of the sensor, the greater the associated error. The same is confirmed also in the Y-direction in Figure 8. Next, attention was focused on the relation between the size of the display and measurements. Results showed that even if the size of the display was changed, no significant difference was noticed with the measurements in the X-axis direction in Figure 7 and in the Y-axis direction in Figure 9. Results of the present experiment confirmed that measurement on the order of centimeters is possible.

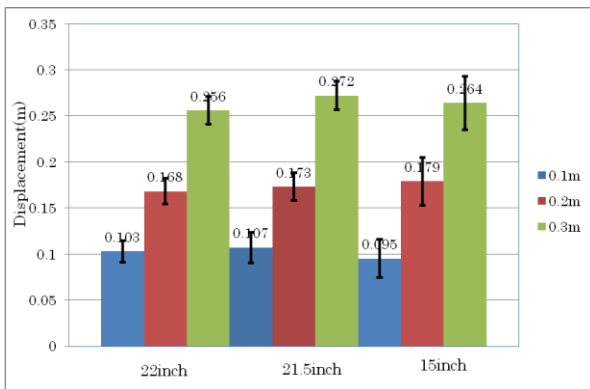


Fig.8 The measurement result X axis

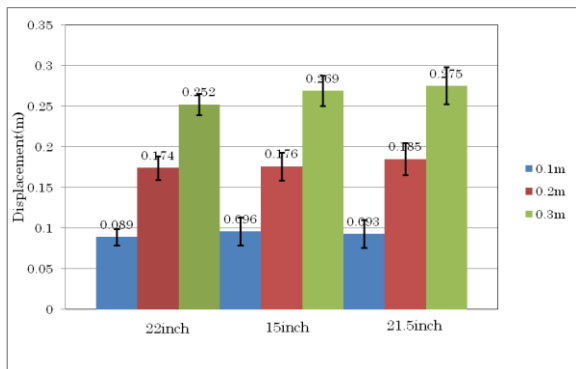


Fig.9 The measurement result Y axis

5. CONCLUSION

In this study, we have developed a passive gravity balanced arm support system for training. We evaluate the arm support system for training.

In this experiment, measurement errors between sensor movement distance and distance measured by the measurement software are checked.

This time, healthy male adults participated in the current measurement, although it is considered that experiments including participation by elderly people must be undertaken. The Arm-balancer will verify the fail safe mechanism when a patient subjects use. They will examine the use of active actuator system.

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