Active training machine with muscle activity sensor for elderly people

Goichi Matsuda*, Motohiro Tanaka*, Sung Jae oon*, Takakazu Ishimatsu*
Seok-Hwan Kim* and Shunji Moromugi*
*Department of Mechanical System Engineering, Nagasaki University
Bunkyo-mach1-14, Nagasaki city, Japan 852-8521
Tel : +82-95-819-2508 Fax : +82-95-89-2508 E-mail: ishi@net.nagasaki-u.ac.jp

Abstract: For elderly people, an advanced training machine that uses actuator and can adjust load according to muscle activity is proposed. The proposed machine allows users to have a safe and effective training through exercise close to ordinal motion appears in daily life such as stretching or stooping motion. A muscle activity sensor real-timely monitors the activation level of user s muscle during the exercise and the training load is adjusted based on the measured data. The training load is exerted and continuously controlled by electric/pneumatic actuator.

Keywords: Machine training, Elderly people, Preventive approach, Load control, Muscle activity sensor

1. INTRODUCTION

The welfare issues accompanying by the aging of society are highly concerned in most of the advanced countries. It is strongly hoped that the government provides adequate care and accommodation to people when they become old. However, it is extremely difficult to support all the people perfectly because each aged person needs different care. In addition to the fact, it costs huge and needs many hands to achieve it. Under this situation in Japan, that is one of the most aged society, the government started to focus on the approach to reduce the number of aged people who need nursing care more than to offer perfect caring system for them. The government promotes aged people to maintain enough strength to keep their independent life and allocate budgets for activities to promote the preventive approach against becoming bedridden status. The importance of the preventive approach is currently being recognized among other aging countries as well.

As one of the effective preventive approaches the physical training using machines is recommended. It is reported that the constant physical training is highly effective for aged people to maintain their strength and quality of life. Some care center introduced machine training in their program. However, there are several problems. One is that those machines are designed for sports training not for training of elderly people therefore users cannot use the machines comfortably in some cases. The other is that the exercise required in the machine training is too hard for those aged people. That could be a reason to keep aged people away from the machine training. The third is that too much machine training might cause damage in one s body, therefore it is hard to ensure the safety in the training because aged the people s body is somewhat weakened. Thus the training machine that is designed for elderly people is needed. It should be enough safe and comfortable to use for aged people and also have high adaptability for wide range of the size and ability of aged people.

In our last research, we introduced pneumatic actuated training system [1]. In this paper, we propose an active training machine for the elderly people that is actuated by electric/pneumatic actuators and uses muscle activity sensor and can interface with user.

2. FEATURES OF T E TRAINING MAC INE PROPOSED

An advanced training machine is proposed for keeping elderly people healthy and energetic so that they can keep living an independent life. The training machine let user to work on an exercise to maintain/recover physical abilities to support their body against the gravity. We focus on the leg strength because the ability to support their body or to stand up by themselves is very important both for aged people to keep their quality of life high and for therapists to care their patients with less energy. This training machine has four major futures as follows.

1) Leg pressing exercise

Usually sports training machines are designed to develop specific muscles through a simple exercise such as knee flexion, elbow extension and twist of main body. It is effective for sports players to shape their body as they desire. However, for elderly people, those machines are not always comfortable because the purpose of the training is different from that of athletes. It is not for strengthening their muscles to compete against other players but maintaining or recovering their physical function to do everyday movements such as stretching or stooping of leg. The training machine proposed in this research is specially designed for aged people to train stretching and stooping ability. By using this training machine users can enforce their strength of both legs through leg pressing exercise. In addition to the physical training effect, it also works for recovering sense of body motion or

strong desire to support their own body by themselves.

2) Adjust load and stroke with simple interface

Training load is generated by weights in the case of most of conventional training machine. Users select preferable load level before the exercise with simple interface display.

3) Feed back of muscle activity on load control

In the elderly training safety issue needs to be considered carefully more than the case of sports training. Different from the sound body of young athletes elderly people s body is generally remarkably weakened. The proposed system monitors the activation level of user s muscles and output force of the leg. It is possible to select optimum load simultaneously and achieve effective and safe training for elderly people.

4) Data management for more effective care.

Each user s data can be saved in file for more effective care. Therapist selects optimal load, training machine, and number of times by referring user s exercise history.

3. MEC ANICAL S STEM CONFIGURATION

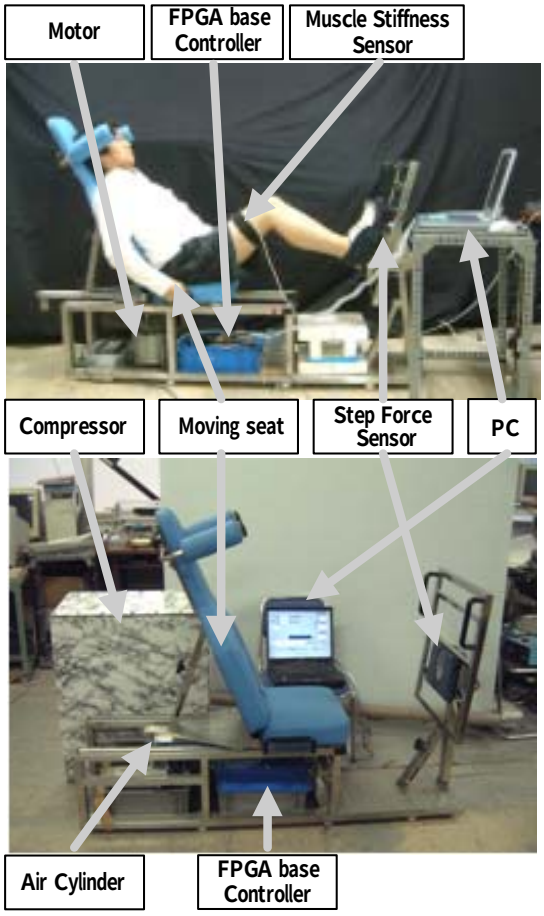


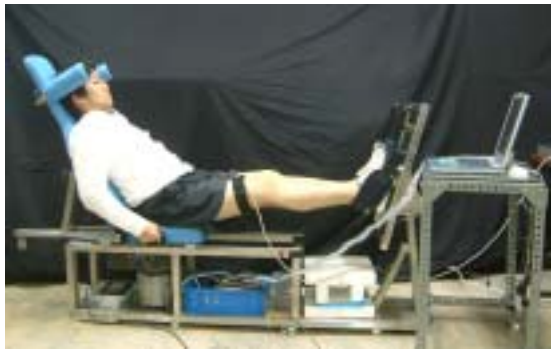
Figure 1 Overview of the system

The proposed training machine is shown in Fig 1. The system is composed of a moving seat, an electronic/pneumatic actuator, step force sensor, muscle stiffness sensor (MSS), FPGA based control circuit and PC. MSS is used to detect user s muscle activation level. In this research, two kinds of leg pressing training machines are experimented. One use electric motor and the other use pneumatic actuator.

3.1 Moving Seat

While the target of the custom sports training machine is designed to help user to strengthen his muscle ability, the proposed training system is to help user to maintain his physical ability. With the system, one s legs are free from gravity and the only load to leg is given by actuator that is controlled by PC&FPGA based controller. User can enjoy exercise by just setting the reference load according to his physical ability.

Figure 2 shows two states of the electric actuated system. During the stretching motion, user has to stretch his legs against the pre-defined load generated by the actuator. And during the stooping motion, user does not have to strengthen his leg, just enjoys stooping motion against a light pre-defined load actuated by the motor.



(a) Stretch

(b) Stoop

Figure 2 Two states of leg pressing exercise

If necessary, direction of load can be changeable and no load moving is possible. No load means that the proposed system can be used to stimulate very weakened muscles or to loose hardened knee joints.

Table 1 and Table 2 show the specification of two kinds of actuators.

Table 1 Major specification of motor

M del ame	H da DD 2020 ize
V ltage	24 V
l ad Ma imum rpm	65 rpm
Rated rpm	40 rpm
Rated t rque	52 m

Table 2 Major specification of air cylinder

M del ame	MB 50-500F
B re ize	50 [mm]
Str e	500 [mm]

3.2 uman Machine Interface

Figure 3 Muscle Stiffness Sensor

To detect user intentions of stretching, stooping and controlling the speed, the proposed system adapts two kinds of sensors, one is a stepping force sensor and the other is a muscle stiffness sensor. The step force sensor is used to detect the force between stepping force to the foot plate and the load that is generated by an electronic actuator. With this sensor, the proposed system controls the load on the foot plate in real time base. Figure 3 shows the muscle stiffness sensor. The muscle stiffness sensor is attached to thigh and detects muscle activity as stiffness parameter that shows high similarity with EMG sensor. It is developed as man-machine interface for the power-assisting system. It was confirmed that there was high correlation between the data obtained from this muscle stiffness sensor and the activity level of the muscle through author s studies. Figure 4 shows change of stiffness parameter according to muscle activity change. The detail of this muscle stiffness sensor is described in [2]-[4]. One advantage of this sensor is that it is easy to put on/off from the body. The other advantage is its high robustness on measurement against the disturbing contacting force from outside. By using this sensor user can work on the training comfortably and safely with this training machine.

3.3 PC FPGA based Controller

As a controller, PC and FPGA (Flexibly Programmable Gate Allay) based control circuit are adapted. PC interfaces with the user to set up the target load and notices the present state to user. FPGA based control circuit is used to archive position data, muscle stiffness parameter, and stepping force signal through A/D converter, and send control command to the actuator through D/A converter. Figure 4 shows the configuration of the control system.

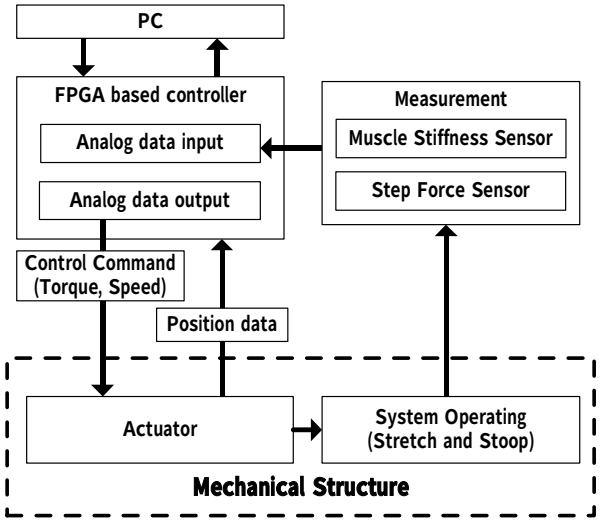


Figure 4 Configuration of a control system

Figure 5 shows the computer screen that is used to set up the reference force and moving distance based on each user, and displays present state during the training. With this program, training data is classified and analyzed for the better management. Contrary to custom training machine that has no display or something, user can check every parameters likes loads, number of times, stretching stroke, training interval and muscle activity level on PC screen. And the program notifies each motion with sound effects for users who have bad eyesight.

Figure 5 Interface display

4. EXPERIMENT

The proposed training machine is experimented to verify the effectiveness and controllability. Muscle stiffness sensor is used to detect muscle activity and to trigger stretching or stooping motion. And step force sensor is used to control load

to leg. So even if the stepping force is changed, the controller tries to maintain load to leg to the reference value. Three kinds of load are tested with both electric and pneumatic actuated systems.

4.1 Control algorithm

Simple control algorithm is adapted for the proposed training machine system as followed:

In real-time base, the error between the stepping force and the reference force is calculated by equation (1).

$$\Delta = _{STEP} - _{RE} \quad (1)$$

where, $_{STEP}$ is the stepping force measured by step force sensor, and $_{RE}$ is the reference force.

And, based on the error (Δ), the control force $_{M}$ is calculated by Equation (2).

$$\Delta > 0, \quad _{M1} = _{M0} - C \quad (2\text{-}1)$$

$$\Delta < 0, \quad _{M1} = _{M0} + C \quad (2\text{-}2)$$

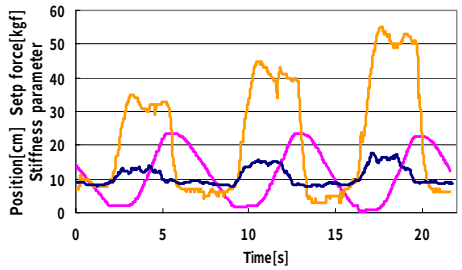
$$\Delta = 0, \quad _{M1} = _{M0} \quad (2\text{-}3)$$

where, $_{M0}$, $_{M1}$ are the previous and present control forces to the foot plate, and C is the control offset. Based on the error (Δ), C is also chosen by equation (3).

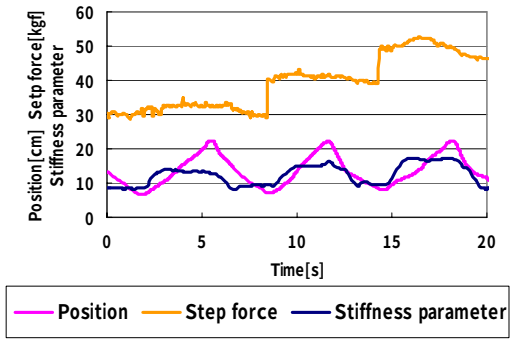
$$\text{If } \Delta \geq 5, \ C = 5 \quad (3\text{-}1)$$

$$\text{If } \Delta < 5, \ C = 1 \quad (3\text{-}2)$$

4.2 Result



(a) Electric actuator



(b) Pneumatic actuator

Figure 6. Experiment data of leg pressing motion

According to the posture change of leg, correlated muscle makes stiffness change in their activity and other parameters change. Muscle stiffness sensor is used to measure the muscle activity level and step force sensor is used to control the reference load of the training. Fig 6 shows graphs of stiffness parameter, stepping force, position data, and reference value at each load 30kgf, 40kgf, and 50kgf.

Because of different characteristics of the pneumatic and electric actuator, a little different stooping motion is adapted. The pneumatic system is controlled to maintain reference load for both stretching and stooping motion, and electric actuated system is only for stretching motion.

And two types of the proposed system show different responses as shown in Figure 6. Electric actuated system shows rapid response, and pneumatic actuated system shows tender response that makes user comfortable.

In each case, the experiment result shows that both systems succeed in controlling the stepping force to the reference value.

5. CONCLUSION

An active training machine with muscle stiffness sensor for elderly people was proposed and experimented. Both electric and pneumatic actuated systems were experimented, and showed controllability and reliability.

Contrary to custom training machine that had no actuator and interface, the proposed system showed that it could provide various control patterns and user oriented interface display. And in the point of motivation, user could enjoy training with computer screen that displayed training states.

Through the experiment with two kinds of actuated training machine, it is confirmed that the proposed system can be a great help for elderly people and their therapists, and for the social burden.

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