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Rehabilitation After Stroke Using Automatic Technology

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Abstract: The adjustment of the support force during rehabilitation training is still mainly done by hand. This paper describes the method and algorithm to control the servomotor using a microcontroller and a computer for rehabilitation equipment for patients after a cerebrovascular accident. The use of microcontrollers combined with computer software will accurately adjust the device's active force, reduce human manipulation and easily store and evaluate training results to help doctors. The doctor has a more accurate assessment of the patient's condition.

Keywords: rehabilitation, stroke, robotics

1. INTRODUCTION:

Currently, stroke is one of the most common diseases for the elderly, with many patients having hemiplegia and movement problems after having a stroke. According to statistics in Vietnam, about 7.8% of the population, equivalent to 6.1 million people, are people with disabilities in a specific function such as movement, vision, hearing, and language. The number of people with disabilities in motor function accounts for the highest rate, up to 35.5% [1]. Unfortunately, our team of rehabilitation specialists is not enough; training equipment is still very lacking, mainly classical and conventional exercise equipment.

There have also been some companies that produce walking aids, but they are still simple devices such as support frames, canes... Some in-depth research on walking aids such as Self-propelled wheelchairs for the disabled has been implemented by a group of authors at Hanoi University of Science and Technology [2]. The research, design, and manufacture of training aids for motor rehabilitation have just begun to receive attention. For example, the research and design of wrist training equipment were carried out by a group of authors at Danang University of Science and Technology [3]. However, these are not devices that support the patient's standing rehabilitation exercise. Thus, it can be said that this is the first research topic towards the design of equipment to support the patient's standing rehabilitation exercise.

Applying new advances in information technology, automatic control, and mechanics to research and manufacture equipment to assist with standing rehabilitation for patients with hemiplegia due to cerebrovascular accidents is necessary. The equipment, after successful fabrication, can be applied in departments, rehabilitation rooms of hospitals, health care centers. In addition, this device can also be used to restore standing function for patients at home under the detailed and meticulous instructions of the doctor. This paper discusses implementing the dynamic control algorithm for the standing rehabilitation device for post-stroke patients, based on the Atmel AVR Atmega 128 microcontroller [4]. The research team

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has also built software that connects to control the system and can store results for the convenience of doctors during monitoring and evaluation.

Hardware Design For Dynamic Drive Control Circuit

The model of a standing rehabilitation support device for patients after a cerebrovascular accident is illustrated in Figure 1. The main components of the device include a SERVO DC motor linked to a lead screw and a nut. In addition, the lead screw runner is attached to a cable tension pulley to provide support for the patient. When the motor rotates, it will make the pulley stretch the rope to move up and down, thereby lifting and lowering the patient.

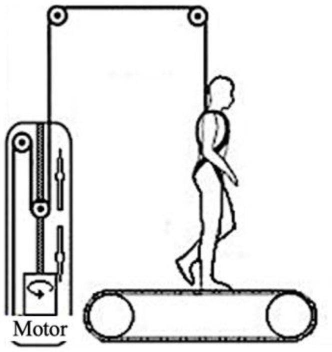

Figure 1: Rehabilitation model

The main problem is to calculate and generate the correct lift or assist force for the patient according to each exercise on the computer. That process is done automatically after the patient is immobilized. The set parameter is transmitted down from the computer to compare with the servo force will be read from the sensor, then calculate the difference value and then put it into the control block to adjust the servo force (lift force). The PID control algorithm [5] will calculate the output value (as a position control parameter) based on the relationship between the input (which is the difference between the actual lift and the required lift). The block diagram of the control system, including the microcontroller, the force sensor and the motor control circuit, is shown in Figure 2. The controller will control the lifting force by rotating the motor to move the force-generating pulley, cable tension. Auxiliary force is measured with a Loadcell CAS BCL100 load cell [6]. Next, the analog electrical signal from the Loadcell will be sent to the analog-digital converter block. The analog-to-digital converter block is responsible for converting analog signals to digital signals, putting digital signals into the central microprocessor block to process and display mass information. From there, the microcontroller will calculate the actual driving force of the cable car and then put it into the PID controller.

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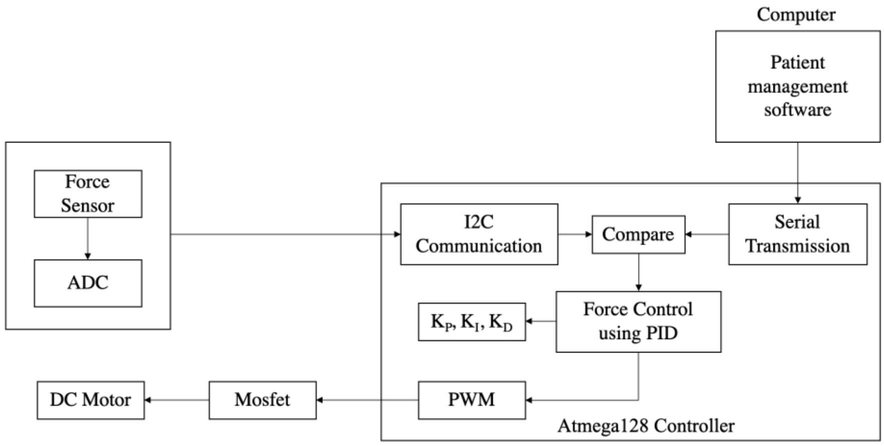

Figure 2: Block diagram of the lift controller using AVR microcontroller [4]

Hardware Design

- *Microcontroller block:* The circuit diagram shown in Figure 2 has been designed around the Atmel AVR Atmega128 microcontroller [4]. This is a microcontroller with built-in on-chip peripherals such as external I/O, Timer and Reset programming ports, RC oscillator, EEPROM, Power-On Reset (POR) being used to reduce cost and improve performance and reliability. So this makes AVR microcontrollers the best choice for embedded systems. The MCU uses an external quartz 8 MHz standard oscillator for the system clock.
- *Computer communication block:* Using UART standard with IC MAX232 and built-in UART interface in Atmega128 microcontroller.
- *Signal conversion block:* After understanding the product requirements and analyzing the output analog voltage signal of the Load cell, the research team chose to use the 24-bit HX711 ADC converter [7] that fully meets the above analysis requirements. The schematic diagram of the signal converter block is shown in Figure 3.

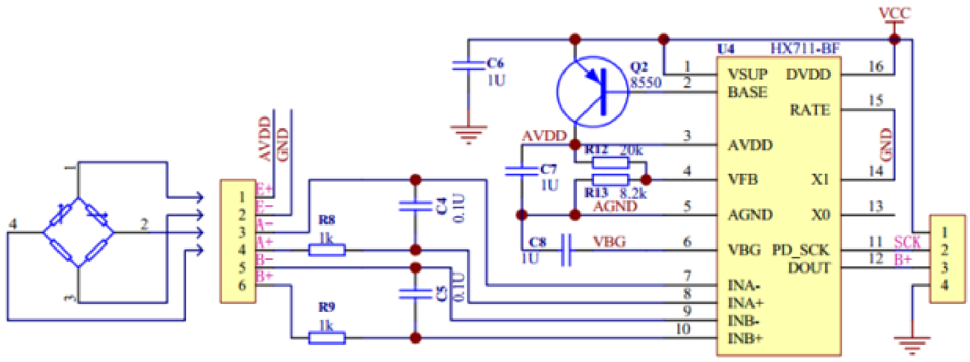

Figure 3: Block design diagram of analog-to-digital converter using ADC 24-bit HX711

- *Block IC MOSFET:* The research team uses an H-bridge circuit to control the servo motor, as shown in Figure 4. The motor is controlled by the PWM method.

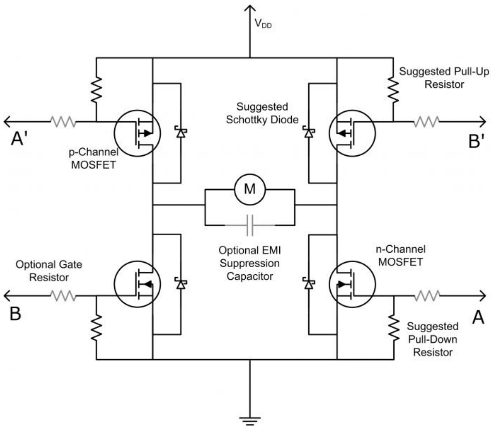

Figure 4: Circuit diagram of motor control with H bridge

Implement PID Controller

In essence, the lift force is generated by controlling the position of the tension pulley, as shown in Figure 1. From that, the lift control problem can be based on the position control problem. To control the position by using PID (Figure 5), there are two steps: i) calculate the position to be reached ii) switch to calculating the speed and rotation direction of the motor during moving to the position that needs to be achieved.

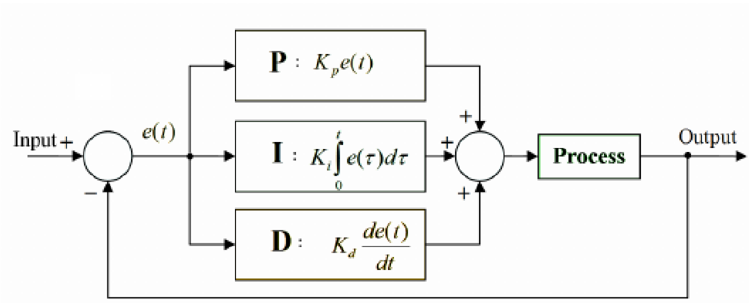

Figure 5: PID Controller

The proportional compensator block: The main function of the proportional compensator is to generate a signal level proportional (K_p) to the difference (error) generated from the comparison between the system's output and input.

Derivative compensation block: In a feedback system, the derivative compensation block will produce a value that is the product of the derivative of the difference signal by a factor K_d. In other words, the slope of the differential signal waveforms will affect the output. Its primary purpose is to improve the transient response of closed-loop control systems.

Integral compensation block: Is the product of the integral of the differential signal with a factor of K_i. This means that the area under the function curve under the differential signal will affect the output signals. Therefore, this block of the controller will increase the stability of the whole system.

The research team used two PID controllers to perform precise lift control; the input is the lifting force to be set, and the output is a PWM signal to control the motor speed. The most commonly used PID controller design technique is the Ziegler–Nichols method [8], which requires a response graph of the control signal model, as shown in Figure 6.

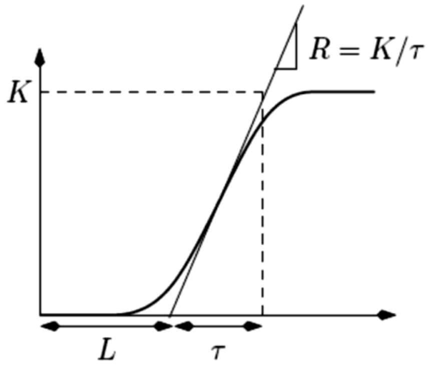

Figure 6: Reaction curve used by Ziegler and Nichols

According to the Ziegler- Nichols method, there are four steps to take to calculate the three parameters Kp, Ki, Kd. That is:
1) Build signal response graph.
2) Draw a tangent to the variable segment.
3) Measure and calculate the parameter of that line (Figure 6).
4) Define the parameter as shown in Table 1.

Controller	K_P	K_I	K_D
P	1/a	-	-
PI	0.9/a	K_P/3L	-
PID	1.2/a	K_P/2L	K_P/2L

Table 1: Measure K_P, K_I, K_D

The coefficients for two controllers PD and PI of the system are selected as shown in Table 2.

Controller	K_P	K_I	K_D
PD	10.86	-	0.085
PI	0.118	1.847	-

Table 2: Estimate K_P, K_I, K_D

Training support process

A nurse performs exercise support. After receiving the request from the patient (or the patient's family) or a pre-planned plan by the doctor, the nurse will check the information related to the patient based on the code (ID) of the patient to check the treatment regimen, thereby determining the necessary exercise at that time. After checking the parameters and physical conditions of the safety of the exercise machine, in case there are no problems, the nurse will transmit the parameters of the corresponding exercise to the patient to the exercise machine, connect and press the button to start the exercise. Thus, the nurse is responsible for assisting the patient during exercise and recording the exercise results for each patient. In this process, the subject performing the functions is a nurse (can be an aide/nurse), the object of support is the patient. Nurses perform functions programmed into the following software programs:
- Connect and control the exercise machine: Based on the treatment regimen of each patient and the exercise results stored in the database, the nurse sets up a treatment session for each patient, searches for the exercises. Exercise corresponding to each patient at the time of exercise

to connect the control software to the exercise machine. The nurse controls the exercise machine to support the patient.
- Manage patient's exercise results: The patient's exercise results data is automatically updated to the central database through the control software module. Nurses mainly make reports on exercise results for each patient and for each exercise at each time. Statistical data for doctors and perform data entry and correction at the request of the doctor.

2. Results:

Figure 9 illustrates the mechanical mechanism for generating and measuring the servo force, also shown in figure 10 is the actual servo control circuit image.

Figure 9: Mechanical mechanism for generating and measuring the driving force

Figure 10: Force control circuit

The force control test (as illustrated in Figures 11 and 12) shows that the system completely meets the requirements set forth for the stability control of the servomotor. As shown in Figure 11, that is the PWM signal to control, and in Figure 12, it is the servo force corresponding to the setting level of 5 kg.

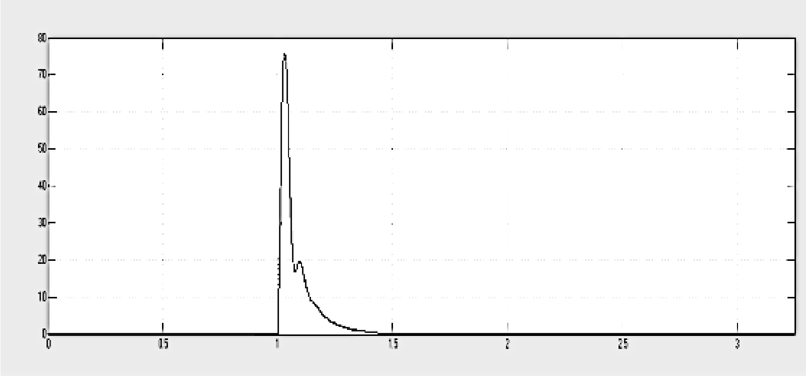

Figure 11: PWM signal regarding to the applied force at 5kg

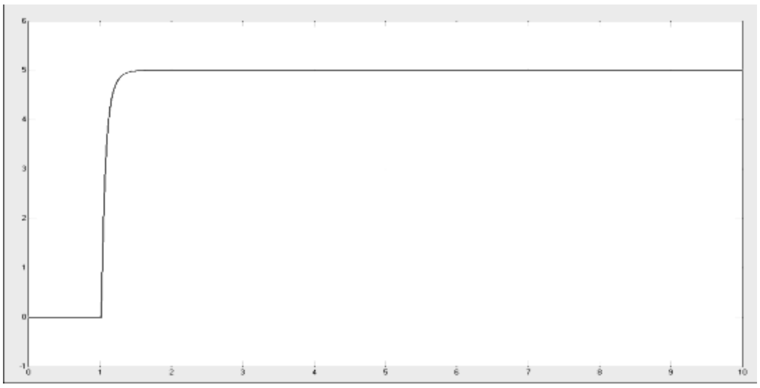

Figure 12: Measure applied force

3. CONCLUSION:

This paper has introduced a method of force control to support standing rehabilitation for patients after cerebrovascular accidents. A microcontroller paired with a computer has allowed precise control of the support force, reducing manipulation for nurses and technicians. At the same time, it is easier to store and evaluate exercise results, helping doctors have timely and accurate assessments of the patient's situation. This is very suitable for the current condition of lack of equipment and overload in rehabilitation today.

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