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The Mechanical and System Design of Finger Training Rehabilitation Device Based on Speech Recognition

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Abstract

Aiming at the problem of long diagnosis and treatment recovery period and low recovery efficiency of traditional stroke patients, a finger rehabilitation training control system based on speech recognition is designed to help patients carry out finger exercise training and obtain the perception ability of finger angle, speed and position, and provide rehabilitation physicians with finger rehabilitation evaluation and training data reference. In order to realize the finger rehabilitation training control system, based on the finger movement perception system, the system is divided into hardware circuits, lower computer control systems, and voice recognition human computer interaction systems. Combining the unique advantages of the HMM algorithm, the HMM algorithm is applied to the voice interaction system for pattern matching, and the simulation test of the finger rehabilitation system is performed. The application results show that the rehabilitation training system based on speech recognition proposed in this study meets the design requirements, has good safety and reliability, and has high application value for future finger rehabilitation training.

Keywords: Speech Recognition; Perception Ability; Finger Rehabilitation Training; Human-Computer Interaction; HMM

1. Introduction

Cerebral stroke, also called stroke or cerebrovascular accident, is an acute cerebrovascular disease. The survey results show that most people with stroke are over 40 years old, most of them are middle aged and elderly people. The common symptoms of the disease are numbness of the face and limbs, sudden weakness, fainting, etc., and most stroke patients will lose the ability to perceive finger movement. At present, the rehabilitation of the finger function of such patients still uses the traditional one-to-one training rehabilitation therapy of doctors. This method has a long recovery period and low recovery efficiency, and the training effect is mostly obtained by the experience of rehabilitation physicians. Therefore, it is difficult to obtain objective rehabilitation evaluation and rehabilitation training data, and the training method cannot be optimized to obtain a better rehabilitation training program. In response to these problems, many scholars have proposed solutions and research. The former scholar Sun Guangmin proposed the design and implementation of the upper limb rehabilitation network system based on Kinect [1]; Wang Junhua proposed the design of the training module of the limb rehabilitation system based on motion feedback virtual reality [2]. However, the above research has not really solved the problems in the diagnosis and treatment of stroke patients with loss of finger motion feedback perception ability. Based on this, combined with the experience research of many scholars, a finger rehabilitation training control system based on voice recognition is designed. Through this system, the patient's finger-to-finger training can be realized, shorten the recovery period of the finger function of stroke patients, and collect the objective data in the process of finger training in real time, assisting rehabilitation physicians to perform more effective rehabilitation assessments, reducing the labor intensity of rehabilitation physicians, and improving training efficiency. This is a cutting-edge technical approach to effectively solve finger rehabilitation problems and has important research and application value.

2. Methodology

2.1. Overall system design

As shown in Figure 1, the finger rehabilitation training system designed in this study is mainly divided into five sections based on the finger motion perception system, namely as traction mechanism, motion perception system, lower computer control system, touch and voice recognition human computer interaction system and the host computer monitoring system [3]. Among them, the main function of the main controller with ARM as the core is to receive instructions from the host computer monitoring system or human-computer interaction system, and to control the traction mechanism to complete finger rehabilitation training. The function of the motion sensing system is to transport the collected sensor information to the main controller. Then the main controller decomposes and calculates the received information, and calculates the speed, position, joint attitude angle and finger force of the finger movement and transmits them to the human-computer interaction system and the host computer monitoring system. The human-computer interaction system completes the evaluation of finger function rehabilitation according to the received information and realizes the adjustment of training parameters and training modes to achieve the best training effect [4]. The host computer monitoring system completes the real-time follow-up of the 3D virtual hand model according to the received information and realizes the feedback of the details of the finger joint movement, thereby enhancing the fun of training.

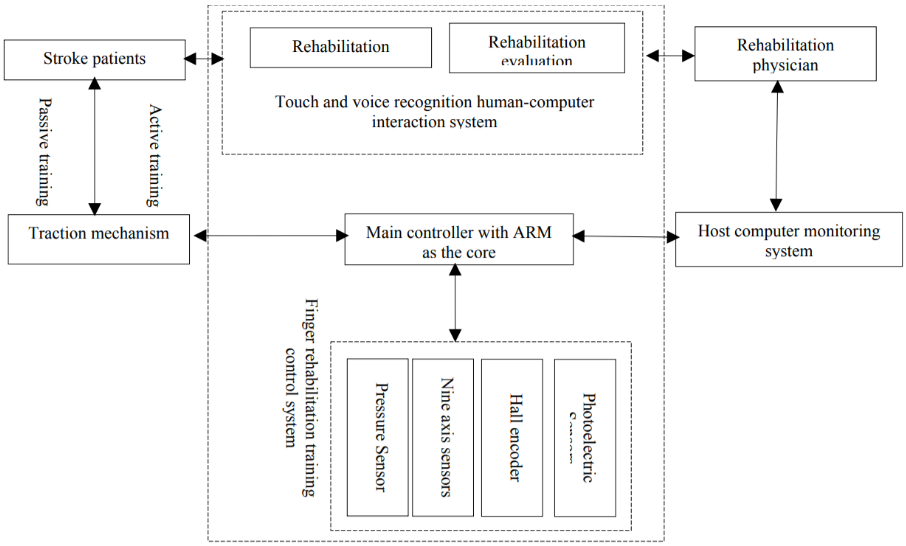

Figure. 1. The overall framework of the system

2.2. The overall structure of the hardware circuit

In order to realize the finger rehabilitation training control system, the hardware circuit of the system will be introduced in detail below. Combining the modular design concept and distinguishing according to the different functions in the system, the hardware circuit is divided into six modules, which are the main controller, sensor measurement, motor drive, data storage, power management, communication and debugging interface modules [5].

Among them, the main function of the main controller module is to collect and calculate the data in the sensor measurement module in real time. The calculated finger force, finger AROM, speed and position are transmitted to the DC motor drive unit in real time to form a closed-loop control of finger movement; real-time transmitted to the human-computer interaction system to complete interactive rehabilitation training; and it also transmits to the virtual environment in real time to complete the realtime follow-up of the 3D virtual hand.

The system hardware used in this study is ST's STM32F103RET6 microprocessor, the hardware core is ARM Cortex-M3, and its main frequency can reach up to 72Mhz, with 512K bytes of program memory, two 12-bit analog-to-digital converters, and two IIC bus and SPI bus and three USARTs. At the same time, the power supply voltage of the system is 2.0~3.6V, and a series of power saving modes can meet the system's requirements for low power consumption.

2.3. Software design of lower computer control system

In the finger rehabilitation training control system, the lower computer control system software is the basis for the realization of finger active training mode and passive training mode, finger force perception algorithm, and dual nine-axis sensor measurement finger AROM algorithm [6]. On the other hand, the lower computer control system software also has functions such as data receiving and sending, sensor data acquisition and processing, and I/O operations.

The front-end MCU terminal service program and the back-end application wireless cycle system both have the characteristics of simple structure and occupy less resources. Therefore, the lower-level computer control system software is designed to use these two front and back systems. Among them, after the microcontroller with ARM as the core completes a series of operations such as power-on reset, system initialization, stack initialization, and positioning interrupt vector table, it jumps to the application main function main for module initialization [7]. After the initialization is completed, it enters the infinite loop of the embedded front-end and back-end system. The background application program is a super loop, and the application program can call the corresponding function to complete the corresponding task. The foreground program can also be referred to as an interrupt-level task. This program can handle operations with high real-time requirements and exit without doing other tasks. It can avoid consuming too much time in the interrupt program and affecting subsequent operations and other interrupts.

2.4. Speech recognition human-computer interaction design and implementation

In the finger rehabilitation training system during the diagnosis and treatment of stroke patients, because the finger rehabilitation training process is very boring, it is easy to reduce the participation and enthusiasm of stroke patients, which affects the training and does not achieve the best results. Therefore, in order to solve this problem, this research designs a human-computer interaction system based on speech recognition, which improves the participation and enthusiasm of stroke patients.

At present, there are two common speech recognition systems, namely specific speech recognition and non-specific speech recognition. Among them, the specific speech recognition system is characterized by high recognition rate and low flexibility. The non-specific speech recognition system has better performance than the specific speech recognition system. This system can meet the needs of different users and does not need to input a large amount of speech for training before use. Therefore, this research chooses a non-specific speech recognition system to achieve the functional requirements of the finger rehabilitation training system. In the voice interaction system, the hardware design uses the LD3320 voice recognition chip. The voice recognition technology of this chip uses a matching method based on the "keyword list" [8]. First, the specific person voice recognition system transmits the voice content of different speakers to the system through a microphone for spectrum analysis, and then the LD3320 voice recognition chip extracts voice features based on the input voice, and the voice recognizer lists the voice features and key words After matching the entries in, the matching result is used as the recognition result and sent to the micro-control unit.

Among them, the core algorithm of speech recognition is template matching, and this algorithm needs to be selected according to the characteristics of the speech signal to be recognized. The matching algorithm mainly includes three forms, namely DTW (Dynamic Time Warping), artificial neural network model ANNM (Artificial Neural Network Models) and hidden Markov model HMM (Hidden Markov Models) [9].

Through in-depth research and analysis of the three matching algorithms of DTW, ANNM and HMM, it can be seen that DTW has the advantages of good recognition performance in the specific person speech recognition system; ANNM has strong learning and processing capabilities, but has the disadvantage of a long training and learning cycle, and the application of actual engineering is not mature enough; HMM can be used in different speech recognition systems, and does not require users to input speech for training before doing things. Compared with the other two algorithms, the HMM algorithm has a more prominent advantage in unspecified person speech recognition.

On the other hand, HMM can handle small and isolated vocabulary well, which just meets the characteristics of the voice command of the finger rehabilitation system [10]. Therefore, compared with the other two algorithms, the HMM algorithm is more suitable for pattern matching in voice interactive systems. The speech recognition process of the HMM algorithm is shown in Figure 3.

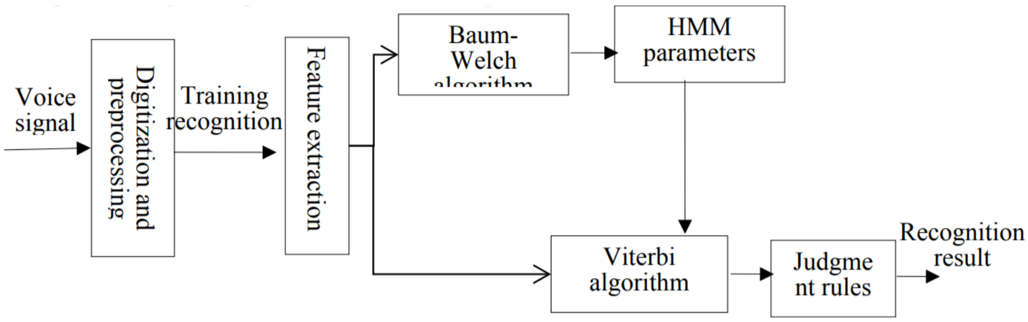

Figure. 2. Speech recognition system framework based on HMM algorithm

The operation process of the HMM algorithm is a double random process. One process can directly observe the feature change of the unstable signal in the speech recognition in a short time. In another process, the dynamic characteristics of statistical characteristics can be observed during the short-to medium-to-short-term speech. The following applies the HMM algorithm to speech recognition to solve the problem of HMM distinguishing different signals and tracking the conversion between different signals.

Assuming that the number of states of the HHM model is N, then the collective symbol of the state is: $S = \{S_1, S_2, S_3, \ldots\ldots\ldots\ldots\ldots\ldots S_n\}$; then the number of observed symbols is set to M, which is expressed as the number of observed symbols that may be output in the speech recognition process, the collective formula is: $O = \{O_1, O_2, O_3, \ldots\ldots\ldots\ldots\ldots\ldots O_n\}$; set the transition probability distribution in the speech recognition state to A, and the matrix of A is shown in formula (1):

$$A = \{a_{ij}\}, a_{ij} = P[q_{t+1} = S_j | q_t], 1 \le i, j \le N \tag{1}$$

Set the probability distribution of observed symbols in the speech recognition state to B, then the expression of B is

$$B = \{bj(Ok)\}, bj(Ok) = P \tag{2}$$

the input symbol at time t is

$$O_k | q_i = S_j] \; 1 \le j \le N, 1 \le k \le M \tag{3}$$

Set the initial state distribution in speech recognition to , the number of states N, the number of observed symbols M, and the other two probability densities A and B will be formulated. Use formula (3) to express the relationship between these parameters.

$$\pi = \{\pi_i\}, \; \pi_i = P[q_1 = S_i], 1 \le i \le N \tag{4}$$

In the speech recognition system, its hardware structure is mainly composed of five parts, which are the main control chip, the speech recognition chip, the audio module, the communication module and the power supply module. After the system receives the voice data of the stroke patient, it can use the voice recognition chip to process the data, and then transmit the processed data to the main control chip, Then the main control chip transmits the corresponding data to the lower computer, so as to control the fingers for rehabilitation training. Among them, the core part of the hardware structure is the main control chip and the voice recognition core.

3. Result

In order to test the accuracy of the voice command on the training device control, the test selects 3 experimental samples of different timbres to conduct the voice control training device experiment under 3 different environments, and each voice command is tested 100 times. Among them, the experimental environment is three different environments, namely a laboratory in a quiet environment, a hospital in a noisy environment, and a residential area in a noisy environment.

Table. 1. Comparison table of unspecified person speech recognition in three different environments

Control accuracy %	Unspecified person 1	Unspecified person 2	Unspecified person 3
Laboratory	95.125	95.500	96.000
Hospital	90.375	90.750	92.375
Residential area	84.500	85.625	86.250

During the test, it was found that the interactive system based on speech recognition is more practical, faster in response, and more accurate in control. It can be seen from Table 1 that in the quiet environment of the laboratory, the control accuracy of the voice on the training device can reach more than 95%, and the response time is about 1s; in noisy environments such as residential quarters and hospitals, the accuracy of voice control of the training device reached 90% and 85% respectively, indicating that the speech recognition-based interactive system proposed in this study can meet the basic requirements of rehabilitation training.

4. Conclusion

The study found that the finger rehabilitation training control system based on speech recognition designed in this study can help patients carry out finger movement training, gain perception of finger angle, speed and position, and provide rehabilitation physicians with finger rehabilitation evaluation and training data reference. To realize the finger rehabilitation training control system, based on the finger movement perception system, the system is divided into hardware circuits, lower computer control system, and voice recognition human-computer interaction system. Combining the unique advantages of the HMM algorithm, the HMM algorithm is applied to the voice interaction system for pattern matching, and the simulation test of the finger rehabilitation system is performed. The application results show that the speech-recognition-based rehabilitation training system proposed in this study meets the design requirements, has good safety and reliability, can shorten the recovery period of the finger function of stroke patients, and collect objective data in the process of finger training in real time, assist rehabilitation physicians to conduct more effective rehabilitation assessment, reduce the labor intensity of rehabilitation physicians and improve training efficiency. This is a cutting-edge technical approach to effectively solve finger rehabilitation problems and has high research and application value.

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