Intelligent Music Rehabilitation Hand Based on Voice Recognition

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Abstract. Music therapy has its unique clinical application value in improving conscious state, emotional state, language communication ability, motion function, sleep state and the rehabilitation of the brain’s cognitive function of the patients who suffer from cerebral apoplexy and cerebral injury. With the rapid development of music rehabilitation therapy, it has become an important power in modern rehabilitation medicine, which is valued by rehabilitation workers. During rehabilitation training, the therapists, with the help of apparatuses, carry out hand technique and lower limbs training for the patients, or help them train by means of apparatuses. Rehabilitation equipment is a rehabilitation therapy facility widely used in the field of clinical care. At present, the existing rehabilitation equipment is mostly heavy, which makes the rehabilitation training dull and boring, and induces irritation of those receiving rehabilitation therapy through finger training to the disadvantage of the therapy. In the paper, an intelligent music rehabilitation hand is designed to help them for therapy at different stages. Different modes can be selected with voice interactive mode and control device. By using the theory of steering engine driving, the intelligent music rehabilitation hand can drive the steering engine with the rhythm of the music to achieve the aim of rehabilitation through driving the clenching and spreading of the fingers. With such a device, people can carry out their rehabilitation therapy while enjoying the music.

1. Introduction

In recent years, with the constant improvement of the treatment means and technological levels for cerebral apoplexy, the death toll of patients who develop acute cerebral stroke decreases. However, around 75 percent of the survivors have sequelae, who suffer from dysfunction to varying degree [1]. The clinical manifestation is in awareness, exercise, aesthesis, consciousness, language as well as spirit and emotion, such as the motor function of the limbs, activity of daily living (ADL) and disorder of cognitive function and speech function. It causes the patients’ inability to take care of themselves in life and influence their living quality, bring much burden for the them, their families and society both spiritually and financially. Such pressure and pain from the family members aggravate the psychological burden of the patients, leading to psychological problems, of which depression is the most common, with the morbidity of 40 percent [2]. The patients will suffer from fear, despair, self-abasement and anaclisis, who pull a long face, become silent, become passive, and even refuse to eat
and partner treatment, directly affecting the therapy and rehabilitation. So those who develop cerebral apoplexy undergo a long rehabilitation process.

It is proved by a large number of clinical practice at home and broad that the survival quality of the stroke patients depend on the recovery degree of their limb functions. Thus, introducing an effective physiotherapy as early as possible is undoubtedly a key for the rehabilitation of the patients, while their active coordination and the functional rehabilitation of their psychology are the foundation [3].

There is a great deal of research into the rehabilitation hand at home and abroad [4]. In China, Yang Weibin and others at Henan Anyang People’s Hospital have invented a patent for utility model--- Multifunction Hand Rehabilitation Apparatus. This is a multifunction mechanical rehabilitation device for hand and arm for all ages and parts. The spring and fingerstall serve as its main functional units with active movement of the patients’ finger for the rehabilitation training. Zhao Liang, Feng Pei’en and Pan Shuangxia in Zhejiang University have developed CPM (Continuous Passive Motion), also known as micro finger rehabilitative apparatus. The equipment includes electrical machinery, speed controller, reducer, amplitude mechanism and executing mechanism, which can be used for repeated exercise training of a singer finger. Zhang Lixun and others from Harbin Engineering University have invented a utility model patent called “Intelligent Hand Rehabilitation Training Equipment”. This is a finger exercise training device which uses mechanical link mechanism and is motor-driven. Overseas, the United States has invented Kinetec8091 portable hand continuous passive movement apparatus, which uses bilateral soft splints in coordination with hand for rehabilitation training. South Korea has developed RELIVER RL-100 hand rehabilitation training apparatus. This is a device uses wave air pressure for forced exercise rehabilitation training. With such apparatus, the symptom of paralysis and palsy of fingers and wrists is greatly improved, which works for the brain nerve and blood vessel to promote the rehabilitation of the brain damage [5, 6].

Based on the previous research by the scholars, the paper design a intelligent music rehabilitation hand to help the patients for therapy at different stages. Different modes can be selected with voice interactive mode and control device. By using the theory of steering engine driving, the apparatus can drive the steering engine with the rhythm of the music to achieve the aim of rehabilitation through driving the fingers being clenched and spread. With the intelligent music rehabilitation hand, people can receive the rehabilitation therapy while enjoying music.

2. Hardware design of the system

2.1. Overall design of the system

Electronic hardware designed in the paper mainly include main control module, sensor detection structure and executive structure. Of them:

1) The main control module is Arduino UNO, where the functions are completed, such as data acceptance and transmission, data calculation and processing, instruction acceptance and transmission.

2) The sensor detection structure include the touch sensor module which control the voice of buzzer.

3) Executive structure includes the electric steering engine rotating and driving the fingers with the music, and the voice recognition module which produces voice when receiving voice prompt as well as the buzzer for playing the songs.
Model selection and operating principle of each module in the system will be introduced in detail as below.

2.2. Appearance design

A prerequisite for a good product is to have a beautiful appearance and firm mechanical structure. It is required in the paper to design a firm loading structure and reasonable arrangement of the numerous electronic components for the loading platform.

The model of rehabilitation training hand is designed by using CAD modeling in the paper is shown as the following Figure:

![Figure 2. CAD design chart of the master drawing](image)

In the paper, the clever fingers of exoskeleton hand is composed of crank-link mechanism. Its power source is the steering engine for driving the rotation of the crank, and then the crank pulls the connecting link, finally the connecting link pushes the rotation of the finger joints to achieve the aim of their clenching and spreading. The exoskeleton hand in 3D printing is shown as the Figure below:
Figure 3. Design drawing of the exoskeleton

The actual appearance of the system is shown as the following Figure:

Figure 4. Overall appearance figure

3. Software design for the system

3.1. Overall design of the software

Software design, the program design based on automatic movement and manual movement mode, provides an option for the users to control the intelligent platform. Moreover, the operation priority and error adjustment of the steering engine angle can be controlled through the algorithm design. The program is the development board program of Arduino UNO, where sensor data is received and the state of executive structure is controlled.

Flow chart of overall algorithm for the system
The whole rehabilitation training is composed of the following steps:
Step1: the speech of power on is played;
Step2: According to the voice recognition contents, the training mode is selected (early rehabilitation and late rehabilitation);
Step3: Selection of the rehabilitation songs;
Step4: The steering engine operates with the selected music rhythm to lead the hands to do the rehabilitation training accordingly;
Step5: The end of the song follows the next training.

3.2. Design of the rehabilitation mode
Rehabilitation therapy is the subsequent and supplementary part of the clinic treatment. The rehabilitation therapy stage for the patients starts with the end of their clinic treatment. The rehabilitation stage of the patients can be divided into two periods according to their functional status and athletic ability: earlier stage and later period of the rehabilitation.
When the patients is at the earlier stage of the rehabilitation, their own functional status and athletic ability get into a weak state, with not any or poor active movement ability. At this moment, the rehabilitation training for the patients mainly depends on the external assistance to help them realize the training and achieve the desired effect of rehabilitation therapy. When the patients get into the later period of rehabilitation, their functional status and athletic ability have almost recovered, so they should receive the rehabilitation training independently when they can reinforce the strength and intensity of the training.

Based on different individual functional status and athletic ability in different rehabilitation periods, the controlled finger rehabilitative apparatus for the project is divided into two different periods accordingly. At early stage of the rehabilitation, the patients do not have any automatic movement ability, who depend much on the finger rehabilitation apparatus for rehabilitation training. At this moment, they get into a passive training state. At this stage, the intensity of the training and range of movement should be strictly controlled through the finger rehabilitation apparatus according to the actual athletic ability and range of motion of the patients. It can prevent the the training beyond their motion range, inducing adverse effect of the rehabilitation therapy. In the later period of the rehabilitation, the automatic movement of the patients have achieved a sound recovery. So they can do the exercises for rehabilitation training, or do the obstacle exercises to overcome the external resistance to realize rehabilitation training. At this moment, the patients get into the obstacle exercises to overcome the resistance.

Based on the above-mentioned thought, the rehabilitation apparatus is set to three modes: 1) passive mode, 2) combination of passive and active mode, 3) obstacle mode.

1) Passive mode: depend totally on the finger rehabilitation apparatus for the desired training effect.
2) Combination of passive and active mode: reduce accordingly the output voltage of the finger rehabilitation apparatus for 50 percent of that in passive mode.
3) Obstacle mode: with no voltage is provided accordingly, the patients overcome the elastic force from rubber tubing and spring of the bending joints of the finger rehabilitation apparatus for an independent training.

Mode one and mode two respectively have the following four rehabilitation training manners: 90 degrees bending movement of the index fingers, 90 degree bending movement of the middle finger, 45 degrees bending movement of the index finger and 45 degrees bending movement of the middle fingers.

4. System testing and result analysis

4.1. Functional test of voice recognition
To test the stability and utility of the voice module for the device, a test is carried out on the voice recognition and system stability. The experimental results by respectively testing the voice module of the device and the common LD3320 semantic device in the market under different environment, which is shown as below:
It can be found from the above experimental results that under various environment, the voice recognition module in the paper have better recognition rate than that of the LD3320 module. What’s more, its voice recognition rate reaches up to 92 percent under the noisy environment, which well guarantees the voice recognition reliability of the system.

4.2. System test scheme and its results

After the design of hardware and software of the rehabilitation hand has been completed and the service platform has been built, the system functions are tested to verify its effectiveness. The purpose of the test is to check if the designed rehabilitation hand can realize the functions accordingly.

There are the following steps during the experimental process:
Step1: Put the designed rehabilitation glove on the hand of the testee.
Step2: Start up the apparatus and choose training mode.
Step3: Select the music for rehabilitation training and start the training.
Step 4: After one experiment, choose other training modes and training music for repeated training. It can be found that during the experiment process, fingers can be trained driven by the steering engine, with the expected results. However, during the manufacturing process, there is nuance in each rubber tubing out of the not uniform distribution of the embedded spiral steel wire by human factors leading to difference of elasticity modules by causing differences in angle of bending. In the meantime, owing to the stickiness of the rubber tubing and friction from the revolving shaft of the bending joints, it is impossible for the finger rehabilitation to achieve high accuracy during the rehabilitation training, with slight error. But such error has little effect on rehabilitation training, with the overall experiment meeting the requirement of the training.

5. Conclusion
Intelligent music rehabilitation hand is a smart recovery device which has a promising application prospect. It can help the patients who suffer from cerebral apoplexy in their early and late rehabilitation training while enjoying the music. With the Arduino as the platform of the control center, the project achieve the rehabilitation purpose finally. The work for the project is completed including the following aspects:

1) The electronic hardware for the system has been designed in detail, and all the electronic sensors and executive components have been selected.
2) The system software has designed in detailed, namely, the software of the Arduino end, to realize the collaborative use of all the components.
3) Based on the beautiful and firm requirement, CAD has been used to design the appearance of the work.
4) In practical test, we constantly debugged the voice module and rotation of the steering engine to finally achieve the aim.

In conclusion, the design of the intelligent rehabilitation hand for the project has made a gratifying progress with encouraging research achievement, but there remain areas for improvement. We hope we can make some improvement in the future in the following aspects:

1) The songs are not limited to the ones being tested for the program, the users can select the those they like and write them to the program.
2) The appearance of the work still remain areas for improvement, such as making it more small and exquisite and more wearable.
3) The hardware should be protected to prevent malicious damage and dismounting.

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