Simulation System of Cochlear Implant

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Abstract. Different types of hearing loss can be treated according to the etiology and degree. Commonly used methods include drug therapy, surgical treatment, wearing hearing aids and implanting electrical stimulation equipment. Among them, cochlear implant is an effective way to restore the hearing perception ability of patients with very severe deafness and total deafness, and it is the most commonly used electrical stimulation implant device. Cochlear implant is still not widely used in China because of its high price and long training period. In order to facilitate speech training and improve speech perception ability of cochlear implant, this paper designs a speech training and speech simulation system of cochlear implant. The designed software and hardware system is a simulation test platform, with low price, simple test mode, and potential huge market value and application value.

Keywords: Cochlear implant · Simulation system · Speech processing strategy

1 Introduction

Hereditary diseases, infectious diseases, delivery syndrome, chronic ear infection, improper use of drugs, excessive noise, aging and other factors can lead to hearing loss. Among them, the main cause of hearing loss of young people aged 12 to 35 is often excessive noise in entertainment environment, while one third of the elderly over 65 years old suffer from hearing loss due to disability. According to the cause and degree of hearing loss, different treatment methods can be selected. Common methods include drug therapy, surgical treatment, wearing hearing aids and implanting electrical stimulation devices. Among them, cochlear implant is an effective way to restore the hearing of patients with severe deafness. For normal people, the outer ear and the middle ear are mechanical transmission devices of external sound signals, in which the outer ear is used to collect sound and the middle ear ossicular chain is used to amplify mechanical vibration. The amplified signal from the middle ear is transmitted to the inner ear, and the sound signal is transformed into bioelectric signal through hair cells. Then, bioelectric signal is used to stimulate auditory nerve to produce auditory perception. Electrical stimulation can stimulate the residual auditory nerve in the cochlea of the deaf, and transmit it to the brain along the auditory pathway, producing the similar auditory feeling with the normal people. Therefore, as an alternative device, the

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cochlear implant directly converts the voice signal into electrical pulse signal, which stimulates the auditory nerve to produce similar neural transmission mode and auditory perception.

At present, there are three major cochlear manufacturers in Australia, Austria and the United States. In recent years, acoustic research institutions and research universities in China have carried out research work related to cochlear implant. A company in Hangzhou has also developed a domestic cochlear implant. The clinical performance of related products are being tested and evaluated, and some products have been used in clinical.

With the development of recent decades, the performance of cochlear implant has been greatly improved, but the recognition rate is still very low in practical application. Scholars have shown that for 50% sentence recognition rate, the signal-to-noise ratio required by normal people is about −10 dB, while the signal-to-noise ratio required by cochlear users is between 5 and 15 dB. Therefore, under the noise of normal living environment, the speech recognition rate of cochlear users is still low. The factors that affect the low speech recognition rate of the cochlear implant include the interference of noise environment and the mismatch of application scenarios, which will greatly reduce the performance of the cochlear implant. Improving the speech recognition rate of cochlear implant in noisy environment is still one of the research focuses in this field. At present, the research of cochlear implant mainly focuses on the following aspects: first, improving speech processing algorithm, such as extracting and transmitting more effective information, extracting the fundamental frequency and change information for the unique tone features of Chinese; second, the improvement of device and electrode. For example, the high-resolution strategy of the cochlear implant can obtain the fine structure of the signal and improve the stimulation rate of the electrode to transmit more abundant information. At present, more research focuses on the enhancement of the front-end signal of the cochlear implant [1–6], virtual channel technology [7, 8] and the optical cochlea [9–11].

The reason why cochlear implant is not widely used in China is that the technology is not mature enough, the operation cost is expensive, and the population is large. At present, only a few research institutes and universities in the mainland have cochlear debugging platforms authorized by three major foreign cochlear companies, which are not open to the outside world or sold. This paper designs a portable cochlear implant voice simulation and speech training system. The hardware and software system is a simulation test platform, which has low price, simple test mode, large customer base and potential market value.

2 Structure and Function of Cochlear Implant

For normal people, the outer ear and middle ear are mechanical transmission devices of external sound signal, which use the auricle of the outer ear to collect sound. The sound vibrates the tympanic membrane through the external auditory canal, and the ossicular chain of the middle ear can amplify the mechanical vibration. The amplified signal from the middle ear is transmitted to the vestibular window of the inner ear, causing the fluctuation of the lymph and the vibration of the basement membrane, stimulating the spiral organ of the cochlea, converting the sound signal into bioelectrical signal through the hair cells, stimulating the auditory nerve and transmitting it to the central system of the vestibular window of the cochlea, and finally generating the auditory perception. Functional electrical stimulation can directly stimulate the residual auditory nerve in the cochlea. As an alternative device, the cochlea replaces some functions of the ear. The main part of the cochlea is shown in Fig. 1.

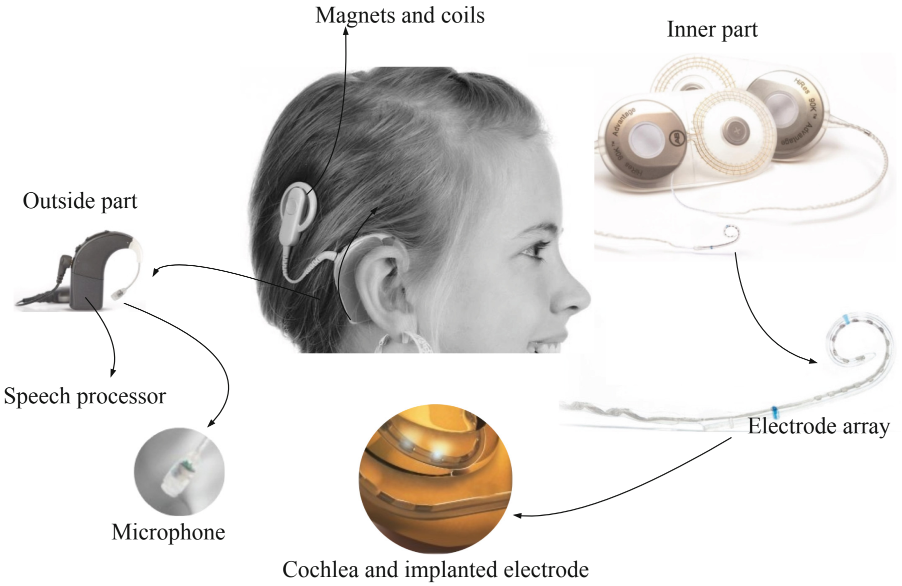

Fig. 1. Structure of cochlear implant.

The external cochlear implant mainly includes a microphone for collecting sound signals and a speech processor for processing sound signals. Microphone is a kind of transducer for acoustic electric conversion. The external voice signal is converted into electrical signal through microphone. After amplification and filtering, the electrical signal is transmitted to the speech processor. The speech processor extracts the time-domain envelope and frequency-domain parameters of the signal. The speech processor sends signal parameters through an external modulation coil to send signals and energy. The internal receiving coil receives the signal and sends it to the corresponding electrode. Finally, the electrode array stimulates the auditory nerve at a certain rate and in a certain way, and produces the auditory perception similar to that of the normal human ear.

3 System Design

3.1 Hardware Circuit

The average cost of cochlear implant is about tens of thousands of dollars. The high price is not only the product cost of cochlear implant itself, but also the pre-operative evaluation, hospital costs, doctor costs, as well as the post-operative external debugging and regular maintenance costs. After the operation, there will be a series of follow-up costs. There is a huge demand for cochlear implant in every country in the world, but there is a lack of a cheap platform for cochlear signal acquisition simulation and algorithm research. The front-end signal acquisition and simulation system developed in this paper can make up for this gap.

This system includes two parts: hardware and software. The hardware consists of two ARM processors to form a dual channel acquisition system, which can be started at the same time by pressing the key, which is helpful to improve the portability and real-time of signal acquisition. At the same time, the two microphones are placed at adjustable distance. The two ARM processors collect and save the information of the two microphones at the same time, and accurately record the spatial orientation information of the two microphones, which can be used for the design of microphone array algorithm. The main modules of the system are described as follows.

Control and processor module: because the system is to collect dual channel signals and accurately record the differences between signals, the system uses two ARM processors to collect and process at the same time (STM32 chip is selected for the system). In order to accurately and synchronously start signal acquisition, the system uses a key switch to connect two STM32 pins at the same time, which can simultaneously start signal acquisition to reduce the time delay of two signal acquisition.

Voice signal acquisition module: the system uses the key switch to start two STM32 at the same time for signal acquisition, each STM32 controls the audio decoder, and two audio chips are connected with high-sensitivity acoustic and electrical sensors for signal acquisition.

Program download and online debugging module: the signal acquisition program, software interface and other programs of the system need to be downloaded through USB, and STM32 is connected through chip CH340G, so that the program can be downloaded to STM32 directly through USB, and serial communication can also be realized. On the other hand, the USB interface connected by CH340G chip also has the functions of power supply and serial communication. Another JTAG interface is used for online debugging.

Power module: the system provides 5 V power through power adapter, and converts the power into 3.3 V through power regulator chip, which is also provided to STM32 chip and flash chip.

Signal storage module: the system collects and controls the signal information of the two channels through two STM32 chips, and the information of the two channels is stored in two SD cards through the SD card interface. The SD card of this system adopts SPI communication mode. The SPI interface of SD card is connected to the corresponding pin of STM32 to realize SD communication and data storage.

3.2 Software GUI

The sound is collected by microphone, filtered and amplified by a pre-processing circuit, and finally connected to a computer. Through the development of voice simulation software GUI on the computer, after selecting and setting parameters on the GUI, the specific voice processing strategy is called, the collected voice signal is processed by the voice processing algorithm, then the corresponding analog voice in the synthesis algorithm is synthesized, and finally the synthetic voice is played through the speaker. The sound played by the speaker is based on the cochlear speech processing strategy and actual parameters. Therefore, the synthesized sound signal can simulate the hearing of cochlear users under the stimulation of electrodes. We use Matlab to develop the software GUI, as shown in Fig. 2.

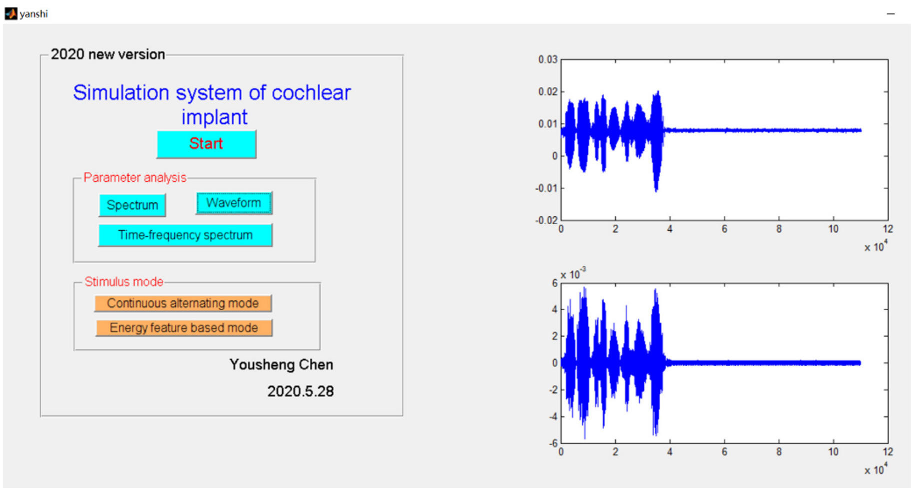

Fig. 2. Software GUI of the simulation system.

Besides speech synthesis and speech training, the GUI of the software can also extract and analyze parameters. For example, the spectrum parameters and time-frequency spectrum parameters of the signal can be extracted, as shown in Fig. 3 and Fig. 4:

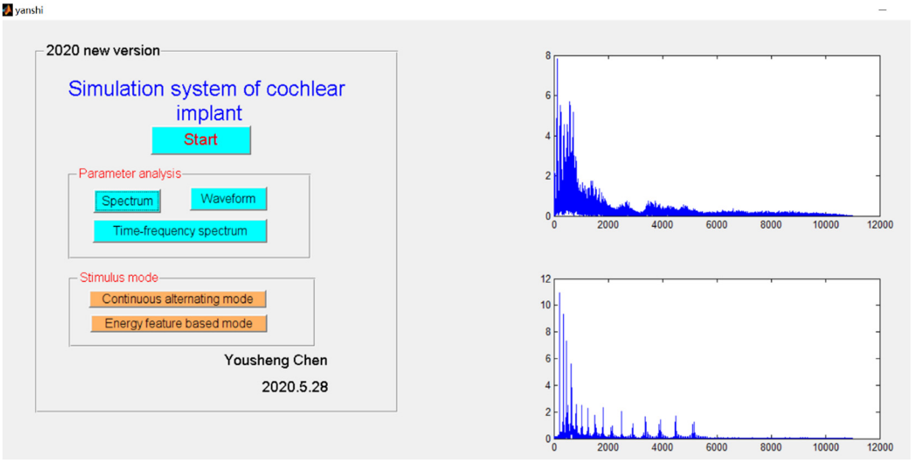

Fig. 3. Display of the spectrum parameter in the GUI.

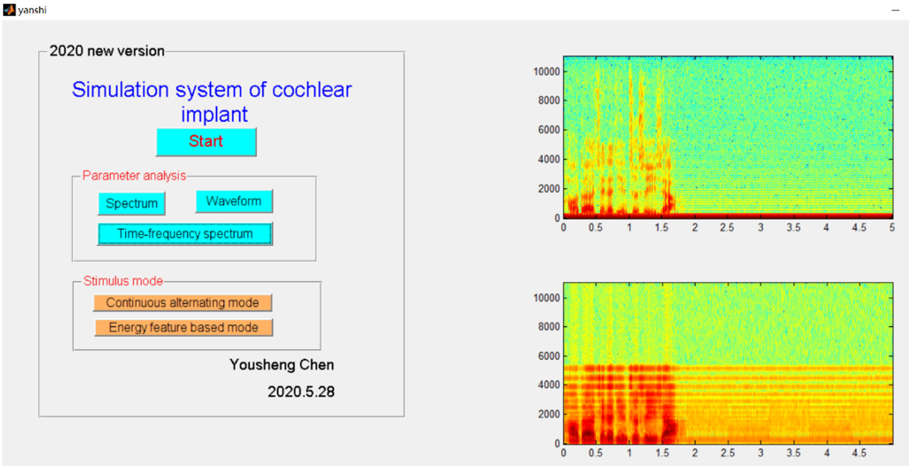

Fig. 4. Display of the time-frequency spectrum parameter in the GUI.

As can be seen from Fig. 3 and Fig. 4, the software GUI can analyze various effective speech parameters, which is helpful for speech training and system simulation of the cochlear implant.

4 Conclusion

There are a large number of hearing impaired patients in *Shenzhen* and other mega cities, which have great potential demand for cochlear implant, especially for obtaining high-quality hearing perception in noise environment. Improving speech recognition rate in noise environment is one of the final destination for the improvement of cochlear implant. This paper has accumulated technology in the early stage, and developed a sound simulation and deafness simulation training system for cochlear implant. The system has not only technological innovation, but also high social and commercial value. It can not only simulate signal and synthesize speech, but also extract parameters and train users of cochlear implant. It is an auxiliary device for deaf patients wearing cochlear implant.

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