

Intelligent Control System of Wheelchair Based on Brain Wave and Voice

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Abstract: In order to improve the quality of life of the elderly and the disabled, the system fully considers the lifestyles of the elderly and the disabled and realizes the intelligent control of the wheelchair by using the Internet of Things and the intelligent control technology. By designing wearable equipment, the system can obtain the original EEG signals from the brain, and after filtering the noise and power signals, the brain waves are converted into output signals to realize the control of the wheelchair. Wearable devices are called brain wave collection caps. In addition, the system also has infrared obstacle-avoidance function, speech recognition and other functions, and ultimately to help the elderly and disabled people to achieve the “body with the brain moving” goal. Long-term testing of the system shows that the equipment is easy to operate, suitable for the elderly and disabled people with limited mobility, and it is of great social significance to improve the quality of life and happiness index.

Keywords: Brain wave, Face recognition, Intelligent wheelchair, IoT, Speech recognition.

I. INTRODUCTION

With the progress of science and technology and the improvement of medical standards, human beings to prevent and control a variety of diseases, so the population aging is increasing, at the same time, due to age, disease, accidents, disasters and other reasons for the loss of free movement of disabled persons, how to protect this special group of medical, nursing and to give the disadvantaged groups care and help is an important issue that we have to face.

Since 1986 Britain began to develop the first intelligent wheelchair, many countries have invested more money in the study of intelligent wheelchairs [1-9]. For example, since Spain began research on the SIAMO project in 1996, the wheelchair uses modular design ideas, with flexibility as the design guideline, and the system designs artificial intelligence wheelchairs with three main functions of Man-machine interface, complete environment sensing module and decision navigation and control module; shortly thereafter, the MIT Intelligent Laboratory developed the intelligent wheelchair Wellesley, it's a semi-autonomous robot wheelchair, the

wheelchair is equipped with a computer-controlled, sensor-powered wheelchair and a laptop computer for Man-machine interface; at 2015, Researchers at Kanazawa University of Japan have made further research based on the intelligent wheelchair developed by Toyota, which reads brain waves to obtain the destination of a wheelchair navigation, and then automatically moves the wheelchair away from the barrier to the place where the user's mind “wants” to go; the Institute of Automation of the Chinese Academy of Sciences has developed a robotic wheelchair with visual and password navigation, which also features language interaction, which incorporates speech recognition, and integrates the latest scientific research in machine vision and speech recognition into wheelchairs, in order to realize the function of intelligent man-machine conversation.

The above system is analyzed and found that scholars in the field of intelligent wheelchair research has made great achievements, these research results have greatly improved the quality of life of the elderly and disabled people, but the combination of national conditions is not difficult to find that the above system has some deficiencies, such as: Brain radio control wheelchair research level is still at a relatively low stage; the human-computer interaction terminal interface has low recognition rate; low system modularization degree and high cost, and is not suitable for mass production.

II. OVERALL DESIGN OF THE SYSTEM

Based on the system function analysis, the intelligent wheelchair control system is divided into seven modules: Micro-Processing Module, Brain Wave Acquisition Module, Intelligent Speech Module, Motor Drive Module, Obstacle Avoidance Module, Road Condition Detection Module and Mobile Communication Module. The overall framework of the design system is shown in Fig. 1.

The control system can realize the control of three kinds of intelligent wheelchairs: Brain wave control mode, intelligent voice control mode and manual control mode. In the brain-wave control mode, the brain radio control commands sent by the human brain are received and after a series of processing, through the serial interface to the microprocessor, the

microprocessor after analysis and then send the corresponding PWM control waveform to control the motor drive chip, driving the chip again through the relevant pin closure to control the two DC motor movement, and then realize the movement of various state of the wheelchair. In Speech control mode, users only need to issue “open”, “front”, “after”, “left”, “right”, “fast”, “slow”, “stop” and other instructions and after the microprocessor analysis and processing, will send the corresponding PWM control waveform to achieve the wheelchair movement. In manual control mode, the operator needs to manually manipulate the buttons to control the movement of the wheelchair. In three kinds of control mode, wheelchair obstacle avoidance module and road condition Detection module will be started, realizing the wheelchair’s autonomous obstacle avoidance and intelligent voice prompting function.

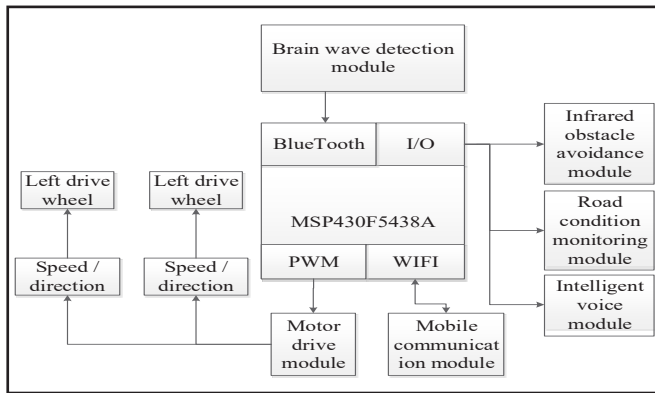


Fig. 1: Overall Framework of the System

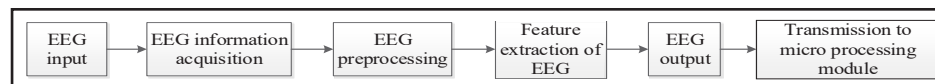


Fig. 2: Brainwave Acquisition Module's Workflow

- First of all, we use the average filtering algorithm to first define the sampled value C , accumulator s , average A , sampling number n .

Initialization: $a = \text{initial value}$, $s = a * n$, $s = s - a + c$, $a = s/n$.

The idea of this algorithm is average filtering, which improves the computation and memory footprint, and the smoothness is better when n value is large.

- The periodic graph method is used to extract the feature, which is obtained directly from Fourier transform without calculating autocorrelation function. The N -point acquisition data $x_n(n)$ of random signal $X(n)$ is regarded as a finite energy signal, take the Fourier transform of $x_n(n)$ directly $x_n(e^{j\omega})$, and then take the square of its amplitude, divided by N , as an estimate of the true power spectrum $P(e^{j\omega})$ of $X(n)$, the interval value of the W is obtained:

$$P_{per}(k) = 1/N|XN(k)|^2 \quad (1)$$

The $P_{per}(k)$ is expressed as the power spectrum estimated by the periodic method. The EEG power spectral density was obtained, and the characteristic values were analyzed, and the different states of different EEG signals were represented by the eigenvector.

- Characteristic signal classification is the relationship between the type of motion or consciousness and the characteristic signal according to different movement or consciousness which can make the EEG activity produce different response characteristics. The linear discriminant analysis is used to make the similar samples gather together as far as possible, to determine the projection direction W and threshold y_0 by the given test data, i.e. to determine the linear discriminant function, then to test the test data according to the linear discriminant function,

III. HARDWARE FUNCTION IMPLEMENTATION

A. Micro-Processing Module

The micro-processing module is the core of the entire system and is mainly used for information processing and control. The module takes msp430f5438a as the main core microprocessor, which has the advantages of strong processing ability, fast operation speed, ultra-low power consumption, rich in-chip resources and convenient and efficient development environment, which plays a very good coordinating role for the processing of more data and the common use of multiple serial ports. Other integrated Peripherals: Analog Comparator, DMA, hardware multiplier, SVS (power supply voltage monitoring module), 12-bit DAC. MSP430F5438A supports JTAG simulation, which realizes on-line simulation debugging and facilitates the porting of embedded real-time operating system.

B. Brainwave Acquisition Module

BCI is a brain-computer interface technology, which is a direct link between the brain and external devices of human or animal, and we receive EEG signals through micro-processing modules and Bluetooth peripherals. The brainwave sensor uses ThinkGear TGAM as the acquisition chip, can detect the 512Hz original EEG signal from the brain, filter out the noise around the other noises and power signals, and then filter, feature extract, signal classify and convert the EEG signal, and finally convert to the output signal to control the wheelchair. Its workflow is shown in Fig. 2.

and finally get the test data category.

i) Determination of W

All kinds of sample mean vector m_i

$$m_i = \frac{1}{N} \sum_{x \in X_i} X, \quad i = 1, 2 \quad (2)$$

Sample class internal dispersion matrix S_i and total class dispersion matrix S_w

$$m_i = \sum_{x \in X_i} (x - m_i)(x - m_i)^T, \quad i = 1, 2 \quad (3)$$

$$S_w = S_1 + S_2 \quad (4)$$

Sample class Dispersion Matrix $S_b = (m_1 - m_2) (m_1 - m_2)^T$

In one dimensional space after projection, the average value of all kinds of samples $m_i' = W^T m_i$. Internal dispersion and total class dispersion in sample class $S_i' = W^T S_i W$. Sample class See dispersion degree $S_b' = W^T S_b W$.

The two important properties of linear discriminant analysis are:

- All types of samples are as dense as possible, that is, the smaller the total class is, the better.
- All kinds of samples as far away as possible, that is, the greater the dispersion between the sample class the better. According to this property to determine the criterion function, according to the criterion function to obtain the maximum value, we can find W :

$$W = S_w - 1(m_1 - m_2) \quad (5)$$

ii) Determination of the Threshold Value

Methods adopted in the experiment: $y_0 = (m_1' + m_2')/2$

iii) Decision Planning of Linear Discriminant Analysis

For a sample vector x of an unknown class, if $y = W^T x > y_0$ then $x \in w_1$, otherwise $x \in w_2$. Then, the classification of the test data can be judged by the normalized processing.

In the EEG signal, there are 12 different EEG signals, these include RAW WAVE Primitive Brainwave, Delta, Theta, Low Alpha, High Alpha, Low Beta, High Beta, Low Gamma, Mid Gamma, Noise, Attention, Mediation, in these 12 different EEG signals, the brain wave signals collected from RAW WAVE and Attention channel are used as the reference signals, which is the first choice for brain wave processing signals.

The TGAM chip sends about 513 packets per second, sending packages with small packets and two large packages: the packet format is AA AA 04 80 02 High, Low, Check Sum (the previous AA AA 04 80 02 is the frame head, after three bytes for data and checksum), High and Low compose the raw data raw_data, Check Sum is the checksum.

To obtain a set of raw_data, you should first verify the checksum.

Formula:

$$sum = ((0x80 + 0x02 + High + Low) \wedge 0xFFFFFFFF) \& 0xFF \quad (6)$$

If sum and Check sum are equal, then the package is correct, then the raw_data is computed, otherwise the package is ignored.

Analyze the original data by packet analysis:

$$raw_data = (High \ll 8) | Low \quad (7)$$

if (raw_data > 32768) {raw_data = 65536;}

Sample data collection, as shown in Fig. 3.

0	1	2	3	4	5	6	7
AA	AA	04	80	02	00	4C	31
AA	AA	04	80	02	00	59	24
AA	AA	04	80	02	00	63	1A
AA	AA	04	80	02	00	58	25
AA	AA	04	80	02	00	52	2B
AA	AA	04	80	02	00	4C	31
AA	AA	04	80	02	00	53	2A
AA	AA	04	80	02	00	74	09
AA	AA	04	80	02	00	94	E9
AA	AA	04	80	02	00	A4	D9
AA	AA	04	80	02	00	A0	DD
AA	AA	04	80	02	00	97	E6
AA	AA	04	80	02	00	C8	B5

Fig. 3: Data Collection

The acquisition of concentration will be obtained directly from the wheelchair output signal. The following pictures show the waveform of the normal blink of a person, the waveform produced by normal teeth, the waveform produced by two consecutive blink signals in 0.5s, and the waveform of a person's attention level. The output of EEG is mainly transmitted to the microprocessor through the Bluetooth module, and the microprocessor receives the data and converts it into a wheelchair control signal. A normal blinking signal does not produce a control command on a wheelchair, when the user wants to control the wheelchair direction only needs to blink two times in the short time, when the brain wave State signal light is illuminated the instruction to be effective; When the user wants to control whether the wheelchair advances through the concentration degree, only needs to grind teeth to open the wheelchair to move forward the switch. In the course of the wheelchair, the user's concentration controls the speed of the wheelchair, the higher the concentration, the faster the travel speed. The brain wave data collected are shown in Fig. 4.

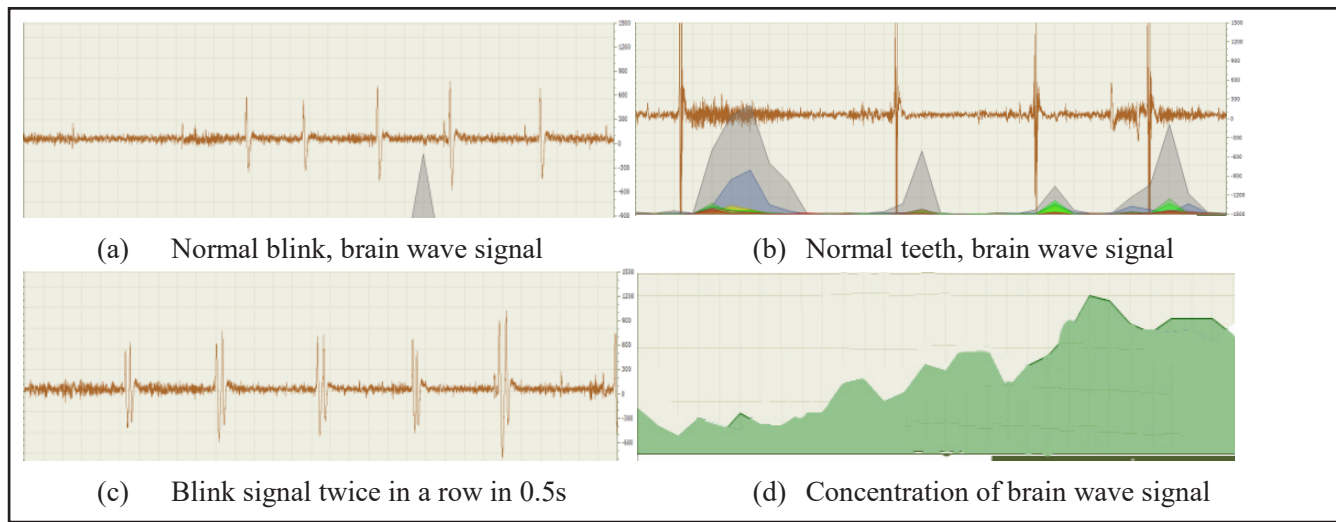


Fig. 4: Brainwave Information

C. Intelligent Voice Module

Intelligent speech Module Using XFS5152 speech synthesis module, XFS5152 is a highly integrated speech synthesis chip, can achieve Chinese and English speech synthesis, and integrated voice coding, decoding function, can support users to record and playback, in addition, also innovative integrated lightweight speech recognition function, support 30 Identification of the command word. When the system needs to generate voice output (such as the front of the obstacle to remind, road environment reminders), the microprocessor through the serial port and voice module communication, voice module received instructions for analysis and processing by the Speaker broadcast voice information.

D. Motor Drive Module

The system uses two DC motors, the speed and direction of the motor control to be achieved by changing the motor voltage. DC Motor Drive module, the internal integration of Bipolar H-bridge circuit, I293d through the internal logic to generate the enabling signal. The input of H-bridge circuit can be used to set the motor rotation direction, so that the energy signal can be used for pulse width adjustment (PWM). Each 1 motor needs 3 control signal ENA/B, IN1, IN2, which ENA/B is to enable the signal, IN1, IN2 for the motor rotation direction control signal, IN1, IN2 1, 0 o'clock, the motor is turning, on the contrary, the motor reversal. Selection of PWM connection ENA/B pin, by adjusting the duty ratio of PWM can adjust the speed of the motor. The drive circuit of the motor is shown in Fig. 5.

E. Obstacle Avoidance Module

The system uses the Anti-interference high-performance infrared Obstacle avoidance module, the current side has the obstacle, the infrared diode sends out the signal, receives after

the infrared receiving tube, the integrated chip amplification, the voltage comparator compares, lights up the module the LED luminous tube, and outputs the low level, The microprocessor controls the travel status of the wheelchair and makes a voice alert by detecting the input of the low level signal.

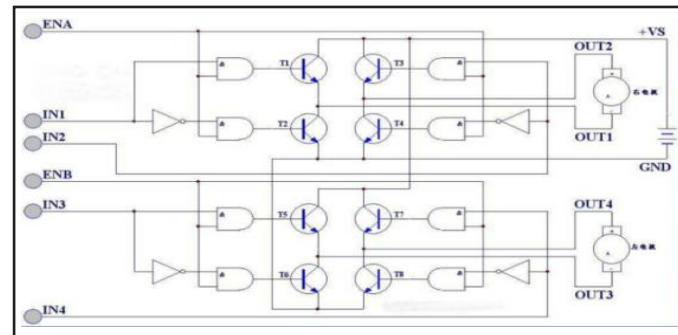


Fig. 5: The Drive Circuit of the Motor

F. Traffic Detection Module

Road condition detection module using vibration sensor, when the road conditions are stable, the vibration switch is disconnected state, output high level, vibration indicator is not bright; when the road is not good, the vibration switch is instantaneous, the vibration indicator light is bright, the output is low level signal. The microprocessor detects whether the road environment causes a greater degree of vibration of the wheelchair by setting down the detection interrupt, and when the vibration signal is generated, the Intelligent voice module prompts the user to pay attention to the current road condition and drive carefully.

G. Mobile Communication Module

The microprocessor connects the Wi-Fi module through the serial port to the mobile phone app communication, when the user

speaks the control command, the voice after the cloud processing returns the local formation specific instruction, passes through the Wi-Fi module to the microprocessor, the microprocessor carries on the data to verify, the analysis, the processing forms the different wheelchair control signal. Users can also use the mobile phone app to manually control the wheelchair, the signal transmission principle and the same voice.

IV. MOBILE TERMINAL

Through the mobile phone to achieve the keyboard and voice interactive control. The main technologies used in the implementation of the handset end are face recognition based on Deep Learning and speech recognition based on FSMN.

In order to enhance the security of the system, using the face recognition technology, using the region feature analysis algorithm, extracting the portrait feature point, the paper establishes the mathematic model and obtains the face feature template by the principle of biostatistics.

At the same time, using the built Face feature template and the person's face image analysis, according to the results of analysis to give a similar value, through this value can determine whether the same person. Speech recognition to achieve a higher degree of human-computer friendly relations, at the same time realize the system multi-directional comprehensive control. The user input the audio through the cloud processing, returns the local output text, on the other hand, detects the user to enter the instruction, transmits through the Socket to the system microprocessor, realizes to the wheelchair control.

First, the mobile terminal actively requests to establish a socket connection to the server that specifies the IP address and port and passes the instruction to the microprocessor via the Wi-Fi module. The control instructions for transmission are agreed in advance, for example, the control instructions for advancing are "pwi." The control command for the back is "pzi." The microprocessor converts instructions into electrical signals and ultimately controls the wheelchair equipment.

A. Face Recognition Based on Deep Learning

Face recognition as the most superior, experience the best biometric technology, the main use of the system DeepID2+ to achieve face recognition, DeepID effective, first of all, the convolution neural network learning to distinguish the characteristics of the strong, in order to get more strong results, DeepID has adopted the most commonly used technique-increasing data sets, only large data sets can make convolution neural network training more fully.

B. The Basic Principle and Realization Process of Face Recognition

First, the SDM algorithm is used to detect 21 landmarks per face, then according to these landmarks, the position, the scale,

the channel, the horizontal flip and so on, each person's face forms 400 sheets of patch, and uses 200 CNN to train them. The patch of the horizontal flip form is trained with the original picture. Thus, the vector of the 400x160 dimension is formed. This formation of the feature dimension is too high, so to carry out feature selection, different from the previous DeepID direct use of PCA, DeepID2 first to select the patch, using the forward-back greedy algorithm to select 25 of the most effective patch, so that only the 25x160 dimension vector, Then the PCA is used to reduce the dimension, then the dimension is 180 d, and then input into the combined Bayesian model to classify. Then the combination model is strengthened, which is seven times when the feature is selected. The first selected effect of the best 25 patch, the second time from the remaining patch 25, and so on. Then seven combined Bayesian models are fused using SVM. Finally reached 99.15% results.

C. Speech Recognition Based on FSMN

Compared with traditional DNN, this technique adds a module called memory block to the hidden layer to store historical information and future information useful for judging current speech frames. The memory function of RNN, FSMN memory block, which is different from the traditional cyclic feedback, is realized by using feedforward structure. This feedforward structure has two advantages: first, the bidirectional FSMN to the future information memory, there is no traditional two-way must wait for speech input to end the current speech frame to determine the limit, it only needs to wait for a finite length of future speech frames. In addition, in the aspect of model training efficiency and stability, because the FSMN is completely based on feedforward neural network, there is no situation in RNN training due to the fact that the sentence length of the mini-batch needs to be 0, which leads to the waste operation, and the feedforward structure makes it more parallel and can maximize the GPU computing ability.

This system through the speech cloud processing, receives the cloud processing result locally, generates the control instruction, transmits to the hardware receives the device.

CONCLUSION

After testing and optimization, the system performance stability, high human-machine friendliness, features mainly in a few aspects:

- The system designed and developed a brain wave reception processing equipment, which is based on the brain-machine interface module developed, it can receive different thinking produced by different brain wave signals. At the same time, the device has the accurate recording function, it uses the noninvasive brain wave to obtain the way, it realizes the user body with the brain movement goal.
- The control system emphasizes the modular design idea and divides the control system into seven modules:

micro-processing module, human-machine interface module, intelligent speech module, motor driving module, obstacle avoidance module, road condition detection module and mobile communication module. And each large module is divided into a number of sub modules one by one design, and finally the various modules connected to complete the entire system to build, to achieve our analysis of the system function.

- The development and application of human-computer interactive speech recognition technology can accurately control the intelligent wheelchair, combine the EEG, voice and manual mode to realize the multiple guarantee of wheelchair control, and greatly improve the stability and security of the system.

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