Design of Smart Home System Using EEG Signal

Zhendong Mu, Jinghai Yin, Jianfeng Hu*

Institute of Information Technology, Jiangxi University of Technology,
NanChang 330098, JiangXi, China
**Corresponding author*

Abstract
In order to convenience of the disabled people living more convenient, using EEG signal is a good way, this paper design a smart home system based on the results of EEG signal studies, through this system can carry out the identify authentication in the room, can by EEG signal to control power switch. In order to reduce the noise signal interference, the high pass and low pass were used to cut extra frequencies, and in order to prominent the feature signal, the power spectrum method was used to convent the time domain signal to frequency domain, and then fisher distance was used to extraction the feature. All EEG signal was acquired by Neuroscan. In the simulated environment, identity authentication is using the visual evoked potential, and control switching is using motor imagery. The results showed, the subjects in identity authentication, an average of three times certification can identify subjects, switch control experiment, the accurate control of switching frequency to 86%.
Key words: EEG, SMART HOME SYSTEM, SYSTEM DESIGN,BCI

1. Introduction

With the advance of electronic information technology and computer network, the life of people becomes more and more convenient. Smart home technology is a new technology, this technology is means that a family in various household life related communications equipment, computer technology, network, biological technology, connected to the home intelligence system, in order to realize the monitoring and control, make household life more comfortable safe and convenient. Now, a lot of researchers on smart home, such as remote control scheme in smart home research, nursing bed used in the smart home environment, this all results promote the development of smart home technology.

Though the smart house technology has been fully developed, but this technology for some people such as disabled people, old is not so convenient. EEG signal is a kind of biological signal from brain. The study of EEG signals obtained many achievements, this paper use this result develop a smart home system, this system include two aspects: identity authentication and switch control.

In the results of research on identity recognition based on EEG signal, use VEP as tool is very successful. Paranjape et al [1, 2] Acquisition subjects wide open, EP signal is generated when the eyes closed, use AR model parameters as recognizable features. In a recent research results, Riera et al [3]chose the two electrodes , collecting subjects wide open , EP eyes closed when the signal is analyzed using auto-regressive , Fourier transform, mutual information , etc. multi- feature fusion achieved 87.5% to 98.1% recognition rate.

When there is a specific visual stimulus will produce visual evoked potential (Visual Evoked Potential, VEP), which is a good entry point , Singhal et al [4] use VEP peak there are individual differences in characteristics , setting relevant peak potential matching algorithm identifying subjects also achieved good results. In study Biel, etc., then the design of the subjects viewed a picture , the choice of the three electrodes , using VEP as a signal source analysis , implementation verification using multivariate statistical methods. Palaniappan et[5] The definition of an automatic identification method using Davies-Bouldin index information to select the largest electrode, the black and white pictures of common objects as visual stimuli , using a neural network classification . Touyama [6] et al study is unfolding from the perspective of ERP , they take advantage of the characteristics of the P300 , P300 evoked that will only appear when the target stimulus , the experiment they let 9 photos randomly , participants selected targets stimulation, selected different subjects of different target stimulus , they choose a password that is .
Motor imagery EEG signal is successful used in BCI study, left and right motor imagery is most successfully [7, 8, 9, 10]. In this paper, this result is used in controlling switch open and closed.

2. Data processing

2.1 Filter

Intermediate signals received useful signal selection process is called filtering, "received signal" corresponds to the observed random process, the "useful signal" corresponds to the random process is estimated. E.g., aircraft tracking radar, the measured position data of the aircraft, the other containing the measurement errors and random noise, how to use them to estimate as accurately as possible the position of the aircraft at each moment, velocity, acceleration, and to predict future aircraft position, is a filtering and prediction problems. Such problems in electronics, aerospace science, control engineering and other scientific and technical sectors are abounding.

Filtering is carried out in accordance with, or just on some sampling points can be divided into a continuous-time filter and a discrete-time filtering on the entire time. The former set time parameters T will be desirable half real axle $[0,\infty)$ or the real axis; latter T desirable non-negative integers {0, 1, 2, 3…} or integers {…,-2,-1, 0, 1, 2,…}.
Set $X=\{X,t\in T,t\in T\}$ is limited, that is to say:

$$C(H_j\mid r)=\sum_{i=1}^{M-1}C_{ji}P(H_i\mid r) \tag{1}$$

Where X is a process to be estimated, it cannot be directly observed; Y is the observed process, which contains some information of X. Use $y^t=\{y_s: s\in T, s\le t\}$ to represents the observed data with the time t until the whole. If you can find a function f(x) about a variable in y making it reach the minimum mean square error of $E\mid X_t-f(y)^t\mid$, $X_t-f(y)^t$ is said to the optimal filtering Xt
In order to facilitate the application and narrative, sometimes also above definition to classify more detail. Let τ t is a real number or integer determined, and the process is considered to be estimated as

$$(X_{\tau+t},t\in T)\ ,\ X_{\tau+t}=\tilde{E}(X_{\tau+t}\mid y) \tag{2}$$

Or

$$\tilde{E}(X_{\tau+t}\mid y^t), \tilde{X}_{t+\tau|t}=X_{t+\tau}-\tilde{X}_{t+\tau|t}, D_{t+\tau|t}=E(X_{t+\tau}\mid y^t) \tag{3}$$

According to τ = 0, τ> 0, τ <0, are called optimal filtering, (τ-step) prediction or extrapolation, (τ step) smoothing or interpolation. $\tilde{X}_{t+\tau|t}$, $D_{t+\tau|t}$ corresponding to each error and the mean square error, and collectively these problems for the filter problem.

According to brain wave frequency characteristics, this paper 1Hz high pass and 55Hz low-pass method of combining the signal source is filtered, collected EEG first by 1Hz high-pass filter to reduce direct impact, and then conduct a 55Hz low-pass filter, so You can select 1-55hz useful EEG.

2.2 Power spectrum calculation

The original EEG is a signal domain, the features are hidden between the various noise data, through the original EEG feature extraction speed and accuracy will be affected, in order to improve the speed of analysis and analysis accuracy, can be converted to the original EEG power spectrum, the frequency analysis.

A simple way to estimate the power spectrum of the stochastic process is a direct request sampling DFT, and then takes the results of the square of the amplitude. Such a method is called period gram

A length L of the signal $x_L[n]$ is estimated period gram PSD as follow

$$\tilde{P}_{xx}(f)=\frac{|X_L(f)|^2}{f_s L} \tag{4}$$

Where $X_L(f)$ is defined using the fft matlab inside without normalization coefficients, so dividing L.

$$X_L(f)=\sum_{n=0}^{L-1}x_L[n]e^{-2\pi jfn/fs} \tag{5}$$

The actual calculation of $X_L(f)$ may be performed using FFT, and only on a limited frequency. Application in practice is most period gram PSD estimation to calculate the N-point:

$$\tilde{P}_{xx}(f)=\frac{|X_L(f)|^2}{f_s L},\ f_k=\frac{kf_s}{N},k=1,2,3...,N-1$$

$$X_L(f_k)=\sum_{n=0}^{L-1}x_L[n]e^{-2\pi jfn/N} \qquad (6)$$

2.3Feature extraction methods

EEG feature extraction in order to extract useful brain signals, thereby to classify the feature extraction method to identify subjects used herein are described below:

Step 1. Common average: In this paper, we use Hjort derivation to reduce interference from the neighboring electrode,

The Hjort derivation C_i^H is calculated as

$$C_i^H=c_i-\frac{1}{4}\sum_{j\in S_i}sc_j \qquad (7)$$

Where ci is the reading of the center electrode scj, with i=1…30 and j is the set of indices corresponding to the eight electrodes surrounding electrode ci.

Step 2. Filter: EEG signal acquisition band from 0.05Hz to 200Hz, in order to extract features, we filter EEG signal band from 0.05Hz to 50Hz.

Step 3. AR conversion: time-domain EEG data disorganized EEG in order to better highlight the characteristics of EEG signal, we use AR model to convert the time domain signals into frequency domain, and extract the feature from the frequency domain signals.

Step 4. Calculate the add of Fisher' distance: Calculated the Fisher distance between two classes. Fisher distance $F_{i,j}$ is calculated as

$$F_{i,j}=\frac{(\mu_i-\mu_j)^2}{\sigma_i^2+\sigma_j^2} \qquad (8)$$

Where $F_{i,j}$ is Fisher' distance between the subject I and the subject j. μ and σ are the mean and the standard deviation of the feature they correspond to.

The add of Fisher' distance F_i is calculated as

$$F_i=\sum_{j\neq i1}F_{i,j} \qquad (9)$$

Step 5. Sort the Fisher’s distance adds: The Fisher distance was often used to denote differences between classes in classification research. The bigger the fisher distance was the more notable the difference was. So we sort the Fisher’s distance on descending order.

Step 6. Feature extraction: Through analysis the five subjects Fisher's distance, we select three thousand as feature range, all feature are selected from this range.

Step 7. Get the classifier: Use BP neural network to calculate the feature then can get these five subjects classifier. To the test sample of these subjects, if the result is in credibility, that is to say, this sample is right

2. Results and discussion

Results 1: In the intelligent home furnishing authentication, the authentication and the biggest difference is that the authentication intelligent home furnishing is finally verified by people can be determined, so the key point in the intelligent home furnishing authentication is to prevent the non through the use of. We use the mature visual evoked potential of EEG is more appropriate, because compared to visual evoked potential and electrical signals to other brain, relatively stable feature, the study also more mature, for use in the detection process, in recent years the use of visual evoked potential of personal identification has some achievements, such as the study group the use of photo identification studies, reveals the different user to own photo reaction induced by users, with characteristics of EEG signals, thus realizing the identification. In the intelligent home furnishing in the system, can use and users or items of interest, such as music stimuli evoked tools, the following figure shows the photo when authenticating users EEG features.

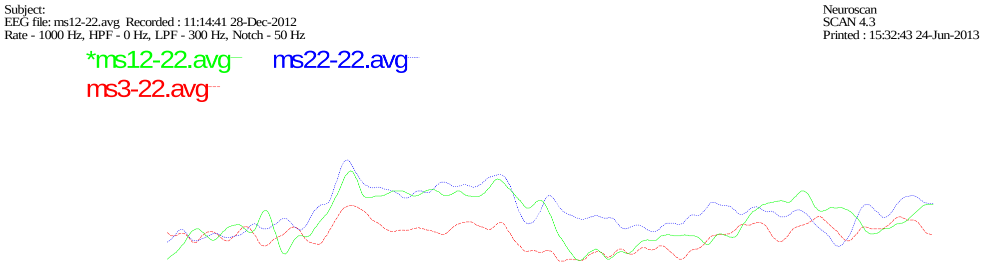

Figure 1. Pay attention to their own and others comparison chart

Figure 1 shows the subjects in the picture appeared different event EEG, the solid is subjects to see their familiar pictures to produce the EEG, long dashed line is the subjects watched a background picture output EEG, the short dashed line is the participants of noise in EEG, shown in Figure 1 results show, when the subjects to see their photos in different time of 150 ms, there was a significant gap.

Result 2: The frequent signal difference in the switch control, during motor imagery process, in order to highlight the characteristics of better, the time domain signal into the frequency of EEG signal, Figure 2 shows the difference

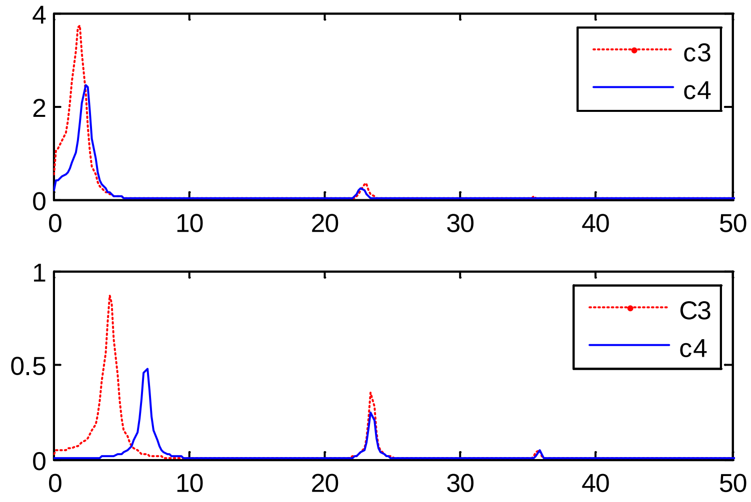

Figure 2. C3 and C4 electrode frequency domain signal contrast

Figure 2 show C3 and C4 electrode frequency domain signal contrast, from this figure, we can draw a conclusion: Features of motor imagery EEG concentrated in 2 ~ 8Hz, 12 ~ 15Hz and 35 ~ 39Hz three frequency segments.

Result 3: The time domain difference in the switch control. On the left and right to imagine two movements were superimposed and compared, superimposed by the signal enhancement, in the time domain signal shows certain characteristics, which FC3, C3, CP3, FCZ, CZ, CPZ, FC4, C4, CP4 The most clear and stable.

In order to compare the brain feature that caused by different motor imagery, this paper overlap the EEG signals, and projected it to 2D brain mapping. The brain mapping were sampled every 220ms. The brain mapping of right motor imagery as figure 3 show, in 0~1760ms, the brain mapping is no obvious change, at 1980ms, the right motor imagery begin, and show as figure 4, at 1980ms, the left brain appear obvious change in brain mapping, starting from 1980ms, is C3 volatile areas of the brain as the central location, strong fluctuations in brain areas until 2640ms, from 3080ms to 3520ms the phenomenon of 1980ms~2640ms appear again. After a period of rest, during the period of 4180~4840ms the volatility appear the region that C3 as the center. The pattern of motor imagery show, motor imagery every time in between 880ms.

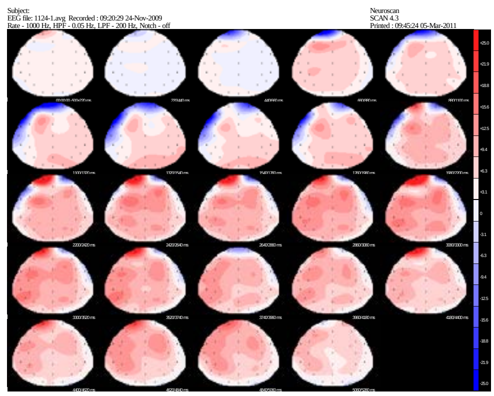

Figure 3. Electrode comparison chart

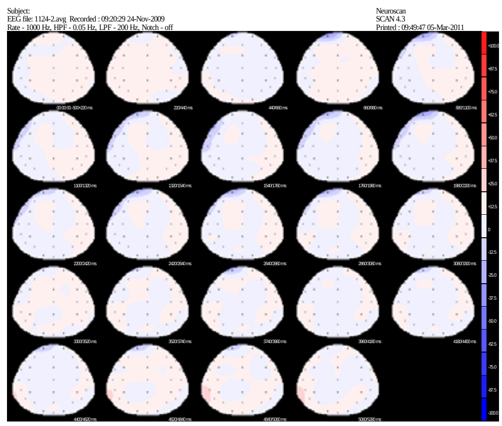

Figure 4. Left brain mapping

EEG of the left movement as shown in Figure 4, relative to the right imagery, brain mapping shows that the EEG signal energy is relatively weak, not as the right motor imagery features strongly.

Result 4: stimulation of identity authentication.

In order to test whether can use EEG control, we conducted a simple experiment, the experiment is designed to test the intelligent home furnishing room in the system, whether the owner can enter the room. The theory is based on when the subjects saw familiar items, reflecting the goods more than other people to see, we according to the theory of testing a group of experimenters, a group of experimenters consists of five people, each test thirty times, the recognition system recognition rate as shown in fig 5:

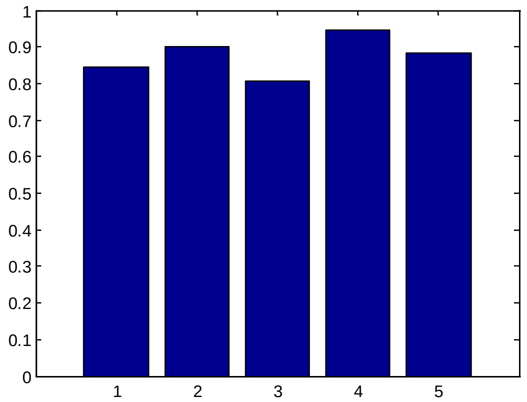

Figure 5. Correctly identify host ratio

In order to better results, we design a set of other people, the same group of people is five, and the purpose of the experiment is to identify refused entry to the test system, the results as shown in Figure 6

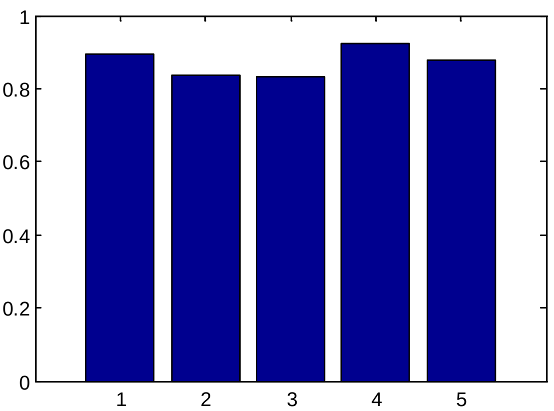

Figure 6. Correctly identify stranger ratio

From the above two results, a good system to identify the owner, and good refused to strangers.

Result 5: stimulation of control switch. In this paper, according to the above results, use the left to imagine as lights, turn off the lights to the right imagine, respectively to extract features of the subjects, were fitted by BP neural network, each experiment lasted three minutes, three minutes, each subject the final recognition rate of five individual results are: 83.3%, 85%, 75%, 80.5%, 65%.

4. Conclusions

We present our study about a novel intelligent system for smart home. In EEG biometric details, we take the EEG recognition idea, and use motor imagery as tool control switch, the results are all some study successful experimental results, this paper use this paper design a smart home system, and build a stimulate environment. the results of stimulation shows, use EEG as tool of smart home system is success. We present an approach to improve EEG recognition towards noise. We believe this idea will result on efficient and convenient authentication system and control switch when deployed in smart home.

Acknowledgements

This work was supported by Natural Science Foundation of Jiangxi Province [No 20142BAB207008] and project of Science and Technology Department of Jiangxi Province[No 2013BBE50051]

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