EEG-based identification system for mobile devices

Jianfeng Hu*, Zhendong Mu, Jinghai Yin

Institute of Information Technology, Jiangxi University of Technology, Nanchang, China

Received 1 November 2014, www.cmnt.lv

Abstract

The brain is the most mysterious and powerful of human organs, with the development of science and technology on the brain brainwave applied research, more and more brain-computer interface technology matures, making people use brain waves to control peripheral devices ideas become possible. With advances in hardware technology, portable EEG acquisition instrument has emerged, portable, miniature brain wave EEG acquisition instrument enables application developers to use in daily life has become a development trend of brain wave study. The development of mobile-related hardware and software technology, making all kinds of intelligent terminals become everyday essential goods. Mobile equipment has now become a new platform for information exchange, spend a lot of information exchange, how to effectively protect the mobile platform information security? Research has shown that, EEG signal can be used as identification tool, the user's information protection and good, this paper to protect the information security of mobile devices to research how to use EEG; the EEG signal is feasible for mobile equipment identification.

Keywords: EEG, smart home system, system design, BCI

1 Introduction

Generally, users create their passwords by themselves, user select weak passwords for all mobile devices for easy remembrances. And also users reuse the same password for different mobile devices and mobile websites. An opponent steals the password through compromising a weak websites became users use the same password across several mobile websites. Through fishing, an opponent steal the user's sensitive information such as username, password.

Biometric is one of the authentication techniques that rely on measurable physiological and unique characteristics that can be automatically verified. A biometric system may operate either in authentication mode or identification mode depending upon the application context.

The need for highly secure identification and personal authentication technologies is becoming apparent due to the level of security. An authentication system based on EEG in mobile web services proposed in this work.

Two groups of biometric recognition tasks are identification and authentication.

If the user sample is only matched with a claimed identity stored template and is often used to access places or information when the authentication requires less computer load.

With the deepening of EEG studies, the EEG signal in a certain time there is a relatively stable, cannot easily be forged and deciphered, so more and more studies focus on whether the EEG can be used as identification of biological tools. Palaniappan is the EEG-based identification of the most active biological researchers, their main uses is called evoked potential in visual evoked potential (Visual Evoked Potential) were analyzed by neural networks and self-learning methods, and use of genetic Elman BP neural network algorithm and enhanced recognition efficiency, the highest recognition rate reached 96.63%[1-3]. In Touyama's EEG evoked potential studies, the use of the EEG characteristics of P300 as a research tool for identification, they let 9 photos randomly, the subjects selected target stimulus. Subjects selected a different target with different stimulation, which is the password of their choice. Through the PDA and the LDA analysis, and achieved 87.2% to 97.6% recognition rate [4]. Brigham, Poulos used α wave of the EEG signal as tool of identification, used the AR model for feature extraction, the final recognition rate between 72% and 84% [5-8]. K investigate the potential of using electrical EEG signals during imagined speech to identify which subject the signals originated from[9]. And in Fei Su and Bin Hu' studies provided EEG-based personal identification from proof-of-concept to system implementation is promising [10, 11].

The existing method of identify recognition based on EEG is use special EEG acquisition instrument to get EEG signal, then transmit the EEG signal to computer, and then run various algorithms on the computer. According to the results of reference, the EEG signal identification research and application based on mobiles platform is very few. The mobile platform identity and common desktop is different, the main difference lays in the brain a mobile EEG acquisition equipment precision than ordinary collecting equipment; the mobile equipment operation and software support ability than the desktop.

* ***Corresponding author's*** e-mail: huguess@21cn.com

2 Proposed system

User Authentication System based on EEG (AS-EEG) designed to generate specific EEG signature. In Figure 1, shows the AS-EEG architecture of the process.

Where the left part is the client architecture, based smart phone operating system on top of EEG recognition middleware, the middleware encapsulates all about EEG acquisition, data analysis and feature recognition, the electrode cap data interface, application programming interfaces and other functional modules isolation of hardware devices and BCI application that allows application developers do not need to learn and understand the access methods that have been brain electrode cap machining process analysis and identification process signals directly calling the middleware application interface to the results obtained through the analysis of brain wave data is processed. With these results the data, we can develop the game, EEG detection, brain pattern recognition, EEG pairing and so on.

The right part is server-side architecture, the server provides a user-centred, online payment, application downloads and other basic services, while also providing the core applications and third-party applications on the server side programs.

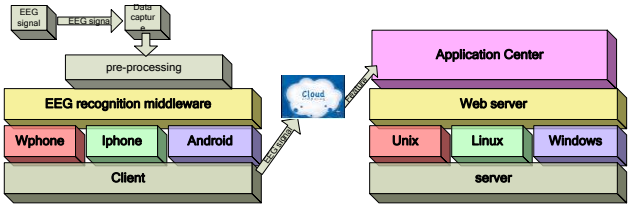

FIGURE 1 AS-EEG architecture

EEG signal: The EEG signal is used for the identification of the user of the tool, the EEG signal acquisition device of mobile devices is a portable EEG, EEG signals obtained from the EEG signal acquisition device is the original a time domain signal, if used as identification tool, must carry on the various feature extraction and classification.

EEG (EEG] is produced by the brain activity and is always present in the central nervous system of spontaneous electrical activity, rich in brain activity information is brain research, an important means of physiological research, clinical diagnosis of brain diseases. Through Brain based on the electrical signal recorded to provide clinical data and diagnosis. Therefore extracted EEG has very important clinical significance.

Identification and verification is to ensure public safety and information security an important prerequisite in national security, public security, judicial, e-commerce, e-government, security checks, security monitoring and other applications, we need accurate identification and verification. The traditional identification methods have keys, certificates, smart cards, user names, passwords and so on. However, these methods are easily lost or forged or decipher brain signals as identification tools, has its own advantages: First, it has universal, every living has EEG signal; secondly due to the characteristics of each person's brain, thinking methods, such as different memories, resulting in the presence of different characteristics between people EEG signal is be unique; third, EEG signal with stability within a certain time, EEG signal can be maintained relatively stable; fourth, EEG signal is easy to collect, there are already commercial collection devices. After years of research and development, today's EEG signal acquisition, from the original need for grounding, set the reference, coated conductive paste, complex procedures, such as installing the electrode cap, reduced to only put on a headphone-like device, you can get to corresponding EEG.

First, based on biometric systems EEG signal can reach a certain accuracy and faster speed; Second, EEG signal acquisition does not produce any harm to the human body, it is easy to accept; Third, because EEG signals from the brain thinking activities between people thinking patterns and habits are not the same, one cannot be "cracked" the individual's thinking, on the other hand, it is difficult to forge even decipher the same EEG signal, making it impossible to come by subjective fraud "decipher".

Data capturing and pre-processing: When users take a mobile EEG acquisition instrument, after the power is switched on, the EEG acquisition instrument can real-time the EEG signal is transmitted to the mobile device, the data acquisition can be used in two ways, one is passing the original signal, the second is the transfer of data must be pre-processed, the so-called pre-treatment the EEG signals, is the original time on the conversion of rejecting noise, filtering, selection and data characteristics, the signal reaches the output than the original time-domain EEG signal better for feature extraction.

EEG collected include a lot of noise, in order to better extract features and to prepare for the following calculations, this paper on the initial EEG, using scan4.3 software preliminary data processing, processing steps are as follows:

1) Removal the larger drift of EEG: the EEG acquisition process, something such as movement、inattention and outside sound will affects initial EEG great drift appear. These will affect the calculation of follow-up EEG. So during the EEG before calculated, must remove this part of the EEG.

2) Removal of EOG interference: blink or look around will affect the original EEG signals, and this effect will affect the feature extraction. So, before extract the feature, this effect must be removed. In this paper, we mainly remove the effect of vertical EOG.

3) Filter: EEG is a multi-band signal a complex mix of weak signal, depending on the intended use, different EEG frequency bands concerned, in order to be more prominent EEG frequencies used, before making use of EEG must be filtered EEG.

4) Eliminate the interference of white noise: EEG, contains a lot of white noise, before use, you must reject these white noise signal, commonly used approach is to use Hjort method, using a common electrode average method removed. The Hjort derivation C_i^H is calculated as:

$$C_i^H = c_i - \frac{1}{4}\sum_{j\in S_i} sc_j \,, \tag{1}$$

where c_i is the reading of the center electrode sc_j, with i=1,…,30 and j is the set of indices corresponding to the eight electrodes surrounding electrode c_i.

EEG recognition middleware: Middleware consists of five main modules, which electrode cap access interface module provides API functions for various types of electrode cap for data exchange, and application program interface module is to provide a series of open application layer to the external application API, the API will return directly to the desired application of various types of brain wave analysis, shielding all associated with brain-computer interface technology implementation details.

Except for the two interface modules, middleware library also contains models and algorithms library. The main purpose is to help pattern library on a specific algorithms and applications, select the most appropriate mode of its own software applications, its main operating mode is combined with an embedded algorithm based on different parameters of the user's own choice. Library is a set of algorithms for the various possible applications of the platform, including a variety of algorithms designed for a variety of practical applications, but also features such as data analysis, feature extraction, and other common underlying algorithms. The main purpose of the algorithm is based on the library user input data using a variety of data analysis algorithms library and feature extraction work. The core module is more than four modules for data exchange and processing manager, bear EEG data flow analysis, the results of the output, models and algorithms manual or automatic selection and matching, etc., the entire BCI middleware core.

Client side, Cloud and Server side: To enable multi device authentication from both PC-like and Mobile-like applications. System has been developed. For that a touch screen in the mobile is required. By this EEG signal is captured. The EEG data is captured from an application, and then it's send to another application to translate into EEG signature. EEG signature can be send to the cloud server. In the mobile device, a mobile application with Java programming environment has been developed for data acquisition.

An Apache server and Tomcat application server is used in the server side. The server modules are used to capture and pre-processing has been developed in the hypertext-processor (PHP) programming language.

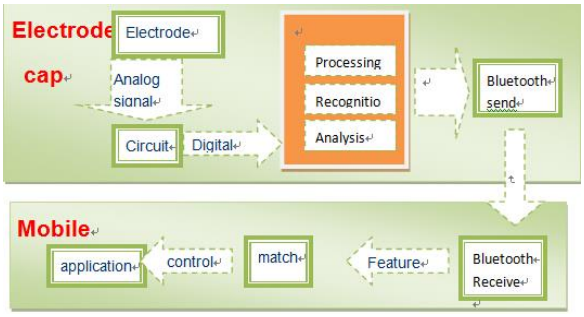

FIGURE 2 System data flow diagram

Application of the system through the information contained in the brain waves to drive the motion of its data stream as shown below, when the brain waves generated by the first brain thought scalp will cause a corresponding change in the potential of these cortical potentials changes were collected through the contact electrode, the analog signal generated in the circuit through the electrode cap analog to digital conversion, filtering, amplification processing to generate a digital signal of a specific frequency band and sampling rate, the EEG signal acquired through the EEG acquisition API function, an application Depending on the application developer needs, call the relevant arithmetic functions, the parameters set by the user through the appropriate analysis of the digital signal processing and pattern recognition, the features of the signal transmitted to the Bluetooth transmitter, via a Bluetooth connection, the program received on mobile devices Bluetooth transmission digital signal and inputs it to the signal processing and pattern recognition module, the final processing result is passed to the mode control signal to the application.

3 Practical application

The main application is to use biometric for accessing mobile devices. For example, it is used in mobile-commerce or mobile-banking etc.

In this system, mainly using EEG on mobile devices for authentication, in lieu of the original password. Using the above method, after the original EEG classification calculation, the characteristics of the user's EEG and EEG features of this stored into the database, when the user uses the mobile device, the first EEG input signal feature extraction, and then EEG database with the feature comparison, when using the right after reaching a certain tolerance, we can determine the input feature is valid, otherwise input fails. Detailed data flow diagram shown in Figure 3.

As shown in the features collection refers to the user perform several experiments, collecting user EEG, EEG features for collecting, this module includes the following major data flow:

1) Signal acquisition means that users wear portable EEG acquisition instrument EEG acquisition.

2) Classification model refers to the characteristic EEG user modelling.

3) Classification calculation refers to the EEG collected calculated EEG feature extraction users.

Database: in this case, is a local database.

Authentication: in this case primarily through the use of brain signals to the user for authentication. Signal acquisition of which is accessible online users EEG, Feature Extraction is an online collection of EEG using Feature collection process model for feature extraction; Authentication is EEG features and database features extracted by the model match calculations.

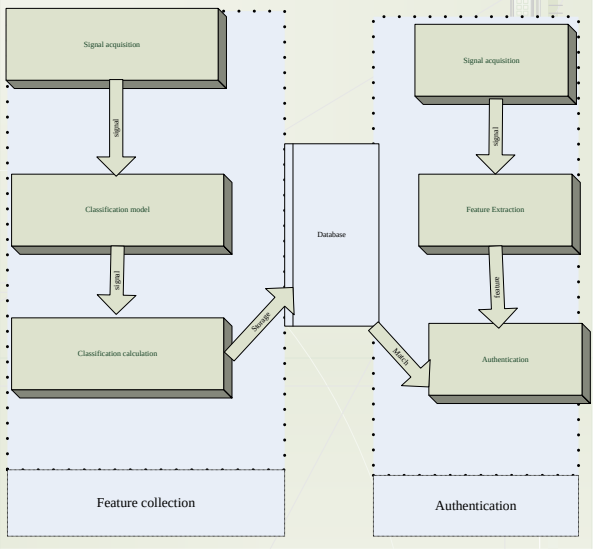

FIGURE 3 System data flow diagram

The simple application of this paper only used to a tool taking the place of password, the core of system includes classification and match.

Classification: When the EEG signal is acquired mobile devices, in order to achieve the EEG signal input to identify, must EEG feature extraction, and after feature extraction, it is necessary to establish EEG features - corresponding relationship between users, Therefore it is necessary to apply certain classification algorithm to classify the characteristics of complex calculations and population sample, thus establishing the exact characteristics - correspondence between users. The mainly step show as following:

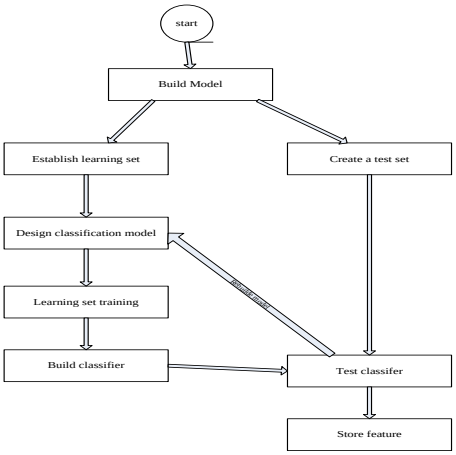

FIGURE 4 Classification

Identity recognition based on visual evoked potential in small range, feature extraction is relatively small range of subjects, in order to compare results; we also extract relative characteristics in the small scope, this paper use Fisher distance to extract relevant features, such as Fisher distance calculation formula under:

$$F = \frac{(\mu_1 - \mu_2)^2}{\sigma_1^2 + \sigma_2^2} \quad , \tag{2}$$

where F denotes the Fisher distance matrix, μ and σ respectively, the mean and variance.

Wavelet analysis is a rapidly developing new collar domain in mathematics, which has both theoretical significance and profound and extensive application. The concept of wavelet transform is by French engineers engaged in J. Morlet oil signal processing is first proposed in 1974, by physical intuition and signal processing of the actual need to experience established inversion formula, it and Fourier transform, window Fourier transform (Gabor transform), this is a time and frequency domain transform, and so can effectively extract information from signal, multiscale analysis of functions or signals through extension and translation operations (Multiscale Analysis), solves many difficult problems cannot be solved by Fourier transform, and wavelet transform is known as "mathematical microscope", it is the milepost type harmonic analysis in the history of the development of. The properties of time is constant, the ideal tool for processing is still Fu Liye analysis. But the vast majority of signal in practical application is not stable, and is especially suitable for non-stationary signal is wavelet analysis tools.

Signal continuous wavelet transform for $f(t)$:

$$WT(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} \varphi(\frac{t-b}{a}) dt, a \neq 0 \ , \tag{3}$$

where $\varphi(t)$ is the mother wavelet, a is a scaling factor, B is the translation factor. If a=2, the translation factor b=2k; then the discrete wavelet transform into Equation:

$$WT(a,b) = \int 2^{-i/2} f(t)\phi(2^{-i}t - k)dt, \ j,k \in Z \ . \tag{4}$$

The wavelet decomposition of the signal is decomposed into low frequency and high frequency signal, frequency information is slow to change part, accounted for most of the information of all the high frequency information; is a small part of the total part of rapid change of information. The above is the first layer decomposition. Based on the first floor of the high-frequency information part is divided into two parts: low frequency and high frequency. The third layer is the decomposition of high frequency information of second layers separated into low frequency and high frequency.

Multilayer back-propagation neural networks were trained to classify any two of the four classes' motor imagery EEG. The two classes were coded by 1 output unit. The hidden layer consisted of 20 units. The input layer had 200 units, 100 representing a channel and 100 for another.

The traingdx learning algorithm has been used to train the network, which uses gradient descend with momentum and variable learning rate in batch learning mode. Gradient descend with momentum can avoid a shallow local minimum and a variable learning rate can make the

learning as fast as possible while maintaining stability. The batch learning was used to update the network weights after all training data was presented.

Matching step occurs during the use phase, users of mobile devices before using EEG identification system for pre-EEG feature extraction and classification for the purpose of calculating the establishment features - correspondence between the user during use, the mobile device a correspondence between the calculated matching users, and ultimately calculate the corresponding EEG users matching algorithm to measure the pros and cons - the real-time collection of user performs EEG, bring out the collected EEG features, and based on the characteristics indicator is the matching accuracy. In order to improve the accuracy and speed of matching users to extract EEG reduction processing performed for different users, create different classifiers.

Matching step occurs in the online course, assuming that the online collection to the user EEG. After feature extraction, electrical characteristics of time series on the brain get set $A_{real}=\{Ar_1,Ar_2,\ldots,Ar_i\}$, EEG corresponding user features in the offline processing sample set Boff, Boff=$\{Bo\}i\times n$. This paper setting matching threshold q=0.005, That match error in the q range, the calculation of a match. Matching ϖ is calculated as follows:

$$\varpi = \left| Ar_i - \frac{1}{n}\sum_{x=1}^{n} Bo_{ix} \right|. \tag{5}$$

Matching is used to calculate the collected EEG features meets validation requirements, matching σ is calculated as follows:

$$\sigma = \frac{\sum_{x=1}^{i} \varpi_x}{i}. \tag{6}$$

With the above method, the seven subjects verified, during a number of EEG is collected five subjects can be confirmed, two subjects could not be identified, as shown in Figure 5.

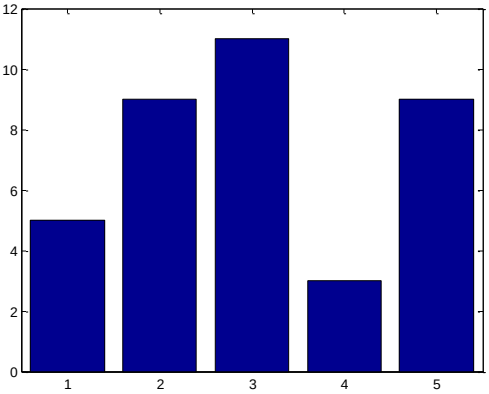

FIGURE 5 Subjects identification number

Acknowledgments

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).

References

[1] Palaniappan R, Mandic D P 2007 EEG Based Biometric Framework for Automatic Identity Verification *The Journal of VLSI Signal Processing* **49**(2) 243-50

[2] Palaniappan R 2004 Method of identifying individuals using VEP signals and neural network *IEEE Proceedings - Science, Measurement and Technology* **151**(1) 16-20

[3] Palaniappan R 2006 Electroencephalogram signals from imagined activities: a novel biometric identifier for a small population *Intelligent Data Engineering and Automated Learning (IDEAL), Lecture Notes in Computer Science* **42**(1) 604-11

[4] Touyama H, Hirose M 2008 Non-target photo images in oddball paradigm improve EEG-based personal identification rates *Annual International Conference of the IEEE Engineering in Medicine and Biology Society* **1**(41) 18-21

[5] Poulos M, Rangoussi M, Kafetzopoulos E 1998 Person identification via the EEG using computational geometry algorithms *Proceedings of the 9th European Signal Processing (EUSIPCO '98)* 2125–8

[6] Poulos M, Rangoussi M, Chrissikopoulos V, et al. 1999 Parametric person identification from EEG using computational geometry *Proceedings of the 6th International Conference on Electronics, Circuits and Systems (ICECS '99)* 1005-8

[7] Poulos M, Rangoussi M, Alexandris N, et al. 2001 On the use of EEG features towards person identification via neural networks *Medical Informatics & the Internet in Medicine* 26(1) 35-48

[8] Poulos M, Rangoussi M, Alexandris N, et al. 2002 Person identification from the EEG using nonlinear signal classification *Methods of Information in Medicine* **41**(1) 64-75

[9] Brigham K, Kumar B V K V 2010 Subject identification from electroencephalogram (EEG) signals during imagined speech *Biometrics: Theory Applications and Systems (BTAS), 2010 Fourth IEEE International Conference* 1-8

[10] Su F, Xia L, Cai A, Wu Y, Ma J 2010 EEG-based Personal Identification: from Proof-of-Concept to A Practical System *Pattern Recognition (ICPR), 2010 20th International Conference* 2 3728-31

[11] Hu B, Liu Q-y, Zhao Q-l, Qi Y-b, Peng H 2011 A Real-Time Electroencephalogram (EEG) Based Individual Identification Interface for Mobile Security in Ubiquitous Environment *Services Computing Conference (APSCC) 2011 IEEE Asia-Pacific* 436–41

[12] Wang J F, Fan X L 2011 Scheduling for the flexible Job-Shop Problem Based on a Hybrid Genetic Algorithm *Sensor Letters* **9**(4) 1520-5

[13] Wang J F, Chu K Y 2012 An Application of Genetic Algorithms for the Flexible Job-shop Scheduling Problem *International Journal of Advancements in Computing Technology* **4**(3) 271-8

[14] Jiang D 2011 Study on Auxiliary Game Platform based on PC and PDA *AISS* **3**(7) 287-95

Authors

Jianfeng Hu, 07.07.1976, China.

Current position, grades: professor of Jiangxi University of Technology, China.
University studies: Ph.D. degree in Neurobiology from Chinese Academy of Sciences, China in 2002.
Scientific interest: EEG signals analysis and car security.

Zhendong Mu, 01.11.1975, China.

Current position, grades: researcher at Jiangxi University of Technology, China.
University studies: M.E degree in computer science and technology from Nanchang University, China in 2004.
Scientific interest: information security, algorithm design and EEG analysis.

Jinghai Yin, 28.01.1977, China.

Current position, grades: researcher at Jiangxi University of Technology, China.
University studies: M.E degree in computer science and technology from Nanchang University, China in 2005.
Scientific interest: information security, algorithm design and EEG analysis.