

## Research of Brain-computer Interface Technology Based on LabVIEW

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### Abstract

*The research adopts the classical visual evoked potentials paradigm, designs the stimulation program and experimental scheme base on the labview platform,and the way of visual stimulate is studied in this paper.In this way we can produce event-related potentials more effectively . On the platform in labview,achieve the event-related potential signal acquisition and processing.Explore how extract the weak signal event-related potentials in the background of strong noise rapidly and accurately,and structures based on event-related potentials of the brain machine interface platform.*

### 1. Introduction

Brain-computer interface (BCI) is the "brain - computer interface is an output channel communications system that not dependent on the normal peripheral nervous system and muscle tissue composition "[1].Over the last 10 years, BCI technology has advanced by leaps and bounds development ,its technical coverage brain science, cognitive science, signal processing technology, pattern recognition technology, control planning, computer interface, computer control, and many other fields in

which science and technology Comprehensive Application of the direct manifestation.Its important scientific significance and its academic value lies the research and development process contribute to the brain cognitive model, and the control of information flow in-depth understanding, as well as Reading and brain mode of thinking and awareness to provide new channels and methods for the formation[2][3].

The first BCI International Conference ,according to the nature of the input signalBCI system is divided into two broad categories, namely: The use of spontaneous EEG systems and the use of evoked EEG BCI system.The use of spontaneous EEG systems is the one use spontaneous EEG characteristics as the input signal, which was characterized by, the subjects were trained to independently control EEG changes to the direct control of the external environment, but usually the need for volunteers do a lot of training and the subjects of the system vulnerable to physical condition, emotional illness, such as the influence of various factors. the use of evoked EEG use external stimulate, and the corresponding parts of the cerebral cortex induced electrical activity changes, and was used as signal features. External stimulate BCI system does not require too much training of external evoked on the subjects, but needs of specific environment

This paper based on the LabVIEW platform designed visual stimulation, and visual stimulation to study ways to stimulate the model can produce more effective event-related potentials. LabVIEW platform in the realization of the event-related potential signal acquisition and processing. Explore how strong noise in the context of rapid and accurate extraction of the weak signal event-related potentials and structures based on event-related potentials of the brain machine interface platform.

P300 is an event-related potentials (ERP), the peak appears in about 300 ms after the incident, the smaller the probability of incidents related to be, the more notable P300 be caused.

The research adopted the classical visual evoked potentials paradigm, designed the stimulation program and experimental scheme base on the labview platform, and the way of visual stimulate was studied in this paper. In this way we can produce event-related potentials more effectively. On the platform in labview, achieve the event-related potential signal acquisition and processing. Explore how extract the weak signal event-related potentials in the background of strong noise rapidly and accurately, and structures based on event-related potentials of the brain machine interface platform.

## **2. P300 brain machine interface technology based on event-related potentials**

### **2.1. Event-related potentials P300**

P300 is a positive later component of event-related potential, is found by Sutton in 1965. P300 which is the third positive wave P3 of Late component, as the P3 was found in about 300 ms of the wave, so called P300, P300 is the most classics, and found the earliest and most extensive study of ERP. Mainly reflecting on the external information of the cognitive process, it is an endogenous cognitive function associated with the

mental state of the trial, attention and psychological factors.

P300 metrics as other general evoked potentials which is mainly latency and amplitude, latency is a indicators which reflect the human brain stimulation judgement time. Generally it is 300 ~ 900 ms. Donchin scholars think that the P300 latency memory reflects occasions updates on the speed and stimulate the identification of the selection process. Fluctuate depending on the subjects on the occasion of updating, and that the more obvious P3 wave, the greater the amplitude, and its contents were also remembered better. P300 scalp widely distributed, and waveform obviously distributed in the parietal lobe most near the center line. Relatively concentrated in the middle part (Fz, Cz, Pz, Oz), the volatility is in the top rear (Pz) the largest and the Central top (Cz) followed by[4]. Using auditory, visual or physical stimulation can induce P300, but the latency and amplitude are differernt. In addition, the P300 is strictly a lock of which is the most notable features.

### **2.2. Design of P300 visual stimulator based on virtual instrument**

**2.2.1. Implementation of P300 visual stimulator.** The graph stimulation usually is produced through the hardware and the software on the computer monitoring device or the television. the vision evoked potential stimulator in The clinical examination mostly uses the hardware to realize the graph stimulation. Uses the hardware to realize the graph stimulation, its biggest merit is the stable property, but revision and upgratde is difficulty. Sutter, etc. when design based on vision evoked potential brain machine connection, also selected the hardware method to realize the stimulator, but if, once needed to revise the stimulation intersurface or change function, then needed to improve even redesign circuit boards related the stimulation, (it)was very inconvenient. At present, software-based approach also has been researched,

mostly visual stimulation has been achieved in the DOS environment and the use of TurboC Programming in graphics mode (640 × 480) in addition, under the Windows environment, realized the graph stimulation with the VisualC ++ programming also already to have the research.

The typical model of the P300 signal is the Oddball experiment pattern (Oddball Paradigm), which is also called the P300 model. The Oddball experiment pattern is refers to uses two kind or many kinds of different stimulations continues to present alternately, they appear probability remarkable different, the stimulation appears frequently is called the big probability or the standard stimulation (Standard Stimuli), accidentally appears is called the small probability or the deviation stimulation (Deviant Stimuli). Makes to carry on trying to response to the deviation stimulation , therefore this deviation stimulation is called the target stimulation (Target) or the goal stimulation. This is also the commonly used classics experiment pattern induces ERP ingredient related other the stimulation probability.

The platform of BCI tests this research institute discusses is based on the hypothesized instrument technology construction, and in the software and hardware platform the NI Corporation developed. The software uses the LabVIEW programming, the hardware is based on the PXI 8 slot engine case, which contains the PXI-8187 controller, PXI-6024 multi-purpose I/O, PXI-5102 high performance oscilloscope, the PXI-1422 image gathering card, PXI-7344 movement control card and other modular instruments. the stimulator take the P300 classical model as a template, has the effective visual stimulation function. second, 36 character options represent the separately different choice or the control signal which the user possibly makes. In addition, the stimulator take the software as a foundation, can have many kinds of different stimulation patterns, easy to revise and upgrade, may adjust to the easiest pattern to users to accept. Like Figure 1 show, for visual

stimulator's front panel, here for initialization condition.

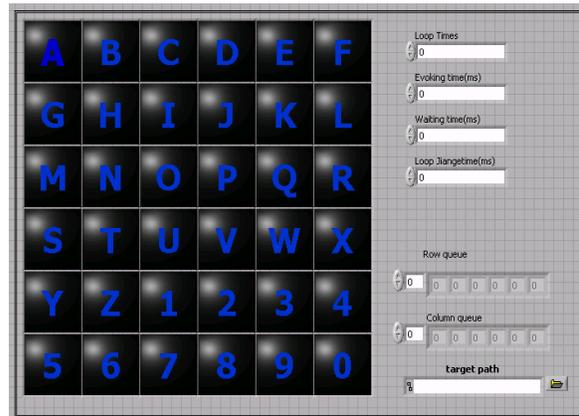


Figure 1. **P300 visual evoked initialization state**

As figure above Figure 1 show, what presents in front of in receives trying is one includes 36 unit character tables for six to six row matrices. The stimulation produced through adds the bright character table stochastically some line or some row obtains. This is a typical P300 model, trying may express a string of character information through the computer. It is similar the event related electric potential inspection on clinical, what trying facing is a computer screen, which gives the Oddball stimulation sequence. the experiment requests trying to concentrate the attention to the unite include the character he or she want to express, and count to the bright times of this unit . Therefore when the line or row does not include this character is bright, because which does not belong the trying's attentional object, therefore constituted stimulation will be non-target stimuli, but when the line or the row includes this character is bright, which constituted the target stimulation, at the moment trying were asked to respond. In each experiment appearance probability of the target stimulation is 16.7%, the non-target stimulation appears is 83.3%. The low probability appearance of the target stimulation can induce cognition electric potential ingredient P300. In experiment, trying presses a key as soon as possible or memory its number after discovery goal stimulation,. This time the goal stimulates get into the target

stimulation ,and after the target stimulation appearance approximately 300ms observes a positive wave, which is P300. Therefore, so long as can determine the time this P300 ingredient appears correspond which stimulation (i.e. which line or which adds brightly) appears, can determine the character trying paid attention to .thus achieves the goal of communication.

**2.2.2.Stimulator control time confirms.** The vision stimulator is the first link based on the vision evoked potential BCI system, which is significant to realize the goal function and achieve the good effect relations. Whether does the stimulator defer to a control request to provide the strict time corresponding relationships, which is needs to confirm. This research joins the system time-monitor to VI in the program, thus monitor stimulator’s running time. This time-monitor VI is laid aside in the cycle program for recording each the system time by the array form of minor cycle start time, pre and post data’s difference namely for oprating time segment of neighboring minor cycle program.

By calculating, we can see that each circulation's ideal running time is:  $(50\text{ms}+550\text{ms}) \times 12=6000\text{ms}$ . from the empirical datum, we know except that the first line /row running time has the deviation ,then the time-gap of adjacent cycle operation fixed to 6000 ms,the labratuing is the time sum of “Evoking time” and “Waiting time”.

### 3.BCI system based on the P300

#### 3.1.BCI system experimental platform

Based on the P300 BCI experimental platform, the function is that selecting the character by EEG, and the output displayed on the computer screen. Block diagram of experimental platform Figure 3 indicated. Experimental Platform system can be divided into the following four modules: visual stimulation modules, EEG acquisition module, EEG processing module and character output interface. From Figure 2 can be seen,

signal acquisition module includes three steps, mining EEG from the scalp electrode, the EEG go through amplifier and signal acquisition card into the computer.

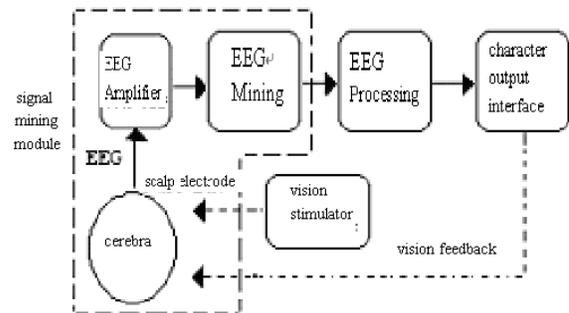


Figure 2. **Experimental platform system module chart**

Signals of the brain be processed complex in the LabVIEW software platform, extracted P300 evoked EEG, then to determine the objectives of the subjects characters, the last characters be output on BCI interface.

The hardware platform including the external EEG amplifier, PXI chassis, signal acquisition cards, as well as various terminal annex.All programs are written by LabVIEW.

#### 3.2.EEG Acquisition

**3.2.1.Signal acquisition hardware.**The function of EEG acquisition is to send brain signals which be collected from scalp to a computer,and provide stable and reliable source. The main functions of EEG acquisition depended on hardware , hardware scalp electrode, EEG preamplifier and signal acquisition cards. Because EEG amplitude range  $-100$  to  $+100 \mu V$  between  $\mu V$ , it is necessary to enlarge them.

Data acquisition card send the data to the computer under synchronous acquisition mode. PXI-6070 precision-acquisition card, a 16-channel analog input, two analog outputs, eight digital I / O, a timer / counter, as well as digital I / O multifunction data acquisition cards, a high-performance data acquisition capability, 12 input and output resolution, a

maximum sampling rate of 125 MS / s, the output speed of up to 1 MS / s, the signal input range of  $\pm 0.05$  to  $\pm 10V$ .

**3.2.2. signal acquisition of software.** Software is the most important part of The experimental platform, except some hardware which collected data, other functions are achieved on LabVIEW platform. LabVIEW as a powerful software program ,it can reduce the workload and more appropriate to achieve the design intent. Since the actual collection is the one mining a large number of continuous signals from multiple channels,so it must use intermediate programming analog input VI. Figure 3 shows the acquisition process flow chart. Procedures implemented in the following order, first of all, the hardware and software equipment Initialization (AI Config.vi), and then start the analog input (AI Start.vi), and then start reading data from multiple channels (AI Read.vi) , two-dimensional arrays of data to the structure of transmission data processing module (Data Process), after the completion of treatment, and also the end of the analog input operations (AI Clear.vi). In addition, the continuous acquisition, it needs to be helped to achieve circulatory function. Upon completion of acquisition, in order to carry out off-line analysis of the data, increase data storage procedures Module (Data Storage), the data from the buffer to read out after the text of the document was deposited.

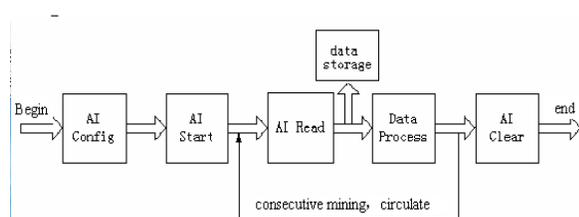


Figure 3. Acquisition program flowchart

## 4. EEG processing

### 4.1. EEG Pretreatment

In the pretreatment, we use filtering and wavelet transform to eliminate low-frequency trends, the baseline drift, and eyes, pseudo-noise pseudo-track and other tracks. At this time, for the non-smooth transition EEG, the Fourier spectrum analysis was limited by time domain can not processing signals effectively. of course, can also use the traditional method to eliminate noise filtering denoising[5]. but since the low-pass characteristics of Filters, therefore, we can also use the classic method of filtering non-stationary signal denoising, reducing noise when broadening the waveform smoothing mutation in the peak of the signal components, excessive use of it may lost the point which may carry important information. The wavelet transform is a time-frequency analysis method which combine time domain and frequency domain[6], in the time-frequency domain signal has the ability of characterized local features. it can overcome the deficiencies of above two methods ,can effectively remove all kinds noise, extracted from EEG time-varying information.

### 4.2. P300 Feature Extraction

In the BCI P300 system which based on event-related potentials, using three methods to extract P300 signal.

**4.2.1. Peak extraction.** Peak extraction method is a conventional extraction P300 peaks methods, in procedures, we used the signal processing template peak capture Waveform peak Detection.vi, the VI is based on the peaks and the second fitting trough testing procedures. Figure 4 peaks capture procedures shown , input signal, setting the threshold value (threshold) and width (width) by the location of the peak or trough, amplitude, and peak / trough collection point second derivative. Width port settings for the least-squares fitting the number of data points, the width can not be

larger than the width of the peak or trough half, if the General Assembly so as a position offset by inaccurate data.

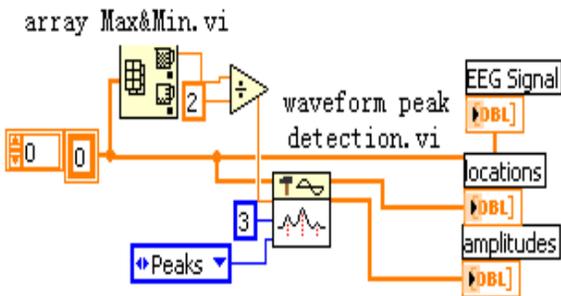


Figure 4. Peaks capture procedures

The collected EEG data which be mined from the experiment is an example in Figure 3 - 7 shows, it is a pretreatment EEG data which prolong 3.6 seconds. Because the sampling rate is 250 Hz, so there were 900 points. Set thresholds as the half of maximum of the EEG data, set width of 3, detect the peaks of the signal. After the peak detection, obtain Figure 5 EEG peaks plans, as Figure 6 below. After the peak detection, gain 75 points of peak. Because of the use of secondary peak detection algorithm, the location of the peak corresponding peaks is not the actual location of the peak position, the threshold can be convert by using the following formula:

$$\text{Time Locations}[i] = t0 + dt * \text{Locations}[i] \quad (1)$$

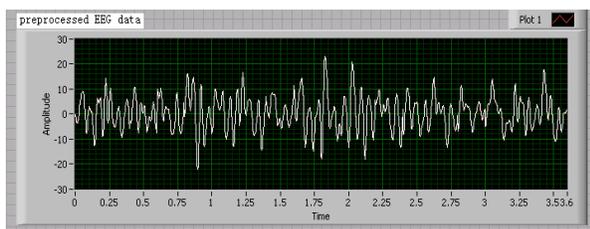


Figure5. 3.6 seconds after the pretreatment EEG data

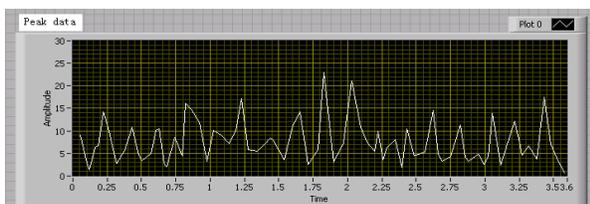


Figure6. EEG data preprocessing peak map

**4.2.2. Correlation analysis method.** This experimental use of the cross-correlation function to calculate the similarity of two signals. Use P300 signal that has been processed by typical average as a standard sample. Judge the similarity between analyze signal and the signal standard VEP, the higher the similarity, the more possibility of higher VEP.

After the state for the random process,  $x(t)$  and  $y(t)$  cross-correlation function  $R_{xy}(\tau)$  as:

$$R_{xy}(\tau) = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T x(t) y(t + \tau) dt \quad (2)$$

**4.2.3. Wavelet analysis.** Noisy signal was decomposed by multiresolution wavelet transform, obtain the dispersion coefficient and the details of discrete approximation factor. In this paper, using wavelet analysis feature extraction P300 signal from the basic idea is wavelet decomposition of low-frequency scale testing positive wavelet coefficients. In order to test the validity of the above conclusion, the following make an experimental waveforms collected as an example to illustrate the use of a period after the pretreatment length of 3.6 seconds waveform, as Figure 8 shown. The length of the waveform from 6 to 0.6 seconds subparagraph waveform composition, each 0.6 seconds waveform represents a different character of this waveform including a P300 response waveforms goals and 5 of the non-response target P300 waveform. P300 target because response has been predictable waveform position, the interception of the waveform, and the interception of a period of non-P300 response samples, the use of these two sections respectively Db4 wavelet waveform wavelet decomposition, the observed decomposition-scale wavelet coefficients.

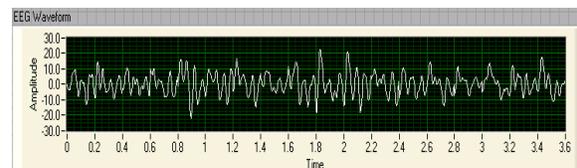


Figure7. 3.6 seconds after the pretreatment waveforms

## 5 .Systems test

### 5.1.Wavelet transformation to eliminate baseline wander .

In this experimental platform the eeg signal's pretreatment process including four steps: The low-pass filtering, the wavelet transformation eliminate the baseline wander, the single division/blocking and the wavelet denoising. the assemble primitive eeg signal which passed through the low-pass filtering still had the quite obvious baseline wander. this is caused by the receptor breath. The second step of signal pretreatment is uses the wavelet to hasten VI eliminates the baseline wander, In the experiment process, we needs to establish a key parameter tendency level (trend level), this parameter decide wavelet decomposition's level, the value scope is: 0~1. Along with its value's increase, obtains the signal eliminated the tendency and the input signal similar degree reduces gradually, but the other behind tendency is getting more and more similar with the input signal. If the tendency level is too small, then cannot eliminates the baseline wander, if chooses too big, then has the possibility to eliminate the low frequency wanted signal.

Effect eliminated the trend for brain wave passed by filter in the different tendency level(0.2,0.3,0.5). Each subgraph contains 3 curves, the white curveis brain wave shape passed by filter, the red curve expressed wave eliminated the tendency under the corresponding tendency level, the green curve for the eliminated tendency. After tests many times ,we discovered that this parameter's establishment also needs to consider the sampling time and sampling number when actual eeg signal gathers. When the sampling frequency is 250Hz, 0.35 can be well to this parameter to eliminates the trend.

### 5.2 .Threshold value's selection

It is a efficient algorithm to based on the wavelet transformation's denoising to removes artifacts in the digital signal . principle of this method is: Selects an appropriate threshold value, and carries on the interruption with this threshold value to each wavelet space's detail wavelet coefficient after wavelet decomposition .but maintains in the criterion space the approximate coefficient is invariable, then carries on the inverse transformation again, after then obtains the denoising signal. In the practical application, this misalignment denoising method has two questions to need to solve, one is the threshold threshold value selection, another is the determination of threshold value readjustment method. This experimental platform uses the soft threshold value to eliminate artifacts in the high frequency criterion, uses the hard threshold value law to eliminate the eye electricity false mark in the low frequency criterion.

In wavelet transformation, soft threshold value law including four kind of threshold value selection criterion: Valves for general use value criterion (sqrtwolog criterion), agonic risk threshold value criterion (rigrsure criterion), mixed threshold value criterion (heursure criterion) and maximum and minimum valve value criterion (minimaxi criterion).

The general threshold value criterion (the sqrtwolog criterion) uses the fixed threshold value form, the threshold value size determined through the below formula:

$$Th_1 = \sigma \sqrt{2 \ln(n)} \quad (3)$$

In the formula, Sigma is the noise standard variance, n is the length of high frequency wavelet coefficient.

The agonic risk threshold value criterion (the rigrsure criterion) uses Stein the agonic likelihood theory to carry on the auto-adapted threshold value choice, which is a soft threshold value selection method to assigns threshold value T to carry on the likelihood estimation, and to the non-likelihood

estimation T carries on the minimum to select the threshold value. The mixed heuristic threshold value method (the heursure criterion), uses the most superior forecast variable to carry on the threshold value choice, is suitable for the situation with big noise, low signal-to-noise ratio. The maximum and minimum valve value criterion (the minimaxi criterion) uses the minimax principle to have the threshold value. it is a threshold value selection way based on statistics in extreme value estimator principle to has an extreme value by taking the smallest mean error as the objective function.

After threshold value designation, whether the threshold value each formation number uses does need to readjust is the threshold value readjustment method. This method is to computeate product factor so as to update the threshold value. This parameter choice dependent on noise nature. If the noise is the standard white gaussian noise or it's chirp wave proportion is 1, establishes the product factor on all levels is "one"; If the noise for the Gauss noise, but chirp wave proportion is not 1, then establishes as "sln"; estimated that the product factor on first according to the detail partial coefficients and applies it in all levels; If the noise is not a white noise, then establishes as "mln", because of non-white noise chirp wave proportion is related each other, therefore needs to estimate product factor layer upon layer.

On this experiment platform, when denoising processing, we uses heursure and the mln readjustment method in the high frequency criterion. that can achieve the good denoising effect. Heursure is compromised method between the rigrsure method and the sqtwolog method. We use the hard threshold value law in the low frequency criterion, the threshold value is determined by the formula  $E_0 = r\delta_0$ ,  $E_0$  is the signal expected value,  $\delta_0$  for the signal standard variance,  $r$  is the threshold value coefficient. The threshold value coefficient  $r$  scope is  $1 < r < 3$ . we can adjust  $r$  according to the system and the experiment situation.

This experiment uses the simulation method to

confirm advantage and disadvantage of each threshold value. Selects a section of eeg of non-P300 response, then by different singal noise radio mix respectively with a model P300 wave to constitute the analytical simulated data. Carries on denoising processing separately again to it under each kind of threshold value establishment, compare the change of the signal-to-noise ratio after denoising, and uses the root-mean-square error (RMS) to discuss the relevances of two signals. Following table2 shows. We can see from the data result, when the signal-to-noise ratio is small, some denoising method has an bad effect, but effec of this method in this article is good.

Table 2. **Under the rules of different threshold effect compared denoising**

SNR (Db)		-2	5	10
The SNR after denoising / RMS error	Sqtwolog rule	0.6546/2.8354	9.0532/1.3454	20.2046/0.6454
	Rigrsure rule	0.6546/2.8354	9.0532/1.4454	20.9382/0.6240
	Heursure rule	6.1870/1.6420	8.3675/1.0531	20.4381/0.6454
	Minimaxi rule	5.4691/1.6647	8.9095/1.2852	20.4195/0.6012
	The method of this research	8.3256/1.2483	8.4721/1.2936	22.1038/0.4533

### 5.3. Compared of feature extraction method

This article to use three method of signal extraction to carry on the pattern recognition, passed through tests repeatedly to compare these three methods, the method of wavelet transformation better than the other two methods obviously, and the accuracy is high. All of experiment of this research institute completes by the non-specialty trying under the non-shield environment. The receptor brain imposition tradition's silver chloride electrode and completed the experiment strictly according to the laboratory procedure. Is been in the attention, when receptor is centralized and not yet weary condition, the peak value extraction process accuracy is high, if centralized is not

too stable, and has disturbance of the eye moved or the forehead muscle, the peak value method effect greatly will reduce. The correlation coefficient method has great change with difference individual. This is because uses the unitary sample profile form in the procedure, but P300 characteristic of different receptors are different under the dissimilar condition, the identical sample profile cannot satisfy the demand of dissimilar condition. Different with above two string analysis method, the wavelet method of transformation is a misalignment analysis method, its multi-resolution causes the probability to observe the signal characteristic under the different criterion, the small degree of distortion also enables the signal the partial characteristic to be able to preserve. In analysis low eeg signal of time-variable and low signal-to-noise ratio, the wavelet transform method has surpassed the above two methods.

## 6. Conclusion

This research build a brain machine connection testing platform to use in the character exchange which based on P300 in the LabVIEW platform, we try to use hypothesized instrument concept realize the overall system, and, realize event related electric potential signal gathering and processing in the platform, discussed to withdraw the weak vision evoked potential signal accurate and fast under the strong noise background. This article uses three feature extraction method carries on the pattern recognition, and does the massive experiment contrast, confirm the method of uniting the wavelet transformation and the statistical to determine the P300 component compare the forward coefficient in 300~600ms in the low band limits, which has the high accuracy.

This research is develops in the traditional Oddball experiment model foundation[8], therefore it is essential to improve the stimulation pattern, and uses the compound stimulation pattern, which reduces the running time of command control cycle effectively;

On the other hand, it is necessary to improve the testing plan, seeks for the more highly effective security novel experimental pattern.

## 7. Acknowledgement

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