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(54) **SYSTEM AND METHOD FOR PERSON IDENTIFICATION AND PERSONALITY ASSESSMENT BASED ON EEG SIGNAL**

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(Continued)

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CPC **G06K 9/00885** (2013.01); **A61B 5/04012** (2013.01); **A61B 5/0476** (2013.01); **A61B 5/0478** (2013.01); **A61B 5/117** (2013.01);

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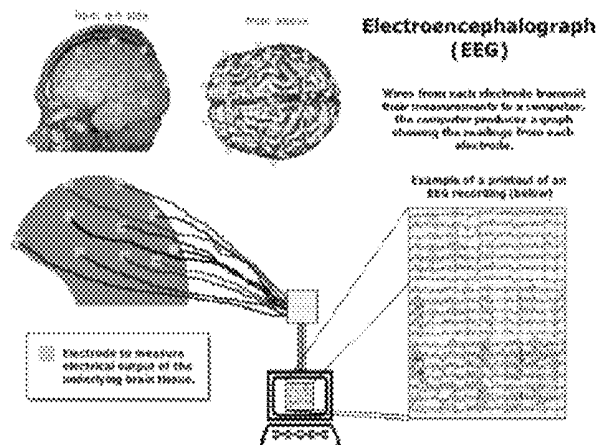
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(57) **ABSTRACT**

The present invention relates a novel system and method for person identification and personality assessment based on electroencephalography (EEG) signal. More particularly, this invention relates to a novel method of EEG recording and processing to map the inherent and unique properties of brain in the form of highly specific brain signature to be used as means for person identification and personality assessment.

17 Claims, 6 Drawing Sheets



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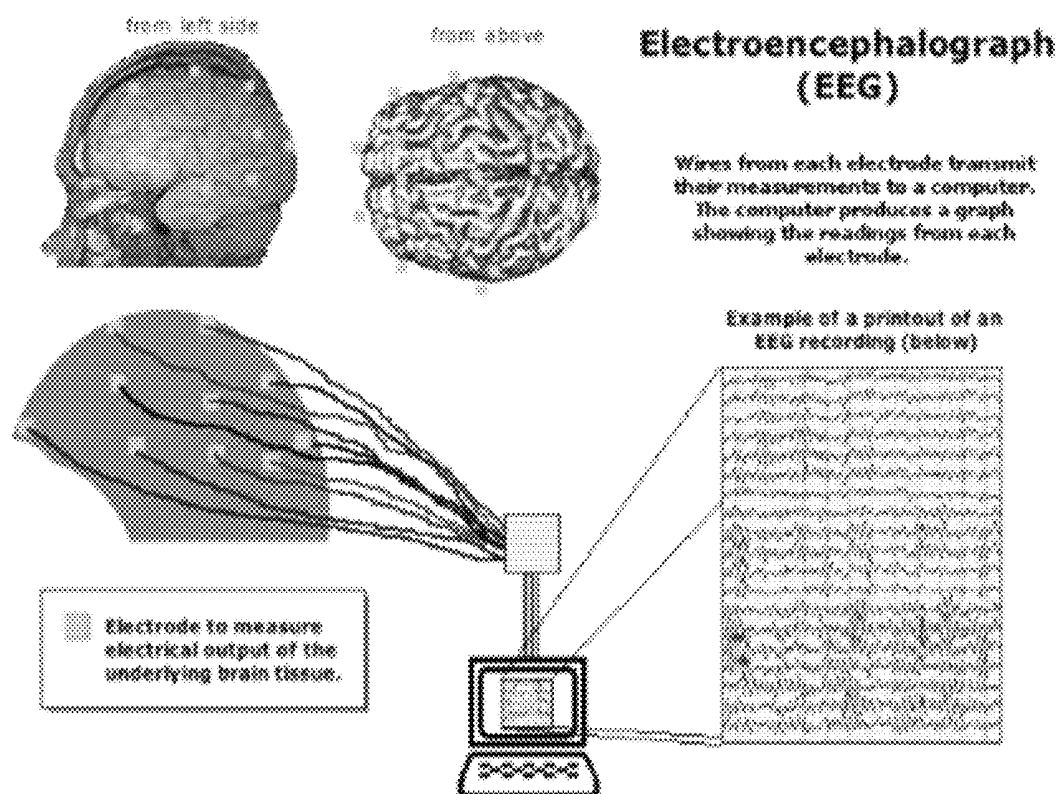
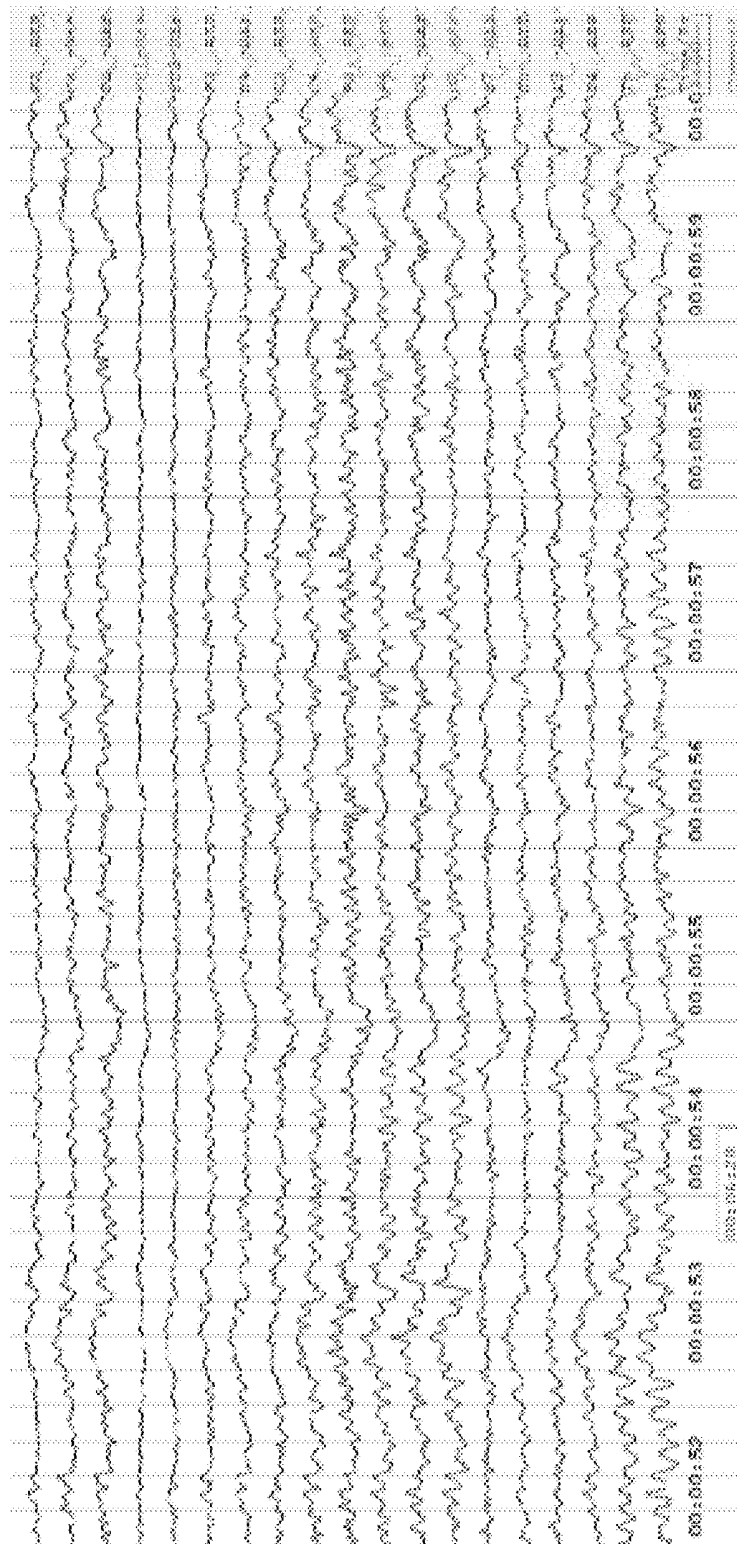


FIG. 1

**FIG. 2**

	338 77	338 78	338 79	338 80	338 81	338 82	338 83	338 84	338 85	338 86	338 87	338 88	338 89	338 90	338 91	338 92	338 93	338 94	338 95	338 96	338 97	338 98	338 99	339 00	339 01	339 02	339 03	339 04	339 05	339 06	339 07	339 08	339 09	339 10	339 11	339 12	339 13	339 14	339 15	339 16	339 17	339 18	339 19	339 20	339 21	339 22	339 23	339 24	339 25	339 26	339 27	339 28	339 29	339 30	339 31	339 32	339 33	339 34	339 35	339 36	339 37	339 38	339 39	339 40	339 41	339 42	339 43	339 44	339 45	339 46	339 47	339 48	339 49	339 50	339 51	339 52	339 53	339 54	339 55	339 56	339 57	339 58	339 59	339 60	339 61	339 62	339 63	339 64	339 65	339 66	339 67	339 68	339 69	339 70	339 71	339 72	339 73	339 74	339 75	339 76	339 77	339 78	339 79	339 80	339 81	339 82	339 83	339 84	339 85	339 86	339 87	339 88	339 89	339 90	339 91	339 92	339 93	339 94	339 95	339 96	339 97	339 98	339 99	340 00	340 01	340 02	340 03	340 04	340 05	340 06	340 07	340 08	340 09	340 10	340 11	340 12	340 13	340 14	340 15	340 16	340 17	340 18	340 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FIG. 3

	1	2	3	4	5	6	7	8	9	
1	1013.035	772.4686	1010.943	1306.416	1069.249	1126.309	994.4431	962.749	983.8137	C1
2	772.4686	930.7475	958.2692	1371.434	905.3931	1029.344	750.9833	836.0429	786.7128	Fp2
3	1010.943	958.2692	1322.706	1629.754	1301.435	1363.969	1142.621	1096.675	1115.698	F4
4	1306.416	1371.434	1629.754	2368.216	1694.967	1831.514	1461.635	1495.445	1403.401	F8
5	1069.249	905.3931	1301.435	1694.967	1685.329	1566.096	1451.442	1331.021	1412.942	C4
6	1126.309	1029.344	1363.969	1831.514	1566.096	1734.303	1450.451	1422.764	1381.981	T4
7	994.4431	750.9833	1142.621	1461.635	1451.442	1450.451	1612.988	1361.478	1497.77	P4
8	962.749	836.0429	1096.675	1495.445	1331.021	1422.764	1361.478	1559.591	1265.041	T6
9	983.8137	786.7128	1115.698	1403.401	1412.942	1381.981	1497.77	1265.041	1617.576	O2
	C2	Fp2	F4	F8	C4	T4	P4	T6	G2	

FIG. 4

Eigenvalues	42.3642	103.267	104.553	118.394	157.355	148.753	347.972	371.652	31703
Eigenvectors	0.01475 -0.9855 0.1141 0.4098 -0.1814 0.03534 -0.457 0.11623 0.38023	0.34436 -0.0802 -0.0303 0.1484 0.0240 0.13024 0.07913 -0.1836 -0.0934	0.01131 -0.1829 0.06674 0.36626 0.13717 -0.7738 0.37123 0.0819 -0.235	0.05354 -0.25512 -0.1834 -0.1586 0.58418 -0.3605 -0.3056 0.74498 0.1813	-0.798 0.13326 0.0121 0.23521 -0.1209 -0.2439 0.07138 -0.0677 0.16103	-0.4319 -0.396 0.04027 0.065 0.03499 0.31649 -0.0308 -0.0308 -0.4103	0.19797 -0.0248 0.03171 0.0376 0.1301 -0.1194 0.26316 -0.0463 0.37951	-0.1073 -0.4282 -0.2457 -0.4894 0.13061 -0.0316 0.46342 0.2133 0.46138	0.15649 0.23408 0.31472 0.41598 0.45878 0.27251 0.23834 0.20844 0.35023

FIG. 5

$$\begin{aligned}
 & 48.36423 \begin{bmatrix} 0.024791 \\ -0.65638 \\ 0.114397 \\ 0.430964 \\ 0.19036 \\ 0.029931 \\ -0.45704 \\ 0.11022 \\ 0.260286 \end{bmatrix} + 103.267 \begin{bmatrix} 0.044583 \\ -0.08073 \\ -0.43082 \\ 0.1484 \\ 0.104825 \\ 0.130028 \\ 0.07839 \\ -0.18197 \\ -0.04244 \end{bmatrix} + 104.5527 \begin{bmatrix} 0.014624 \\ -0.18278 \\ 0.098742 \\ 0.086048 \\ 0.537168 \\ -0.77578 \\ 0.372329 \\ 0.081803 \\ -0.10849 \end{bmatrix} + 118.3638 \begin{bmatrix} 0.050397 \\ 0.295118 \\ -0.18362 \\ -0.15887 \\ 0.56518 \\ -0.36248 \\ -0.58368 \\ 0.246988 \\ 0.048121 \end{bmatrix} + 197.1853 \begin{bmatrix} -0.78901 \\ 0.330348 \\ -0.13322 \\ 0.529113 \\ -0.12038 \\ -0.04382 \\ 0.075884 \\ -0.08797 \\ 0.061091 \end{bmatrix} \\
 & + 349.7209 \begin{bmatrix} -0.45588 \\ -0.55622 \\ 0.040173 \\ 0.093 \\ 0.812492 \\ 0.110658 \\ -0.02848 \\ -0.11758 \\ -0.43083 \end{bmatrix} + 547.9721 \begin{bmatrix} 0.187891 \\ -0.02481 \\ 0.102708 \\ -0.02777 \\ 0.120529 \\ -0.11844 \\ 0.055197 \\ -0.84128 \\ 0.178923 \end{bmatrix} + 971.8516 \begin{bmatrix} -0.10707 \\ -0.43815 \\ -0.24571 \\ -0.43858 \\ -0.15061 \\ -0.03178 \\ 0.465418 \\ 0.123397 \\ 0.462386 \end{bmatrix} + 11708.98 \begin{bmatrix} 0.164062 \\ 0.118076 \\ 0.134752 \\ 0.419985 \\ 0.188759 \\ 0.172809 \\ 0.138588 \\ 0.128462 \\ 0.13801 \end{bmatrix} = \text{Response Vector}
 \end{aligned}$$

$\begin{bmatrix} 2826.689 \\ 2324.75 \\ 3405.53 \\ 4578.035 \\ 4620.775 \\ 4248.773 \\ 4396.512 \\ 3725.832 \\ 4436.201 \end{bmatrix}$

FIG. 6

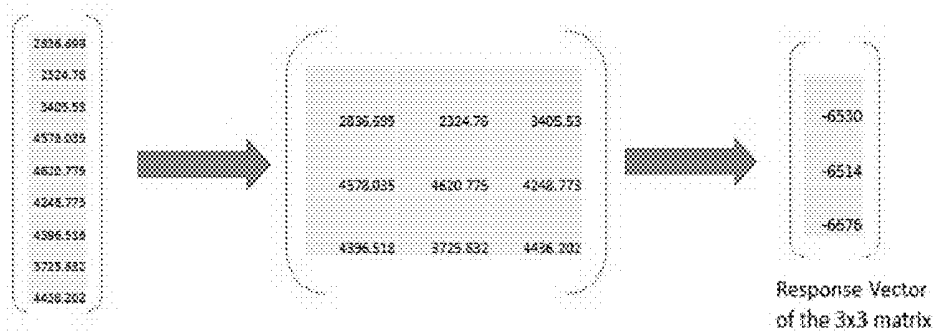


FIG. 7

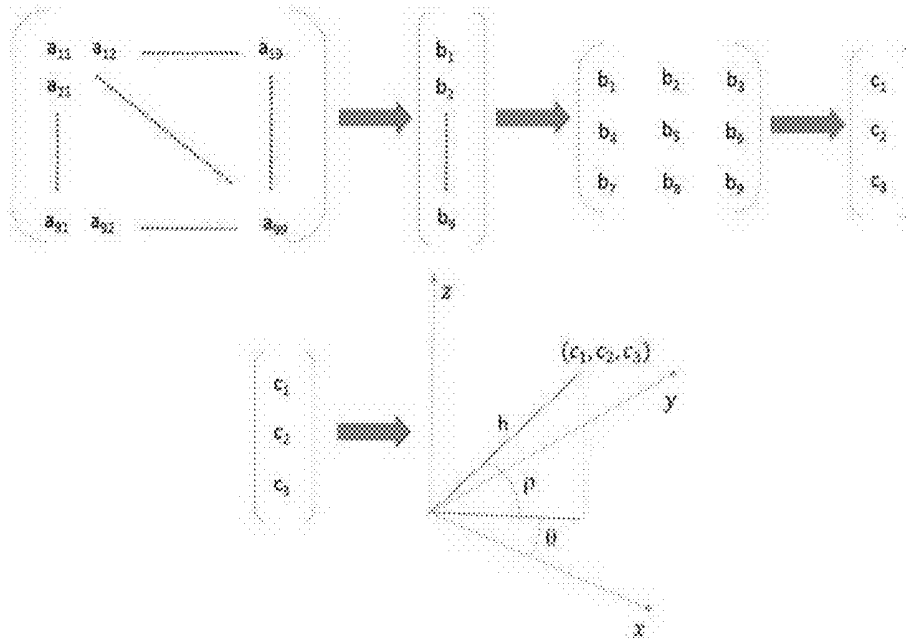


FIG. 8

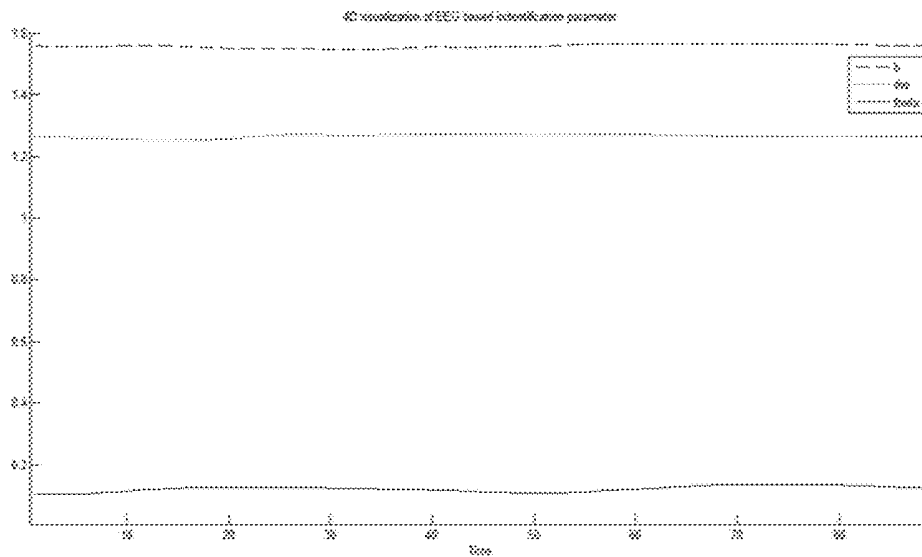


FIG. 9

SYSTEM AND METHOD FOR PERSON IDENTIFICATION AND PERSONALITY ASSESSMENT BASED ON EEG SIGNAL

FIELD OF THE INVENTION

The present invention relates a novel system and method for person identification and personality assessment based on electroencephalography (EEG) signal. More particularly, this invention relates to a novel method of EEG recording and processing to map the inherent and unique properties of brain in the form of highly specific brain signature to be used as means for person identification and personality assessment.

BACKGROUND OF THE INVENTION

There are available various biometric systems that use the human inherent physiological or behavioral characteristics for personal identification. The biometric system works on physical characteristics and behavioral characteristics kind. Physical characteristics are innate, congenital human physical characteristics, such as fingerprints, iris, hand geometry; face, etc. have genetic virtue. Behavior is performed from a person's motion features extracted, mostly acquired, such as handwriting, keystroke, gait, etc. Biometrics is considered as one of the technologies that changed the world and as expected in the near future, biometric authentication technology will delve into all aspects of our lives, and its influence will be integrated as much as the Internet.

Everyone has a biometric different from others in uniqueness and stability in the same period of time, not easy to forgery and counterfeiting, so the use of biometrics for identity finds a safe, reliable, and accurate. However, no single biometric is perfect, and various biometric identification methods have its certain scope and requirements of a single biometric system in practical applications show their limitations. The reliability of fingerprint identification is relatively high but requires actual physical contact; human face and iris recognition does not require physical contact, but in practice theft applications are subject to more environmental restrictions. Studies have shown that using gelatin fake finger can easily fool the fingerprint recognition system, the iris of people suffering from cataracts will change. With the continuous criminal means, intelligent, science and technology, the biometric system has security challenges.

In comparison with biometric identification method an EEG identification method is a relatively new idea. In fact, as early as in 1960s, neurophysiologists and psychiatrists proposed and validated "human EEG carries genetic information and the existence of a correlation between them". However, most of the early research is committed to pathological analysis and clinical diagnostics; until recent years, researchers have only put more energy into the health of the human body, trying to establish some sort of individual characteristics and their EEG carries genetic information which will serve as an effective EEG characteristic for identification.

It is proven that the EEG signals based biometric systems can achieve a certain accuracy and faster speed, and does not produce any harm to the human body. Since EEG signals are basically the brain's thinking activity, it is difficult to counterfeit. The human brain EEG analysis shows that different individuals in different brain regions will produce different neural impulse response and hence it is individual specific.

However, there is a common problem with normal EEG data processing. EEG usually reflects thousands of simulta-

neous on-going brain processes. EEG is still interpreted as two dimensional in clinical practice plotting voltage values in relation to time which does not reveal any unique quality of an individual. The brain response to a single stimulus or event of interest is not usually visible in the EEG recording of a single trial. In order to view the brain response to a specific stimulation applied to a subject under study, multiple trials (i.e. 100 trials or more) must be conducted to cause random brain activity to be averaged out and hence to remain the relevant ERP. Furthermore, multi-trial averaging contributes to loss of distinctive physiological information, which may prove useful for individual identification, disease diagnosis, and other fields of study such as psychology and pharmaceuticals. As such, an estimation scheme based on a single trial, which uses new signal processing EEG techniques, minimizes the information loss and reduces ERP or EP recording time is highly desirable.

The importance of accurate, timely detection of brain activity is crucial if to be used in identification and authentication. However, most mental and neurological states are evaluated mainly through interviews and subjective exams based on the subjects' temporary performance at that time. There is no objective quantitative test for evaluating baseline brain function. Imaging technologies such as standard magnetic resonance imaging (MRI) show only structure within the brain without providing an indication of dynamic brain function. Magnetic resonance spectroscopy and functional MRI provide functional status of different regions of brain but their use is very limited due to high cost, non-portability and limited availability of machines. EEG is the most effective, accurate and cheap method for evaluating brain function, but interpretation requires interpretation of multi-channel graphs based on visual analysis by highly trained experts. Moreover current interpretation of EEG by expert does not provide any individual identification or early disease prediction due to lack of use of advanced signal processing techniques.

The present invention overcomes the above shortcomings by providing a novel methodology, which will be helping in diagnosing the different brain activity more accurately and comprehensibly as a brain signature. The matrix formed using EEG data will characterize the unique features of an individual, which can be used as person identification and assessment.

OBJECT OF THE INVENTION

The main object of the present invention is to provide a novel system and method for person identification and personality assessment based on electroencephalography (EEG) signals.

Yet another object of the present invention is to provide a novel method of EEG recording and processing to map the inherent unique properties of brain in the form of highly specific brain signature.

Yet another object of the present invention is to provide a novel system based on EEG which can be used as person identification.

Yet another object of the present invention is to provide a novel system based on EEG which can be used for personality assessment.

Yet another object of this invention is to provide a novel method of EEG recording and processing.

Yet another object of this invention is to identify the individual in a novel manner.

Yet another object of this invention is to perform EEG analysis that further includes statistical, temporal and spec-

tral property assessment of the EEG signals through four dimensional visualisation of eigenvectors/eigenvalues, and properties of inner product spaces plotted with time.

Yet another object of this invention is to perform EEG wherein multiple output data resulting from recorded EEG patterns are taken together and the structure of their correlation and higher-order statistics matrices are analyzed in relation to time through its eigenvalues, eigenvector, eigendirection and eigenspaces and other signal processing techniques like fast Fourier transform compression sensing, wavelet transform to obtain said four dimensional activity.

Yet another object of this invention is to analyze the EEG recording using eigenvalues, eigenvectors, eigendirections and eigenspaces.

Yet another object of this invention is to use the Spinal EEG and its analysis to predict different diseases as well as source of EEG signals.

Yet another object of this invention is to create and use 4 dimensional EEG images.

Still another object of this invention is to record EEG from the surface of the brain bypassing the skull bone for diagnosing specific brain activity.

SUMMARY OF THE INVENTION

Accordingly, the present invention relates a novel system and method for person identification and personality assessment based on electroencephalography (EEG) signal. More particularly, this invention relates to a novel method of EEG recording and processing to map the inherent and unique properties of brain in the form of highly specific brain signature to be used as means for person identification and personality assessment.

In a preferred embodiment of the present invention eigenvectors/eigenvalues, properties of inner product spaces and 4D visualization of EEG signal's statistical, temporal and spectral properties is proposed to assess and interpret brain signature and personality of a subject. The proposed system analyses the EEG signals and giving values for three parameters each for left and right side of the brain, namely, ρ , θ , and h , which represent the underlying mathematical structure of the signals appearing on the scalp. The three parameters are then plotted with time to give the novel 4 dimensional visualization of the entire EEG activity of the brain.

In another preferred embodiment of the present invention, a biometric kit for EEG based identification of person and/or personality assessment of a user is proposed. The kit comprises a means for data input, a processing unit, and an output device. Characterized in that, the processing unit provides 4 dimensional visualization of brain activity resulting in projection of brainwave based signature.

BRIEF DESCRIPTION OF DRAWINGS

A complete understanding of the device and system of the present invention may be obtained by reference to the following drawings:

FIG. 1 shows a general overview of procedure of recording EEG signals.

FIG. 2 depicts a sample of EEG signals recorded from a subject.

FIG. 3 shows the raw data of the signals represented in FIG. 2 that are used as input for the algorithm.

FIG. 4 shows 9x9 covariance matrix of the data obtained in FIG. 3.

FIG. 5 shows the 9 eigenvectors, with corresponding eigenvalues of the matrix in FIG. 4.

FIG. 6 shows the computation of the response vector of the covariance matrix in FIG. 4 from its eigenvectors and eigenvalues.

FIG. 7 depicts populated 3x3 matrix of rearrangement of values obtained in FIG. 6.

FIG. 8 shows process of taking a covariance matrix and reducing it to 3-dimensional spherical coordinates depicted in FIG. 7.

FIG. 9 shows the 4D visualization for the left group of a subject.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates a novel system and method for person identification and personality assessment based on electroencephalography (EEG) signal. More particularly, this invention relates to a novel method of EEG recording and processing to map the inherent and unique properties of brain in the form of highly specific brain signature which is to be used as person identification and personality assessment. The present invention involves in creating a correlation matrix from EEG signals obtained in a fixed duration of time from the various locations of the scalp. The dynamics of the eigenvector together with the eigenvectors is studied to characterize brain function. Every individual has a specific rigidity in the dynamic behavior of their eigenvectors and that allows in creating a specific brain signature on such different brain activity more accurately and comprehensibly. This EEG based brain feature will be very specific and sensitive for individual.

In one aspect, the present invention is a novel EEG product which is composed of unique method of EEG recording and processing. The EEG product involves EEG recording by using spinal EEG and different scalp EEG electrodes. The EEG analysis is done by a unique process in which output data streams are taken together from a system like brain and the structure of their correlation matrix is studied through its eigenvector, eigenvalues, eigendirection and eigenspaces. The unique and persistent feature of the brain as brain signature is identified in this brain model which will be used as security key for any network or defense system.

In another aspect, the methodology of recording and processing EEG signals from multiple output data streams, comprising of the following steps:

- i. Performing EEG of individual scalp including suboccipital as well as spinal electrodes. The EEG will be done in normal, patients or criminals;
- ii. EEG is analyzed with different signal processing techniques like eigenvalues, eigenvectors, eigendirections, wavelet transform, fast fourier, compression technologies;
- iii. Functional modeling, aided with scalp bone transfer function characterization and functional imaging of brain is done by using said techniques.

This brain model is validated in different brain activity for creating specific brain signature so that identification of person can be done more effectively. The unique and persistent feature of the brain as brain signature is identified in this brain model which will be used as security key for any network or defense system. In addition to the same, personality assessment in various fields of application is also feasible.

Thus, the proposed system and method is capable of creating specific brain signature unique to an individual. The system and method provides for effective identification of a

person. It further measures and assesses the personality and behavioural patterns for various fields of application. The system and method uses eigenvectors/eigenvalues, properties of inner product spaces and 4D visualization EEG signal's statistical, temporal and spectral properties to create the unique brain signature.

In another preferred embodiment of the present invention, a biometric kit based on the inventive concept of the present invention is proposed. The kit comprises at least a means for data input, a processing unit to process the data, and at least one output device to present the processed data as the result or assessment. The kit is capable of quickly identifying an individual to provide access to a security aspect. The kit uses eigenvectors/eigenvalues, properties of inner product spaces and 4D visualization EEG signal's statistical, temporal and spectral properties to interpret the brain signature.

The present invention will now be described more fully hereinafter with reference to the accompanying drawings in which a preferred embodiment of the invention is shown. This invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiment set forth herein. Rather, the embodiment is provided so that this disclosure will be thorough, and will fully convey the scope of the invention to those skilled in the art.

Thus the present invention relates to providing a system and method using EEG signals, commonly known as brainwaves, for authenticating a user to give user access to a secure system. The system gives three parameters that allows unique identification of an individual representing "brain signature", irrespective of what activity the person is engaged in or the kinds of thoughts that are appearing in his/her mind.

In an alternate embodiment of the present invention, a method of EEG based authentication and assessment of a user is suggested, the method comprising the steps of:

- a. recording EEG signal data to obtain a brainwave pattern;
- b. optionally grouping the signals obtained in step a. into at least two groups;
- c. breaking the signal data into frames;
- d. creating covariance matrix of each frame obtained in step c.;
- e. computing eigenvectors and eigenvalues;
- f. computing response vector covariance matrix from its eigenvectors and eigenvalues;
- g. reducing the covariance matrix to three dimensional spherical coordinate parameters;
- h. plotting the three dimensional parameters as a function of time to obtain four dimensional visualization of the EEG signals of step a.; and
- i. observing distribution pattern of the parameters for deviation;

wherein any deviation in distribution pattern is indicator of abnormality.

Further, the signal data comprises at least 100 samples of each signal per second, and each group comprises plurality of signals. The frame comprises data consisting of at least 100 samples, of all the signals in each group taken separately. In a preferred mode, covariance matrix is a symmetric matrix constructed with the signals obtained and at least 100 samples for each signal. An eigenvector of a matrix is a vector which when multiplied by that matrix results in a scaled version of the original vector itself and the eigenvectors and eigenvalues are computed by equation $Ax_i = \lambda_i x_i$, where x_i is one of the eigenvectors of A and λ_i is its corresponding eigenvalue and wherein a nxn symmetric

matrix gives n eigenvectors with corresponding n eigenvalues, n being any arbitrary integer. The three spherical coordinates comprises an angle a vector makes with the z-axis represented by ρ , an angle a vector makes with the x-axis represented by θ , and the length of the vector represented by h.

The present invention will now be described more fully hereinafter with reference to the accompanying drawings in which a preferred embodiment of the invention is shown. This invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiment set forth herein. Rather, the embodiment is provided so that this disclosure will be thorough, and will fully convey the scope of the invention to those skilled in the art.

The present invention provides an EEG based method to study and monitor functional aspects of the human brain in real time. Current technology is severely limited in being able to provide a decisive measure for every individual's neurological health by recording the functional behavior of the brain.

As shown in FIG. 1, EEG signals appear on the entire area of the scalp of every person, from where they are recorded using multiple sensors. The proposed invention looks for a mathematical structure within the various signals recorded from different locations on the scalp and reports it via the 3 parameters. This mathematical structure is unique and all 3 parameters would match, within certain tolerance limits, only to a specific individual. The concept of this idea is explained in the following steps:

1. A set of sensors are placed on the scalp of a subject and signals emerging from the brain are recorded via an EEG device.
2. The system begins to analyse the EEG signals and starts giving values for three parameters each for left and right side of the brain, namely, ρ , θ , and h, which represent the underlying mathematical structure of the signals appearing on the scalp.
3. The three parameters are plotted with time to give the novel 4 dimensional visualization of the entire EEG activity of the brain.
4. At the time of authentication the parameters are again measured and compared with previously stored values and the person is given access to the secure system if they match, within a pre-set tolerance limit.

The following minimum components are required for the foregoing steps to be completed.

1. EEG Scanner—Electroencephalography scanner is used to monitor and record brain activity. EEG measures the brain activity of various neurons and then reports them back to the system for further interpretation.
2. Algorithm based processing unit—This is a system that analyses the mathematical structure of the signals being received from a subject's scalp and, in real-time, produces parameters that are compared with previously recorded values to authenticate that individual.

Example 1

Sampling of EEG Data of Subject

The internationally recognized 10-20 system is used to place the sensors on the scalp and record the EEG signals. FIG. 2 shows a sample of the EEG signals recorded from a subject. The name of each signal recorded is mentioned along with it on the extreme right of FIG. 2. First three

signals, namely, Fz, Cz, Pz, lie along the line running at the centre of the scalp from the front to the back of the head. The signals ending with an odd number, for example, C3, lie on the left side of the scalp and those ending with an even number, for example, P4, lie on right side of the scalp.

Once the signals are recorded, they are separated into two groups, namely, left and right. The left group has all the signals that are obtained from the left side of the scalp, along with the signal Cz, and the right group has all the signals obtained from the right side of the scalp along with signal Cz. Therefore, each side has 9 signals each, listed as follows:

Left: Fp1, F7, F3, T3, C3, T5, P3, O1, Cz

Right: Fp2, F4, F8, C4, T4, P4, T6, O2, Cz

It does not matter in which order the signals are placed within the group. Once the left group and right groups have been created, the algorithm works independently of the order in which signals are put in each group. In general, any number of groups can be formed with any number of signals in them. In our study we have considered groups with number of signals that are powers of 3 and 4. This amounts to groups having 3, 4, 9, 16 etc. signals. The number of parameters generated in the end depend on whether the number of signals taken at the outset were a power of 3 or 4. If they are a power of 3, like 9 taken in each group in this embodiment, then there will be 3 parameters and 4 parameters will be produced when signals taken are a power of 4. Data is taken on an EEG machine that records 256 samples of each signal per second. FIG. 3 shows the raw data of the signals represented in FIG. 2 that are used as input for the algorithm. This entire data is then broken into 'frames' that are the size of 1 second each for both the left and the right group. In other words, 1 second worth of data, i.e., 256 samples, of all the 9 signals in each group is taken separately and called a frame. The process that follows now describes just one frame taken from one of the groups, but applies identically to all the frames of both groups.

Example 2

Constructing Covariance Matrix of Sample EEG Data of Subject

A covariance matrix is constructed with the 9 signals and 256 samples for each signal. FIG. 4 shows this covariance matrix. It is a symmetric 9x9 matrix that is populated with the covariance values of each signal with every other signal, computed using the 256 samples we have for all 9 signals. One can obtain the covariance between any two EEG signals by going to the row and column, with their respective names written next to each row and column of the matrix, and reading off that value from the matrix. For example, the covariance between F4 and C4 is 1301.435, and its location is at the 5th column-3rd row and also, since the matrix is symmetric, 3rd column-5th row.

With covariance matrix constructed we then proceed to compute its eigenvectors and eigenvalues. An eigenvector of a matrix is a vector which when multiplied by that matrix results in a scaled version of the original vector itself, i.e., $Ax_i = \lambda_i x_i$, where x_i is one of the eigenvectors of A and λ_i is its corresponding eigenvalue. A 9x9 symmetric matrix gives 9 eigenvectors with corresponding 9 eigenvalues. FIG. 5 show the 9 eigenvectors, with corresponding eigenvalues written on top, of the matrix in FIG. 4.

Example 3

Identifying Response Vector

With all 9 eigenvectors and eigenvalues obtained, we first multiply each eigenvalue with its eigenvector and then add

all the eigenvectors together, i.e., $\sum_i (\lambda_i v_i)$, to give what we call the response vector, A, of the covariance matrix. FIG. 6 shows the computation of the response vector of the covariance matrix in FIG. 4 from its eigenvectors and eigenvalues. This response vector is of the same size as the eigenvectors, i.e., 9x1, and its elements can be rearranged to populate a 3x3 matrix, as shown in FIG. 7. Using the process outlined above, we now compute the 3x1 response vector of this 3x3 matrix. Then a transformation from Cartesian coordinate system to Spherical coordinate system is performed for this 3x1 response vector. The 3x1 response vector shown in FIG. 7 is (-6530, 6514, -6676) in Cartesian coordinates. When transformed to spherical coordinates the vector becomes (-35.9, -135.1, 11385). The first two coordinates, ρ and θ , are the angles this vector makes with the z and the x-axis respectively and the last coordinate is the length of the vector denoted by h. This entire process of taking a covariance matrix and reducing it to 3-dimensional spherical coordinates is schematically depicted in FIG. 8.

Example 4

4D Visualization of EEG

The above process is carried out for all the frames of 1 second duration, and three parameters for each frame are computed. These three parameters for each frame are plotted as a function of time to give the 4 dimensional visualization of the EEG. FIG. 9 shows the 4D visualization for the left group of a subject with 3 parameters as a function of time. We also analysed the distributions of the theta and rho parameter of EEG taken over a period of time and they too were specific to the individual person.

For security systems these parameters are recorded from any number of previously constructed groups of signals. In authentication process a subject's 4 dimensional EEG plots are generated acting as "brain signature" and compared with the previously recorded parameters. Access is provided only when the two match.

We claim:

1. An EEG based personality assessment system comprising:

- a means for sensing brainwaves of a user;
- a means for recording a pattern of the brainwaves of the user;
- a means for processing the recorded pattern, the means capable of performing an analysis of the brainwave pattern by giving values for three parameters each for left and right side of the brain, namely, ρ , θ and h, and plotting them with time resulting into a four dimensional visualization;
- a means for representing four dimensional visualization of the entire EEG activity of the user's brain obtained by the means for processing, as brain signature; and a means for securely storing the brain signature, wherein, multiple output data resulting from the pattern recorded are taken together and the structure of their correlation and higher-order statistics matrices are analyzed through its eigenvalues, eigenvector, eigendirection and eigenspaces and other signal processing techniques like fast Fourier transform compression sensing, wavelet transform to obtain said four dimensional visualization.

2. The EEG based system as claimed in claim 1, wherein said means for sensing and recording brainwave pattern comprises an Electroencephalograph (EEG).

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3. The EEG based system as claimed in claim 1, wherein the means for sensing and recording brainwave pattern includes spinal EEG and different scalp EEG electrodes.

4. The EEG based system as claimed in claim 1, wherein said means for processing pattern comprises a programmed processing unit.

5. The EEG based system as claimed in claim 1, wherein said brainwaves comprise EEG signals.

6. The EEG based system as claimed in claim 1, wherein said analysis further includes statistical, temporal and spectral property assessment of the EEG signals through four dimensional visualization of eigenvectors, eigenvalues, and properties of inner produce spaces plotted with time.

7. The EEG based system as claimed in claim 1, wherein the analysis further includes the step of creating correlation matrix from EEG signals obtained in a fixed duration of time from the various locations of the scalp.

8. The EEG based system as claimed in claim 1, wherein the means for representing four dimensional visualization of the entire EEG activity of the user's brain is an output device selected from the group comprising a printer, a visual output screen, an audio-visual output device or a combination thereof.

9. The EEG based system as claimed in claim 1, wherein the brain signature is unique to a user and is capable for being used as biometric authentication as well as a personality assessment tool.

10. A method of EEG based authentication and assessment of a user comprising the steps of:

- recording EEG signal data to obtain a brainwave pattern;
- optionally grouping the signals obtained in the recording step, into at least two groups;
- breaking the signal data into frames;
- creating covariance matrix of each frame obtain in the breaking step;
- computing eignenvectors and eigenvalues;
- computing response vector covariance matrix from its eigenvectors and eignevalues;
- reducing the covariance matrix to there dimensional spherical coordinate parameters;

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plotting the three dimensional parameters as a function of time to obtain four dimensional visualization as unique brain signature of the EEG signals of the recording step;

storing the brain signature for subsequent references; and authenticating the user on the basis of stored brain signatures.

11. The method of EEG based authentication claimed in claim 10, wherein the signal data comprises at least 100 samples of each signal per second.

12. The method of EEG based authentication as claimed in claim 10, wherein each group comprises plurality of signals.

13. The method of EEG based authentication as claimed in claim 11, wherein a frame comprises data consisting of at least 100 samples, of all the signals in each group taken separately.

14. The method of EEG based authentication as claimed in claim 10, wherein covariance matrix is a symmetric matrix constructed with the signals and at least 100 samples for each signal.

15. The method of EEG based authentication as claimed in claim 10, wherein an eigenvector of a matrix is a vector which when multiplied by that matrix results in a scaled version of the original vector itself and the eigenvectors and eigenvalues are computed by equation $Ax_i = \lambda_i x_i$ where x_i is on of the eignevectors of A and λ_i is its corresponding eigenvalue and wherein a $n \times n$ symmetric matrix give n eignevectors with corresponding n eigenvalues, n being any arbitrary integer.

16. The method of EEG based authentication is claimed in claim 10, wherein the three spherical coordinates comprises an angle a vector makes with the z-axis represented by ρ , an angle a vector makes with the x-axis represented by θ , and the length of the vector represented by h.

17. The method of EEG based diagnosis as claimed in claim 10, wherein the brain signature is unique to a user and is capable of being used as biometric authentication as well as personality assessment tool.

* * * * *

专利名称(译)	基于EEG信号的人员识别和人格评估系统和方法		
公开(公告)号	US10318833	公开(公告)日	2019-06-11
申请号	US15/544004	申请日	2016-01-18
[标]申请(专利权)人(译)	潘瓦尔Siddharth		
当前申请(专利权)人(译)	阿加瓦尔普尼特		
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发明人	AGARWAL, PUNEET PANWAR, SIDDHARTH JOSHI, SHIV DUTT GUPTA, ANUBHA		
IPC分类号	G06K9/00 A61B5/117 A61B5/0476 A61B5/00 A61B5/04 G06K9/62 A61B5/0478 A61B5/16		
CPC分类号	G06K9/00885 A61B5/0476 A61B5/0478 A61B5/117 A61B5/167 A61B5/7239 G06K9/00496 G06K9/00523 G06K9/00536 G06K9/6214 A61B5/04012 G06K2209/05 A61B5/7246 A61B5/7257 G06K2009/00939 G06K2009/00953		
优先权	2007DEL2014 2015-01-16 IN		
其他公开文献	US20180025241A1		
外部链接	Espacenet		

摘要(译)

本发明涉及一种基于脑电图 (EEG) 信号的人员识别和人格评估的新颖系统和方法。更具体地, 本发明涉及一种新的EEG记录和处理方法, 以高特异性脑特征的形式映射大脑的固有和独特特性, 以用作人物识别和个性评估的手段。

