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The Study on BEAM for the Space Domain Analysis of EEG

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=Abstract=

In this paper, computerized BEAM was implemented for the space domain analysis of EEG. Transformation from temporal summation to two-dimensional mappings is formed by 4 nearest point interpolaton method.

Methods of representation of BEAM are two. One is dot density method which classify brain electrical potential 9 levels by dot density of gray levels and the other is colour method which classify brain electrical 12 levels by red-green colours. In this BEAM, instantaneous change and average energy distribution over any arbitrary time interval of brain electrical activity could be observed and analyzed easily. In the frequency domain, the distribution of energy spectrum of a special band can easily be distinguished normality and abnormality.

Key words : BEAM, EEG, Spectrum

Introduction

The electrical activity of brains was done on animals and it was not until 1929 that Hans Berger published the first report of electroencephalogram(EEG) of man. Since that time, many researchers has been investigating the EEG for a number of years. The result is that the EEG has become a routine clinical procedure of considerable diagnostic value as well as a powerful research tool in the neuroscience.

The interpretation of EEG records generally practice the sence of sight from temporal patterns. But it frequently result in error because of complexity of EEG waveforms. Therefore, it is essential to classify and interpret EEG patterns quantitatively and objectively. The method is temporal summation, spectral characteristics, spatial analysis, and statistical comparison. Because the electrical activity of brain occur in the whole head in time and space, we are hard to interpret EEG waveforms for temporal signal, so topographic modification nessary.

In this paper, computerized BEAM was implemented in the space domain using multichannel EEGs which displayed instantaneous voltage and average energy distribution over any arbitrary time interval.

Characteristics of EEG and BEAM

EEG is unsystematic waveforms, but has rhythmic patterns. Rhythmic activity is an inherent property of groups of cells in the thalamic nuclei. The rhythmicity is produced by a simple mechanism in which the discharge of one thalamic neuron causes inhibition of many adjacent neurons which is shown in Fig. 1.

The intensities of the brain waves on the surface of the

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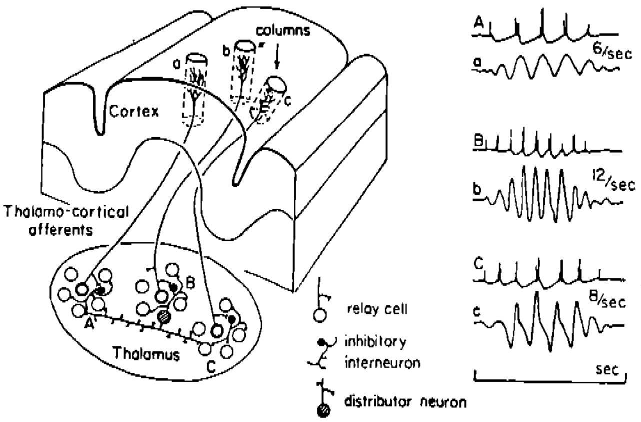

Fig. 1. The model for a generation of EEG rhythmicity.

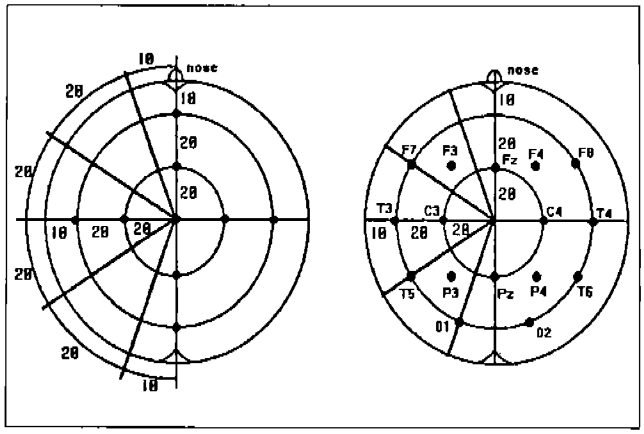

Fig. 2. Placement of 16 channel electrodes.

brain may be as large as 10 mV, whereas those recorded from the scalp have a smaller amplitude of approximately 100 μV. The spectral content of brain electrical activity provides crucial data on the normal and abnormal functioning of the various regions of the brain. The electrical signal record at a given electrode site can be decomposed into its consitituent frequency components delta (<4 Hz), theta (4 to 8 Hz), alpha (8 to 13 Hz), and beta (>13 Hz).

The brain electrical activity mapping (BEAM), defined as the topographic analysis of EEG or EP, is the analysis of spatial dimension and a cartographic science. Topographic mapping gives a conceptually simple view of the distribution of electrical activity over the scalp with changes in signal voltage and frequency relating to changes in the gradient level of the map. For instance, smooth image changes display when recorded data real-such as sleeping "spikes", but topographic image dramatically change with discontinuity when electrode artifact-such as "pops"-occurs. And, non-symmetrical image in the right and left is displayed when half-brain get damage. But, the EEG pattern is analylzed with mutual dependence of many of methods, -temporal summation, spectral characteristics, and statistical comparison-but alone the BEAM.

Measurement of EEG signals used Ag-AgCl scalp electrode in order to reduce contact resistance between cortex and electrode. The number of electrode which attached scalp is 8, 12, 16, and 32 channel. We used the electrode placement recommended by the International Federation of Socities for Electroencephalography and Clinical Neurophysiology known as the 10-20 system. We employed 16 channel under symmetrical arragement in the left and right which is shown in Fig. 2.

Method

The BEAM must include an algorithm for interpolating values to fill in the scalp areas between the recording electrode used in performing a topographic analysis. And, to approximate interpolation method is required in projection of skull because we employ 2-dimesional map. That is, while the head is a three-dimensional object, the algorithm format obviously is two-dimensional. Because direct projection from 3-D to 2-D cause maps to be distortion, we decided to attempt an approximate equal area projection such that an equal area on the surface would be represented by an equal on the plane.

There are several reasons for this choice. First, the gradient change of the mapped variable would be directly comparable in all regions. Because the distances to electrode locations would be in the same metric when expressed as screen coordinates, this would allow a simple interpolation scheme to fill in the map vlaues between actual data points. Second the goal of the system was to have maps that would be comparable to positron emission tomography data. Metabolic rates for cortex as determined from such scans could be easily displayed on the projection and com-

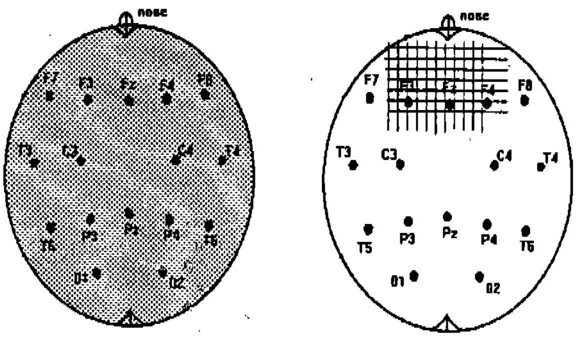

Fig. 3. Decomposition of surface of brain.

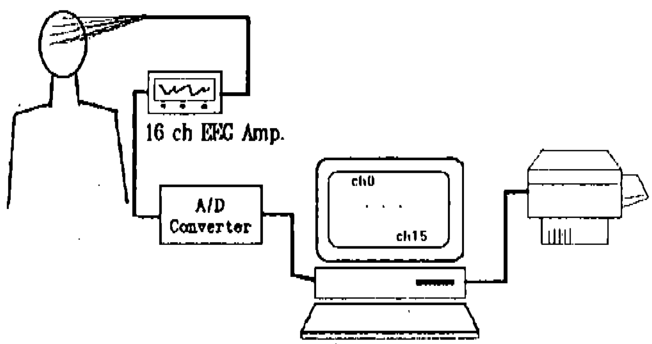

Fig. 5. System block diagram.

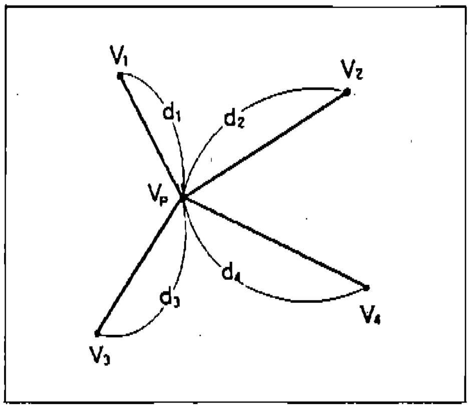

Fig. 4. Principle of 4-point interpolation method.

pared to the electrical activity maps.

Projection mappings compose many of partition elements, dividing the head montage in the vertical and in the horizon by 1 centimeters which is shown in Fig 5. Values for element of the extended montage bordering the head are provided by reproducing the value over the cloest measured position, if just one, or by averaging the closest ones. We computed voltage or energy level of element of partition using 4-nearest neighborhood point interpolation method which is shown in a formula as follows.

Two-dimensional BEAM would be constructed, when we apply entire surface of brain composing element of 5140 to the 4-point interpolation algorithm.

$$T = d_1 + d_2 + d_3 + d_4$$

$$S = \sum_{i=1}^{4} \frac{T}{d_i} \quad w_i = \frac{T}{d_i} * \frac{1}{S} \quad \sum_{i=0}^{4} w_i = 1$$

$$V_p = w_1 * V_1 + w_2 * V_2 + w_3 * V_3 + w_4 * V_4$$

V_p : voltage in an arbitrary point.

w_i : weight.

d_i : distance from an arbitory point to nearest neighborhood 4 electrode position.

Experiment and Result

4. 1. System block diagram.

Fig 5. shows system block diagram carrying out acqusition of data of BEAM.

Because amplitude of EEG voltage via electrode leads of scalp is verylow(5~100μV), amplifier with excellent CMRR is necessary to acquire data. Voltage level of amplifier output is -5~5 V and lead of output be linked with DT2811 A/D converter of Data Translation which composed resolution of 12 bits. Digitizing is performed at a sampling rate 200 Hz each of channel. And data would be saved infinitely until press any key on hard disc in real time using interrupting program without loss of data, while visually displaying to investigate temporal signal in the monitor. Saved data would be compared each channel at any point and would be seperated into 16 channels for Fourier Transform. Fig 5 shows collected EEG data of 16 channels.

4. 2. Software.

When we compute element's value of decomposition using 4 nearest interpolation, weight of interpolation is composed of fixed·matrix vector. Hence, we make up position

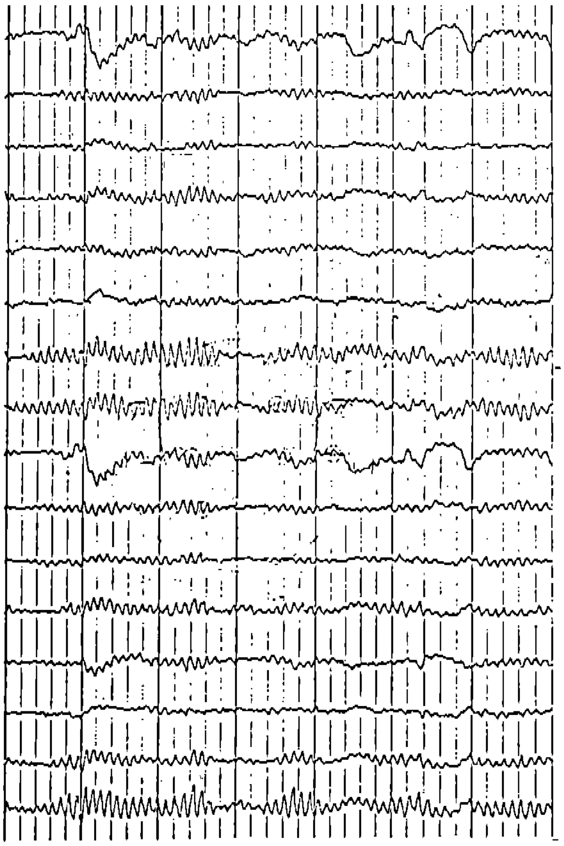

Fig. 6. Collected 16 channel EEG

matrix and weight matrix, and value of pixel is computed as follows.

$V_p = V_p + V_i[dat_i] * W_i$

V_p : Pixel value of element.

$V_i[dat_i]$: Value of data. W_i : Weight vector.

$i = 1, 2, 3, 4$ $p = 1, 2, \cdots\cdots 5140$

Setting up weight vector file and position vector file, there are great advantage to increase speed of computation and to reduce memory waste. Table. 1 shows vector of weight in the 16 channel electrode. Table 2 shows vector of position in the 16 channel electrode.

The procedure of BEAM is implemented as follows. At first, the surface of brain is diveded into 5140 elements and positon of each element make positoin file. Second, the weight of each element is calculated by 4-point interpolation and weighting file is made by this value. Third, the calculated value seperate 9 and 12 levels for dot and col-

Table 1. Vector of weight in the 16 channel.

W_1	W_2	W_3	W_4
0.485128	0.184862	0.169142	0.160868
0.449990	0.204890	0.179996	0.165124
0.418216	0.225256	0.189044	0.167484
0.389284	0.246205	0.196300	0.168211
0.362724	0.267987	0.201763	0.167526
0.338122	0.290863	0.205415	0.165600
0.315105	0.315105	0.207228	0.162563
0.338122	0.290863	0.205415	0.165600
0.362724	0.267987	0.201763	0.167526
0.389284	0.246205	0.196300	0.168211
.	.	.	.
.	.	.	.
.	.	.	.

Table 2. Vector of position in the 16 channel.

Dat_1	Dat_2	Dat_3	Dat_4
4	12	8	3
4	12	8	3
4	12	8	3
4	12	8	3
4	12	8	3
4	12	8	3
4	12	8	3
12	4	8	11
12	4	8	11
12	4	8	11
.	.	8	.
.	.	.	.
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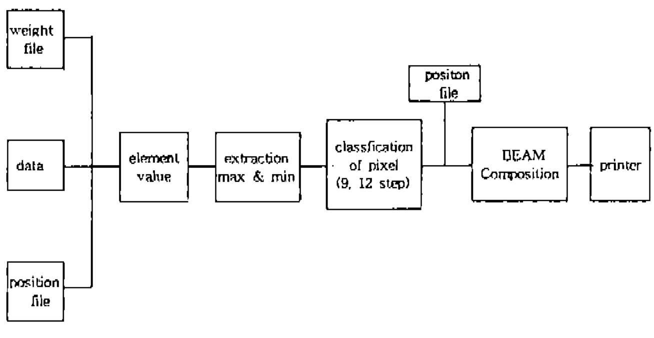

Fig. 7. Flow chart of BEAM composition.

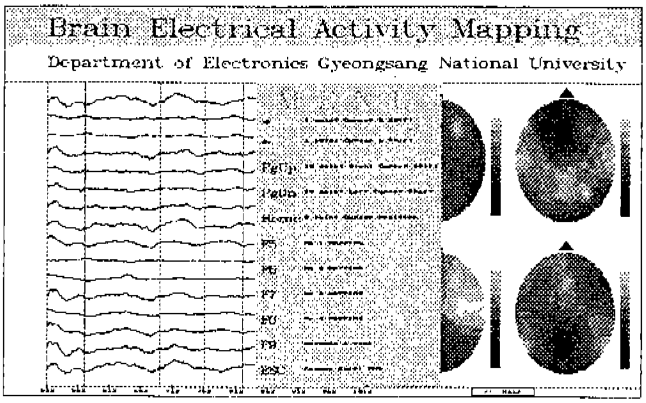

Fig. 8. Main menu of BEAM.

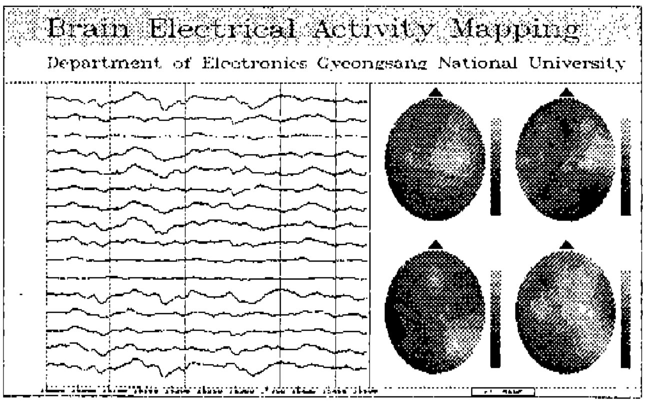

Fig. 9. BEAM in the time domain.

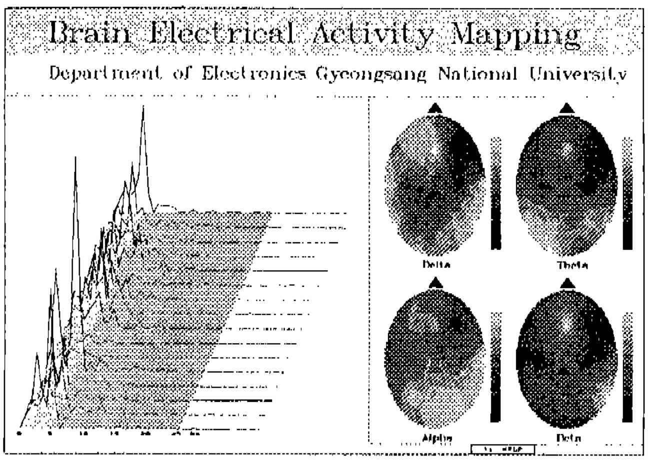

Fig. 10. The BEAM in the frequency domain.

our display. The last, BEAM is composed combining seperated values with position files. Fig 6 shows flow chart of image construction

4. 3. Picture display

Main menu is displayed temporal 16 channel EEG signals in the left and one~four BEAM in the right. Shifting of data be achieved arrow ←, →, PageUp and Page Down. Data of an arbitrary time interval could be delete, save and seperate, and HELP set up for user.

The BEAM is implemented for dot density of gray level and gradient colour density of mixed red-green in time and frequency domain. In time domain, potential distribution and change over any arbitrary time interval could be observed. Four BEAM could be composed for instananeous change and temporal signals are displayed in the left which shown in Fig. 9. The second BEAM compose paticular patterns which occured "pops" in the temporal signals, in constract to other three BEAM. And we setted up BEAM of extended mode for observation in detail.

The BEAM of frequency domain was composed of power spectrum using Fourier transform and window function. In frequency domain, energy distribution and change over a special frequency band -α, β, γ and δ band-could be analyzed. Fig. 9 shows the BEAM of α, β, γ and δ band.

Discussion

Replacing polygrapher of EEG signals by digitized saving and editing, we could easily apply tool of analysis to computerized EEG signals and take a safe-keeping. The use of pre-calculated interpolation weight vector files have great advantage to increase speed of computation and to reduce memory waste. The number and locations of electrodes or brain projection can easily be changed and multiple projections and electrode arrays retained. Further, it automatically allows for giving more weight to certain areas by increasing the density of the electrode placement and could be used for other measures such as blood flow, synaptic receptor counts or other cortically distributed variables. Hence, the BEAM algorithm described here make a merit of simplicity, flexibilty, complete automation and accuracy of map geometry. Besides, analysis of EEG signals is exactly, rapidly, and easily accomplished, implementing computerized BEAM which is composed of two dimensional image in time and frequency domain.

Because colour coding of picture has increasingly difference of mixed red-green levels, we rapidly discriminate among patterns of BEAM. Menu of BEAM is formed conveniently for user using pull-down method.

Observing change and distribution of the BEAM patterns instead of temporal signals in the time domain, EEG signals could be analyzed objectively and easily. In the frequency domain, functional study of brain is expected to support, with the consequence that energy distribution of special band is observed. BEAM system implemented in this study is under experiment for clinical application in the Gyeongsang National University Hospital.

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