REPRESENTATION OF SPATIAL PATTERNS IN THE ELECTRICAL ACTIVITY GENERATED BY THE BRAIN

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ABSTRACT

The Karhunen-Loeve transformation is used for the representation of spatial patterns present in the EEG. Three eigenimages are shown to be sufficient to represent more than 92% of the variance in a 2.5 s segment of both a normal and an abnormal EEG. These images, interpolated to form topographic maps, reveal what appear to be important fundamental patterns in the EEG. These patterns may be reflective of independent generators within the brain. The results suggest that the method may be extremely valuable for the reduction of the data collected during electroencephalography.

Keywords: Karhunen-Loeve transform, electroencephalography, topographic mapping, pattern representation, data compression.

INTRODUCTION

The electrical activity of the human brain can be recorded using electrodes attached to the scalp. Known as the electroencephalogram or EEG, these recordings have been used extensively to study both the normal and the abnormal functioning of the brain. Specialization of the regions of the normal brain for performing various cognitive functions has, for example, been observed through lateralized variations in the EEG. Changes in the patterning of the EEG have been correlated with mental disease and with drug induced states. The locations of tumors and epileptic foci have also been determined from recordings of the EEG (1-3).

An emerging method for the presentation of the EEG is topographic mapping (4). This method involves the interpolation of the potentials recorded at discrete sites on the scalp to form surfaces which are then displayed as color coded maps on a television monitor. These maps serve to assimilate the spatially dependent potentials from the various regions of the scalp and enable the overall character of the EEG to be more easily visualized. From these maps, potential asymmetries reflecting cognitive activity or potential spikes indicating the location of an epileptic focus can be discerned.

One difficulty in the topographic mapping of the EEG is the representation of the temporal variations present. Brain potentials from the normal brain contain variational components extending up to perhaps 30 cps and epileptiform potentials can contain components to near 100 cps. Therefore, topographic maps which represent the potential distribution over the scalp at discrete instants in time change very rapidly and individually may seem to lack any definite character. Solutions to this problem have been to cartoon the maps or to display several maps at once in a sequence to represent the temporal variations. Neither of these approaches have been entirely satisfactory since the extraction of patterns which include the temporal variations must still be done by the observer.

The approach which we have adopted to the solution of this problem is the Karhunen-Loeve transformation (KLT) (5). This transformation allows the spatial and temporal patterns in the EEG to be represented by a parsimonious set of eigenimages. An arbitrary interval of time can be represented with these eigenimages and a measure of the significance of each obtained from the associated eigenvalue. In addition and probably most importantly, eigenimages relate directly to some persistent spatial patterning of the EEG.

METHODS

The EEG was recorded using the 31 electrode shown array in Fig. 1. A left-ear reference was used for the recordings. To facilitate the interpolation method, 4 additional points, X_1, X_2, X_3 and X_4 were assumed to exist at the corners of this array to complete a 5 x 7 grid. Samples of the potential variations at each of the 31 electrodes were obtained at the rate of 120 per second using a 12 bit analog-to-digital converter. Potentials at the corner points were computed at each sampling instant by linearly interpolating the potential values from the nearest 3 electrodes. Interpolation of interelectrode potentials for topographic mapping was obtained using the method of bicubic splines (6). The boundary condition used for the splines was the so-called clamped slope and a value for this was estimated from the potential at each boundary and nearest interior electrodes.

The KLT of the EEG was obtained by representing the array of samples (a potential image) from the scalp electrodes at each instant