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REAL TIME ANALYSIS

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"NEUROPHYSIOLOGICAL RESPONSE TO NOISE"

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Electrical signals recorded from the scalp are part of a family of signals which are studied in many disciplines including geophysics, vibration engineering, acoustics, communication engineering and so on. In all these fields they are generally recorded and analysed by people who wish to understand the properties of the underlying process. An often valuable technique is to determine how the system behaves when it is disturbed from its normal resting state. Most of these signals are random to a greater or lesser degree depending on the particular source, and those who study them are able to benefit from advances in methods of analysing random signals made in seemingly unrelated fields.

In electroencephalography doctors and scientists are trying to gain a better understanding of the brain and to be able to recognise its malfunctioning and that of other organs. The signals which are readily recorded from the scalp are, not unexpectedly, complex, having being generated by processes inside the brain and subjected to much modification and combination with other signals in their transmission to the scalp. Particularly since the advent of digital computers of reasonable processing power many of the methods of time series analysis have been applied with varying success to these signals. This paper does not, however, set out to describe the use of conventional time series analysis, but will concentrate on two methods of describing EEG signals and the use of one of them in improving the assessment of auditory function.

The first method, based on a publication by Leader et al., 1967, considers the signal to be composed of individual waves. This is a concept which is close to that embodied in the traditional visual methods of EEG analysis which have resulted in a considerable body of knowledge about the diagnostic significance of certain types of waveforms occurring in EEG signals. The method is therefore attractive as it offers the possibility of automating some of the skills of the electroencephalographer and allows a more objective description of EEG phenomena leading to greater consistency and ease of communication between observers. Following digitising the signal at an appropriate rate (usually about 100 samples/sec.) a section of 2n + 1 samples is examined. The centre sample is labelled as being a maximum, minimum or neither; the "window" moves on 1 sample, and the process is repeated. If the method is used in real time, the window is moved on 1 sample at a time as each sample arrives. The choice of window width imposes a frequency selectivity, as, by definition, two successive maxima or minima may not exist closer than n samples apart. A wave may now be defined as being an excursion from a minimum to a maximum and back again, and its amplitude, duration, rise time, fall time and sharpness measured.

Transient waveforms having several component waves can be detected by programming the computer to look for waves of specified properties occurring in a particular sequence. More general measures of the continuous signal akin to power spectra can also be obtained by splitting the signal into a number of "wavebands" and then measuring the energy in each band. The bands are selected by defining successive window widths, usually decreasing by a factor of 2. Care must be taken to avoid counting waves more than once, as it is possible that some waves will be passed by more than one window.

The second method, based on work published by Hjörth (1970) is an epoch by epoch type of analysis and derives three parameters for successive epochs. The parameters relate to three independent measures of the power spectrum of each section of signal but are derived directly in the time domain without recourse to fourier transforms. The three parameters, called Activity, Mobility and Complexity, relate respectively to the mean value of the power spectrum (i.e. variance of the sampled signal); r.m.s. frequency of the power spectrum; and the spread or complexity of the power spectrum. The method is easily programmed on a minicomputer for a few channels in real time and has also been implemented in digital hardware for eight channels.

The method has been used both to detect specific types of EEG activity and to describe the more continuous behaviour of the signal. It appears to be very suitable as a feature extraction method prior to classification in a pattern recognition system, and, in certain clinical situations, gives information comparable in its usefulness to that derived from more conventional band pass analysis.

The specific application to be described concerns the use of the EEG to assess a patient's response to stimulation. Of particular clinical relevance is the assessment of auditory function in which a tone stimulus is presented to the subject, and a characteristic EEG response is sought. In normal subjects, it has long been established that a specific response to such a stimulus may be recorded over that part of the brain concerned with hearing, provided that certain measures are taken to increase the ratio between response and on-going EEG activity. Although normal responses have fairly constant shape, even among different subjects, their amplitude is generally only a few microvolts against a background of tens of microvolts. Until recently, conventional signal averaging has been used to increase the contrast ratio between the response and background signal, and this technique is quite satisfactory in normal cooperative adults. About 30 - 60 repetitions of the stimulus are made, and one or two seconds of EEG are averaged by simply adding the sampled signals together, with the first sample time locked to the stimulus. The system tends to break down however in less cooperative subjects, for example in disturbed patients and certain children, especially those with psychiatric disorders, due to the presence of "noise signals" such as muscle artefact of sharp spiky appearance and eye movement artefact of high amplitude low frequency form.

A system has therefore been developed to detect this and other contaminating activity using Hjorth's method in each piece of EEG containing the stimulus. A decision is then taken according to the values of the three parameters as to whether to include the epoch in the average. The process runs in real time with monitoring on two channels to detect artefact. Up to 15 channels of EEG are sampled for the purpose of detecting the evoked response and its spatial distribution. The raw EEG data from each epoch are also stored on magnetic tape in sampled form whether or not the epoch contained artefact as defined by the on-line detection system. This allows different criteria to be applied off-line in order to further increase the quality of the derived response.

Examples will be shown of the improvement which can be made by using this artefact rejection system.

In certain clinical situations, the question asked is not what is the quality of this patient's hearing, but can he hear at all? In this situation it is sufficient to demonstrate that the EEG following a stimulus is in some way constantly different from the EEG preceding the stimulus. Examples will be discussed of some attempts now in progress to use Hjörth's parameters to answer this question. This approach has the advantage of considerably reducing the necessary recording time compared with signal averaging, and alleviates some of the problems of patient management.