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Quantitative EEG Analysis Technique for Computerized Digital Brain Signals

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Abstract- Quantitative EEG (QEEG) analysis techniques can provide additional measurements or displays of digital EEG signals. Several QEEG techniques commonly called EEG Brain Mapping include topographic displays of voltage or frequency. Many technical and clinical problems interfere with simple clinical application. Traditional EEG artifacts can appear in unusual and surprising ways, and new artifacts can be caused by the data processing algorithms. A brain map based on EEG signals shows the potential distribution over the entire scalp. Abnormal activity such as epileptic form spikes or sharp waves may be overlooked, considered arte factual or misinterpreted. The computer may score as abnormal some EEG activity known to have no clinical importance. Interpolation is a mathematical technique workings with these large arrays of number are used to do filtering, frequency and amplitude analysis and color mapping. This approach is called quantitative EEG, because it's different from the traditional approach, which doesn't make any measurements on the tracings; instead, it relies on qualitative assessment or overall appearance of the patterns of waves. A brain map is a picture over the entire scalp so that the potentials around the electrodes need to be calculated. The interpolation should calculate as accurate as possible. This means, that the value calculated by the interpolation should match the real value as good as possible.

Index Terms: EEG Signals, Brain mapping samples, Electro diagnostic instruments, Interpolation techniques, etc.

I. Introduction

QEEG is the mathematical processing of digitally recorded EEG in order to highlight specific waveform components that transform the EEG into a format or domain that indicate relevant information or associate numerical results with the EEG data for subsequent review or comparison. Signal analysis is the quantitative measurement of specific EEG properties or transformations of the raw, digitally recorded EEG signal into numerical parameters other than the traditional amplitude versus time. Source analysis is a form of mathematical analysis in which the recorded EEG values are analyzed. Frequency analysis converts the original EEG data into a representation of its frequency content. The magnitude corresponds to the amount of energy that the original EEG possesses at each frequency. Topographic EEG displays can present visually a spatial representation of raw EEG data. The parameter under study is mapped onto a stylized picture of the head or the brain. In order to use the superior power and flexibility of the computer to store and to analyze the EEG signals, analog-digital converter is needed. Essentially, it is an electronic device that takes a continuously variable wave and transforms it to a list of binary numbers (each binary number being a measurement of the wave's amplitude at regular time intervals. These measurements are called samples, so the whole process is also named sampling). Sampling is performed at a high speed (100 to 200 times per second), and the resulting binary numbers are stored onto the computer's disk. Each channel of EEG has its own separate DAC process, in parallel with the others, and this proceeds in real time. Once all the numbers which were recorded along a period of time are inside the computer, special software programs are used to display the waves in the video screen, print it out, etc.

II. APPROACH AND METHODS

The future of quantitative EEG for clinical applications lies, undoubtedly, in the coupling of digital methods of signal analysis and of image processing. EEG Brain map can be used for a more accurate way of source localization. To properly calculate the location of the source, the brain map should be accurate as possible. Although a brain map, based on measurements are done, only few electrodes are placed and a large part of the brain map is reconstructed from the measured values.

To reconstruct the values between the electrodes, use is made of interpolation techniques. These are mathematical techniques to calculate the most possible value between the electrodes based on the value on the electrodes and distance of these electrodes.

Interpolation technique

Interpolation is a mathematical technique to recreate data on points where no measurement has been done, based on the measurement that has been done in the places of surrounding them. Using a mathematical formula, the value on a specific space is calculated as a function of the surrounding measured values and the distance of these measurements are shown in Figure 1. The interpolation is used in brain mapping because there is only a limited number of electrodes where the measurements take place. A brain map is a picture over the entire scalp so that the potentials around the electrodes need to be calculated. The interpolation

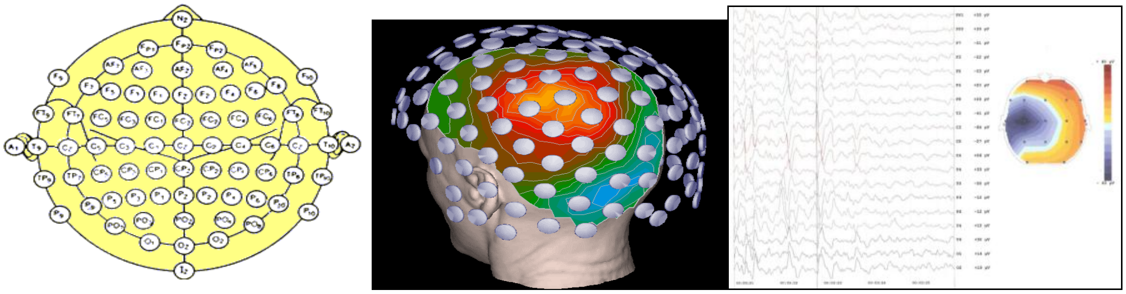

Figure 1.Electrode placement and normal EEG Brain mapping waveforms

should calculate as accurate as possible. This means, that the value calculated by the interpolation should match the real value as good as possible. Since the potential distribution over the scalp is smooth, the interpolation should give smooth results as well. The potentials measured on the scalp are generated by the brain. This generation can be modeled as the generation of an electrical field by several dipoles. To determine the direction and place of the dipoles accurately, the maxima and minima in the picture should be positioned as exactly as possible.

K nearest Neighbors interpolation

The K-Nearest Neighbors interpolation is based on the measurements closest to the point where the values should be calculated. The K is replaced with the number of nearest measurements used. If it is based on the three measurements, it is called 3 nearest neighbor's interpolation. The interpolation formula is given in equation 1.

$$v(P) = \frac{\sum_{i=0}^{k} v(P_i) d_i^{1-m}}{\sum_{i=0}^{k} d_i^{1-m}} \quad (1)$$

The K is the number of nearest neighbours, **v(p)** is the result of the interpolation with p the place where the interpolation takes place. **V(pi)** is the potential of the electrode with **pi** the place of the electrode and **di** is the distance between p and pi. The order of the interpolation is determined by 'm' and is usually 2 or 3. A higher order will cause a smoother interpolation. For brain maps, the interpolation takes place for each pixel in the area of the scalp projection. To demonstrate the effect of the order of the interpolation a simple situation is chosen with k=2. For this example of the interpolation of 2 instead of 3 dimensional, the principle will stay the same. The horizontal axis shows the place and the vertical axis potential.

As can be seen in Figure 2, the nearest neighbor interpolation has some characteristics that are specific for this type of interpolation. The first thing that can be seen that extra interpolation (calculation not between other values but outside the measurement) with this method is impossible. Every point at the edge of the area still has K nearest neighbour, but they are all on one side of the point where the interpolation takes place. Second, the middle line is straight. When the 2 middle potentials are higher than the outside potentials, it is logical to expect the highest value somewhere between the middle electrodes. Would this have been a 3-nn interpolation, the middle line would have been bent downward, because one of the outside electrodes is included in the calculation, instead of upward what is expected from the potential on the electrodes. In Figure 2, this characteristics is closely connected to another one, namely that the global extremes will always be on the electrodes. This can easily be proven. It is obvious that one of the electrodes has the highest potential and that the others have a lower value. The interpolated value will always be between the highest and lowest value of the nearest neighbors and thus the highest value will be on the electrode. If for one point in the interpolation all the nearest neighbors have the same potential and this is the highest potential, the interpolation will also have the same potential. It will never be higher. The same holds for the lowest value. Increasing the numbers of neighbors (K) in the calculation will result in a smoother picture at the cost of detail. When not all electrodes are taken into account (that is, measurements with 20 electrodes and K<20), there is also the problem of the discontinuities. In Figure 2, Pixel a, b and c are another because that is nearer.

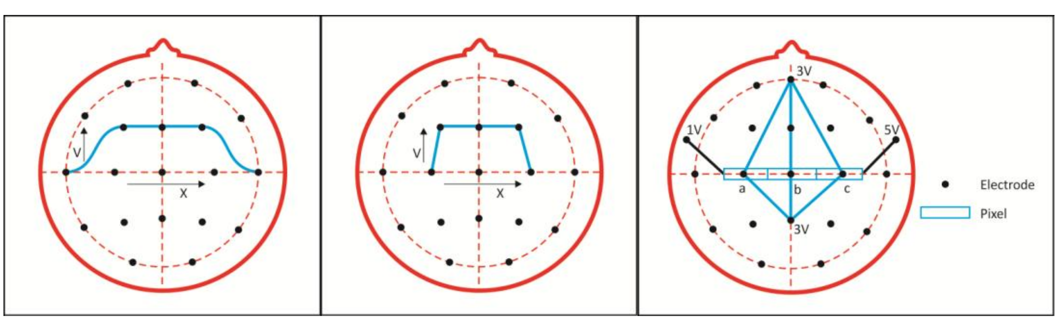

Figure 2 Interpolation methods

Image projection with brain mapping

The result of the measurement and interpolation is an image in which, one way or another, image and color image. The colors are that human psychology interprets colors in different ways and is easily mislead by them and that the small amount of colors will result in re-use of colors. The higher the value, the lighter the grey and lower the value the darker the grey. The most important reason to choose colors instead of grey scale images, because they are not very clear when only grey is used. In a color image the extreme are better visible.

III. EXPERIMENTAL METHODS

EEG is a measurement of the electrical activity of the brain and recorded with the use of electrodes that are placed on the scalp as shown in Figure (4.8). To get a better idea of the source of the signals, a brain map is made. This is a visualization of the measurements of the source of the signals, a brain map is made. This is a visualization of the measurements and shows the distribution of the measured values over the scalp. The images give an idea of the active and less active regions of the brain. A brain map can also be used for accurate way of source localization. The active area in a brain can be modeled as a dipole. A dipole causes an electrical field and the projection of this electrical field on the scalp can be measured. This electrical field is for other source of the signals that are measured with the EEG recording. To properly calculate the location of the source, the brain map should be as accurate as possible. Although a brain map is based on measurements, only at few places the electrodes are placed and a larger part of the brain map is reconstructed from the measured values. Brain mapping is a way to visualize brain activity as shown in Figure 3. For this measurement, two or more electrodes are placed on the scalp, and they measure the potential between these locations. The size of these signals are very small (micro volt) and the signals look like noise. In Figure 3, the QEEG recordings are not written down the paper, but the measurement is immediately digitized and stored on a digital medium. This not only improves the accuracy but more important in this case, it makes it very easy to prepare the measurement ways of analysis Figure 3.

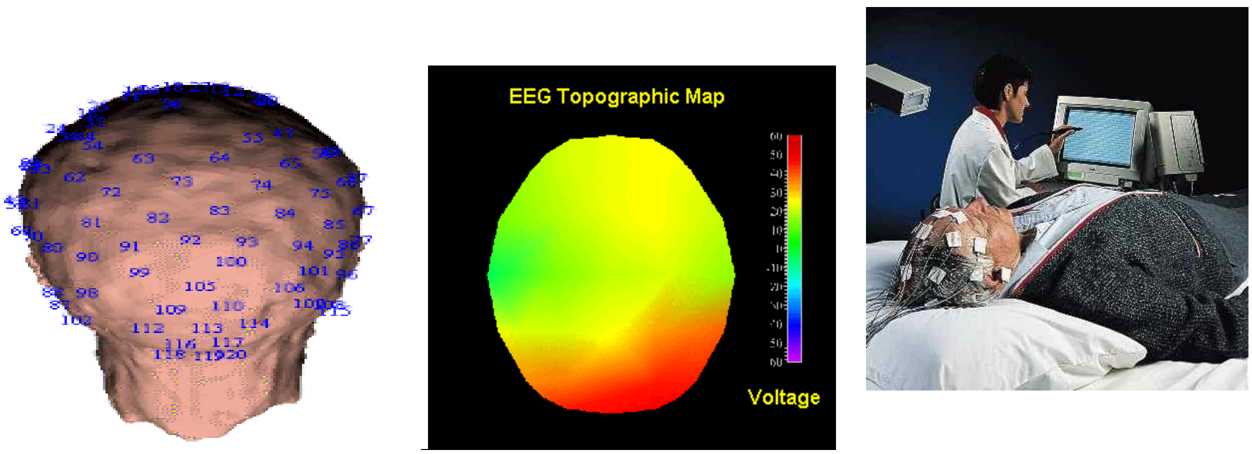

Figure 3 EEG recording and topographic map

It is clear, that a, measurement with electrode is local. This means that the only values that are known are those at the position of the electrodes. The logical way to improve resolution (the spatial accuracy of the measurement) is to increase the number of electrodes. Another method to improve the resolution is interpolation. This method tries to reconstruct the values between the electrodes based on some mathematical calculation. This is possible because of the smearing effect. It should be noted, that interpolation is never been able to reconstruct the real situation other than by coincidence. It is not able to create data and it can only guess at the real value at a given position. Therefore the most important thing to do should be to use as much electrodes as is practically possible, and which are placed in a way that allows optimal recalculation of the values at the places where no measurement take place. For this, the electrode should be placed in a way that the distance between they are almost equal. The international standard for the electrode position is called 10-20 system and uses 19 electrodes.

For this system, the head is regarded as a sphere. It is possible to place extra electrodes or to have the electrodes on the position other than those described in the 10-20 system. Electrodes that are at slightly other positions than described (it is not always possible to place an electrode at a specified place) are marked with ‘a’ for ‘1’ and with’ a’ for ‘2’ cm that can be the distance to the position they should have been placed according the 10-20 system. The accuracy of the brain map is determined by the accuracy of the interpolation technique used. To measure the accuracy of the interpolation, the interpolated value and real value should be known. A way to accomplish this is by interpolating on the place of an electrode, since the potential at that place is known. The interpolation takes place without the value measured at the place of the electrode.

Statistical accuracy measurement with variance

To determine the accuracy of the interpolation, the variance is calculated with the following formula

$$var(x) = \frac{1}{n}\sum_{t=1}^{n}(X(t) - \bar{X}(t))^2 \qquad (2)$$

To calculate the variance for an interpolation, where the difference between the measured value and the interpolated value is relevant, the formula is modified as follows. The average is replaced with the measurement, and the data is replaced with the interpolated value.

$$var(v) = \frac{1}{n}\sum_{t=1}^{n}(v_i'(t) - v_i(t))^2 \quad (3)$$

This type of statistical analysis can give an indication of the expected error. For this standard deviation has to be calculated by taking the square root of the variance.

$$SD(v) = \sqrt{var(v)} \quad (4)$$

The interpolated values will be with 99 % confidence within the interval.

Vi-2.326.SD (v) <v'i<vi+2.326.SD (v) (5)

There is now a fairly accurate estimation of the maximum deviation of the interpolated value in respect to the real value. This, however, is only based on values of specific recording. A simple measurement of two different recordings is used; sample-1 and sample-2.These two measurements are done with the same electrode positions. For reference also the sum of the squared measurements in a recording are also in the table

Table 1 Measurements of two different recording with same electrode positions

Recording	Sample-1	Sample-1	Sample-2	Sample-2
Electrode	Variance	∑(v)2	Variance	∑(v)2
F4	0.372	308.10	0.482	197.10
T3	1.94	2.89	3.74	1.70
02	0.586	216.10	0.586	1.20

Variance and summed squared values of two data files

It can be seen that the accuracy measurements depend on the recordings. Especially the difference of the ratio's between variance and summed squared values is striking. Although sample-1 has a lower variance, the sum of the squared values is higher, so relatively the variance is even lower. Another problem with this type of quality control is that there is no indication on the error that is error. It is impossible to see if all errors are made in one direction, for example if all interpolated values are to low. So calculation of the variance can be used to measure the quality of the interpolation but it can only be used for the same data set. This results in the conclusion that this method is usable for comparison purpose between different interpolation techniques, but isn't suited for detailed research on the errors that are made with the interpolation.

IV. CONCLUSION

The brain maps are calculated from a limited amount of data because the only measurements that are recorded are at the place of the electrodes. All the other values on the scalp should be calculated. This requires are interpolation technique. The K nearest neighbor techniques is the one best fitting the requirements a brain map demands. The result of the K nearest neighbor technique is good, but the interpolated values show a structural deviation from the real values. The deviation depends on the set of data that is used. The brain map will be used for purpose of source localization it is important that the maxima and minimize are located in the right locations, and are not restricted to the locations of the electrodes.

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