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Evaluating of the 3D visualizations of quantitative stereoelectroencephalographic information

Jean-Louis Dillenseger Beatriz Sousa Santos, Pedro Teixeira, José Nunes, Carlos Ferreira

Abstract—Stereoelectroencephalography (SEEG) has been used to define and understand the organization of epileptogenic zones of the brain. The fusion of the SEEG signals and the anatomy on a common referential is a possible method for the analysis of these signals. This work describes an experiment conducted with human observers in order to evaluate three different coding schemes used to visualize the magnitude of SEEG signal in the anatomical context.

Key words—Epilepsy, 3D visualization, quantitative evaluation, quality

I. INTRODUCTION

Epilepsy is the result of abnormal brain electric activities that mainly appear as synchronous (paroxystic) discharges within large populations of neurons belonging to brain structures implied during seizures. Investigation methods used in epileptology are aimed at defining and understanding the organization of the epileptogenic zone (from the areas originating the discharges to those secondarily affected by their propagation). Among these methods, Stereoelectroencephalography (SEEG) provides signals recorded with intracerebral electrodes. These signals bring major information on the dynamics of processes inside the brain structures. The visual analysis of SEEG signals is aimed at understanding the spatio-temporal dynamics of epileptic processes. More precisely, it tries to exhibit: 1) the existence of one or more areas generating independent activities, 2) propagation of paroxystic activities from one cerebral structure to another and 3) phenomena of synchronization or time delays between activities from subsets of structures.

One solution for a spatio-temporal analysis can be given by the fusion of the signals and the anatomy on a same referential [1]. The goal of the present work will be the evaluation of that technique in regard to the objectives of the medical task. In a first step we will restrict our study to the evaluation of the technique for the quantitative visualization of the signals. The magnitude of the signals is encoded by graphical glyphs that have a direct impact on the perception of the values [2], [3]. Our evaluation will be devoted to the influence of the glyphs on the understanding and the analysis of the signals.

In the next sections we will introduce the objectives, describe an experiment performed using three different cod-

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ing schemes for representing the magnitude of the signals, present the obtained results and draw some conclusions.

II. OBJECTIVES

The experiment presented in this work is just the first one from a set of experiments concerned with the evaluation of the influence of the glyphs on the understanding and analysis of the SEEG signals in anatomical context (as shown in figure 2 and 3). Its objectives are related to the evaluation of the performance of human observers in extracting quantitative information from the visual representation of the signal coded through a glyph (a sphere in this case), without the presence of the scale. This evaluation will be performed in static scenes containing only a few glyphs. However, the image of the anatomy and the depth electrodes size will still give an external frame on the experiment.

We have chosen three different coding schemes for the magnitude of the SEEG signal. Each corresponds to a different way of relating the magnitude of the signal proportionally to the size of the sphere (figure 1):

#1 - magnitude \propto Radius of the sphere (R);

#2 - magnitude \propto Projected surface of the sphere (πR^2);

#3 - magnitude \propto Volume of the sphere ($(4/3)\pi R^3$);

where R is the radius of the sphere.

Through this experiment we intent to study specifically if any of these coding schemes allows better performances for the human observers in two aspects: accuracy and speed. A coding scheme will be considered better than the others if it allows a more accurate and/or faster "measure" of the magnitude of the signal in a statistically significant way.

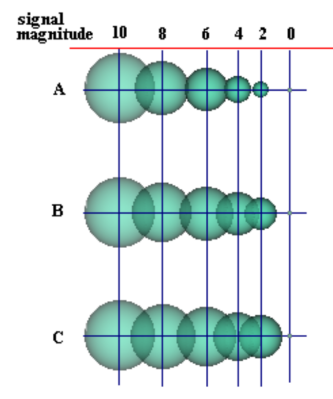


Fig. 1. The 3 coding schemes

III. THE EXPERIMENT

In this experiment only a few factors were manipulated so that the causal relationship between manipulations and observer performance is possible to establish. More precisely we med to demonstrate the relation between the independent variable –the coding scheme– and the dependent variables – the perceived magnitude error (real magnitude - perceived magnitude) and the decision time (approximated by the reaction time an observer takes to answer)–.

The first step was the formulation of clear hypothesis that predicted the expected performance effects associated with the experiment:

- If the mean error in perceived magnitude is equal when using any scheme, then it is possible to consider that scheme #1 is as good as scheme #2 and as scheme #3 in accuracy. Statistically this can be stated as a hypothesis: $H_{0e} : \mu_{e\#1} = \mu_{e\#2} = \mu_{e\#3}$ versus $H_{1e} : \mu_{e\#1} \neq \mu_{e\#2} \neq \mu_{e\#3}$, (where $\mu_{e\#n}$ is the mean error for coding scheme #n), that may be tested through a variety of statistical methods.
- If the mean error in perception time is equal when using any scheme, then it is possible' to consider that scheme #1 is as good as scheme #2 and as scheme #3 in speed. This can also be stated as an hypothesis: $H_{0t} : \mu_{t\#1} = \mu_{t\#2} = \mu_{t\#3}$ versus $H_{1t} : \mu_{t\#1} \neq \mu_{t\#2} \neq \mu_{t\#3}$, (where $\mu_{t\#n}$ is the mean perception time for coding #n).

A s/w package, for Windows platforms, was developed to allow an easy application of the chosen protocol for the experiment. All the test images were generated in the same way, varying only the coding scheme. The point of view was chosen so that the spheres were at equal distance from the observer. During the experiment, viewing conditions should be as similar as possible for all the observers (type of screen, viewing distance, ambient light, etc.).

The protocol has been the following:

- 1) All observers received a simple explanation about the context and aims of the experiment and what is expected from them. After they are fully informed and agree in proceeding, they are asked the information needed to define their profiles and then the protocol starts.
- 2) For each observer, the following variables are collected in order to establish the user profile: Age ($i=25$; $i=55$), nationality, gender, familiarity with 3D video games or synthetic images; profession (Medical doctor, or not); number of years of speciality and familiarity with 3D medical imaging (for doctors);
- 3) The protocol was divided in three similar parts (one for each coding scheme). In order to minimize the side effects, the order of the 3 coding schemes was chosen randomly for each observer.
- 4) For each coding scheme, the observers trained themselves (figure 2) before observing all the images corresponding to same coding scheme. This training was interactive and ended only when the observer decided he/she is ready to proceed.

- 5) After training for each coding scheme, the observers are shown three different images containing a certain number of spheres and are asked which is the magnitude of one of the spheres (as shown in figure 3). The value coded by a sphere and the position of the sphere are also chosen randomly. The error in magnitude (real magnitude - perceived magnitude) and the reaction time are registered.

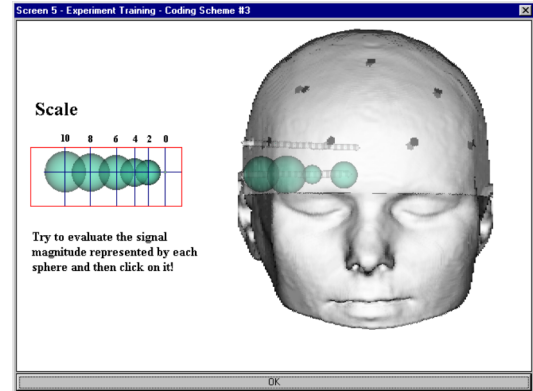


Fig. 2. The training screen

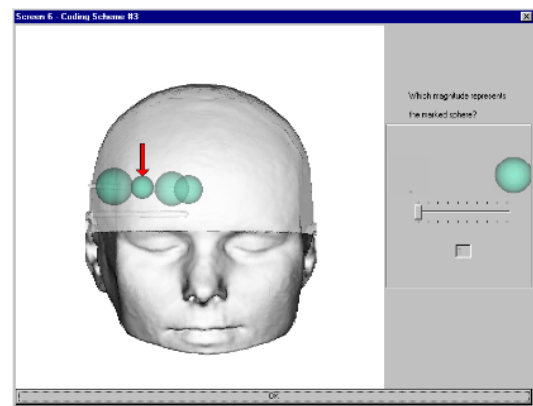


Fig. 3. Evaluation

IV. RESULTS

The results presented in this work were obtained from a first experimental set implying 40 human observers. These observers exhibited a relative homogeneous profile (University teachers and students; 25% of female). The aim of this first step was mainly to verify the statistical analysis sequence (40 observers can be seen as statistically significant) but we hoped also that it would induce to some results about the performances of the coding scheme. In this first step, the coding schemes have been taken into account as independent variables.

The framework of the statistical was the following (all the statistical analysis of these data were performed using the commercial s/w package MINITAB [4]):

- 1) The first analysis performed on these data was an Exploratory Data Analysis (EDA) in order to get an overview of certain data characteristics (such as ranges, asymmetries,

the existence of outliers, etc.). It allowed a preliminary comparison among the three coding schemes and helped on the choice of other statistical techniques to be used to further analyze the data.

Perceived magnitude error (table I).

The errors corresponding to coding schemes #1 and #2 seem very similar. They have the same minimum, median and 50% of central values (between 0 and 1), the only difference being the existence of a maximum value (3) for the coding scheme #2 (which, however, is considered as an outlier). On the other hand, coding scheme #3 presents a larger range; it must be noted that the minimum values for coding schemes #1 and #2 are considered outliers and this is not the case for coding scheme #3. Moreover, the 50% central values of coding scheme #3 are spread between -1 and 1.

TABLE I

MEDIAN, MIN., MAX., QUANTILES AND RANGE FOR THE 120 ERRORS VALUES (E_1, E_2, E_3) CORRESPONDING RESPECTIVELY TO CODING SCHEMES #1, #2, #3.

	Median	Min	Max	Lower quart	Upper quart	Range
E_1	0	-2	2	0	1	4
E_2	0	-2	3	0	1	5
E_3	0	-3	3	-1	1	6

Reaction time (Table II).

The minimum, maximum and median values of the perception times obtained for coding scheme #1 are smaller than for any of the other coding schemes; this is also the case for the 50% of central values. However the great difference observed in the range of the three coding schemes may be not so significant since the (worst) maximum values of coding schemes #2 and #3 are considered outliers.

TABLE II

MEDIAN, MIN., MAX., QUANTILES AND RANGE FOR THE 120 TIME VALUES (T_1, T_2, T_3) CORRESPONDING RESPECTIVELY TO CODING SCHEMES #1, #2, #3.

	Median	Min	Max	Lower quart	Upper quart	Range
T_1	10	3	25	7	13	22
T_2	11	5	36	8	13	31
T_3	12	5	42	9	15	37

2) On the basis of the first results, a normality test indicated that the data sets are in conformity with the normal law. The data sets could so been characterized by their means and standard deviations.

3) The hypotheses H_{0i} (the equality between the three means corresponding to the absolute error values and times of all the coding schemes) has been verified by help of a one way analysis of variance (ANOVA [5]). This test applied on our data rejected both null hypothesis (H_{0e}) and (H_{0t}) for a confidence level of 95%. This analysis revealed that the differences between the data sets are due to the independent variables and not to the variability between the observers.

4) A proportion test (the Tuckey's pairwise comparisons method [6]) was used to establish which of those means were responsible for this rejection. In our case, and for both the perception error and the reaction time, the test indicated that coding scheme #3 was different from coding scheme #1 differences were noticeable between coding scheme #2 and coding scheme #1

5) From the previous analysis results, we propose a first attempt of a subjective classification of the coding scheme's performances. From the observations from EDA and the chosen performance criterions in term of accuracy and reaction time, a first conclusion can be made. The coding scheme #3 seems to be less accurate (the errors are more spread) and the reaction time seems to be slower. This strengthen some remarks from Bertin [2] saying that only 10% of observers are able to estimate a volume with less than 15% of errors. Coding scheme #3 will be considered as having poorer performances as the two other schemes. However, the statistical analysis was not able to separate the coding scheme #1 and #2.

V. DISCUSSION

The previous statistical analysis could not discriminate the coding scheme #1 from the coding scheme #2. Several factors could explain this result:

- The small sample of observations. In this first test, we reduced the length of the experimentation to 3 images per coding schemes in order to avoid a saturation of the observers. After this first evaluation we decided to enhance our protocol to 10 test images per coding schemes. This extension is still well supported by the first observers of the new experimental set.
- The observers' profile. This first test was conducted on a relatively homogeneous population (University teachers and students). No physicians have been involved in this test. The new experimental set will include more different profile of population and in particular neurologist.
- The number of independent variables. We do not use for the moment the information contained in the observers' profile (gender, familiarity with 3D images and profession). A first informal test showed that they are a difference in results between the male and female groups whatever the coding scheme (higher accuracy but slower reaction time for the female). This informal test proves that other independent variables could influence the results and have to be taken into account for the new experimentation.

VI. CONCLUSION

The experiment described on this work was only the first one from a set of experiments concerned with the evaluation of the influence of glyphs on the understanding and analysis of SEEG signals visualized in anatomical context. The obtained results seem to indicate that a coding scheme based on the proportion between a value and the volume of a sphere is less appropriate as the coding schemes based on the proportion between a value and the radius or the projected

surface of a sphere. However, due to the small sample used and to the fact that the observers' profiles are similar (mostly engineering students and teachers), no definite conclusions can be drawn from this study.

Nevertheless it allowed to establish a basic protocol and provided several important clues on how to perform further experiments and analyze the obtained results.

An experiment using basically the same protocol will be performed with a greater number of observers having different user profiles, including doctors and observers with formal 3D training. The results obtained from this experiment are expected to allow the confirmation (or not) of the results obtained until now and establish relationships among some of the characteristics of the observers profiles and the performances with some of the coding schemes.

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