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# FUNCTIONAL AND MORPHOLOGICAL DATA FUSION IN ELECTROENCEPHALOGRAPHY

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**Abstract - This paper presents a methodological framework to display three dimensional anatomical data provided by CT-Scan or MRI together with electric (or magnetic) recordings of the brain activity. This fusion of information allows to get a better understanding of the spatio-temporal behaviour of the underlying processes.**

## I. INTRODUCTION

The availability of high resolution 3D descriptions of anatomical structures leads to new insights in medical diagnostic and provides a very attractive basis for more accurate and more efficient computer-assisted therapies. A number of efforts have been first devoted to the rendering techniques of Tomodensitometry or Magnetic Resonance Images [1]. New advances are now expected from multimodality imaging e.g the confrontation of complementary informations featuring morphological as well as functional data (for example, Nuclear Medicine Sources -SPECT, PET- with CT and MRI). These capabilities can also benefit to other observations such as Electroencephalography or Magnetoencephalography recordings. However, these signals are time varying and acquired on a limited number of sensors. Moreover, the display of these signals can be seen as the main goal or as a part of the overall methodology aimed at source identification. These issues will be discussed in this paper and a solution directed to 3D potential mapping will be proposed.

## II. PROBLEM STATEMENT

Five considerations must be taken into account when dealing with the complete problem at hand.

(1) The Direct and Inverse problem solving : several approaches have been developed to identify the sources originating the observations which are based on different assumptions : source models (dipole or multiple dipoles), electrical tissue properties and geometrical approximations (such as concentric spheres). According to these assumptions integral or numerical solutions can be derived. The finite element method for example is used on realistically shaped compartment model of the head. The spatial deconvolution technique has been applied to stratified spherical volume conductors. In this case, a projection rule of the resulting potential distributions on each layer must be carried out on the

real surfaces.

(2) The morphological data representations are based on surface (first or higher order functions), or voxel descriptions : according to the solutions elicited in (1), surface or volume mesh is required.

(3) The sensor registration which means that the geometrical positioning will allow to merge the functional and morphological data into the same coordinate system.

(4) The interpolation scheme which is defined from the sensor locations, the geometrical domain where it is performed and the interpolating function.

(5) The display technique : polygonal surface approximations as well as more realistic (voxel-based) models can be used.

## III. METHODS

Among all the possible choices that can be made to solve (1) to (5), the work has been directed to :

(1) a three concentric sphere model and a spatial deconvolution method [2]

(2) surface and volume representations have been carried out [1]

(3) point, surface and volume based methods have been developed for registration purpose [3]

(4) interpolation schemes using regular or irregular grids and a number of functions can be implemented without problem

(5) Z buffer techniques, octree encoding as well as ray tracing methods have been compared [4].

The solution proposed to (1) leads to surface representations and does not provide a real mean for source location : its output is the potential distributions on internal surfaces close to the sources. It does not imply that all the volume information is lost but only that the mapping of the observed function will be done on anatomically identified layers (such as the scalp, the skull and the like). The registration of the sensors can indifferently be carried out by means of mechanical and optical devices or even by means of external markers seen in a given imaging modality. Another simple (and approximate) way to match the original signals and images consists to make use of standard electrode setting with reference to anatomical landmarks such as inion and nasion points. Whatever the method used, the main concern remains the precision of the location which interferes directly on the reliability of (1). The same issue arises when the interpolation is done. If the interpolation is a part of (1)

and is seen as a mean to introduce additional (or virtual) sensors, some cautions have to be taken. When (4) is only aimed at the display of time varying mapping, simple schemes (linear interpolation based on euclidian distance for example) can be used without need to look for the minimal path between twosurface points. The ray tracing method has been retained here to render the data. The temporal function has been represented through a color look up table where blue (respectively red) depicts the negative (resp. positive) values. The local shading of the surface is classically computed from the surface normal. The combination of morphological and functional data is performed by using the Hue Saturation Luminosity (HSL) color encoding where the potential (or any other variable) function defines the H value and the shading the S and L values.

## VI. RESULTS

These methods have been implemented on a HP-9000 computer. They have been applied to a CT Scanner image set (150 slices, 256 x 256 resolution, courtesy of CGR France). The reference coordinate system has been defined by interactive pointing of theinion and nasion landmarks and the electrodes were automatically placed according to this reference and to the standard 10-20 setting. The electrical potential distribution on the scalp was computed as a weighted sum of the four closest potential values. In order to speed up this computation, the weighting factors of all the seen surface points for a particular viewing direction are precomputed. The shading is estimated from a gradient operator. Two display modes have been developed. They allow to display from the same point of view either, a head sequence surface with time indexed maps [Figure 1] or one head with successive maps. No constraints are imposed in viewing capabilities [Figure 2].

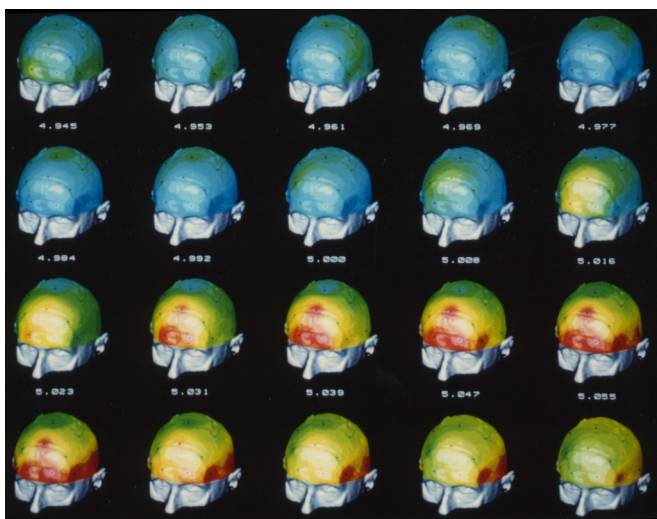


Fig. 1. 3D anatomical EEG potential maps.  
Temporal sequence displayed from the same point of view.

## V. CONCLUSION

A solution has been described to merge morphological and fonctionnal features. This 3D mapping can be easily extended to volume time varying data resulting from direct or inverse problem solving methods. This mapping is a generalization of classical 2D cartographies and leads to more realistic views of spatio-temporal relationships. It can handle either the original or transformed data (e.g Fourier Transforms, Multiscale Decomposition [5] and provides a compromise between fidelity, precision and time computation.

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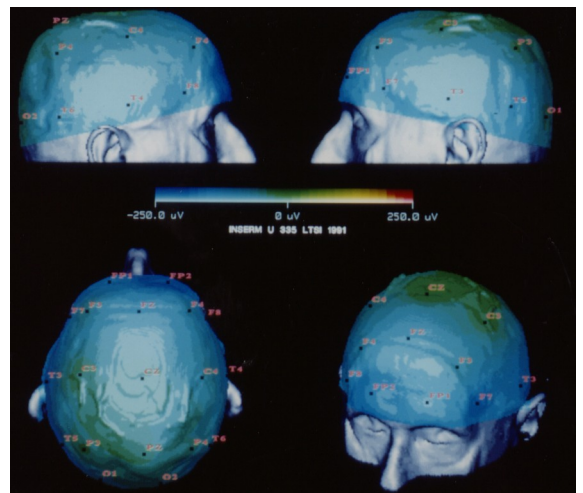


Fig. 2. Different points of view at the same time. Note the scale used for the function representation.