Spherical Mapping of Electroencephalogram Topography

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Abstract

A three-dimensional Electroencephalogram (EEG) / Magnetoencephalogram (MEG) topography system is presented. The purpose of the system is to provide an easy-to-use three-dimensional EEG/MEG topography system which can be run on low cost platforms such as personal computers and low-end workstations. The input data of the system are two-dimensional EEG/MEG topographical data computed by the EEG/MEG topography system currently in use. The input data are a two-dimensional array of EEG/MEG data. The system maps these data onto an upper hemisphere which is a model of the human head. The hemisphere is divided into sub-areas corresponding to cells of the input EEG/MEG data array. Each sub-area has the same EEG/MEG value as the corresponding cell. After the mapping, the system displays the three-dimensional EEG/MEG topographical image on a CRT display. The point of view for this image can be changed in any desired direction. The system is implemented on two platforms: a DOS based personal computer and an Unix-based workstation which have X-Window system.

1 Introduction

Many EEG/MEG topography systems are now commercially available and widely used for the diagnosis of various diseases. They are also important tools for the researchers 1, 4, 8). Currently available EEG/MEG topography systems are two-dimensional, however, and can provide only two-dimensional EEG/MEG topographical images. EEG/MEG topographical data represent the potentials of the EEG/MEG of a human's head; so two-dimensional EEG/MEG topographical images are approximate images of real, three-dimensional EEG/MEG topographical data. These three-dimensional EEG/MEG topographical images are necessarily distorted by being mapped onto a two-dimensional plane.

Fig. 1 shows a two-dimensional EEG topographical image produced by a 7T18 signal processor. The values of each square are represented with 11 distinctive colours.

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The white squares in Fig. 1 and the following figures are the positions of electrodes. Note that the distances between electrodes are not accurately represented. For example, the distances between the centre square and the eight white squares are equal in the 10-20 method. In Fig. 1, however, the diagonal distances are longer than the vertical or horizontal distances. Another problem of the two-dimensional EEG/MEG topography shown in Fig. 1 is related to these characteristics. The four our white squares at the corners of this image are outside the figure of a human head. The distances between these squares to the centre square are as long as for the other outer squares, however. Therefore, the data near these corner squares should be shown. For more accurate diagnosis, three-dimensional EEG/MEG topographical images are clearly desirable.

The recent availability of powerful personal computers and workstations makes it possible to create inexpensive three-dimensional EEG/MEG topography systems. In this paper we describe a three-dimensional EEG/MEG topography system which converts two-dimensional EEG/MEG topography data to three-dimensional images. This system was implemented on an MS-DOS based personal computer (NEC PC9801VX, the most popular personal computer in Japan) and an X-window based Unix workstation (Sun Corp. Sun3/60 and Sparc station 1+).

2 Comparison of Three-dimensional Mapping Methods

The three-dimensional EEG/MEG topography system is designed to be a data conversion program which maps EEG/MEG data onto a three-dimensional surface representing a human head. EEG/MEG values at particular points on the surface are colourcoded according to their values. In the case of a monochrome display, EEG/MEG values can be represented with a gray-scale instead of colour codes.

There are two methods of mapping EEG/MEG data onto three-dimensional topographical images. One method is to map multi-channel EEG/MEG data onto three-dimensional topographical image directly. In this method, the EEG/MEG topography system reads the multi-channel data from the Electroencephalogram / Magnetoencephalogram. The input EEG/MEG data are not topographical data; these data are EEG/MEG values at particular points on a human head. To convert multi-channel EEG/MEG data to topographical form, the system must compute interpolated data between the points. Such interpolation requires great computer power. The three-dimensional EEG/MEG topographical data generated with this method will be more accurate than that which is generated with second method.

The first method, however, has another problem. With this method, three-dimensional EEG/MEG topographical data can be obtained only from the original multi-channel EEG/MEG data. There are many two-dimensional EEG/MEG topographical data sources now. These data can not be used as input in this method. Although approximations of original multi-channel EEG/MEG data can be computed, the formats which are currently used for two-dimensional EEG/MEG topographical data are not sufficient for such approximations.

The second method is to convert two-dimensional EEG/MEG topographical data which are generated by the EEG/MEG topography systems currently in use to three-dimensional EEG/MEG topographical data. This method is suitable for low-cost computers because the interpolations have been done by the two-dimensional EEG/MEG topographical system. The second method has another merit as well. Many two-dimensional EEG/MEG topographical data have already been collected. The second method can display these existing two-dimensional data with three-dimensional image formats. Using this method, existing data will not be wasted. Of course, the images generated with the second method are not as accurate as the images generated with the first method. The distortion incorporated with the second method, however, is usually not significant. Our object was to provide a low-cost and easy-to-use three-dimensional EEG/MEG system. Considering this object, we opted for the second method in our system.

3. Description of the System

As described in the previous section, our system uses two-dimensional EEG/MEG topographical data produced by the EEG/MEG topography systems currently in use. Therefore, the entire system is divided into two parts (Fig. 2): the two-dimensional unit and the three-dimensional unit. The two-dimensional unit reads multi-channel EEG/MEG data and generates two-dimensional EEG/MEG topographical data. The three-dimensional unit maps the two-dimensional data onto a three-dimensional surface and displays them as a three-dimensional image.

We use a signal processor (NEC Shinkosha 7T18) to provide the two-dimensional EEG/MEG topographical data. The format of the two-dimensional topographical data which are obtained from 7T18 is shown in Fig. 3. It is a 49 x 49 two-dimensional array. Each square of the array corresponds to a particular point on a human head. In this data, there is a centre square which corresponds to the peak of a human head. Adjacent to the centre square, there are eight squares. The squares which are diagonally situated are considered to be adjacent to each other. Adjacent to these eight squares, there are sixteen squares, and so on.

The three-dimensional unit converts the two-dimensional data described above to a three-dimensional image. The procedure of this task is as follows,

1) Map two-dimensional data onto a three-dimensional surface.

2) Display the mapped data as a three-dimensional image.

The surface on which the two-dimensional data are mapped is hemisphere, or an ellipsoid of a revolution. A hemisphere is used for the personal computer version of this system and an ellipsoid is used in the workstation version. The reason for utilizing these surfaces is to minimize computational cost. To map the two-dimensional data onto such surfaces, hemisphere (or ellipsoid) is divided into concentric circles (or ovals). The centre of these circles (or ovals) is at the peak of the hemisphere (or ellipsoid). Therefore, there are many rings formed on the hemisphere (or ellipsoid). The ring which is adjacent to the centre circle (or oval) is evenly divided into eight areas. The next ring is divided into sixteen areas, and so on (Fig. 4). There are a number of areas on the hemisphere (or ellipsoid), as in the two-dimensional EEG/MEG topography data. The mapping itself is done by copying the two-dimensional EEG/MEG topographical data onto the corresponding areas on the hemisphere (or ellipsoid).

After mapping, the three-dimensional unit displays the hemisphere (or ellipsoid) on a CRT display. The surfaces are modeled with polygons. Each area on the hemisphere (or ellipsoid) is represented as a polygon. On the CRT, each polygon is assigned a colour corresponding to the EEG/MEG value of the area. The edges of a polygon are shown as black or white lines. When these polygons are displayed on the CRT, backface culling is executed using well known techniques 2, 7) in three-dimensional computer graphics (Fig. 5).

4. Implementation

We implemented this system on two platforms. One was a MS-DOS based personal computer; another was a Unix-based workstation on which a X-Widnow system has been installed. Both systems had almost the same capability for displaying three-dimensional EEG/MEG topographical images, while the user-interfaces of these systems are different in appearance.

a) Personal computer based system

The personal computer on which this system is implemented is an NEC PC9801VX. This is a popular personal computer in Japan, and has a Intel 80286 CPU. It can display 16 colours which can be selected from a total of 4096 colours. The system is programmed with Turbo-C 2.0 (Borland Inc.) and uses its graphic environment. The graphic environment of the Turbo-C is almost the same as that of the IBM PC/AT. The compiler was ported on many MS-DOS based personal computers, and the system does not use PC9801VX-specific features. Therefore, the system can be ported on any personal computer on which a Turbo-C is ported and has sufficient graphic capability. Of course, a recompiling is necessary, and simple adaptations of the source code may be required.

b) Workstation based system

We also implemented this system on Unix based workstations (Sun Corp. Sun3/60 with colour display and SPARCstation 1/+ with monochrome display). Colour and monochrome versions of the implementation exist. For portability's sake, the program is written on a standard X-Window environment (X11R5). It uses standard Xlib library and Xt Toolkits with Athena widgets sets. Again, we did not use machine specific features in the program; any workstations (or high-end personal computers) on which X-Window system is implemented can run this system. For example, we confirmed the portability of this system on a NWS-1850 workstation (Sony Corp.). By only re-compilation, the system can be executed on NWS-1850.

5. Results

(a) Personal computer based system

Fig. 6 is the output from the personal computer three-dimensional EEG/MEG topography system. The large hemisphere divided into small areas is a three-dimensional EEG topographical image. This image is based on the two-dimensional EEG topographical data shown in Fig. 1; the point of view in Fig. 6 is from the peak of the head. The eleven squares near the right side represent the correspondence of magnitude of each area to the colours.

The two small line figures represent the point of view. In Fig. 6, the distances between electrodes are displayed accurately. Thus, it is a more accurate image than that of Fig. 1 in spite of using the same two-dimensional data. Fig. 7 is the same EEG topographical image as Fig. 6, but from another point of view. The EEG/MEG topographical data can be inspected from any point of view.

(b) Workstation based system

Fig. 8 is the output from the workstation based three-dimensional EEG/MEG topography system. This system is intended for use with a monochrome CRT display, so the values of each area are represented with black and white dot patterns. The workstation based system has a better mapping capability than the personal computer based system. It can map two-dimensional data onto an ellipsoid. Fig. 8 shows this feature. The user interfaces of this system have been improved. In the workstation based version, a user can do any operation with this window while a number of menu screens has been used in the personal computer based system. Fig. 9 is a colour version of the workstation based system.

6. Discussion

The system described in this paper uses two-dimensional EEG/MEG topographical data as its input. The advantage of this system is that two-dimensional EEG/MEG topographical data which are currently used can be shown in a more accurate, three-dimensional image. The distances between each area are more accurate than in a two-dimensional EEG/MEG topographical system; the areas which are not displayed by a two-dimensional system can be shown. Many two-dimensional EEG/MEG topographical data exist now. Using our system, these existing data will not be wasted.

Using two-dimensional topographical data as input has another merit. In this method, low cost computers can be used to implement this system. It is unnecessary to compute topographical data from multi-channel EEG/MEG data.

To implement our system on low cost machines, we decided not to interpolate two-dimensional EEG/MEG topographical data. In our system, the areas on the hemisphere are divided with black lines. The usage of these lines enables the easy distinction of adjacent areas and the recognition of the hemisphere as a three-dimensional surface. It is possible, of course, to interpolate three-dimensional EEG/MEG topographical data and display such data with a shading process. These techniques are highly developed in the three-dimensional computer graphics field. The purpose of developing this system, however, was to use low cost computers for obtaining three-dimensional EEG/MEG topographical images. Three-dimensional computer graphics is one of the areas which need much computer power, requiring a lot of floating-point operations and a huge memory. It is impractical to use low cost computers for such task.

When the system was programmed, we gave much consideration to the portability of the system. Industrial de facto standard X-window or Turbo-C were used. Moreover, no hardware-dependent features were used. As a result, the implementation on other platforms, such as Macintosh, will not be difficult.

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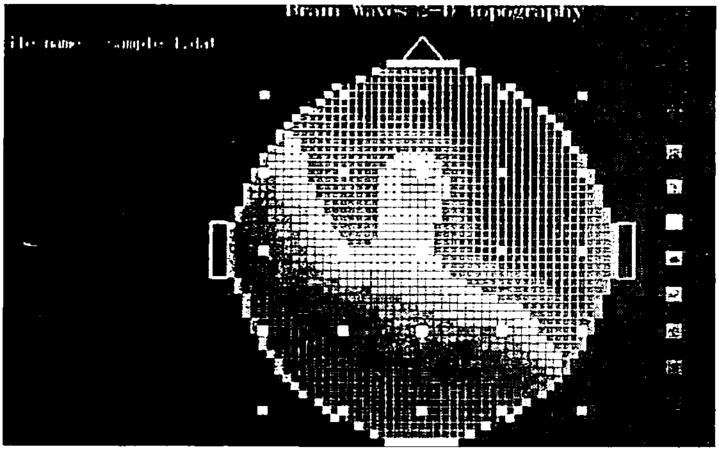

Fig. 1 Two-dimensional EEG/MEG topographical Image

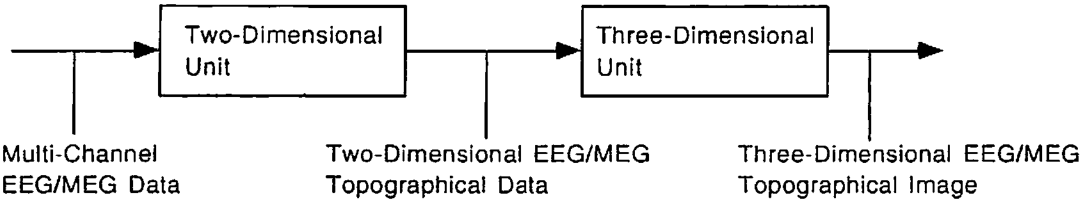

Fig. 2 Three-dimensional EEG/MEG topography block diagram

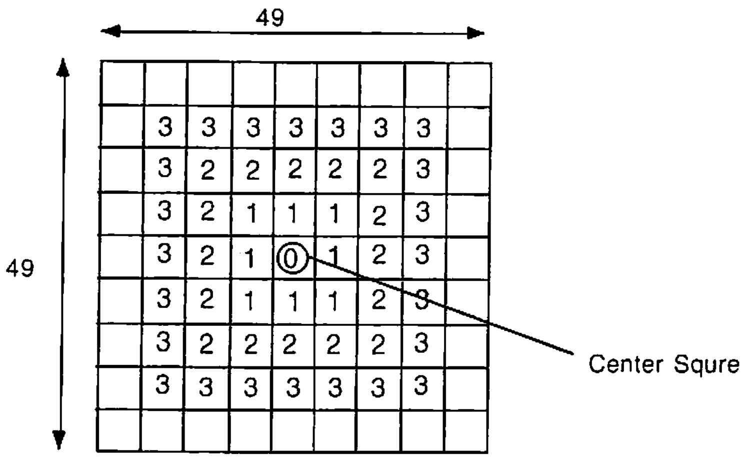

Fig. 3 two-dimensional EEG/MEG topographical data format

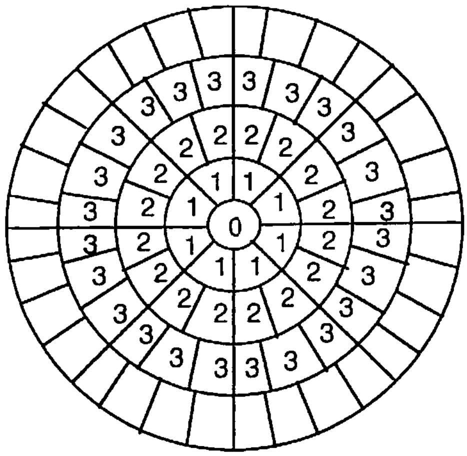

Fig. 4 Three-dimensional EEG/MEG data format on a hemisphere

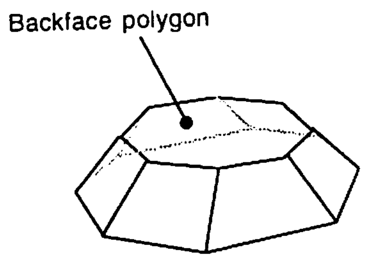

Fig. 5 Representation with polygons

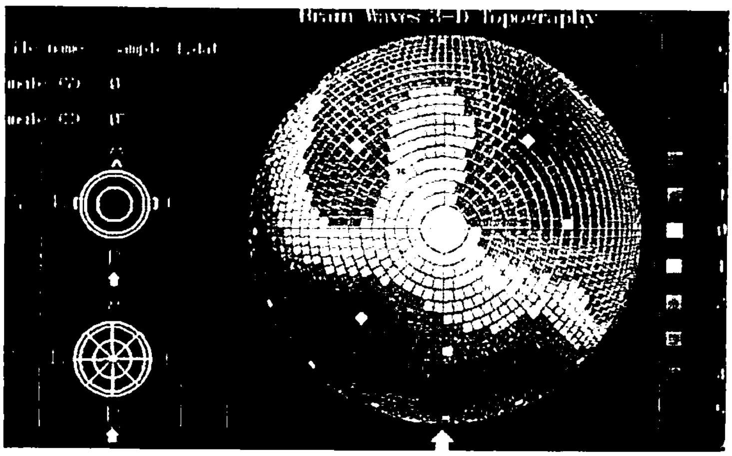

Fig. 6 Three-dimensional EEG/MEG topograhical Image
(Personal computer version)

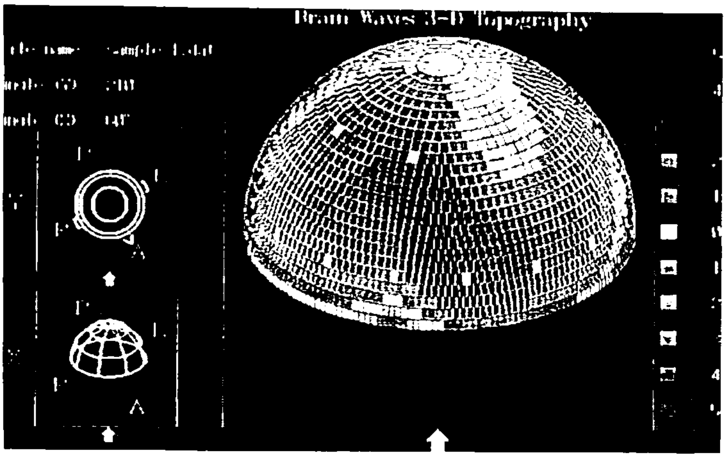

Fig. 7 Same as Fig.6 (From another point of view)

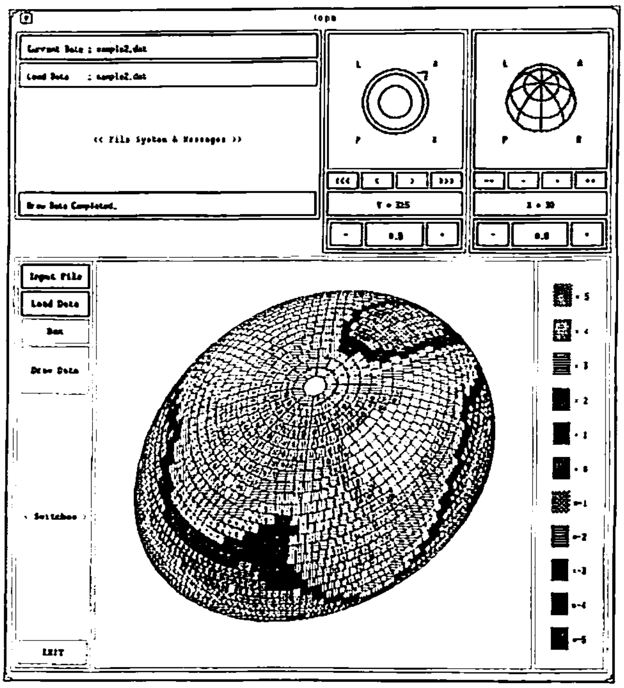

Fig. 8 Three-dimensional EEG/MEG topographical image (Workstation version for monochrome CRT)

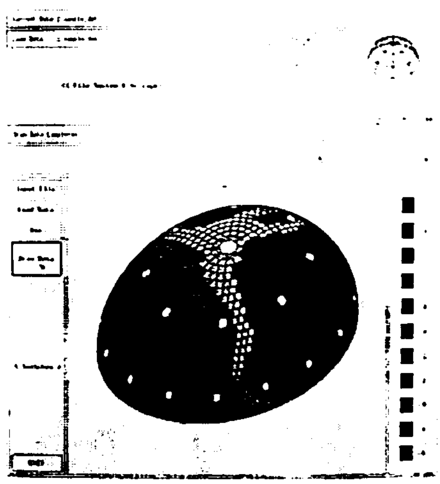

Fig. 9 Three-dimensional EEG/MEG topographical image (Workstation version for colour CRT)