Computerized model for the integration of data associated with the human brain

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SUMMARY

Our current work aims at compiling a computerized procedure that will allow different data sets to be integrated via the generation of a brain mapping system using the Linux operative system. This will provide a digitized model of the brain based on serial sections of the organ. The sections will be voxelized, thus obtaining spatial control of the images processed. The system will permit the linking of specific brain areas to associated data bases, creating true spatial thematic maps. Our development includes the use of physical and logical computer elements that will allow the collection, management, analysis, modulation, representation and output of data to brain territories.

Key Words: Geographic Information Systems – Data Bases – Human Brain – Neurosciences – Workstation.

INTRODUCTION

Insight into brain morphology and function is one of the greatest challenges currently occupying modern science. In recent years, innovations in imaging techniques have afforded brain research a new dimension in which to expand our knowledge of this organ.

It is today unquestionable that computerized techniques play a key role in our knowledge of both the structure and functionality of the brain owing to the fact that, either alone or combined with diverse medical techniques, they allow us to reconstruct images of the brain directly from patterns of electromagnetic signals.

However, current demands mean that technology must be given priority in our attempts to improve the services available to humankind. All this information must be processed and presented in graphic form.

The past decade has seen an enormous spurt of development in the field of programs able to manage files (especially geo-referenced files) contained in a database and linked to graphic files aimed helping researches to create new information (Hall et al., 1996). These programs are called Geographics Information Systems (GIS).

Geographic Information Systems are a specialized type of database characterized by their ability to handle spatially referenced information and to represent this graphically (Gatrekk and Bailey, 1996; Bosque Sendra, 1997). To date, in the field of the health sciences these systems have only been used to obtain epidemiological maps relating to certain diseases, permitting the planning of health policies in areas of prevalence (Hall et al., 1996; Vine et al., 1997).

In the field of medicine, the possibility of using suitably processed, graphically– and spatiallyzlinked information is of incalculable value in decision making. Accordingly, our purpose is to create a computerized information mapping system of the human brain with a view to facilitating decision-making based on spatially related data. The convergence of very diverse fields of knowledge of the brain, all of them orchestrated and ordered, will afford complete information about this structure, ranging from embryonic

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development, which reveals the keys to anatomy and higher organization, to brain pharmacokinetics, which encompasses the role different drugs in brain function.

We believe that the use of such systems as applied to brain geography is of great importance for the generation of a large data base, with its spatial correlations, which should be of enormous practical use in research in neuroscience.

METHODOLOGY AND SUPPORTS

For the anatomical generation of the whole of the human brain, a digitized and very precise model of this structure is required. We therefore decided to use 1 mm thick serial sections obtained from the Visible Human Project (Fig. 1) since these fulfil the demands of the international scientific community as regards the creation of a virtual model of the brain. Compilation of the graphic information for processing was accomplished using voxel technology, which afforded spatial control over the processed images. Two hundred and fifty coronal, sagittal and axial sections (Figs. 2a, b and c, respectively) of the head were selected for voxelization on a Linux platform.

As a support for better graphic performance, a Silicon Graphics O2 workstation was used. This was later be transferred to Windows NT, W'95 or W'98 systems.

The implementation of this application in the Windows environment for a voxel association linked to a data base was developed in Visual C. The ODBC (Open Database Connectivity) was used to drive the data base; this is an interface defined by Macintosh for connections among applications and different types of SQL (Structured Query Language) databases.

SQL is a tool designed for the organisation, management and retrieval of data stored in databases. As indicated by its name, SQL is a computer language that can be used for interaction with a database and, more specifically, with a specific type of database known as *relational database*. The language is easy to learn and is a complete tool for data handling. Queries about data are expressed in sentences and these must be written according to the language's syntactic and semantic rules. The difficulties inherent to the most updated version of this have been reduced in the sense that most sentences have been replaced by visual commands included within the Windows environment (Moldes, 1995).

Each of the brain sections was assigned certain structured non-graphic attributes that allowed separate visualization of different brain structures and the possibility of navigating through them to determine their morphology. Accordingly, users are able to access three-dimensional images of any brain structure and also make sections of it along the plane they wish.

Once the voxel set had been established, it was possible to make consultations and analyze spatial maps. Thus configured, the brain was subdivided into finite elements of approximately 1 mm^3, implying a data base of between 5 and 10 million entries. Data input was accomplished by tracing the maps by sections with an interface that filled in the nodes of the database. This way of dividing brain volume into discrete finite elements offered a considerable advance over traditional methods since it permitted spatial analysis of the brain and hence the possibility of analyzing the relations between different brain areas.

A system based on universal stereotaxic atlases (Tailarach et al., 1967; Schaltenbrand and Wahren, 1977; Riechert, 1980; Tailarach and Tournoux, 1988; Mai et al., 1997; Kretschmann and Weinrich, 1998) was developed that allowed the precise localisation of any point of the brain and that also defined the names of the nodes or entries. These coordinates are of great use in neurosurgery.

The minimum hardware recommended for the development would be a computer with a Pentium II 266 MHz processor, 128 Mb of RAM, an 8Mb SVGA video control card, a 15 inch screen or larger, a 32x CD-ROM player and a sound card.

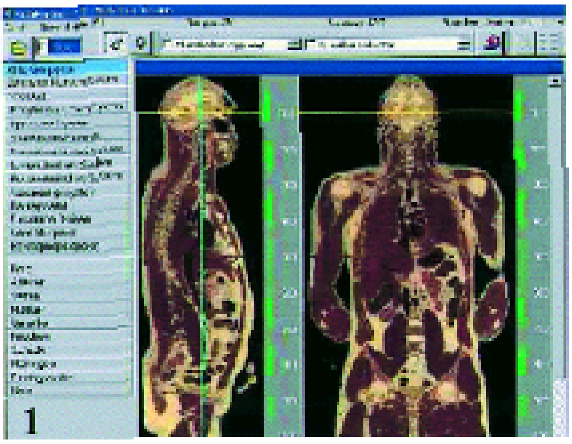
For the management of the whole setup, a user-friendly interface was used; this was operated through intuitive menus that offer high resolution brain images accompanied by informative texts.

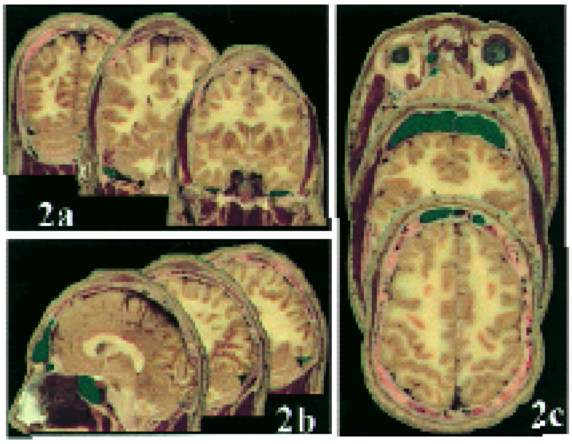
RESULTS AND COMMENTS

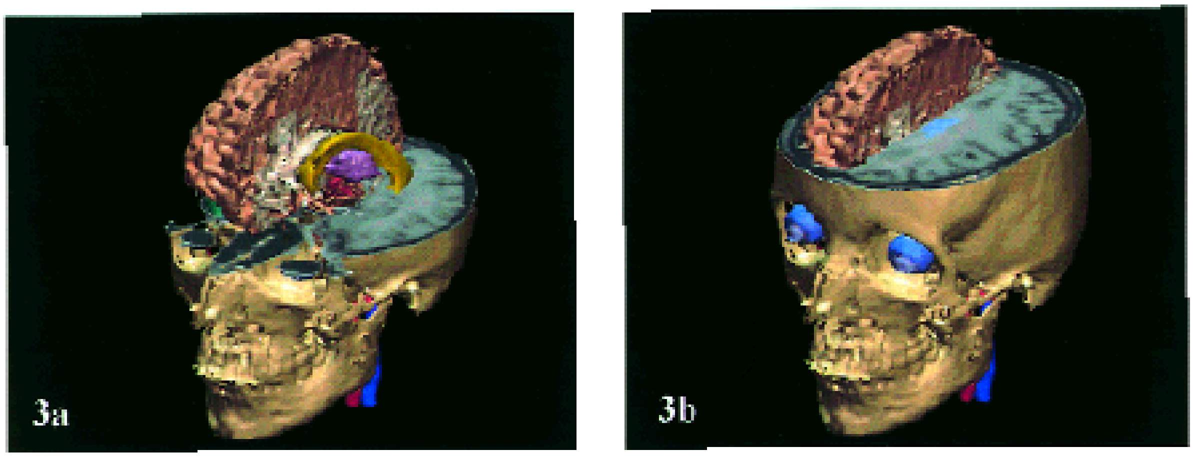
Our computer application allows the retrieval and presentation of documentation in a special (Fig. 4) way; it therefore serves as an excellent database on brain territories based on a user-friendly interface for instantaneous visualization and retrieval of associated information about the brain area in question (Fig. 4). Thus, the brain is incorporated into a huge isotopic network of active nodes, each of them being a database entry whose fields are the intrinsic characteristics of the node.

Since all data are assigned geographically, it is possible to obtain the brain maps requested by users, offering a powerful tool in research and the management of information about the human brain.

It is also possible to make simple or complex consultations based on the data location of non-graphic objects located in the sections, and of







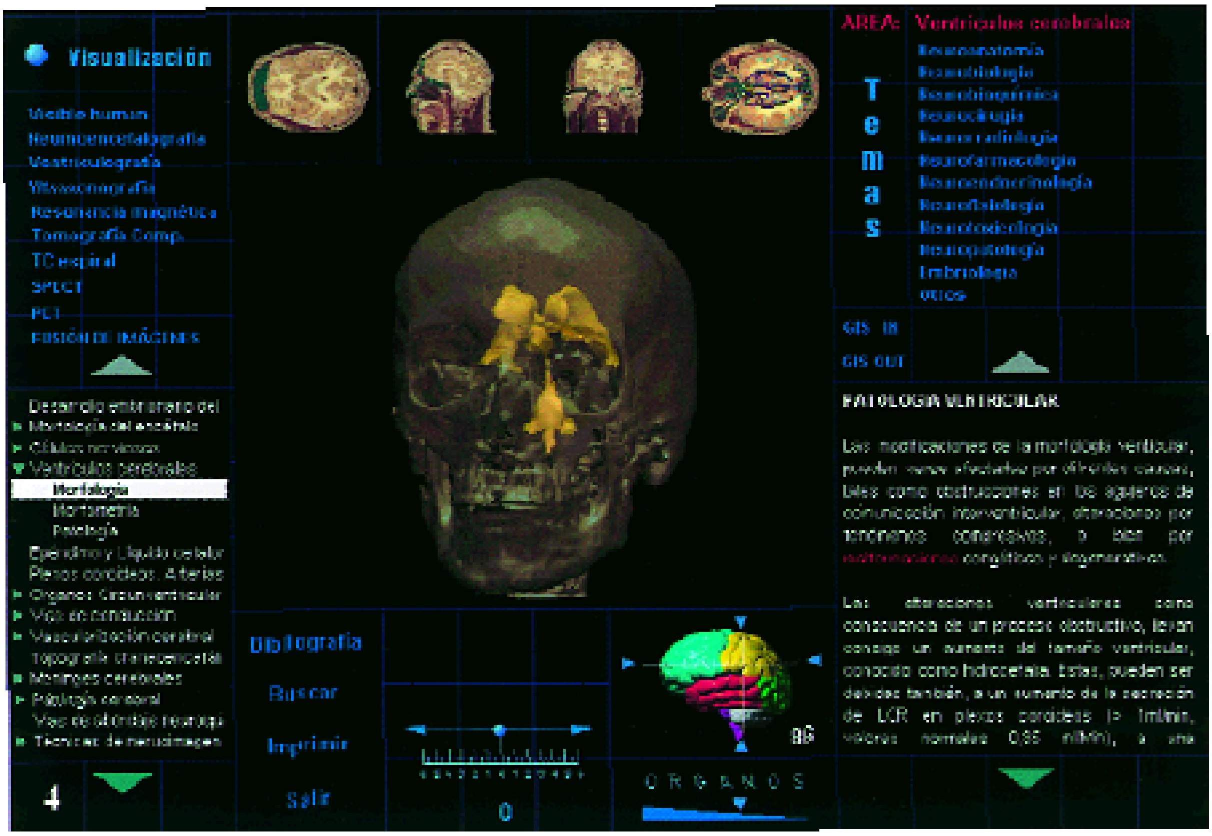


Fig. 1.- Screen from the Visible Human Program used in our study, from which the different brain sections were taken.

Fig. 2.- Set of a serial sections on three spatial planes: coronal (**a**), sagittal (**b**) and axial (**c**) used for the generation of a virtual three-dimensional model of the brain.

Fig. 3.- **a**, **b**: Representative examples of the generation of a three-dimensional image of the human brain from serial sections from the Visible Human Project by voxelization.

Fig. 4.- Representation of different screens with the different options offered by the menu and complementary informative text.

data stored in external databases. These consultations can be saved in working sessions.

In a well-structured data base, the use of finite elements for brain studies facilitates data input to a considerable extent. Thus, on highlighting any area of the brain section the system automatically opens the corresponding entries (node of the network detecting them) both for adding written infomation concerning them and for requesting information. The application is able to link two- and three-dimensional areas with associated databases. It also has the capacity to accomplish topographic reconstructions of areas for analytical purposes.

Users are able to make specialized consultations with a view to creating thematic spatial maps that highlight the different types of elements retrieved from a single database. It is possible to make any section of the brain on the three spatial planes (coronal, sagittal and axial) or to create transparent areas or spatial structures of empty zones.

A further aim of our application was to include a cross-reference system (links), allowing users to access sites of interest for additional infomation. Undoubtedly, the increasing interest of physicians in the Intemet has made it a powerful tool for the transmission of information among large numbers of people and hence a very useful additional resource in biomedical research.

Geographic Information Systems are designed to work with information organized in databases and referenced to spatial units of analysis via their geographic coordinates (Bullen et al., 1996). They are also able to analyze the information through a set of predefined operations and functions (Croner et al., 1996). The great advantage of GIS technology as compared with conventional databases lies in the possibility of interrelating data from internal and external sources as well making rigorous analyses of such data.

The Linux operative system used for our work –32 bits, multi-area and multi-user– permits compatibility with Internet communications protocols (TCP/IP, Transfer Control/Internet Control). It provides a graphic user interface (GUI) similar to X-Windows based on UNIX. Linux permits access to the source code to create a new executable (runnable) program; that is, it is possible to compile the nucleus of the operative system again to obtain a “custom” version. Since Linux is a UNIX version, it maintains compatibility at source-code level with System V and BSD, which are better known and more representative of UNIX.

We believe that the development and implementation of the first GIS on the human brain proposed by us offers a novel tool for consultation and allows the association of as much information and scientific knowledge as is available about this organ in the different specialities of the neurosciences (Neuroanatomy, Neuroendocrinology, Neurosurgery, Neuroradiology, etc). The computerized system will help to orient the judgments of professionals in decision making since it offers the possibility of recording, storing, refining, analyzing and visualizing information.

Technological innovations and the use of sophisticated mathematical models are currently permitting three-dimensional reconstructions of brain images that will facilitate diagnosis and the localization of pathological processes, as well as the most appropriate approaches for surgery where indicated (Juanes et al., 1996, 1999). Thus, the huge potential of brain images to increase our knowledge in this field is fast becoming a fundamental tool for specialists researching all areas of the human brain.

Computerized documentation systems are indeed proving to be highly efficient tools in all the health sciences. The spectacular advances in information technology have led to the emergence of highly specific applications that afford complete and very detailed access to many areas of knowledge and there is no doubt that they now allow professionals to carry out their activities in ways radically different from just a few years ago. Digitized information systems, the information highways, remote medicine, etc., are now widely used by such professionals and these increasingly feel that no innovation can be possible without the accompanying information and communications technology. With this in mind, we aim to set up a web site for such purposes. Currently, when physicians refer to the Internet they are well aware of its immense possibilities: access to large databases, rapid connection to different sources of infomation, or the development of multifocused research through a cheap, user-friendly communications system. These aspects, together with the large amount of graphic documentation that is available to us, are what prompted us to publish our application on this network of networks.

In recent years, in the sphere of scientific enquiry GIS have proved to be excellent tools for any type of research in any scientific field. Currently, GIS applications in medicine are limited to the field of epidemiology, focusing on the location of mainly infectious diseases in relation to environmental factors. As example as applied to medicine would be the so-called GIS-EPI (EPIdemiological GIS); the aim of these is to help strengthen the analytical capabilities of workers in the health sector, providing efficient tools to cover the contingencies that might arise in such tasks (Abdel-Rahman et al., 1997; Yilma and Malone, 1998; Bamford et al., 1999; Zenilman et al., 1999). These computerised tools will allow the

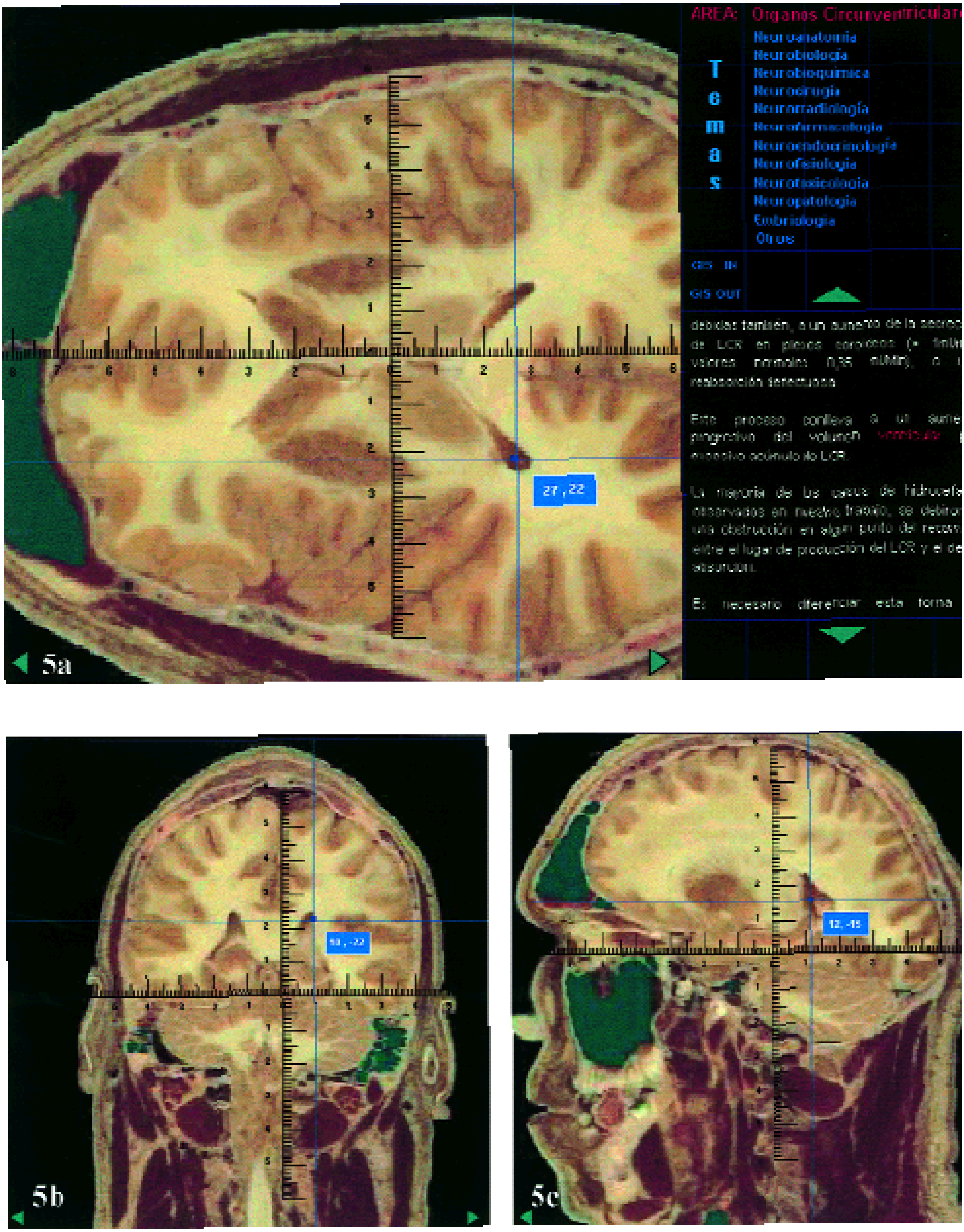


Fig. 5.- **a, b** and **c:** System of stereotaxic coordinates used for the search for specific infomation about a specific part of the brain, analyzed with different imaging techniques.

analysis of health situations and the monitoring and assessment of the effectiveness of possible interventions, so crucial in decision-making and planning in the health sector.

We believe that this application could become the greatest database on the human brain, both as regards anatomy (the precise definition of each of the physical elements) and as regards information related to anatomy (Radiology, Pathology, Neurosurgery, etc.). It therefore seems evident that the Internet will serve to agglutinate the information we have compiled so that other professionals will be able to access them and keep them updated with new information as it becomes available.

In sum, we believe that our application will allow access to the complex structure of the brain through a convergence of information compiled in different databases orchestrated for the handling of large amounts of very important information from different fields of the neurosciences. Additionally, it will provide many blocks of information that are readily integrable thanks to GIS technology.

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