STASSIS: PC-based three dimensional system for stereotactic neurosurgery

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INTRODUCTION:

In modern stereotactic neurosurgery the computer-assisted planning has become the way of choice for obtain higher precision, safety and efficacy during surgical procedure. It is an indispensable tool for manipulated efficiently all information presents in medical images available nowadays. As specific techniques increase its necessity, requirements for surgical planning systems grow constantly. Planning systems, developed for the low-cost personal computers, obtain similar precision and offer most of the main facilities that few years ago were available only in expensive workstations.

Our system **STASSIS,** is a software package that was developed at the International Centre for Neurological Restoration (CIREN) for intraoperative planning, using an IBM-PC. The system fundaments its computation in an accurate method for stereotactic calculation that led to a submillimetric precision and integrated, in one complete module, all of the basic facilities that are presents in other advanced programs.

METHODOLOGY

The system **STASSIS** is based on a PC type microcomputer, running under Windows 9x/2000 platform, and written in C++ programming language.

Accurate calculation of stereotactic coordinates

Our system is oriented to detect all references and its center of mass automatically.

For calculation of stereotactic coordinates we created a vector approach that is based in the analytical description of all geometrical relations in the positions of the fiducials. The resulting over-determined system of linear equations is solved using a least-squares method. The clear geometrical interpretation of this procedure allows an easier application for different frames.

The used method facilitates the correction in the determination of stereotactic target in functional neurosurgery, where target first is established on an empirical basis, usually relating it to its distance from the intercommisural line, defined by anterior commissure (AC) and posterior commissure (PC). We used a simple mathematical solution for alignment correction, considering that angulations can occur in three dimensions, using only three points, AC, PC and another point located on the interhemispherical line. This corrective algorithm can be used with any stereotactic frame that are include for our planning system.

Treatment of images and multiple image visualization facilities

Some basic techniques of image treatment were introduced. Image bright and contrast can be modified to obtain visual improvement and rectangular zooms in any orientation can be made. Different visualization modes and synchronized 3D views can be display. Orthogonal and non-orthogonal reconstructed images could be obtain efficiently.

Volume calculation

Method used for volume calculation allows graphical edition in any plane, original planes or reconstruction. To obtain a precise and completely three-dimensional representation of the volume we create a model based on small cubic elements. To decrease memory requirements we used a bit representation of these small volume elements. To increase the speed during visualization we applied an algorithm for visualization of isocurves that considerably reduce the volume of computation.

Brachytherapy

Our system includes a brachytherapy module which provides dosimetric support for Iridium-192 and Iodine-125 wires. The dose integration for the data file takes into account the contribution of primary and scattered radiation on the tissue. The isodose curves can be overlaid on the CT slice or on any other reconstructed image, magnification is also corrected in each case.

Stereotactic Atlas

Frontal, Sagittal and Horizontal series from Schaltenbrand and Wahren atlas were vectorized. After definition of AC-PC plane the contour of the atlas structures can be display and identified in overlay with CT or MRI patient's slices. The atlas can be translate or scaled to obtain the best fit with real anatomy.

3D Visualization

The display of 3D data sets from CT and MRI slices using a volume rendering approach was implemented for non-uniform distributed slices. This approach employs a ray-tracing technique. Transparency and colour images could be customized for any 3D reconstructed images independently. Is possible defined 3D cut in orthogonal planes that allows display inside information or isolate the contours.

Storage and retrieval of planning information

All planning information is stored and efficiently compressed in one file. This information includes all images initially supplied to the system together with 2D and 3D reconstructed images, targets, probe's trajectories, volumes and implants that were created. Also include patient related information, comments about the procedure and names of medical personnel.

DISCUSSION

STASSIS constitutes the main tool of our stereotactic surgical planning for a wide range of techniques. In spite of its modest hardware requirement, if compared with other system, the overall performance of the system is remarkable: image processing, arbitrary 2D reconstruction, atlas matching are carried out in real time, while 3D reconstruction takes less than 10s, acceptable in clinical conditions in order to obtain major information.

In the calculation of stereotactic coordinates the use of all the geometrical information reduces the magnitude of the error introduced by deviation in one particular value. The vector approach assures this and is recommendable due to its universality.

All of the techniques used for our system was test in different conditions. We designed three different test that allowed us to obtain a precise estimation of the sources of error in every step of the surgical procedure: The accuracy test evaluates the precision of the system under ideal conditions, and it was oriented to detect any errors introduced during the execution of any techniques or as a result of the mathematical operations needed to report stereotactic coordinates. The stability test allows the evaluation of the precision when the input to the system is not ideal and the input deviations are even bigger than the permissible for these surgical procedures. The functional test, based on specially constructed phantom, is a standard method used to obtain a close estimation of the precision in a real surgical procedure.

Currently the planning software STASSIS is used by eight hospitals in Cuba and one in Santiago de Chile. During period 1997-2003 was applied in more than 600 surgical procedures and any error has been reported. The experience of the clinical practice with this system at the operating room of the CIREN allows its regular improvement, based on the requirements of minimal invasive surgery. Further improvements are being planned for 3D rendering facilities.