3D Reconstruction Method for the Head Skeleton

Virgilius Stănciulescu [1], Adriana Albu [2], Doina Drăgulescu [3]

[1] General Inspectorate for Communications and Information Technology Timisoara, gilistanciulescu@yahoo.com
[2] Politehnica University Timisoara, adrianaa@aut.utt.ro
[3] Politehnica University Timisoara, ddrag@cmpicsu.utt.ro

Abstract: 3D representation of surfaces and volumes is considered to be an important investigation method. The surfaces and volumes built on the base of 2D images, issued from computed tomography (CT) or magnetic resonance (MR) investigations, are very helpful for a correct diagnose. The paper proposes an original method for 3D reconstruction, based on 2D image acquisition, applicable to all types of human tissues.

Keywords: biomedical imaging, three-dimensional visualization, isosurfaces

1 Introduction

One of the most important aspects in medicine is the ability to decide in any circumstance about the illness level of the patient. The experts have to set a diagnosis, which will have major implication in the therapy orientation. In this case, the information from medical imagines domain could be very useful (together with physical symptoms and laboratory analysis). Some of the most important medical imaging investigations are: scintigraphy, echography, computed tomography, radiography, quantitative microscopy and magnetic resonance. Continuous evolution of image acquisition, processing and interpretation procedures provides more and more performing results.

Anywhere the imagines processing is used, a mathematical approach must be implemented. The term image defines a two-dimensional function *f(x,y)*, where *x* and *y* are the points coordinates in *xOy* space and *f* is a function defining the grey level of the respective point [1]. An image could be considered a matrix whose rows and columns indexes identify a point, every element, called *pixel*, of this matrix representing the grey level of that point.

The digital image processing consists in a sequence of steps meaning a theoretical methods implementation, having as final objective a solution for the problem. The fundamental phases of image processing are [1]:

- Image acquisition and digitization;
- Digital image preprocessing, consisting in: segmentation, boundary detection and description;
- Recognition and interpretation.

Image processing uses some algorithmic techniques, so that the most of processing functions can have a software implementation.

Biomedical image processing systems are used to provide specific information better than the human experts could do that. These information include recognition, numbering, measurement of shape, position, density or other similar properties of some objects from an image.

One of the most available ways to obtain medical images is the computed tomography. CT is a computer-aided X-ray technique, which offers the possibility of analyzing soft and bone tissues, as well as, blood vessels. X-rays penetrate the body to varying extents depending of the density of the investigated structures. The result is represented by black and white images of interior sections (slices) through different parts of the body [13].

The images obtained by computed tomography can be used to display the investigated organ in a manner very closed to the reality. In this case, the 3D reconstructions made by using CT slices are very useful. Three-dimensional visualization of the human body parts has a very large field of applicability, from the medical statistics to reconstructive surgery, offering the possibility to indicate a correct diagnosis, to choose the treatment, to plan a possible surgical intervention or to model implants or prosthetic devices.

2 The Reconstruction Technique

The following actions were considered to build a 3D image based on acquisition of 2D slices:

— Reading and structuring the initial data (CT slices) in order to be memorized in their natural sequence; the input data are represented on the slices taken as a result of CT investigations. The input variables are considered: number of files to be read, their size, spacing and prefix. This prefix together with the number allocated to the respective file will represent its label in order to be accessed. An instance of the Reader class is used on this purpose:

```
// reading the volume
Reader *v = Reader::New();
v->DataDimensions(64,64);
v->FilePrefix ("../../../data/img");
v->Range(1, 100);
v->Spacing(1,1,1);
```

having as result the reading of files: img1, img2, img3, …img100, everyone having 64x64 pixels.

— Image segmentation and identification of zones of interest from the diagnosis point of view; this action is taken into account because it is enough strong and flexible even if the proposed method does not involve a beforehand identification of the different surfaces with certain density. But, a segmentation pre-processing operation is useful [2], [3], [4], [5], [6], [7], [8].

Two major strategies are considered to accomplish the needed segmentation process: boundary detection and homogeneous regions establishing. The boundary detection means to find the regions with sudden variation of properties, delimiting the object boundary (bone tissue, for example). Homogeneous zones establishing means to select and to store different image pixels as function of their properties. This selection will determine the appearance of some distinct zones characterized by a relative uniformity. These zones allow the separation of the analyzed object from the other objects in the scene.

— Detection of the isosurfaces realized by an algorithm based on a threshold value of the density able to build the boundaries by using the sets of volumetric data [9], [10], [11], [12].

The main idea is to divide the volume represented by the pile of images into a 3D network realized by cubic unity cells (*voxels*). The surface to be extracted (isosurface) is placed inside this volume and the filter will select from all the points belonging to this volume, only these ones situated on the isosurface. Any surface can intersect a certain cell in a finite number of nodes. So, it is possible to realize a table containing all possible topological states of unity cell, containing the points of intersection between isosurface and cell edges. The number of topological states depends on the number of cell vertexes and also on their placement inside/outside with respect to the isosurface. A vertex is considered inside the isosurface if its associated scalar is bigger than the surface associated scalar; contrariwise it is outside the isosurface. Since the intersected edges are determined, the points of intersection can be exactly computed. The set of resulted intersection points is situated on the searched isosurface, defining it.

So, the isosurface is represented by triangular patches each of them being determined by the points of intersection between the voxels edges and the respective surface.

In order to elaborate an efficient method approximating the intersection points there were taken into account the density values at the interval ends. The intersection point was determined by linear interpolation of the density values registered at the vertexes belonging to the intersection edge.

The algorithm for linear interpolation and triangular patches determination is:

```
for ( ; edge[0] > -1; edge += 3 ){
   for (ii=0; ii<3; ii++){ //insert triangles
    vert = edges[edge[ii]];
         t = (value-s[vert[0]]) / (s[vert[1]]-s[vert[0]]);
    x1 = pts[vert[0]];
    x2 = pts[vert[1]];
    for (jj=0; jj<3; jj++){
     x[jj] = x1[jj] + t * (x2[jj] - x1[jj]);
    }
        //insert a new point
        if ( (ptIds[ii] = locator->PointInsert(x)) < 0){
     ptIds[ii] = locator->NextPointInsert(x);
    }
        //verifies the degeneration of the triangle
        if ( ptIds[0] != ptIds[1] && ptIds[0] != ptIds[2] &&          ptIds[1] !=
        ptIds[2] ){
          newPolys->NextCellInsert(3,ptIds);
        }
   }
}
```

Before storing the triangle patches in the table *newPolys*, a check-up process was provided in order to eliminate the *degenerat*e triangles whose 2 or 3 vertexes are overlapped. In this way: memory is saved, supplementary calculations are avoided and correct result is fast displayed.

In the process of image rebuilding a very important parameter is the value of voxel edge (network step). If this step is large, then the loss of details will be produced. The smaller is the step, the bigger is the network resolution and the result will be much more realistic.

3 3D Reconstruction for Cranium Structure

The method offers the possibility to achieve 3D isosurfaces for different kinds of tissues, by applying different filters for different values of the density. For example, it can be showed a part of a bone or a part of tissue that cover the bone (figure 1).

This reconstruction method can show in the same time and in the same image different tissues (figure 2).

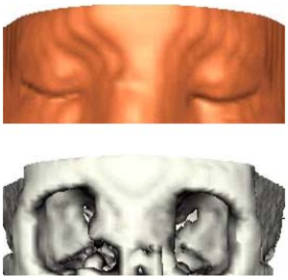

Figure 1
Epithelial tissue and bone tissue

Figure 2
3D reconstruction of soft tissue and bone tissue, simultaneously

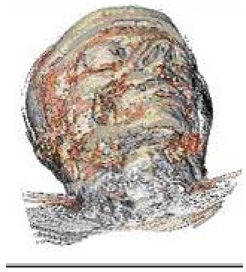

Figure 3
Modeling using a data set with small scan resolution

In figure 3 can be observed that if the scan resolution is too small, the reconstruction accuracy decrease. These cases are frequently in reality because there are insufficient slices.

This 3D reconstruction method offers the opportunities of rotation and zoom (figure 4).

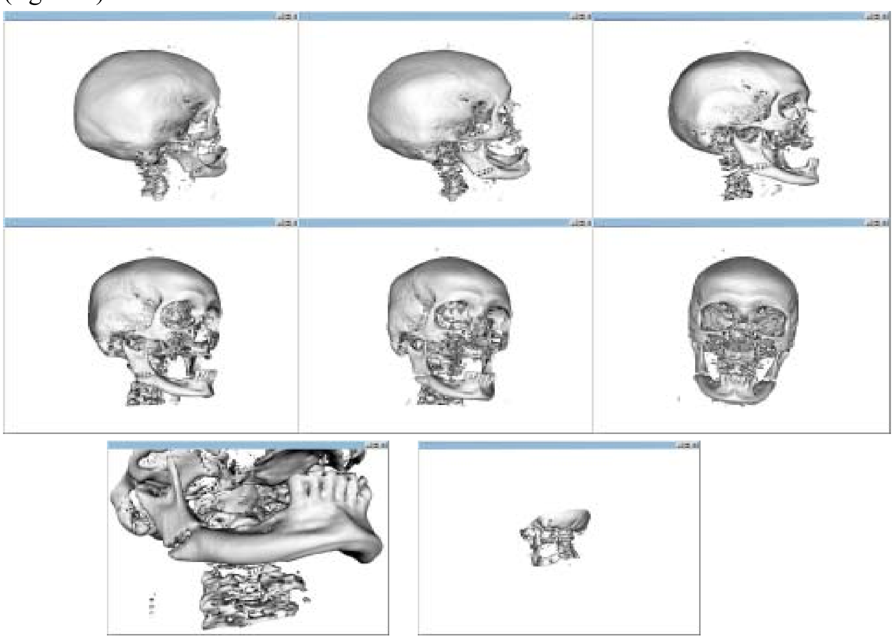

Figure 4
Successive images, which show the possibilities of visualization from different angles and zoom facility

Conclusions

The proposed reconstruction method is an original one offering a good accuracy of representation, original optimization based on a very simple processing algorithm, differentiated treatment for different tissues, possibilities of zooming and orientation changes.

References

[1] A. Vlaicu: Prelucrarea digitala a imaginilor, Editura Albastra, Cluj-Napoca, 1997

[2] P. Bolon, M. Mouhoub: Une famille de detecteur de contours bases sur le filtrage d'ordre, GRETSI, 1989

[3] J. F. Cany: A Computational Approach to Edge Detection, IEEE-PAMI, 1986

[4] R. Challapa: Digital Image Processing, 1993

[5] R. Deriche: Optimal Edge Detection Using Recursive Filtering, in Proc. First Conf. on Computer Vision, London, June, 1987

[6] T. Pavlidis: Integrated Region Growing and Edge Detection, IEEE Transactions on PAMI, March, 1990

[7] S. Tabbone: Corner Detection Using Laplacian of Gaussian Operator, SCIA, Tromso, 1993

[8] A. Visa: Texture Classification and segmentation Based on Neural Network Methods, Helsinky University of Technology, 1990

[9] Hope: Hugues Surface Reconstruction from Unorganized Points, Ph.D. Thesis, University of Washington, 1994

[10] P. Kari: Surface Reconstruction and Display from Range and Colour Data, 1997

[11] P. Kari, M. Segal: Fast Rendering of Subdivision Surfaces

[12] Narkhede, Atul, Manocha, Dinesh: Fast Polygon Triangulation based on Seidel's Algorithm, Dep. of Comp. Science, UNC Chapel Hill

[13] V. Stanciulescu: 3D tomography. Computed modeling of 2D images. Results. Advantages, Proceedings of the VII-th Symposium "Acustica si vibratiile structurilor mecanice. Biomecanica", Politehnica Publishing house, Timisoara, 2003