Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
Make Harmony Between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals of DAAAM International

COMPUTER ASSISTED ANALYSIS OF 2D/3D MEDICAL IMAGES

MORAR, A[nca] - A[ndreea]; MOLDOVEANU, F[lorica]; MOLDOVEANU, A[lin]; ASAVEI, V[ictor]; BOIANGIU, C[ostin] - A[nton] & EGNER, A[lexandru] I[onut]

Abstract: *Over the past few years, computer assisted applications have become indispensable in many domains. The medical domain does not make an exception. The need for accuracy and speed has led to collaborations between programmers and doctors in improving the medical activities of gathering, processing and managing patient's data, in giving diagnoses and even in performing surgeries.*
We propose a technique for medical applications, meant to reconstruct the 3D shape of the human body parts (bones, muscular tissue, etc.), and to allow doctors to remodel the 3D shape (in order to simulate a prosthesis or to simulate the resulting shape of a body part after performing surgery).
Key words: *X-rays, CT-s, processing, visualization*

1. INTRODUCTION

Medical image processing includes a series of methods, like image acquisition (from specialized devices, such as CT devices), image enhancement, analysis and 3D model reconstruction techniques (Bankman, 2000).

Among many research projects in this area of interest, we present:

- The SCANIP image processing software that provides visualization, image processing and segmentation tools for the medical domain.
- The 3D-DOCTOR Project that proposes an advanced 3D modeling software with tools for processing MRI-s, CT-s, PET-s, etc.
- The HIP-OpCT software that allows the visualization of CT data, meant to help doctors in planning the size and the position of orthopedic prostheses.

This article proposes a technique that combines 2D and 3D Image Processing methods, in order to visualize the 3D model of a human body part for the improvement of preoperative planning, and for monitoring the patients' evolution after the surgeries. Canny Edge Detector, Hough Transform and Marching Cubes are very popular, but the combination of these methods still stands on unfamiliar ground. This technique has been tested on few data sets and the application that we propose is incomplete, but the idea seems to be promising. We will present you our current work in this domain and the directions for our further research.

2. 2D IMAGE PROCESSING

Our research has been directed to the implementation of a medical application, in the Arthroplasty domain. Arthroplasty (Botez, 2001) represents a surgical procedure in which an arthritic or dysfunctional joint surface is replaced with prosthesis or by remodeling or realigning the joint. Our application gathers radiographic images (CR-s or Computer Radiography) in the DICOM format, and detects the important parameters in Hip Arthroplasty (Chen et al. 2000), before and after the surgery.

Working on this application, we have managed to draw the following conclusions regarding the sequence of steps in 2D Medical Image Processing (Gonzales & Woods, 2002):

- The first step is data acquisition (in our case using the DICOM format)
- An intermediary, but very important part, is image enhancement (noise removal, edge enhancement and contrast improvement)
- The third step is contour detection - using the Canny Edge Detector (Canny, 1986)
- The last step is represented by the parameter extraction

As you can see in Fig. 1, the Canny Edge Detector has not led to a complete contour detection, because of the blurriness and the low contrast between bone and muscular tissue in Radiographic Images.

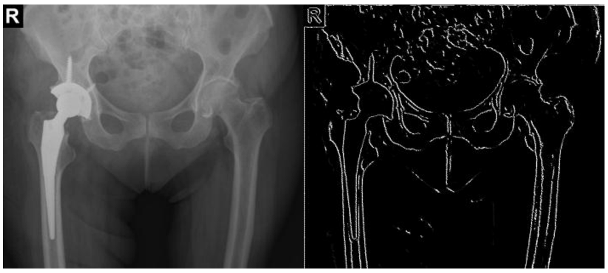

Fig. 1. Radiographic Image of the femoral and pelvic bone: before and after applying Canny Edge Detector

We have observed that many of the human body parts can be approximated by simple curves (lines, circles or ellipses). For example, the femoral body contour can be approximated by two straight lines. Fig. 2 shows the resulting lines after using the Hough Transform algorithm for straight lines (slightly altered).

Fig. 2. Detecting the lines of the femoral body contour, using Hough Transform for straight lines

Also, the femoral head, the ischiadic tuberosities (the lowest parts of the pelvis), the greater and the lesser trochanter can be approximated by parts of circles. So we have implemented an algorithm starting from the Hough Transform, to detect all these bone parts. Fig. 3 shows a series of pelvic and femoral body parts that can be determined using Hough Transform for circles.

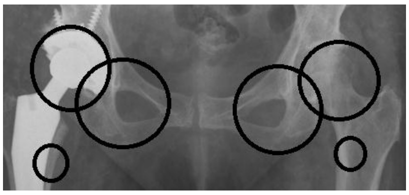

Fig. 3. Detecting the circles approximating the femoral head, the ischiadic tuberosities and the lesser trochanter, using Hough Transform for circles

We have thus come to the conclusion that a combination of Canny Edge Detector and Hough Transform methods can lead to a very good approximation regarding the contour of many human body parts (especially bones).

3. 3D VISUALIZATION

The next step in our research is the transition between 2D and 3D medical images, gathered from CT-s, MRI-s or PET-s. 3D medical images represent stacks of slices (a slice is a 2D image).

The chosen method for visualization is Marching Cubes (Lorensen & Cline, 1987), an algorithm that takes each volume cell (a cube with four neighbour vertices or voxels on one slice and the other four on an adjacent slice) and computes the intersections of these cubes with an isosurface, thus extracting a polygonal mesh (the contour surface of the 3D shape). The volume cells' voxels are divided into two categories:

- vertices outside the isosurface (that have a value lower than the isovalue – the value of all the points on the isosurface)
- vertices inside the surface (that have a value higher than the isovalue)

One of the main presumptions of this algorithm is that the human body parts (bones, blood-vessels, skin) have the same isovalue throughout all their shape, or at least have the same isovalue throughout all their contour (for example, it is assumed that the femoral bone has the same value – or intensity – in all its contour constituent points). In many occasions, this is not the case, because the medical images are blurred and the intensity difference between two kinds of tissue (bone or muscular tissue for example) is almost unperceivable.

We have implemented the Marching Cubes algorithm in C++ with OpenGL and CG, with very promising results. Fig. 4 shows an example of our application's results (visualization of the human brain) using data from a stack of 2D images.

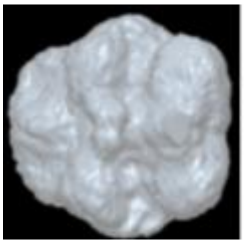

Fig. 4. Visualization of the human brain using Marching Cubes

The 3D shape that can be visualized in Fig. 4 represents a very accurate reconstruction of the human brain, because of the high contrast between the intensities of the voxels inside the isosurface and the intensities of the voxels outside the isosurface. This does not happen always. The thin line between bone and muscular tissue (and between other types of tissue) can lead to non-accurate results.

This is why we propose a preprocessing phase before applying the Marching Cubes algorithm.

4. A COMBINSTION OF 2D AND 3D METHODS

In order to obtain better results in visualizing and extracting the 3D contour surface of human body elements, a medical application should first contain some image processing elements.

We remind you that a 3D medical image is in fact a stack containing a series of 2D images. These 2D images can be processed, as shown in the section 2, leading to the extraction of the whole contour of the desired body part. Consequently, the contour pixels of each slice would have the the maximum intensity value (255), and the other pixels would have the lowest intensity value (0). Choosing the isovalue of the isosurface between the lowest and the highest value (for example 100), the 3D contour polygonal mesh thus detected would be more accurate than the one obtained by applying only the Marching Cubes algorithm.

Although this implementation would lead to better results, the computing time would be very high: the time for processing a 2D image is about a few seconds, so, the time for processing all the slices in a 3D image would take a couple of minutes. This is why we propose the 2D processing of only some of the slices (that will be called "key-slices"). The purpose of this preprocessing stage would be only to supervise the result of the Marching Cubes algorithm and to allow the intervention in case of a too great deviation from the desired output.

5. CONCLUSIONS AND FURTHER RESEARCH

The proposed application would be very helpful for visualizing the chosen human body parts, but also for altering the 3D shapes in order to reconstruct bones, prostheses, etc.

The medical field is very vast and this technique can be personalized according to the need of different sectors. The application has been tested on some data of femoral bones and brains, but it can be extended to any medical field that involves imaging, with the collaboration of doctors and programmers.

The results show that this combination of 2D and 3D processing techniques is the future of medical image analysis. Our application can be improved in many ways, but it represents a first step in a new way of understansding the 3D image processing and visualization.

Our further research in this filed will be centred on finding the best solutions for faster and more accurate applications (for example, the use of parallel programming, with CUDA or OpenCL)

6. REFERENCES

Bankman, I. (2000). *Handbook of Medical Image Processing and Analysis*, Academic Press

Botez, P. (2001), *Ortopedie*, Bit Publishing House, Iasi

Canny, J. F. (1986), *A Computational Approach to Edge Detection*, IEEE Trans. Pattern Analysis and Machine Intelligence

Chen, Y.; Ee, X.; Leow, K. W.; Howe, T. S. (2000). *Automatic Extraction of Femur Contours from Hip X-ray images*

Gonzales, R. C.; Woods, R. E. (2002). *Digital Image Processing*, Prentice-Hall

Lorensen, W. E.; Cline, H. E. (1987).Marching Cubes: A High Resolution 3D surface construction algorithm, *Proceedings of the 14th annual conference on Computer graphics and interactive techniques,* SIGGRAPH '87.

*** (2008) http://www.simpleware.com – SCANIP Project by Simpleware, *Accessed on: 2009-10-10*

*** (2008) http://www.ablesw.com/3d-doctor - 3D-DOCTOR, *Accessed on: 2009-10-10*

*** (2008) http://www.hipop.it/hipopct.html - Hip-OpCT, *Accessed on: 2009-10-20*