

Medical Image Processing in Hip Arthroplasty

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Abstract: - Computers have become indispensable in all domains, and the medical segment does not represent an exception. The need for accuracy and speed has led to a tight collaboration between machines and human beings. Maybe the future will allow the existence of a world where the human intervention won't be necessary, but for now, the best approach in the medical field is to create semiautomatic applications, in order to help the doctors with the diagnoses, with following the patients' evolution and managing them and with other medical activities. Our application is designed for automatic measurements of orthopedic parameters, and allows the possibility of human intervention in case the parameters have not been detected properly. The segment of the application is Hip Arthroplasty.

Key-Words: - Hip Arthroplasty, Canny Edge Detection, DICOM, Hough Transform, Radiographic Image Processing

1 Introduction

Medical image processing is an area of increasing interest. It includes a wide range of methods and techniques, starting with the acquisition of images using specialized devices (for example, CT devices), image enhancement and analysis, to 3D model reconstruction from 2D images. Thus, the research in this field represents a point of interest for both doctors and engineers, in their attempt to improve medical techniques, with computer assistance, in order to obtain more accurate results in treating the patients.

Among many research projects in this area of interest some of the most relevant are:

- The SCANIP [11] image processing software that provides a broad range of image visualization, processing and segmentation tools for medical purposes. This software has been created by Simpleware in Great Britain. The SCANIP programs ensure the conversion of 3D medical images into quality meshes. These meshes can be used in future processing in analysis programs, in fluid dynamics, CAD and the creation of Rapid Prototyping models. The sources for these programs come from MRIs, CTs or MicroCTs.
- The 3D-DOCTOR Project [12] that comes with an advanced 3d modeling software, with strong processing and measurement functions for MRI-s, CT-s, PET-s, and other types of medical images. The possible applications of this software are in the scientific and medical domain, but also in the image

processing industrial field. The functioning principle of this software is based on edge detection techniques using 3D image segmentation functions and on the construction of 3D surfaces and volumes, that are afterwards visualized and measured for the purpose of a quantitative and qualitative analysis.

- The Hip-OpCT software [13] that allows importing CT images in DICOM format. Once imported, the CT dataset is visualized through several modalities from which the doctors can plan the size and the position of the prosthesis.

This article describes a software application that interprets x-ray orthopedic images in order to assist doctors in hip replacement procedure. The application manages patients' general data and x-ray images extracted from DICOM, computes parameters that are important for Arthroplasty and allows automatic or semi-automatic measurements. The second chapter of this paper describes parameters of interest for hip replacement procedure. In the third chapter we refer shortly to the data representation in the DICOM format and interpretation of the DICOM files. The fourth chapter describes the radiographic image processing we have implemented in our application, necessary to facilitate the computation of arthroplasty parameters. In the fifth chapter we present the results obtained with our application: the parameters that are automatically computed and those that can be computed with the human interaction. The sixth chapter refers briefly to the comparison between the automatic and the manual

detection of the parameters important in Hip Replacement. The seventh chapter is dedicated to presenting the structure of the proposed application. Finally, in the last chapters, we draw some conclusions and point out the main future development directions in this domain.

2 Arthroplasty – General Presentation

Arthroplasty [10] represents a surgical procedure in which the arthritic or dysfunctional joint surface is replaced with prosthesis or by remodeling or realigning the joint. The important joint for this article is the one located at hip area. This is the reason why the article details the parameters that belong to the thigh-bone and the pelvis. Fig.1 presents the most important parameters in Hip Arthroplasty, extracted from an anterior-posterior radiography. Fig.2 presents the parameters extracted from an anterior-lateral radiography representing the hip after the insertion of the prosthesis.

For the scope of this article, three areas of the thigh-bone are analyzed: the femoral head (the nearest part to the pelvis), the femoral neck, and the femoral shaft or body (the longest part of the thigh-bone).

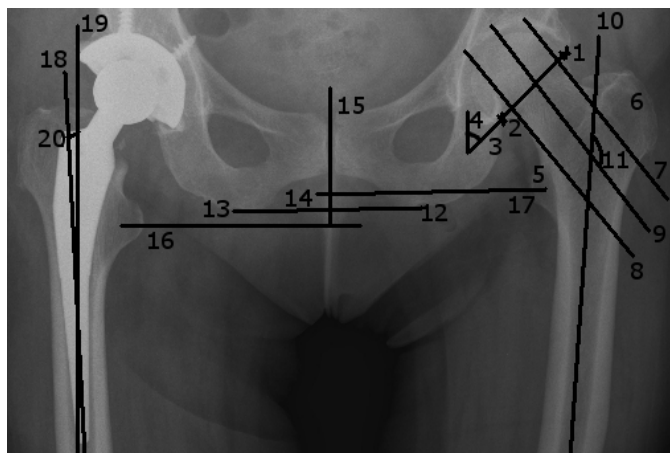


Fig.1. Parameters important in Hip Replacement, extracted from an anterior-posterior radiography

The parameters of interest for the Hip Replacement [7] are listed below:

- 1) the superior margin of the acetabulum (the superior point in which the thigh-bone meets the pelvis).
- 2) the inferior margin of the acetabulum (the inferior point in which the thigh-bone (the femoral head) meets the pelvis).
- 3) the femoral head axis or the acetabulum axis (the line determined by the two points that

represent the superior margin and the inferior margin of the acetabulum).

- 4) the angle created by the acetabulum axis with the vertical line. This angle has to be the same for both of the femoral bones.
- 5) the lesser trochanter (located in the upper left part of the femoral body).
- 6) the greater trochanter (located in the upper right part of the femoral body).
- 7) the tangent to the superior cortical of the femoral neck
- 8) the tangent to the inferior cortical of the femoral neck
- 9) the femoral neck axis (the axis of the cylinder determined by the tangents 7 and 8)
- 10) the femoral body axis or the diaphyseal axis (the axis of the cylinder that approximates the femoral body)
- 11) the most important parameter, extracted from the x-ray before the surgical intervention is represented by the cervico-diaphyseal angle (the angle determined by the neck axis and the diaphyseal axis). Depending on the value of this angle, it can be determined whether the patient needs or not a prosthesis. If the angle has values between 125 and 135 degrees, the thigh-bone is considered to be in normal ranges.
- 12) the right ischiadic tuberosity (the lowest right part of the pelvic bone).
- 13) the left ischiadic tuberosity (the lowest left part of the pelvic bone).
- 14) the ischiadic line or the horizontal reference line (the line determined by the two ischiadic tuberosities).
- 15) the vertical reference line, that is perpendicular on the ischiadic line, in its middle.
- 16) the line starting from the center of the lesser left trochanter, parallel to the ischiadic line
- 17) the line starting from the center of the right lesser trochanter, parallel to the ischiadic line; the distance between lines 16 and 17 represents the vertical distance between the two thigh-bones. If this distance is greater than a chosen threshold, there is an indication of a difference between the lengths of the two femoral bones that has to be resolved surgically (in most cases).

After inserting the prosthesis, some new parameters must be taken into consideration:

- 18) the diaphyseal axis of the femoral bone (the same as parameter 10).

- 19) the diaphyseal axis of the prosthesis or the axis of the prosthesis' body (the axis of the cylinder that approximates the prosthesis' body).
- 20) The deviation of the prosthesis (the angle determined by lines 18 and 19). This parameter will be computed in several radiographic images, following the evolution of the same patient.

The important parameters extracted from an anterior-lateral radiography, after inserting the prosthesis, are shown in Fig.2:

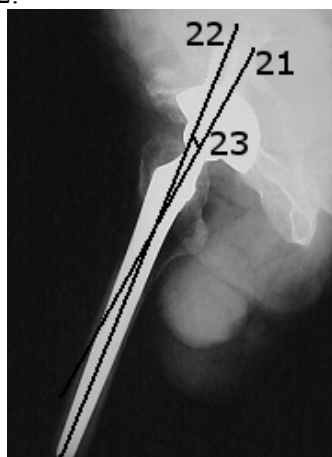


Fig.2. Parameters important in Hip Replacement, extracted from an anterior-lateral radiography, after the insertion of the prosthesis

- 21) The axis of the prosthesis' neck
 22) The axis of the prosthesis' body
 23) The anteversion angle (the angle determined by the axes 21 and 22). If this angle has its value situated between 5 and 10 degrees, it's considered to be in normal ranges.

3 The DICOM Standard

In order to manage and interpret the x-rays data in a simple and organized manner, a standard for the x-ray files is needed. This is the reason why the most popular standard for medical images was chosen: DICOM [14]. The *Digital Imaging and Communications in Medicine (DICOM)* standard is a detailed specification of the coding and transfer of medical images and their associated information.

3.1 Representing Data in the DICOM Format

The clinical data are represented in a variety of formats: the distances are measured in millimeters, the time in seconds, etc. The PS 3.5 part of the standard, entitled

Data Structure and Their Encoding, defines 27 types of standard data, known as "value representations" (VR), that include all types of data that can appear in the medical domain. Any information encoded in a DICOM file has to belong to one of these predefined types. Some of the most important standard data are: Person Name (PN), Date Time (DT), and Age String (AS).

A DICOM file has the following structure:

- A preamble of 128 bytes
- A prefix (4 bytes) for retaining the letters 'D', 'I', 'C', 'M' (the signature of a DICOM file)
- A data set that contains information like: patient's name, image type, image dimension, etc.
- Pixels that form the image (or the images) contained in the file.

3.2 Extracting Data from DICOM Files

Extracting data from a DICOM file can be made using the tags defined in the DICOM dictionary. Every tag is searched in the file, and, if found, is interpreted.

The steps in extracting the information are:

- Checking the existence of the characters 'D', 'I', 'C', 'M'
- Determining of the VR type
- Setting the order of the bytes (Big Endian or Little Endian)
- Searching for a tag in the DICOM file, corresponding to the order of bytes and the VR type

Extracting the values corresponding to that tag

Some characteristics of the DICOM files, important when extracting data, are:

- the number of images contained in the DICOM file
- the number of bits per pixel: 8, 12, 16, 24
- the compression
- the photometric interpretation: shades of gray or color images

In case of images without compression, the extraction of the images is made pixel by pixel, according to the number of bits per pixel. For images with compression, a decompression step should be previously performed.

3.3 The Structure of the CR DICOM files

Computer radiographic images (CR) stored in DICOM files are accompanied by general identification elements and some specific information.

For example, the Patient module contains: the name of the patient, the patient's ID, the patient's date of birth, etc. Another module, specific for CR, CR Series, contains information about the examined body part, the view position, etc.

Our application extracts from every module the important elements for managing and interpreting the patient's data.

4 Radiographic Image Processing

As in any image analysis application, the first step is a preprocessing step, needed to improve the image by noise removal, contrast improvement, edge enhancement and others [4]. In our application, this step is followed by a contour extraction step, which helps in the arthroplasty parameters' extraction.

4.1 Image Enhancement

One reason why the automatic interpretation of radiographic images doesn't give accurate results is the fact that the radiographic images are blurred. This is why enhancing images before applying contour detection algorithms is a step that should not be omitted. In the case of our application, the radiographic images are enhanced by noise removal, edge enhancement and contrast improvement. We will detail each method in the following subsections.

4.1.1. Noise Removal

A series of methods have been tested in order to choose the best way for noise removal.

The first approach was that of using Gaussian filtering, that led to good results.

Another interesting approach would be Impulsive Noise removal [15]. The classic linear unsharp masking is an important scheme in feature based image enhancement category, in which a high pass filter scaled version of the original image is added to itself, in order to give more emphasis on the high frequency components. There is a very big possibility that the noise will be amplified along with the detail features of the image. Thus, the main objective of this approach is to separate the noisy and the noise-free images based on a certain threshold. The creators of the method propose the use of a CV (coefficient of variance) based adaptive threshold technique for impulsive noise detection. The main idea is to train a functional link artificial neural network (FLANN) [16] with a single statistical parameter CV as input.

The third approach meant for image enhancement is Image Noise removal using Graph Theory Concepts [17]. This method first creates an image graph, based on the original image. There are many possible mappings, but the most intuitive approach is to map each pixel in the image onto a vertex of the graph. This graph will be four-way connected, so that each vertex corresponds to a

pixel, and each edge has an associated weight that corresponds to the distance between the color levels of the adjacent vertices. This technique has been tested for impulse noise and for random noise, leading to the conclusion that the proposed method displays good edge and detail preservation, while suppressing impulse and random noise.

The chosen method for noise removal was Gaussian Filtering, because of the need for speed in this preprocessing phase.

4.1.2. Edge Enhancement

The first method used for edge enhancement was Adaptive Smoothing. This represents a filter that enhances edges, being applied like a matrix filter. The main difference between adaptive smoothing and matrix filter is the fact that the first does not apply weights over the pixel's neighborhood in order to compute its new intensity or color, but uses a gradient. The output obtained by using this gradient consists of both positive and negative intensities, but also emphasized high frequency details.

Another method for edge enhancement was the curvelet transform [18]. Curvelet coefficient can be modified in order to enhance edges in an image by $y(x)$ (Veldre function).

We have chosen the first method because it was faster.

4.1.3. Contrast Improvement

The method tried for contrast improvement was histogram equalization that usually increases the global contrast of images, especially when the usable data of images is represented by close contrast values. Peaks in the image histogram (that indicate commonly used grey levels) are widened, while valleys are compressed.

4.2. Contour Extraction

Most of the contour extraction algorithms which are based on edge detection follow these steps:

- detecting the edge pixels (pixels where the intensity changes abruptly)
- eliminating the edge pixels which are not also contour pixels
- connecting the contour pixels using local methods (based on the pixels' relations to their neighbor pixels) or global methods (based on global information, for example the shape of a bone, in a computer radiography).

After trying a series of methods, the Canny algorithm [5] has been chosen in order to extract the contour lines, because this produced the best results. The Canny

algorithm will be briefly described in the following lines. The Canny edge detection algorithm is a very well known algorithm and is considered by many the optimal edge detector. The algorithm is structured into 6 steps:

- 1) filter out any noise in the original image with the Gaussian filter
- 2) apply the Sobel operator on the resulting image, estimating the gradient in the horizontal direction (G_x) and in the vertical direction (G_y). The magnitude, or the edge strength is approximated by the sum between G_x and G_y
- 3) find the edge direction, as the arctangent of G_y/G_x .
- 4) Once the direction is known, relate the edge direction to a discretized direction (all the angles between 67.5 and 112.5 will be considered to be of 90 degrees, all angles between 112.5 and 157.5 are set to 135 degrees, etc). Fig. 3 shows the possible discretized edge directions, previously determined in step 3.

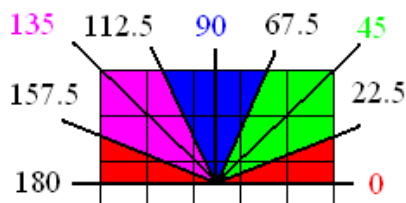


Fig. 3. Gradient direction

- 5) Non-maximum suppression (trace along the edge in the edge direction and suppress any pixel that is not considered to be an edge - that is not a local maximum)
- 6) Hysteresis for eliminating streaking, using two thresholds, $T1$ (high) and $T2$ (low). Any pixel with a value greater than $T1$ is considered to be an edge pixel. After applying the first threshold, any pixels connected to the edge pixels that have a value greater than $T2$ will also be selected as edge pixels. Usually $T1=2*T2$.

The result of applying the Canny detector is a binary image (Fig. 4), where white pixels represent contour pixels. Having the contour lines of the bones, the next step in our application is the extraction of the important parameters in hip arthroplasty (automatic and semiautomatic extraction).

We can observe in Fig. 4 that the contour is disconnected in some parts of the radiography, and that it cannot be reconstructed with accuracy.

That is why we propose to search for some salient parameters (for example the lines representing the contour of the femoral body) that can be identified without the previous reconstruction of the entire pelvic and femoral contour.

In the following section we will present the methods used after preprocessing the image (with noise removal, edge enhancement, contrast improvement and Canny edge detection), in order to extract the parameters important in arthroplasty.



Fig.4. The image after applying the Canny Edge Detector

5 Automatic/Semi-automatic Extraction of the Hip Arthroplasty Parameters

The parameters extracted by our application are: the ischiadic line, the reference vertical line, the difference between thigh-bones, the deviation of the prosthesis, the center of the femoral head, the axis of the acetabulum (femoral head), the angle made by the axis of the acetabulum with the vertical line, the axis of the neck, the diaphyseal axis and the cervico-diaphyseal/anteversion angle.

We have reached the conclusion that the extraction of the *femoral body contour* should be the first step in processing the radiographic image, because it produces the most accurate results, independent of the other parameters. The contour of the femoral body can be approximated by two lines, as shown in Fig.6.

For the detection of the straight lines representing the femoral body contour, we have chosen the Hough transform.

Hough transform represents a feature extraction technique that finds imperfect instances of objects

within a certain class of shapes by a voting procedure. The voting procedure is carried out in a parameter space that allows the extraction of object candidates as local maxima in an accumulator space.

5.1. Hough Transform for Straight Lines – Detection of the Femoral Body

The simplest case of Hough Transform is the linear transform for detecting straight lines.

Instead of considering the description of the line as

$$y = m*x + b \quad (1)$$

we can choose another more appropriate description:

$$r = x * \cos(\theta) + y * \sin(\theta) \quad (2)$$

where r is the distance between the origin and the straight line, and θ represents the angle of the vector from the origin to the closest point situated on the line (see Fig. 5).

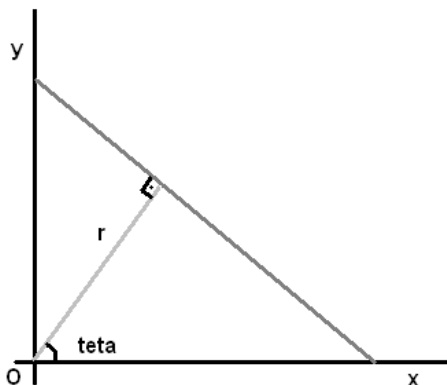


Fig. 5. Detecting straight lines using Hough Transform Algorithm

The (r, θ) plane is referred to as Hough space for the set of straight lines in 2D.

The Hough Transform uses an accumulator to detect the existence of a line. The dimension of the accumulator (array) corresponds to quantized values for θ and r . For each pixel, the Hough transform algorithm determines whether there is enough evidence of an edge at that pixel.

Using this technique, we have extracted all the straight lines in the image that contain a number of white pixels higher than a chosen threshold.

The output is then refined, by choosing the most appropriate lines, using the following algorithm:

- After applying the Hough transform, there will result a series of straight lines, all near the femoral body. Thus, an approximate area framing the

femoral body can be determined (for example, a rectangle like the one in Fig. 6). After that, the contour will be detected by extracting the white pixels of the image, starting from the margins of the framing area towards its interior.

This algorithm generates very good results, due to the large number of pixels of the femoral body contour (the body of the thigh-bone occupies a significant area of the image) and due to the simple shape (straight line) approximating the contour.



Fig.6. Detecting the lines representing the contour of the femoral body

5.2. Hough Transform for Circles – Detection of the Ischiadic Tuberosities, the Femoral Head and the Lesser Trochanter

Based on the idea of the Hough algorithm in detecting parametric curves, we have tried to determine whether some other parts of the pelvic and the femoral contour can be approximated by simple shapes like lines, circles, and/or ellipses. We have reached the conclusion that the femoral head, the ischiadic tuberosities and the lesser trochanters can be approximated by circles (Fig.6). The extraction of these parameters will be detailed in the following paragraphs.

The Hough Transform can be used to determine the parameters of a circle when a number of points that fall on the perimeter are known. A circle with radius R , centered in (a, b) can be described with the parametric equations:

$$x = a + R * \cos(\theta) \quad (3)$$

$$y = b + R * \sin(\theta) \quad (4)$$

If an image contains a number of points that fall on perimeters of circles, the job of the search application is to find parameter triplets (a, b, R) to describe each circle. The fact that the parameter space is 3D instead of 2D (like the case of the Hough Transform for straight lines) makes a direct implementation of the Hough Transform algorithm more complex in time and memory. This is why, it is better if the radius R is known, in order to reduce the search to a 2D space. In our case radius R is not quite a constant, but is not far from it.

Fig. 7 shows the extraction of the femoral head, of the ischiadic tuberosities and of the lesser trochanter, based on the idea that these body parts can be approximated by circles.



Fig.7. Parts of the pelvic and femoral contour that can be approximated by circles

The second parameter extracted by our application should be the ischiadic tuberosity. The Hough algorithm for detecting circles is modified as follows:

- The centers of the circles will be searched only in the area between the two femoral bodies previous detected, down to top, ending at the first circle found. This method leads to very fast results because of the few white pixels located between the femoral bodies and the ischiadic line, that have to be inspected in order to determine whether they form a circle that corresponds to the next two rules.
- The circle radius is not a constant but is contained between $R - \Delta R$ and $R + \Delta R$, where $\Delta R \ll R$.
- The algorithm takes into consideration only those pixels of the circles positioned as in Fig.8 (pixels positioned in the lower part of the circle, that define, together with the center of the circle, an angle with the $\sinus > 0.5$).



Fig.8. Extracting the ischiadic tuberosity

The algorithm for the detection of the femoral head is similar to the previous one, with the following alteration:

- The algorithm takes into consideration only those pixels of the circles positioned as in Fig.9. (pixels positioned in the upper interior part of the pelvic bone – the upper left side in the case described in Fig.9 – that define, together with the center of the circle, an angle with $\sinus > 0.5$ or ($\sinus > -0.5$ and $\sinus < 0.5$ and $x_{pixel} > x_{center}$))
- After detecting a series of circles, with the number of white pixels greater than a threshold, the final circle will be determined as follows: x_{center} , y_{center} , $radius$ will be calculated as the average of x_{center} , y_{center} , respectively $radius$ of all the found circles.



Fig.9. Extracting the femoral head

The detection of the lesser trochanter is similar to the one of the femoral head, with the modification that only the white circle pixels positioned as in Fig. 10 (pixels positioned in the interior part of the pelvic bone – the right part in the case described in Fig. 10 - with $x_{pixel} > x_{center}$) will be taken into consideration.

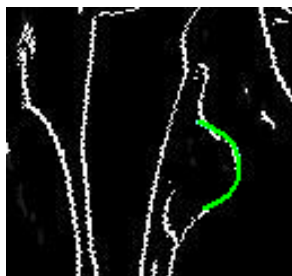


Fig. 10. Extracting the lesser trochanter

After detecting the contour of the femoral body, the ischiadic tuberosities, the femoral head, and the lesser trochanter, all the other parameters can be determined automatically.

5.2. Detection of the Rest of the Parameters Important in Arthroplasty

The ischiadic line is extracted as follows: The ischiadic line represents the line connecting the two lowest points of the circles approximating the ischiadic tuberosities. Thus, after the extraction of the circles that approximate the ischiadic tuberosities, the ischiadic line can be determined automatically.

The reference vertical line is determined in an automatic manner based on the ischiadic line. It is the line perpendicular to the ischiadic line, in its middle.

The vertical distance between the two thigh-bones depends on the ischiadic line, the vertical line, and the two lesser trochanters. The application will draw the lines that start from the centers of the circles representing the two lesser trochanters, and are parallel to the ischiadic line. The vertical distance between the two thigh-bones is computed as the length of the segment that connects the intersection points of the reference vertical line with the two parallel lines previously determined.

The diaphyseal axis depends on the two lines that represent the contour of the femoral body. The body of the thigh-bone can be approximated by a cylinder. The axis of this cylinder is the diaphyseal axis. The axis of the prosthesis' body will be determined similar as the femoral diaphyseal axis. One method of extracting the diaphyseal axis is the following: compute the middle of the segments that represent femoral body contour, and their slope. After that, determine the average of these two middle points (x_point , y_point) and the average of the slopes ($line_slope$). The diaphyseal axis represents the line passing through the point (x_point , y_point) with its slope equal to $line_slope$.

The deviation of the prosthesis can be extracted automatically and depends on the axes of the femoral body and of the prosthesis' body.

The acetabulum axis (the femoral head axis) is determined automatically, after extracting the center of the femoral head. The application identifies, on the femoral neck, points belonging to the inferior and superior parts of the neck contour, and then follows the two contour lines of the neck until they meet the pelvis. The two points where the neck's contour meets the pelvis represent the superior margin and the inferior margin of the acetabulum. After determining these two points, the acetabulum axis can be drawn.

The angle made by the acetabulum axis with the vertical line is determined automatically, after extracting the axis of the femoral head and the reference vertical line.

The axis of the femoral neck is determined automatically, using the center of the femoral head. Similar to the extraction of the information regarding the acetabulum axis, after positioning and delimiting the circle that represents the femoral head, two points on the neck contour can be identified. And then, the entire contour of the neck can be determined. Two tangents are drawn to the neck contour at the points (one on the convex curve and the other on the concave curve of the contour neck) located at the closest distance. The perpendicular bisector of the segment determined by these two points represents the axis of the femoral neck.

The cervico-diaphyseal/anteversion angle is determined automatically, using the femoral neck axis and the diaphyseal axis.

The application is considered semiautomatic because of the possibility for the human intervention, in case the application cannot automatically identify some parameters or does not identify them correctly.

6 Experimental results

The data sets provided by the "Floreasca" Emergency Hospital have been processed both manually and in automatic manner.

The conclusions are:

- The automatic detection of the lines representing femoral body contour and the automatic detection of the ischiadic tuberosities are as accurate as the manual detections (because of the large number of pixels determining the straight lines that represent the contour of the femoral body)
- Also, the automatic extraction of the circles representing the ischiadic tuberosities led to a precision of 90%. The small amount of errors was caused by the fact that the ischiadic tuberosities occupy a relatively small surface of the entire radiographic image, and by the poor contour detection in that area.

- The automatic extraction of the circle representing the femoral head is approximately 85% accurate, compared to the manual one. Another cause for errors (besides the ones previously mentioned) is the fact that in the area of the femoral head there are other forms that can be interpreted as circles, leading to more circles that correspond to the femoral head.
- The algorithm for detecting the circle that represents the lesser trochanter does not generate very good results (50% accurate, compared to the manual detection), because of the small number of pixels representing the lesser trochanter (the lesser trochanter occupies only a small area of the radiographic image)
- The other parameters depend on the previous parameters, therefore the accuracy of the automatic detection of these parameters depends on the accuracy of the femoral body contour, the ischiadic tuberosities, the femoral head and the lesser trochanter automatic extraction.
- The automatic extraction is a lot faster than the manual one. If the automatic image processing takes several seconds, the manual detection of all the parameters could last over 20 minutes.

7 The structure of the application

The application proposed in this paper is divided into two distinct parts, the back-end and the front-end part.

The back-end section represents the part behind the application that processes commands received through the graphical interface from the user and returns results obtained. Here also occurs the communication with the data base.

The front-end part integrates the communication between the user and the system, including the graphical interface that allows users to send different commands to the system.

The data base contains three main tables:

- Patients table (saves information about the patients; the primary key is patient_ID)
- X-ray table (that has the foreign key, patient_ID, and the primary key, xray_ID)
- Measurements table (that has the foreign key, xray_ID, and contains information about all the parameters important in Arthroplasty)

The front-end part consists of three main forms:

1. The first form is used for the management of the patients. From this form the user can add/delete/edit patients, and for each patient, the user can visualize/add/delete radiographic images.
2. The second form, opened by selecting an X-ray of a certain patient, containing four vertical tabs.

- a. File – from here the user can load other files containing X-rays, reload the current X-ray, save images in a known format (PNG, JPG).
 - b. Patient's Information – contains the most important information about the current radiographic image and about the current patient.
 - c. Measurements – contains a tree with all the measurements specific for the current X-ray (anterior-lateral or anterior-posterior)
 - d. Ray Contour – is dedicated for the visualization of the contour obtained by using the Canny Edge Detector.
3. From the second form, the user can open a third form, with information gathered from the DICOM file, in an educative purpose, presenting in a visual manner the content of the DCM files.

8 Conclusions

The research in the field of medical image analysis is a continuous challenge. The need to discover new image analysis algorithms and new automatic learning techniques that would help in computer assisted diagnosis is and will be a topic of interest for researchers.

The results of our research, presented in this paper, prove that solutions do exist. Although not all the arthroplasty parameters determined automatically were 100% accurate, the application proved to be very useful to doctors.

The fact that the application allows patient's data saving management, during a long period of time after the hip replacement procedure is another plus.

This application can be used for a single hospital, or for an entire national/international network of hospitals, integrating other applications of diagnosis or of assisting doctors in planning certain surgeries and following the patients' evolution after the surgeries.

9 Further Research

Our future research direction in the field of computer assisted hip arthroplasty is to make automatic measurements on the femoral bone 3D model, reconstructed from CT/MRI images.

We have begun the research in the 3D medical imaging, starting with the visualization of the volume data, but also with the reconstruction of the shapes, starting from the CTs.

The first approach in visualizing the medical images is the direct rendering using 2D textures, 3D textures and multi-texturing. This method is very fast, but allows only the visualization of the 3D model, and not its manipulation. It also requires a graphical unit with a memory of at least 1Gigabytes.

The second approach is the use of Marching Cubes, another visualization technique that is not as fast as the texturing methods, but allows the construction of the model and its manipulation.

The main idea in Marching Cubes algorithm is to start from the stack of images, constructing a volume of voxels, that are cubes with four vertices on one slice (a 2D image) and four vertices on an adjacent slice. Then, the method intersects these voxels with certain iso-surfaces (that have the same value of intensity in all its pixels – a value called iso-value). The vertices of the voxels are divided into three categories:

- Inside the surface (with the value of intensity greater than the iso-value)
- On the surface (with the value of intensity equal to the iso-value)
- Outside the surface (with the value of intensity lower than the iso-value)

According to this classification of the vertices, the intersection of the iso-surface with the volume of voxels can next be computed (all the voxels that have vertices both outside and inside the surface are considered to be intersected with the iso-surface).

Thus is created a mesh of triangles (a 3D surface) that corresponds to the 3D model. This mesh can be next manipulated in order to simulate for example the insertion of a prosthesis, or in predicting the resulting shape of a human body part after surgery.

Marching Cubes algorithm is based on the presumption that the human body parts have the same value in all the surface. This hypothesis is not very correct, and that is why in many cases the construction of a 3D model starting from medical images (CTs, MRIs) can lead to not very good results.

This is the reason why we consider the possibility of using a combination of 2D and 3D image processing techniques in extracting the 3D model of the human body parts. We believe that a preprocessing phase for the 2D slices would be necessary before applying the Marching Cubes algorithm. For example, some very efficient 2D techniques would be the contour detection using Canny Edge detector and detection of simple curves using Hough Transform algorithm.

This idea would lead to very good results, but also to a very high computational time. This is why we have to take into consideration other implementations of the presented techniques, like Incremental Hough Transform [19] that can lead to real time applications.

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