PROSTATE ULTRASOUND IMAGES PROCESSING

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Abstract. The purpose of this paper is to present a software package for the handling and management of prostate transabdominal ultrasound images. The software package can be used to detect men's prostate in transabdominal ultrasound images, to build a 3D model for the detected object, to represent the 3D model obtained, to calculate prostate's volume and to classify the prostate transabdominal ultrasound images acquired. The software system can be used in hospitals which do not have either CAT scanners or NMR/MRI equipment (the majority of Romanian hospitals). It provides these hospitals with a tool enabling a more accurate diagnosis, which in turn improves the efficiency of the hospital, saves money, and has a profound psychological benefit on the well-being of the patient.

Keywords: ultrasound, prostate, 3D reconstruction, classification.

1 Introduction

It is known that in the gastrointestinal and genitourinary systems, the image processing has mostly been focused on computed tomography images or magnetic resonance images [1], three-dimensional ultrasound imaging being still in a research phase [1]. This is due both to technical problems of data acquisition, and theoretical and practical problems of how to render the complex information contained in ultrasound data onto a display [2].

We developed and implemented a software package which is dealing with prostate transabdominal ultrasound images. The software package allows to acquire images from a 3.5 MHz ultrasound equipment for different incidences, to filter the images, to detect the prostate in the 2D images acquired, to build the 3D model of the prostate, to represent the 3D model in different ways, to compute its volume. Also the software presents information about an image, information which can be used to classify the image in one of the following classes: normal and pathologic. For pathological images a second classification will be made, trying to differentiate between benign and malignant lesions.

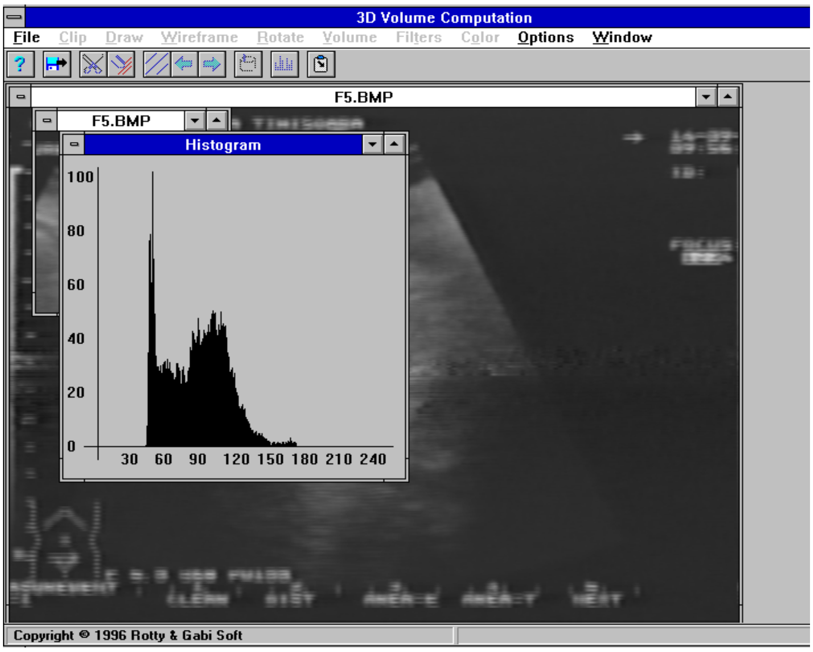

Fig. 1. Histogram of a prostate transabdominal ultrasound image.

2 Medical Preliminaries

Diseases of the prostate gland are common in adult and elderly men, and primary care physicians as well as urologists are frequently consulted for treatment of prostate problems [3]. Correct diagnosis of a prostate disorder cannot be made solely by assessing symptoms, however, as the symptoms of the most common disorders - prostatitis, benign prostatic hyperplasia (BHP), and prostatic adenocarcinoma - are similar and include both irritative and obstructive voiding problems [4]. Because of this, the most important task of the physicians is the early detection of prostate cancer.

Evaluation of prostate volume is very important in the diagnosis of prostatic cancer [5]. Also, for the patients with benign prostate hyperplasia, the selection of an operative procedure is influenced by the size of the prostate as estimated preoperatively. So it is necessary to compute the prostate's volume with an error as small as possible.

3 Technical Preliminaries

Prostate size is reliably measured using ultrasound - either suprapubic, transurethral, or transrectal - and ultrasound is the imaging of choice in most men with BPH [6]. The role of ultrasound is further enhanced by its relatively low cost and its lack of side effects, such as contrast reactions and radiation exposure. In the case of Urology

Clinic of the County Hospital of Timisoara only the transabdominal evaluation of the prostate volume can be used. Since this method is characterised by lack of precision - as it was demonstrated by different studies, including our studies [7] - we developed different image processing algorithms in order to estimate prostate size [7] and the efficiency of bladder emptying [8], and also in order to evaluate the upper tracts and exclude cancer.

Like the majority of studies on ultrasound image processing [6], [9], we first established the characteristics of prostate ultrasound images. We started analysing the histograms of a large test-set of ultrasound images (fig. 1). The conclusions [7] show that image thresholding could not be used to detect the prostate.

It is known that the common approach for localising edges in images is to associate them with the zero crossing of the second derivative of a smoothed version of the image [10]. But we found that these operators did not deliver a closed contour of the prostate's image.

4 3D reconstruction of prostate

We have developed and implemented two methods for the 3D reconstruction of the prostate.

The first method allows to detect the contour of the prostate using an original algorithm [7]. The prostate is then extracted from the image by a region-growing algorithm. The central point of the prostate is used afterwards as the reference point in the criterion of acceptance used, and it is also used in the algorithm of region-growing, as the starting point.

In general, in order to perform a 3D reconstruction of medical images it is necessary to obtain several images from predetermined positions [1] or to use continuous data acquisition [11]. For the Urology Clinic of the County Hospital of Timisoara it was impossible to apply such methods. So, we designed a method of 3D reconstruction of the objects using 2 orthogonal sections: one is the transversal incidence and the other is the sagittal incidence.

In the second method proposed [8], we used the circular filter, the grey level selection and an algorithm for eliminating the multiple points. We obtained then a set of "depth curves" which describes the 3D image of the prostate.

The next step was to represent the 3D model of the prostate. If the efforts are focused to the clinical usefulness of the application (choosing the method of resolving prostate adenoma) it is possible to select a depth algorithm in order to present the 3D object [7]. If the physician needs precious information about the shape of the prostate (especially in the case of prostatic cancer), he can choose the wireframe representation (fig. 2) [8]. The 3D representation of the prostate can be rotated by the user, being possible to show the asymmetrical regions of the prostate.

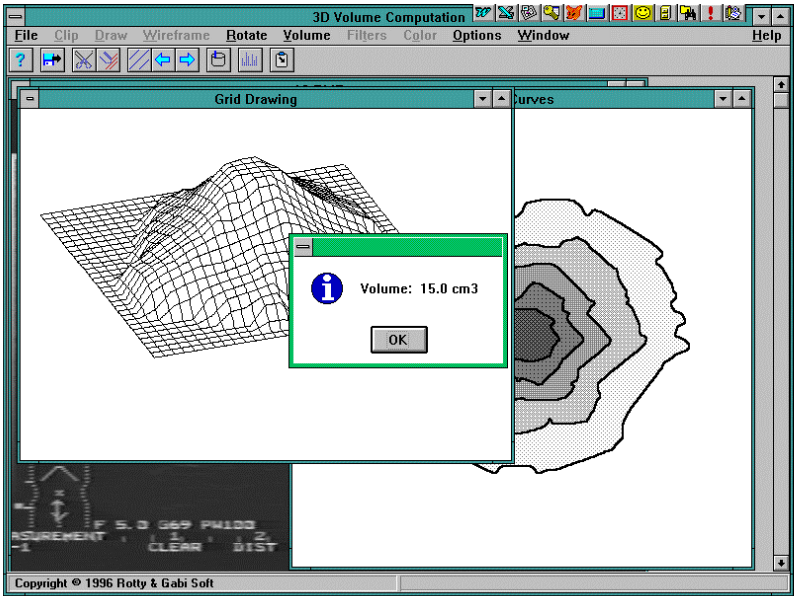

Fig. 2. The wireframe representation of 3D prostate's model.

5 Automatic classification of prostate ultrasound images

It is known that the success of an automatic classification system depends on careful selection of the disease and images. That is the reason why all the images were acquired from the same ultrasound equipment (an Alloka 3.5 MHz) and the examinations were performed by the same experienced sonographers. It was demonstrated that even with these restrictions, it is possible to use artificial neural networks to aid the diagnostic process [12].

At the beginning 60 patients with well defined diagnoses were investigated by ultrasound examination. 20 patients had normal prostate, 20 had benign prostate hyperplasia and 20 presented cancer tumours. For each patient two significant transabdominal ultrasound images were acquired: one from the sagittal incidence and the other from the transversal incidence.

Each original image was transformed into a 640x480 bitmap array quantified on 256 grey levels. Using the mouse the user has to specify a rectangular region for clipping. The chosen region (containing the prostate) is clipped and a new, smaller bitmap is created, a bitmap which will be the source for the next processing stages.

In order to remove noise, the next step was the filtering of the reduced image. We have tried different types of filters, finally choosing the circular filter [8], which non-uniformly illuminates the chosen region (the prostate).

In the papers dedicated to this field of automatic classification of images, there are several approaches. It is possible to select several training areas from identifiable malignant tissue in the data set [13]. Also it is possible to reduce the image to a set of vectors where each member of the set contains information about some salient attributes of the image. The neural network then will take these vectors and learn to map each one into an output which corresponds to a classification [12].

The main problem remains the choosing of significant parameters which will form a training pattern for the neural network. These parameters can be obtained from a histogram and from texture analysis of the image [14] or it is possible to use edge detection and area computations to produce the set of vectors.

Since in the prostate pathology it is known that there are three factors which are relevant in diagnosis (prostate volume, obstruction factor, and irritative factor), we combined the features extracted from images and clinical signs. So we analysed the images for the 60 studied patients, trying to extract the features which are relevant for the three finally classes: normal, benign, and malignant. During this analysis, several image-processing parameters (like uniformity, contrast, inverse differential moment, entropy, correlation) were calculated. We used histograms, texture analysis, prostate volume, and international prostatic symptoms score (IPSS).

6 Conclusions

This paper described a software package which can be used to obtain a 3D representation of prostate from transabdominal ultrasound images and also to obtain an automated classification of transabdominal ultrasound prostate images. With the help of image processing, tissue characterisation was performed to predict the probability of the presence of malignant prostate tumours. The software system developed has proved its usefulness especially in early detection of prostate cancer.

The program was written in C++ (Borland implementation) and data processing was performed on a Pentium 166 MHz computer. The application was implemented and it is used in the present in the Urology Clinic of Timisoara.

Our study proved that it is not always necessary to use advanced mathematical techniques or sophisticated hardware equipment in order to obtain good results in increasing the quality of medical process.

It is known that the most suitable imaging modality for studying prostate tumours is transrectal ultrasonography. But there are several hospital which do not have such equipment and primary care physicians, who have often to solve prostate problems, do not have all transrectal ultrasound equipment. At the same time, transrectal ultrasonography does have some drawbacks, including cost, inability to detect cancer in the transition zone or in those area that appear isoechoic, and with high sensitivity or low specificity for hyperechoic areas.

In this way, a software system for automatic classification of transabdominal ultrasound prostate images, can be a useful alternative to transrectal ultrasonography.

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