MEASURE AND REPORT SYSTEM IN OBSTETRICAL ULTRASOUND IMAGES

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Ultrasound units are indispensable for modern medical diagnosis. Today's equipment allows a great diversity of operations when performing health care diagnosis. An ultrasound unit obtains real time images, through ultrasound signal, of determined human body internal areas, in a non-invasive way. Beyond a general medical tool, the obstetric speciality makes extensive use of this equipment to follow the development / growth of the fetal body. This paper describes an auxiliary measure and report method of obstetrical ultrasound images.

Keywords

Objective

The application presented here, uses a real time video capture card connected to the composite video output of an ultrasound unit, allowing the physician the real time selection of the ultrasound images considered relevant for the parameters he wants to measure. The probe depth information, extracted automatically from the image, enables to perform measures of the obstetrical parameters, necessary to the precise calculus of the fetal age. From the various extracted values, a report can be produced correlating all data and presenting them in an easy and practical way.

Capabilities

The application developed is capable of:
- Capture ultrasound images from a real time source, grab special interest images, and process them in order to calculate a precise gestational fetus age;
  - o Calculate real measures for the following parameters: Crown to Rump length (CRL), Femur length (FL), Occipital frontal diameter (OFD), Biparietal diameter (BPD), Head circumference (HC), Abdominal circumference (AC), Gestational sac (GS), Humeral length (HL), Length Vertebrae (LV), Pregnancy week (PW), computed gestational week (CGW);
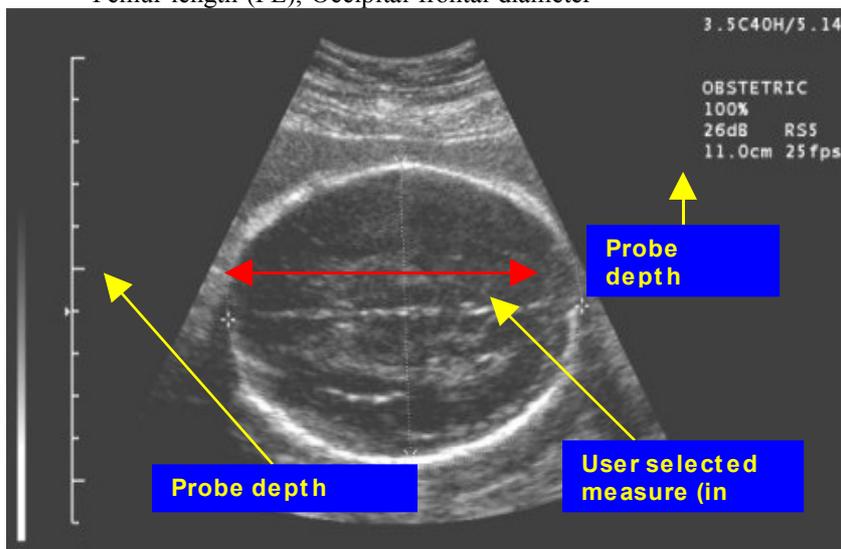 - o Gestational age (GA) calculation for each measure, in days and weeks;
  - o Arithmetic average over the gestational age of various measures;
- Store physician, patient an fetus data;
- Produce a printed report of all the data stored in the exam;
- Import / export of images from / to various standard image file formats.

The application is independent of the ultrasound equipment, as well as the video capture card, requiring however the existence of a probe depth scale displayed in the image in analysis, and that the ultrasound equipment has a video output compatible with the real time capture card, witch in our case is the Matrox ® Meteor ® II [5] capable of capturing standard NTSC and PAL analog video in composite (CVBS) and S-Video (Y/C) formats with either square pixels or CCIR-601 resolutions.

Methods

The work presented in the paper has various stages, among them are some image pre-processing techniques, used for contrast improvement, in order to enhance certain features of the image [3].

Having realised that most of the modern ultrasound unit equipment, presents in the displayed image, information related to the probe depth in the form of numerical digits, as well as an image scale witch relates this value with image coordinates, it is possible capture their real time displays, and establish a relationship between image and real coordinates. Therefore, with an ordinary computer, is possible to develop a specialized

obstetrical application that measure, store and reports all necessary information for the diagnosis.

Besides all the details involved in the application development, special care should be taken in the recognition of the probe depth scale, witch makes possible the relation from image to real coordinates, an attribute that changes its size, according to the physician needs.

In order to recognize the probe depth scale, it would be considered appropriate the use of a contour detection operator, like Sobel (recommended for vertical or horizontal contours), in order to find the line segments correspondent to the scale. However, given that we want only to recognize line segments, we adopted the Hough transform, suitable for the detection of parametric curves.

In order to establish a relationship between image coordinates and real coordinates, we used a modified Hough transform, using the gradient direction [1], resulting in the reduction of the computational complexity of the transform. This technique also allows the increase of precision, achieved with the gradient calculation. The method implemented for contour detection is based on contour detection operators.

After the contour detection stage, the contour map is often very thick, requiring the use of a local erosion operator [1,2], in order to decrease the thickness of contours.

After knowing probe depth value and the pixel measure equivalent in the image, is then possible to establish a relationship between these values, with we will be able to determine the various measures in real units.

Based on parametric information of fetal area contours of interest (not presented in the paper), it is possible to measure values in real units, of the following obstetrical parameters:

Crown to rump length (CRL), femur length (FL), occipital frontal diameter (OFD), biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC).

With the measure of one of the parameters, follows the computation of the gestational age (GA), in weeks and days.

The areas of interest may be selected by the user, or can be automatically detected by a special method, based in parametric contour detection witch is another area of study being developed in Superior Technology School.

Probe depth scale detection algorithm

In order to convert from image to real coordinates, we need to detect the probe depth scale.
The implemented algorithm has the following steps:
1   Application of the Prewitt operator to determine the image contour map;

Masks used in the Prewitt operator:

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \quad \textit{according x}$$

$$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix} \quad \textit{according y}$$

Once we want to detect horizontal segments that belong to the scale presented in the image, we apply the operator only according to the horizontal direction. Such proceeding helps reducing computational time, as well as the possibility of detecting unwanted line segments.
We present a zoomed fragment of an image, and the result after applying the horizontal Prewitt operator.
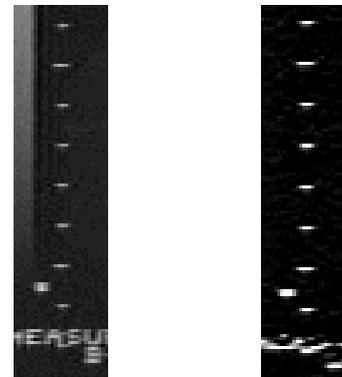
(a) Original image   (b) Contour image

2   Binarize the image corresponding to the contour map.
This procedure is done in order to minimize the Hough transform calculation time. The image has now only two brightness levels.
In order to correctly binarize the image we need a good threshold value, witch can be obtained through a static threshold algorithm [2].
Pixels with value less than the threshold are changed to 0 (black) while pixels with value above threshold get value 1 (white).

3   Application of the Hough transform, to the image resultant from the previous step.
Given that we only want to detect horizontal segments, the calculation is made only for the angle of 90º, contributing to the performance of the algorithm. We proceed calculating the perpendicular distance from the referential origin to the line. As a consequence, we increment the corresponding counter value, adding the pixel to the list of pixels that contributed to the line;

3.1 For each contour point, we need to calculate parameters r and q (90º);

3.2 Parameters space is initially declared with a predefined size, setting all the counters to zero;

3.3 These values are quantized, to vote in the parameter space they belong to;

3.4 Once filled the parameters space (r,q) the differences are calculated between two non-zero cells. The most frequent difference corresponds to the number of pixels between any two consecutive scale marks in the probe depth scale.

Implementation

For the development of this project, we are mainly using Microsoft ® Vision Software Developers Kit [6] (Vision SDK), a tool for research in windows platform. The Vision SDK is a low-level image manipulation and processing library, for use with Microsoft ® Visual C++. With this tool, we have a strong programming foundation for image processing operations, as well as the application independency of the image capture hardware device. With the Vision SDK, we are able to use capture images from the Matrox ® Meteor ® (or Meteor II ®) digitisers, from digitisers whose drivers support the Microsoft ® Video For Windows (VFW) interface, or from digitisers whose drivers support the Microsoft DirectShow interface. Additionally, this development kit already has several image manipulation classes that simplify our application development.

Functional specification

As functional requirements of the developed application, we emphasize the following items:
- It should serve as a tool to help in the practice of the obstetrical medical activity;
- The application must run on any PC with the minimum requirements, within Intel platform;
- Calculate measures in real units, from the image produced by a generic ultrasound equipment;
- Produce complete reports, easy to print and bind to the patient's process;
- Developed in a strong foundation, se we can improve the application easily;
- Have an easy interface, easy to use, oriented to he Windows environment;
- Capture real time images, virtually through any image capture board;
- Import or export images stored in standard formats.

Support libraries

To develop the application, some libraries where chosen, as the basis of development.

Microsoft Vision Software Developers Kit is a set of tools for carrying out research and developing products for image analysis and processing using Microsoft Windows operating systems [6,7]. It is intended to provide a strong programming foundation for research and application development.

The Intel Image Processing Library Suite v1.2 [9] provides a set of low-level image manipulation functions, in the form of normalized DLL's. The functions are optimised for Intel family of processors, and are especially effective taking advantage of MMX technology.

With those functions it is possible to perform many kind of operations, such as filtering, threshold, arithmetical, logical and morphological. There are also functions for linear geometry and linear image transforms, such as FFT and DCT.

IPL uses a flexible image format, with support for integer pixel channels, of 1,8,16 and 32 bits depth, as well as floating point 32 bit pixels, with an arbitrary number of channels per image. The conversion from and to DIB format is supplied, as well as conversions between colour and gray scale images.

The application framework was developed with the use of MFC - Microsoft Foundation Classes [10,11,12,13]. We made extensive use of the document/view architecture, in conjunction with the image processing and manipulation capabilities of the VisSDK and IPL libraries.

Exam report printing and database storage

The still images selected from the real time video captures are part of the exam, and therefore printed and stored in database for future reference. The user can choose to capture one image from the selection of images, or print a complete report, with all the data gathered throughout the exam.

All the information is stored, through an ODBC connection, to a generic database. The physician can retrieve all the images and associated measures, for comparison and reference.

Converting from real measures to fetal gestational ages

The conversion from real unit measures to gestational ages is calculated with the help of linear fits of medical tables, and formulas presented in [14].
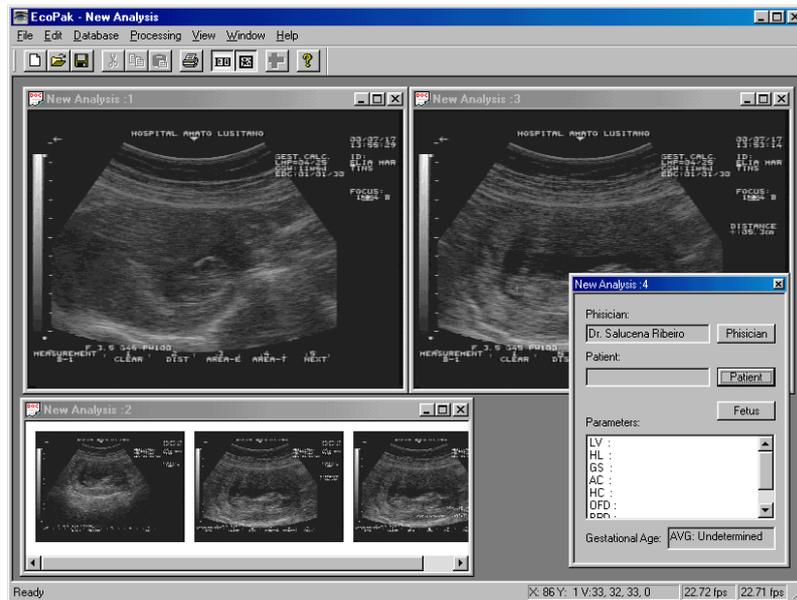
Conclusion

The application developed has the name EcoPak, and has already been tested with Windows 98 running in Intel Pentium III 550MHz, with a Matrox Meteor II frame grabber. The application needed approximately 12 MBytes.

From the practical point of view, the interface of our application is much more user-friendly than an ordinary ultrasound equipment, making work easier.

The financial motivation is also a point to consider, considering the fact that we can use a general ultrasound equipment associated with this king of programs, instead of using a specialized ultrasound equipment, usually much more expensive, but achieving the same kind of results, besides the fact that is always possible to improve the application or change to another. With the use of various specialized applications, we can make general ultrasound equipment, specialized in various medical areas.

The measures and calculations are fairly precise (error <=1mm), obtained from formula conversion, and not lookup tables.

Once this is a medical application it is appropriate to test it thoroughly, to guarantee the correct answer under various conditions, witch hasn't been done yet.

One of the future development efforts should be aimed to store the entire real time exam, once it is dynamic, makes sense. Other development effort should be the integration of the system with Dicom 3.0 medical imaging networks.

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