3D Fetal Surface Reconstruction based on Image Processing Techniques

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Abstract: The research offers an innovative way to represent the fetus in three-dimensions. This is done by transferring scan fetus video to a series of grayscale images. Each image processed individually in order to obtain binary image represents a fetus object. Although the ultrasound image segmentation is difficult, but we were finding two ways to isolate the fetal region of the image. First we improve the contrast and enhance the edges. After that we extract the fetal area by applying Region Growing algorithm, or using Thresholding followed by Morphological operations. Then we get the three-dimensional formation of surface through overlaying the resulting images on top of each other. This paper is important because it helps doctor to detect potential abnormalities or in estimation the gender of fetus.

Introduction

Recently ultrasound techniques have grown in popularity among the gynecology and obstetrics communities [1][2]. Ultrasound technologies have become a standard in detecting several morphologic and functional alterations involving both fetus and internal female genitalia. The success of ultrasonography is mainly due to its non-invasive nature, low cost and ease of use [3]. Ultrasound machines are based on the same basic principle: ultrasound pulses are sent to the part of the body being scanned and echoes are received. 3D visual-haptic models from sets of 2D slices obtained using ultrasound machines. Such models can then be touched using any haptic device [4]. While the system has been mainly developed for the case of interaction with fetal models, so the scope of the research is wider, it allows to be usable from anyone without need doctor help.

Research Objectives and its Methods

The ultrasound images are less contrast and visible between the other different medical images, so the segmentation process is the most difficult task. The formation of a three-dimensions surface helps the doctor to see the entire fetus from different angles. Scan video does not give the doctor enough or accurate information, especially if the doctor relied on one slice without considering the next or previous slices, as well as the scanning process is fast when we run the video, and this may cause to give the doctor a false conception or inaccurate information.

Region Growing Algorithm:

The seeded region growing (SRG) algorithm is one of the simplest region-based segmentation methods [5]. It performs a segmentation of an image with examine the neighboring pixels of a set of points, known as seed points, and determine whether the pixels could be classified to the cluster of seed point or not [6][7]. The algorithm procedure is as follows. First step: We start with a number of seed points which have been clustered into n clusters, called C\textsubscript{1}, C\textsubscript{2}, ..., C\textsubscript{n}. And the positions of initial seed points is set as p\textsubscript{1}, p\textsubscript{2}, ..., p\textsubscript{3}. Second step: To compute the difference of pixel value of the initial seed point p\textsubscript{i} and its neighboring points, if the difference is smaller than the threshold (criterion) we define, the neighboring point could be classified into C\textsubscript{i}, where i = 1, 2, ...,n. Third step: Recomputed the boundary of C\textsubscript{i} and set those boundary points as new seed points p\textsubscript{i} (s). In addition, the mean pixel values of C\textsubscript{i} have to be recomputed, respectively. Fourth step: Repeat Step2 and 3 until all pixels in image have been allocated to a suitable cluster [8]. The threshold is made by user and it usually based on intensity, gray level, or color values. The regions are chosen to be as uniform as possible [9]. There is no doubt that each of the segmentation regions of SRG has high color similarity and no fragmentary problem. However, it still has two drawbacks, initial 3 seed-points and time-consuming problems. The initial seed-points problem means the different sets of initial seed points cause different segmentation results [10].
**Discussion**

First we convert the scan input video (x,y,t) to a series of 2D ordered images (Image1, Image2, ..., ImageN), and then we process these images via increasing the contrast, and enhance the edges, after that we extract the fetus region depending on the Region Growing algorithm or relying on Thresholding followed by Morphological operations. We refine the edges in the resulted segmented binary images, and in the end we are working on repositioning slices over each other to form a surface (x,y,z) of the fetus. Figure (2) shows the block diagram of the proposed system. There are three basic stages in research: Image enhancement, fetal region segmentation, edge refining, and each of them will discuss later.

**Image Enhancement:**

This stage is very important for next step, i.e. Segmentation process. We can enhance contrast through mapping the intensity values in grayscale input image I to new values in J such that 1% of data is saturated at low and high intensities of I. This increases the contrast of the output image J. Figure (3) illustrates the effective of contrast increasing.

**Fetal Image Segmentation:**

We are applying two ways for fetal region segmentation. The first method depends on Region Growing algorithm. We can identify the seed manually, or automatically by selecting a point belong to the fetus region, as Figure (4) shows.

While the second way applies series of steps including: Thresholding (to convert image to binary one), Filling (to fill all holes in desired area), Small Objects Removing (in order to delete all small unwanted objects), and Image Cropping (to remove the surrounding information which appears on image boundary. We can add black contour to the resulted image in order to back it to the old size. Figure(5) shows the result of each step of this method.

After comparing both of segmentation methods, we note that the result is close, with the desirability of the use of the Region Growing algorithm, because it gives softer and smooth edges. Figure (6) shows the result of application of both methods.
**Edge Refining:**

We need to refine the edges in binary resulted image. This is done for getting smooth fetal surface. First we get the convex hull image from binary one, after that we apply Erosion process (with mask 3*3), then we use iterate opening operation. Finally we depends on median filter (each output pixel contains the median value in a 3-by-3 neighborhood around the corresponding pixel in the input image). Figure (7) shows the result of applying these series of steps.

![Figure (7): 1- Resulted Binary Image, 2- Edge Refining.](image)

**Results**

The major reason for the increase in the use of 3D ultrasound is related to the limitations of 2D viewing of 3D anatomy, using conventional ultrasound. This occurs because: Conventional ultrasonic images are 2D, yet the anatomy is 3D, hence the diagnostician must integrate multiple images in his mind. This practice is inefficient, and may lead to variability and incorrect diagnoses. Also the 2D ultrasound image represents a thin plane at some arbitrary angle in the body. It is difficult to localize the image plane and reproduce it at a later time for follow-up studies. 3D ultrasound imaging overcomes these limitations. After applying series of previous steps we are able to form three-dimensional surface easily through overlaying slices on top of each other in the same order. In addition we can colour the resulting binary slices, and coating the output surface with thin skin cover, as the Figure (8) shows.

![Figure (8): 3D resulted surfaces from: 1,2- Vertical Scan Video, 3,4- Horizontal Scan Video.](image)

**Conclusion**

The proposed method gave very acceptable results. We convert the input scan video into series of 2D gray-scale images, then we improved the input image and enhance its contrast. Also we worked on extracting the fetus region in two different ways, the most important algorithm which used for fetal image segmentation is Region Growing. After that we applied edge refining in resulted binary images in order to have a smooth surface as much as possible. Then we overlay resulted images on top of each other to get the fetal surface. The result of proposed method helps doctor to detect potential abnormalities of the fetus, if any, as well as benefit him to estimate the gender of fetus.

**REFERENCES**


