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A REVIEW ON APPLICATIONS OF IMAGE SEGMENTATION IN FETAL ULTRASOUND IMAGING

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Abstract:
With the growing research on image segmentation, it has become important to categorize the research outcomes and provide readers with an overview of the existing segmentation techniques in each category. In this paper, different image segmentation techniques applied on fetal ultrasound images are reviewed. The conceptual details of the techniques are explained and mathematical details are avoided for simplicity. Both broad and detailed categorizations of reviewed segmentation techniques are provided. The categories defined are not always mutually independent.

Keywords: ultrasound, segmentation, fetus, image analysis and processing.

Introduction

Image segmentation is the process of partitioning a digital image into multiple segments (sets of pixels). The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image (edge detection). Ultrasound image segmentation is strongly influenced by the quality of the input data. There are characteristic artifacts which make the segmentation task complicated such as attenuation, speckle, shadows, and signal dropout; due to the orientation dependence of acquisition that can result in missing boundaries. Further complications arise as the contrast between areas of interest is often low. In obstetrics, segmentation provides valuable measurements in order to assess the growth of the fetus and in diagnosis of fetal malformation. Most analysis is based on 2-D scans. Standard measurements include the biparietal diameter(BPD), head circumference (HC) , length of the fetal femur(FL), the abdominal circumference(AC) and the amniotic fluid volume. There is often a sharp contrast between the face of a fetus and the surrounding amniotic fluid, allowing automatic boundary detection. Hence, obstetrics is a potential field of application for volume rendering and visualization [1].

Manual extraction of contours in medical images requires expert knowledge and is a tedious and time-consuming task. In addition, manual contour extraction is influenced by the variability of the human observer, which limits its reliability and reproducibility. The development of automatic techniques for the extraction of contours of fetal anatomic structures, can in principle, eliminate the variability introduced by the human operator, contributing to reliable and reproducible measurements. [2].

The rest of the paper is organized as follows. Section 2 describes the categorization of image segmentation from broad to fine level. Section 3 discusses about the application of segmentation as per the existing review papers on image segmentation. Section 4 states the conclusion of the performed review.

Approaches to image segmentation

There are many methodologies to approach the image segmentation problem. Each of the approaches presents its own advantages and drawbacks, they can be used isolated or combined in any convenient manner to explore the complementary properties of each method or they can be unsupervised without any user intervention or interactive as often required by medical imaging applications. These segmentation methods are often classified in three categories, namely feature domain, image domain and methods that use a combination of these cooperative methods, as it can be seen in Figure 2. Next stage of categorization corresponds to the homogeneity measures used for image segmentation. The possible measures are based on similarity comprises spectral, texture, spatial, size, shape, and temporal. Some other semantic information prior knowledge, context and connectedness are also required.

Feature Domain

In this technique, a vector of local features such as grey Level distribution, intensity gradient, phase, texture measure, shape and temporal models is computed at each pixel and then mapped into the feature space. Feature such as intensity and texture are the commonly used parameters. The feature space is then clustered and each pixel is labeled with the cluster that contains its feature vector. Clusters in feature space can then be used for image segmentation, typically by fitting a parametric model to each cluster and then labeling the pixels whose feature vectors lie in the cluster with the parameters. The common techniques include histogram thresholding, clustering and graphs [3].

Model based approach: It assumes that objects in an image are present in a certain pattern. A list of models generally used for image segmentation are a) Object Background/Threshold Model, b) Neural Model, c) Markov Random Field Model, d)Fuzzy Model, e) Fractal Model, f) Multi-resolution and g)Transformation model namely Watershed model and Wavelet model.

Object-background Model: Object Background models are based on histogram thresholding. They are primitive models for image segmentation. They follow a concept that there is a uniform background and objects are irregularly placed on this background . They are mainly based on spectral properties. Spectral variation is represented by image histogram. This makes image histogram the choice for object delineation. Hence, finding an appropriate threshold between object and background fulfils the task of object identification. Most of the threshold based method follows an image model.

Fuzzy clustering: It is a form of minimizing within group sum of squared (WGSS) error. Each pixel holds a membership value derived from local minimum of WGSS error. Two methods used for hard clustering was confusion matrix oriented merging (percentage of total pixels in that cluster) and minimal spanning tree merging whose nodes are cluster centers and edges are distance between cluster centre. Here, the class information was already available which helped in pruning the spanning tree to form segments.

Image Domain

Image driven approach is also known as bottom-up approach. It can be said that bottom-up approach forms object by combining/merging pixels or group of pixels. Image driven approach operates directly on the image pixels and detects objects solely based on the image feature. Image driven approach extracts object based on the statistical features of the image derived from the pixels. This includes most of the solely edge based segmentation techniques. Edge based techniques detects edges and then closes the regions by contour generating.

With respect to the Image domain, the aim of Region-based techniques is partitioning the image domain by progressively fitting statistical models to the intensity, colour, texture or motion in each set of regions. These techniques rely on the assumption that adjacent pixels in the same region have similar visual features. Boundary-based methods aim to segment an image from the edges of each region by locating the pixels where the intensity changes when compared to the pixels of its surroundings [4].

Watershed transform: It is a mathematical morphological approach and derives its analogy from a real life flood situation . It transforms image into a gradient image. Then, image is seen as a topographical surface where grey values are deemed as elevation of the surface at that location. Then, flooding process starts in which water effuses out of the minimum grey value. When flooding across two minimum converges then a dam is built to identify the boundary across them. This method is essentially an edge based technique . The original watershed algorithm was susceptible to over segmentation so a modified marker-controlled based watershed algorithm was proposed by Beucher. Watershed algorithm produces over-segmentation because of noise or textured patterns.

Edge Based: Thresholds in the edge-based algorithms are related with the edge information. Structures are depicted by edge points. Common edge detection algorithms such as Canny edge detector and Laplacian edge detector can be classified to this type. Algorithms try to find edge pixels while eliminate the noise influence. For example, Canny edge detector uses the threshold of gradient magnitude to find the potential edge pixels and suppresses them through the procedures of the non maximal suppression and hysterics shareholding. As the operations of algorithms are based on pixels, the detected edges are consisted of discrete pixels and therefore may be incomplete or discontinuous. Hence, it is necessary to apply post processing like morphological operation to connect the breaks or eliminate the holes. The method has the ability to segment 3D image with good accuracy.

Application Of Image Segmentation in fetal ultrasound imaging

In obstetrics, measurements based on echo graphic images play a key role as an accurate means for fetal age estimation. Several parameters are used as age and development indicators, the most important being biparietal diameter (BPD), occipital-frontal diameter (OFD), head circumference (HC) and femur length (FL). Each of these parameters provides, through a specific mathematical expression, estimates of the gestational age (GA), given in weeks (w) and days (d) [2].

Several recent papers describe new methods for segmentation of fetal anatomic structures from echo graphic images. [Noble and Boukerroui,2006] In this paper, an approach to unsupervised contour estimation in fetal ultrasound images based on a maximum likelihood formulation of deformable parametric models is described. The method estimates and measures the contours of the femur and of cranial cross-sections of fetal bodies. Contour estimation is formulated as a statistical estimation problem (or likelihood function), where the observation model relates the observed image with the underlying contour. This function is derived from a region-based image model. The contour and the observation model parameters are estimated according to the maximum likelihood criterion via deterministic iterative algorithms. Some examples of cranial cross-session contour estimation on real images can be seen in Figure 3.1. All the experiments reported were obtained using Matlab 6.5 R13 implementations of the algorithms [1]. [K.R.Subramanian,1997] His paper explored the use of two methods, one the region growing and another, a variant of split and merge algorithms for segmentation sequences of fetal ultrasound images. They describe an interactive system that can rapidly process and segment an arbitrary number of features. The user interface was built using the Tcl/Tk toolkit, which is publically available. The biggest weakness of the system is the lack of effective measures that can evaluate the accuracy of the segmentation. It also calls for techniques that are more tolerant of the noise and artifacts because region growing algorithm is highly sensitive to the local neighborhood. Another possibility would be characterizing of the boundary using Binary Space Partitioning tree (BSP) [5]. [Y. Jinhua et al., 2008] Their study describes a semi-automated fetal ultrasound image segmentation system developed to improve the estimation of fetal weight (EFW). Four standardized fetal parameters are measured by the proposed system: BPD,HC,AC,FL. The EFW based on computerized measurements and manual measurements are compared by using regression analysis, artificial neural net-work and support vector regression. Figure 3.2 summarizes the implementation procedure of segmentation algorithms for head and abdomen measurements. Ultrasound measurements were carried out using commercial 2-D ultrasound scanner EnVisor 2540A (PHILIPS, ShenYang, China) with a 3.5 MHz trans-abdominal probe. All images were stored in Microsoft Bitmap (BMP) format of a size 800 9 564 with 24 bit per pixel. Figure 3.2 presents a sequence of steps to represent the algorithms for head and abdomen measurements [6]. [V. Shrimali et al.,2009] Shrimali's paper had as main objective to obtain a time-efficient morphology-based algorithm to recognize femur contour in fetal ultrasound images, refine its shape for automatic length measurement, and thus, attaining accuracy and reproducibility of measurement. The images obtained from the subjects were initially processed using morphological operators to remove the background from the image. Thereafter, to refine the shape of the femur, the images were metamorphosed, using the morphological operators, till a single pixel –wide skeleton of the femur was available in the most time-effective manner. The skeleton-end-points are assumed to be the femur end- points, and the femur length is calculated as the distance between the end-points to estimate gestational age. The proposed algorithm has been tested on real clinical images, and has shown that the measurements made by the proposed method are consistent and in good agreement with the conventional manual method of measurement. The proposed algorithm also provides a possible time-efficient solution to the current inconsistency, difficulty, and subjectivity of fetal ultrasound measurement [7].

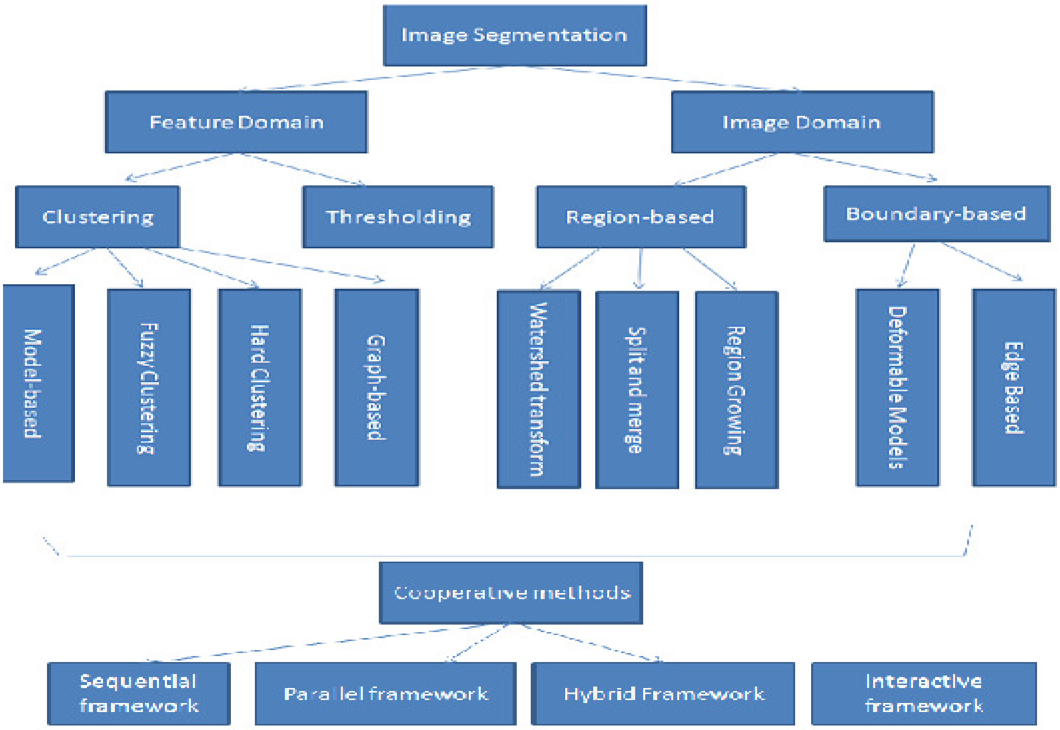

Figure 2. An overview of images segmentation approaches

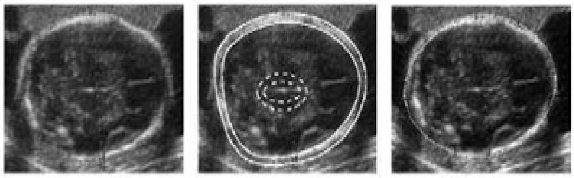

Figure 3.1. Left column: ultrasound image of cranial cross-section. Middle column: Automatic con-tour extraction. Right column: Manual delineation of the object

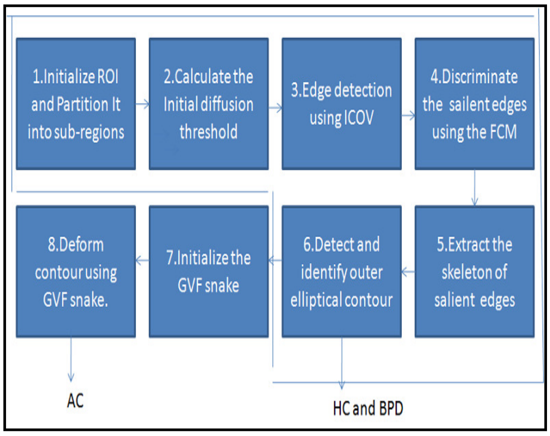

Figure 3.2. Flowchart of segmentation algorithm for head and abdomen measurements

Conclusion

With the numerous amounts of image segmentation techniques presented in this paper, it might be possible to get confused regarding what is presented in this paper. Thus, it is important to summarize all of those to regain the content of this Image segmentation methodologies were categorized in two stages. At first stage comes feature domain approach and image driven approach. The second stage corresponds to homogeneity based measure, and final category corresponds to mode of operations on an image, e.g. edge detection, region growing/splitting.

The selection of segmentation approach depends on quality of segmentation ,scale of information is required. Each method has its suitable application fields, and researchers should combine the application background and practical requirements to design proper algorithms. Accuracy, complexity ,efficiency and interactivity of a segmentation method should all be the considered factors. Because of space limitation very few applications of image segmentation in fetal ultrasound imaging could be explored. Image segmentation can also be applied on 3D images of fetal ultrasound.

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