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# 3D-Imaging Computational Techniques

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***Abstract*— *Three-dimensional (3D) image has a depth perception associated with it thus making the user have a more real outlook. 3D images and its applications have grown particularly in the medical domain most importantly with ultrasound. Ultrasound medical imaging is a tool that helps physicians to view the internal structure of the human body. B-mode ultrasound has contributed significantly in medical analysis over the years. Moving a step forward, three-dimensional (3D) ultrasound was developed that provided more efficient evaluation and diagnosis of the anatomical structure by creating a virtual reality for the viewer. 3D images are complex in nature thus segmentation becomes imperative. The most favorable segmentation techniques for 3D images shall be focused upon.*

***Keywords*— *Image segmentation, three-dimensional (3D), ultrasound.***

## I. INTRODUCTION

Ultrasound being a non-invasive, radiation free and a cheap technique for medical image analysis, it has been very beneficial in providing qualitative and life saving information about the internal organs of the human system. It is widely used to observe the conditions related to abdominal tissues and organs, Bone sonometry, fetal monitoring, breast ultrasound, echocardiograms and much more.

Incorporating the 3D image technology into the ultrasound method was a major advancement in the medical domain allowing the diagnostician to perform accurate and efficient diagnoses as compared to 2D or B-mode ultrasound. In 3D ultrasound the 3D image of the interested object is created by digitally adding together many 2D planes and using the pixel values to determine the voxel value of the 3D image. Huge generation of images has rapidly increased the medical data set which is difficult to handle manually moreover due to the complex internal structure of the human body interpretation and analysis of ultrasound is highly limited hence image segmentation becomes extremely necessary. Ultrasound images usually contain noise speckles, they are affected by shadows, attenuation and missing boundary which makes segmentation process challenging.

Basically segmentation is the process of partitioning a digital image into multiple segments in order to simplify and change the representation of an image into something that is easier to analyze and process. Extending the basic concept of image segmentation- segmentation on 3D medical images can be termed as *volume segmentation*. 3D image analysis in medical applications is represented by voxels. Voxel defines a value of the image in three-dimensional space. The word voxel is a combination of “volume” and “pixels”.3D imaging segments the image voxels into specific groups trying to enhance the depth perception associated with the 3D image.

3D Ultrasound images can be acquired in 3 ways [1]:

1. Using mechanically swept probes
2. Using 2D transducer array
3. Freehand acquisition

Figure 1 shows a comparison of B-mode (2D) and 3D fetal ultrasound [2].

Fig. 1(a). Image of 20 week baby in 2D ultrasound

Fig. 1(b). Image of baby face in 3D ultrasound

## II. SEGMENTATION TECHNIQUES

### A. *Conventional Techniques*

A wide variety of image segmentation techniques have been developed but the general techniques often do not perform well for 3D ultrasound images. Main reasons being the amount of noise present in the image and the poor quality of image developed .Noise also affects the contrast level between the background and region of interest .Low contrast images fail to yield accurate results through the general segmentation techniques. For efficient analysis not only the shape of the structure is important but also the precise location of its border. This precise requirement of border location is the prime necessity in formulating the 3D model for ultrasound images [3], [4].

Presenting a brief overview of the conventional methods:

Edge based approaches [5], [6]: This technique identifies the boundaries/outlines/sharp discontinuities between the different regions of an image. It segregates the desired region from the background by monitoring the abrupt change in intensity levels of the image. Since this method segments based on the detected edge information, the existence of noise



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in an ultrasound image will make it difficult to accurately distinguish the border between the object and the background. Edge-Detection technique works well for gray scaled images only and are not suitable for 3D ultrasound imaging.

Region based approaches [4]: Unlike Edge detection techniques which segment based on abrupt changes in the intensity, region based techniques segment by grouping similar regions according to the predefined criteria. It is closely related to texture discrimination. The image is categorized based on the different variations in textures in the image. This approach works well with images that have distinct texture variation. Low contrast images are not favorable. Also these algorithms are susceptible to noise which is not desirable for 3D ultrasound image segmentation.

### B. *Deformable Model and Level Set Method*

Though a number of segmentation techniques are made available, the decision of using a particular technique that will yield best result is dependent upon the application and the desired quality of result to the user. The segmentation techniques pertaining to 3D ultrasound can be clubbed together with respect to their constraints. For instance the algorithm that deals with speckle noise can be grouped into one, similarly for texture, gradient, echo intensity etc. Most of the times a combination of several algorithms are used to get the best result.

Deformable model and Level Set method are considered the best options for the segmentation of 3D ultrasound as they have been proved to give promising results.

*Deformable models*

Segmentation of non-static, non-homogenous images is a challenging task as the shape of the object keeps varying depending on the subject [7]. For example the shape of the liver will differ from a child to an adult. Under such circumstances deformable model comes to the rescue.

Deformable model technique works by representing the shape of object as a 2D curve or a 3D surface which can be deformed to match an instance by the influence of internal and external forces. The internal force defined within the curve helps in retaining the model during deformation whereas the external force computed from the image data moves the model to a boundary or desired feature of an image[8], [9]. In very general terms deformable models can be viewed as elastic bodies which respond naturally to applied forces and constraints. Through the work of Kass, Witkin and Terzopoulous [10]: “Snakes: Active Contours” deformable model has gained a lot of acceptance and recognition. Active contours, “snakes”, are parametric curves which one tries to fit to an image, usually to the edges within an image. The strong mathematical foundation with the concepts of geometry, physics and approximation theory has given the model a plus point over the other image segmentation techniques. Object shapes are represented using geometry, the variations of shape over space and time work with the principles of physics.

Figure 2 demonstrates the results of deformable technique applied to 3D brain image.

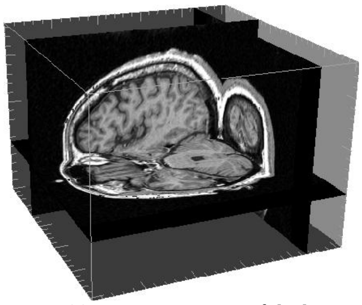

Fig. 2(a). A 3D MR image of the brain

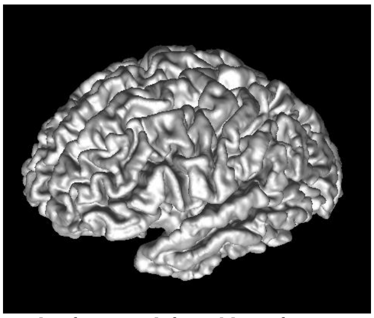

Fig. 2 (b). An example of using a deformable surface to reconstruct the brain cortical surface from a 3D MR image [11]

A formal framework for the method can be expressed [12]; a model $M$ has to be deformed to match a data set $D$. The matched model $M^*$ is sought as the minimum of the energy functional E, which is comprised of the external and internal energies $Eext$ and $E\text{int}$:

$$E[M] = Eext[M, D] + E\text{int}[M]$$

$$M^* = \arg\min E[M]$$

Deformable model are divided into two:

(a) The parametric models or active contours.

(b) The geometric or implicit models.

*Parametric models*

Snakes /Active contours [10] mentioned earlier are basically parametric curves. Here the external energy measures how well the snake matches the image boundaries. It is defined considering the features of the image [12], for example an edge. The external energy $Eext$ is given by:

$$Eext[M, D] = Eext[v, I] = \int_0^1 I(v(s))ds$$

$v : [0,1] \to IR^2$ Parameterization of the curve $M$

$I : IR^2 \to IR$ Edge image of the input image $D$

If $v$ (s) is a point of the curve that on a boundary, the value of the edge image $I$ (v(s)) at this point is low. If the curve is completely on a boundary then the external energy is minimized.

Internal energy for the curve is given by:

$$E\text{int}[M] = E\text{int}[v] = (\alpha(s)|v'(s)|^2 + \beta(s)|v''(s)|^2)/2$$

$\alpha$ and $\beta$ control the weight of the 1st and 2nd derivative terms.



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The goal is to find a smooth curve $M$ with minimum $E[M]$ that matches the edges thus segmenting objects present in the images.

Parametric models involve direct interaction and compactness for real-time application. However a drawback of snakes is that for concave objects it's not able to reach to the object boundary and finding the borders becomes difficult when the initialization is far from the actual border.

*Geometric models*

Geometric models give a better outcome for topological changes, splitting and merging during deformation. This makes use of theory of curve evolution and the level set method (explained consequently).Considering only the geometric features the curves are evolved, eliminating the need for parameterization. The curves and surfaces can be defined as implicit models [13], [14]. As a whole, Deformable models offer a number of advantages. Firstly, the problems of noise, boundary gaps are handled. Secondly, having a strong mathematical background has made the technique reliable and consistent. Mostly importantly in the medical domain they incorporate and consider the anatomical variations existing among individuals. Every method has its downfall; here the initial model needs to be set manually and it works best only for surfaces and is not very suitable for 3D medical images. An alternative to the approach was proposed: The Level Set Method.

*Level set method*

Level set method gained a lot importance due to their capability to handle topological changes, also processing the cavities, concavities, splitting and merging of images overcoming the disadvantages of deformable model. It is an appropriate method that can be used in 3D-ultrasound image segmentation [14]. Another plus point of level set worth mentioning is the ability of level set to segment relatively small features as compared to deformable as shown in the figure 3 [15].

Fig. 3(a). Abdominal aorta using deformable model

Fig. 3 (b). Abdominal aorta using level set method

Foundation to level set method was given by Osher and Sethian [16-18].Level Set method works towards developing an implementation for evolving curves. The concept of Eulerian partial differential equation (PDE) is used to compute interfaces that detect sharp edges and also adapt to topological changes as they evolve. The principle behind the method is to create an implicit representation of the curve as the level set i.e. a contour is represented as a Zero Level Set of a 2D scalar function. In simple terms, level sets can be looked upon as moving curves. The implicit representation is referred to as Level Set Function. Points having the same function value form the Level Set. Zero Level set can be defined as a surface having no height. The zero level set is moved in space to rise, fall and expand keeping the level set function valid. As shown in figure 4.This change is articulated by using PDE in time. The distance function is an appropriate choice to make for the scalar function. Figure 5 shows the split and merge property supported by the level set method. During split, Zero Level Function divides the curve without affecting the validity of the level set function.

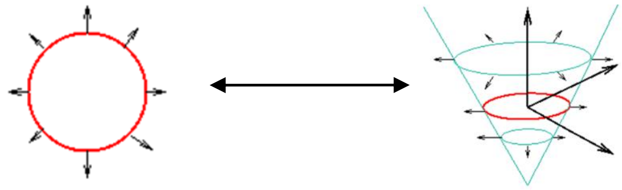

Fig. 4(a). Zero Level Set function

move level set to rise, fall, expand

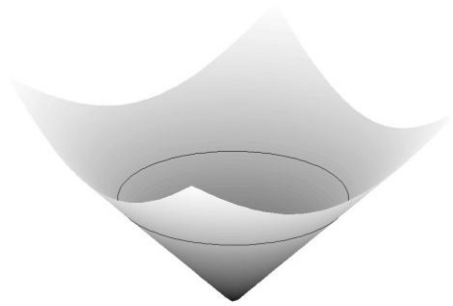

Fig. 4(b). A level set surface

Mathematics of Level Set [13]

The level set function given by $\Phi\ (x, y, t)$

Contour given as $X(s, t)$

We have the Zero Level Set as:

$$\Phi\ [X(s.\ t), t] = 0 \tag{1}$$

Differentiating equation (1) with respect to t, using the chain rule, we get:

$$\frac{\partial \phi}{\partial t} + \nabla\phi \frac{\partial X}{\partial t} = 0 \tag{2}$$

Gradient of $\Phi$ is given by $\nabla\Phi$

Assuming that $\Phi$ is negative inside the contour and positive outside the contour. Hence inward unit normal to the level set curve is given by $N$

$$N = -\frac{\nabla\Phi}{|\nabla\Phi|}$$

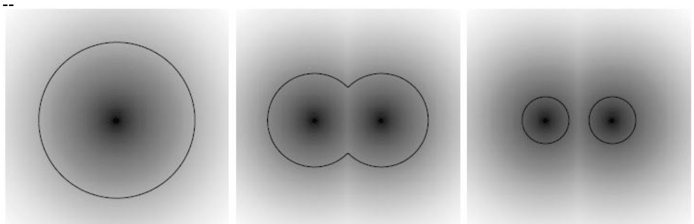

Fig. 5(a) Zero Level set Fig. 5(b) Zero Level Set Fig. 5(c) Function is valid

Level set though a widely used and efficient method in processing 3Dmedical data set it suffers from the drawback of being computationally expensive and time consuming. As a



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result, its use in real-time application is highly limited. An improvement to the method was proposed in the fast marching level set method [19].

The level set method in accordance with fast marching was applied to echo-cardio-graphic images [20] giving satisfactory results. A variant of this method was proposed that combined information of edges and region into the level set method [21]. Recently, in the works of Sethian, he put forth various examples of level set curves and surface for segmenting 3D medical Imaging. Karoui [22] proposed a hybrid technique by combining level set methods and texture statistics introducing a new unsupervised image segmentation method which doesn't require mentioning the independent variable initially thus yielding better results. Additions and constant improvements to the level set method have made it the most appropriate method for segmenting 3D medical data.

## III. CONCLUSION

Among the several medical modalities, Ultrasound is the most frequently used and preferred over the others for accurate diagnoses and efficient analysis. To facilitate in the efficient accurate analysis processing the 3D ultrasound has become mandatory. Segmentation of the 3D images as become an important step in processing. From the various segmentation techniques available the conventional techniques have failed to provide satisfactory results for 3Dmedical data set. Hence The Deformable Model and Level Set Method were developed. Level Set method has shown to produce promising results adapting to topological changes automatically. The advantages of level set have made it the most desired and widely used method for 3DMedical images.

## REFERENCES

[1] A. Fenster, D. B. Downey, and H. N. Cardinal, "Three-dimensional ultrasound imaging," *Physics in Medicine and Biology*, vol. 46, issue 5, pp. 67–99, 2001.
[2] L. L. Hang, T. Fung, and Y. H. Lam, "3D ultrasound imaging," University of Hong Kong, HKSAR, 2010.
[3] J. Noble and D. Boukerroui, "Ultrasound image segmentation: A survey," *IEEE Transactions on Medical Imaging*, vol. 25, no. 8, pp. 987-1010, 2006.
[4] K. Saini, M. L. Dewal, and M. kumar Rohit, "Ultrasound Imaging and image segmentation in the area of ultrasound: A review," *International Journal of Advanced Science and Technology*, vol. 24, 2010.
[5] Y.-Yi Zheng, "Edge detection methods in digital image processing," *IEEE 5th International Conference on Computer Science and Education (ICCSE)*, pp. 471-473, 2010.
[6] S. L. Jeppiar and Dr. V. Sankaranarayanan Crescent, "A study of edge detection techniques for segmentation computing approaches" *IJCA Special Issue on CASCT*, 2010.
[7] F. L. Valverde, N. Guil,, J. Muiioz, Q. Li, M. Aoyama, K. Doi, "A deformable model for image segmentation in noisy medical images," *IEEE Proceedings International Conference on Image Processing*, pp. 82-85 2001.
[8] R. Hegadi, A. Kop, M. Hangarge, "A Survey on Deformable Model and its Applications to Medical Imaging," *IJCA Special Issue on RTIPPR*, 2010.
[9] A. Banda, "Implementing a deformable model image segmentation algorithm for multi-core microprocessor architecture," A thesis in STS 402, 2007.
[10] M. Kass, A. Witkin, and D. Terzopoulos, "Snakes: Active contour models," *International Journal of Computer Vision*, vol. 1, no. 4, pp. 321–331, 1987.
[11] C. Xu, D. L. Pham, M. E. Rettmann, D. N. Yu, and J. L. Prince, "Reconstruction of the human cerebral cortex from magnetic resonance images," *IEEE Transactions on Medical Imaging*, vol. 18, issue 6, pp. 467–480, 1999.
[12] T. Albrecht, M. Luthi, and T. Vetter, "Deformable models," University of Basel, Switzerland.
[13] C. Xu, D. L. Pham, and J. L. Prince, "Image segmentation using deformable models," pp. 146-154.
[14] R. Hegadi, A. Kop, and M. Hangarge, "A survey on deformable model and its application to medical imaging," *IJCA Special Issues on Recent Trends in Image Processing and Pattern Recognition*, 2010.
[15] D. Magee, A. Bulpit, and E. Berry, "Combining 3D deformable models and level set methods for the segmentation of abdominal aortic aneurysms," *Proceedings of the British Machine Vision Conference*, BMVC, 2001.
[16] S. Osher and J. A. Sethian, "Fronts propagating with curvature-dependent speed: algorithms based on Hamilton-Jacobi formulations." *Journal of Computational Physics*, vol. 79, pp. 12-49, 1988.
[17] J. A. Sethian, "Curvature and evolution of fronts," *Communication of Mathematical Physics*, vol. 101, pp. 487–499, 1985.
[18] J. A. Sethian, "A review of recent numerical algorithms for hypersurfaces moving with curvature dependent speed," *Journal of Differential Geometry*, vol. 31, pp. 131–161, 1989.
[19] J. Sethian, "A fast marching level set method for monotonically advancing fronts," *Proceedings of the National Academy of Science*, vol. 93, no. 4, pp. 1591-1595, 1996.
[20] J. Y. Yan and T. Zhuang, "Applying improved fast marching method to endocardial boundary detection in echocardiographic images," *Pattern Recognition Letters*, vol. 24, no. 15, pp. 2777–2784, 2003.
[21] N. Lin, W. C. Yu, and J. S. Duncan, "Combinative multi-scale level set framework for echocardiographic image segmentation," *Medical Image Analysis*, vol. 7, no. 4, pp. 529–537, Dec. 2003.
[22] I. Karoui, R. Fablet, J. Boucher, and J. Augustin, "Unsupervised region-based image segmentation using texture statistics and level-set methods," *in Proceedings WISP IEEE International Symposium on Intelligent Signal Processing*, pp. 1-5, 2007.



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