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# Extraction of Cardiac Chambers from Echocardiographic Images

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***Abstract:*** **For correctly diagnosing various cardiac disorders, a detailed observation of the heart chambers, wall motions and valve functions is required. Echocardiography can provide information regarding the size and shape of the heart and the extent of any tissue damage. A number of segmentation algorithms are proposed for the analysis of cardiac chambers. Here, two methods are considered for extracting the four cardiac chambers simultaneously and in a fully automatic way. In the first method,Phase symmetry approach and levelset segmentation algorithm are used. The second approach consideres a new boundary based object detector for accurate and robust tracking of the four cardiac chambers.**

***Keywords*—Echocardiography, echocardiogram, phase symmetry, level set segmentation**

## I. INTRODUCTION

Echocardiography enables the estimation of global heart function and observation of the heart chambers based on B mode and M mode imaging. It uses two dimensional, three dimensional and Doppler ultrasound for the creation of heart images. Echocardiographic images are a critical element of cardiovascular clinical research. The non- invasive assessment of cardiac structure using echocardiography can provide an insight into the mechanisms of disease and therapeutic benefit. Segmentation is the process of partitioning portions of an image. The goal of segmentation is to change the representation of an image. It is used for locating the objects and boundaries in an image.

There are different types of segmentation which can help in chamber extraction. Most of the heart segmentation methods are semi-automatic which require the user interaction also[1]. In the beginning the segmentation methods succeeded only in segmenting the left ventricle. Andrzej Skalskit[2] presented a novel usage of the level set method to the heart segmentation, the first step leading towards segmentation of the left ventricle. The application of the active contours/shape in segmentation technique is reported in this case. First the region of interest is found using the linear Hough transform. Then, the speckle reduction anisotropic diffusion (SRAD) filter is used. Finally, image segmentation via the level set method is done.

Jose Silvestre Silva[3] and Sofia G. Antunes[4] describes a method to simultaneously extract the four cardiac chambers in a fully automatic way. This method consists of the following steps. First a phase symmetry approach is used which results in substantial noise reduction. Then an edge based approach is considered for level set evolution. The level set evolution uses a new logarithmic based stopping function.

Johan G. Bosch [5] reported about Active Appearance Motion Models(AAMM) for border detection which is a novel extension of the Active Appearance Model(AAM). It allows fully automated, robust and time continuous delineation of left ventricular (LV) endocardial contours. The AAMM demonstrated robustness and accuracy in a large clinical study of LV segmentation using four chamber transthoracic ultrasound image sequences.



Wen Fang [6] incorporated temporal information into the level set functional to solve the leakage problem encountered when detecting the heart wall boundary from the echocardiographic image sequence. The ventricular boundary of the heart is partitioned and classified as strong and weak segments. The weak segments are weakened by dropouts and there is low probability for the presence of boundary. To overcome this, temporal information from neighboring frames is exploited as a regularizer into the level set equation. As a result, the original boundary information in the weak segments can be reconstructed and the curve leakage problem can be remedied.

An algorithm for the segmentation and tracking of mitral valve leaflets in ultrasound image sequences is proposed by Ivana Miki´c [7]. Later this method was successfully applied in the segmentation of other structures including the endocardial surface of the left ventricle and the aortic root. The model successfully handles large frame-to-frame displacements of the object of interest. The presented algorithm requires the user's interaction only in the first frame of the sequence.

An effective method for tracking Left Ventricle borders with a lower time complexity is presented by Suphalakshmi. A and Narendran. S[8]. Here, an improved fast watershed algorithm (IFWSA) is considered,which scans the image only twice, one for generating connected components and other for labeling the catchment basins.

Due to the presence of large amounts of noise, signal drop-out, and unseen wall parts, extraction of endocardium and epicardium from echocardiographic images is a challenging task. Ayse Betul Oktay and Yusuf Sinan Akgul [9] introduces a new technique that automatically extracts cardiac borders by incorporating local and global priors through boosting and level set methods. The shape-based global prior is incorporated into the system by regularly re-initializing the level set surface under the influence of the expert detected contours.

In [10], besides traditional region features (intensity/color and texture), a new boundary-based object detector for accurate and robust tracking in low contrast and complex scenes is described.

## II. PROPOSED METHOD

The input is echocardiographic videos having a duration of 2 to 3 seconds. First, preprocessing is done to remove the noise. Then the four heart chambers are extracted using level set segmentation algorithm. Two different approaches are discussed below.

### 1A. Preprocessing

For the first method, the short duration echocardiographic videos are converted to frames using video to JPEG convertor. Then RGB image is converted to gray scale image as the brightness graduation can be differentiated in gray scale image. Digital images are frequently affected by noise during their acquisition or transmission in a noisy environment. Therefore, to efficiently remove noise from an image while preserving its features is a fundamental problem of image processing. For this purpose, phase symmetry approach is used. Phase-Symmetry (PS) is a dimensionless measure of symmetry defined at each point in an n-dimensional signal. This procedure is based on luminance/gradient information and on log gabor wavelets. Gabor filters can serve as excellent band-pass filters. A complex gabor filter can be defined as the product of a Gaussian kernel times a complex sinusoid.

$$g(t) = ke^{j\theta}w(at)s(t) \quad (1)$$

The use of gabor filter enables the detection of low level features in the image. The output of phase symmetry approach is shown in Fig.1

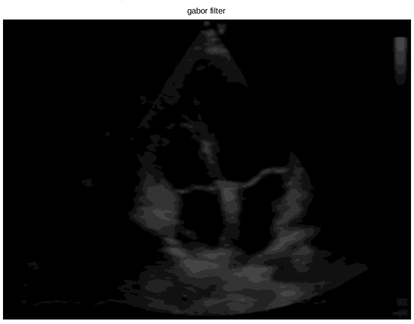


Fig.1 Output of phase symmetry approach

### 1B. Method

Edge based approach is considered for level set evolution. After the preprocessing, edges of the image are found out. Edge means sharp discontinuities in the intensity of an image. Then the level set evolution using a logarithmic dependent stopping function is performed, which gives better results compared to the traditional methods. The main idea of the level set is to minimize a function φ(x,y) by solving the corresponding partial differential equation (PDE) using the level set evolution equation as a numerical method. The method evolves a contour (2-D) or surface (3-D) implicitly by manipulating a higher dimensional function. Here, 2-D images are used, the evolving contour is extracted from the zero-level curve of φ : C = {x|φ(x) = 0}. The general curve evolution PDE in the level set framework is

$$\frac{\partial \phi}{\partial t} = |\nabla \phi| F \quad (2)$$

Where, F is a speed function designed for the boundary detection. The level set function *φ* and the evolving curve C at the zero-level change together with time. The speed function *F* has different evolutions depending on the applied evolution methodology. F is implemented depending on the edge indicator function (P).

$$F = [\,\mathrm{div}(\frac{\nabla \phi}{|\nabla \phi|}) + v]P \quad (3)$$

Where, the term *v* is an outward growing force, providing a faster convergence and div($\nabla\varphi/|\nabla\varphi|$) is the curvature term. The stopping function *P* is responsible for attracting the contour toward the image boundaries. An important advantage of using this stopping function is the capability of the level set to adjust itself to the low-intensity regions. The segmented output is shown in Fig. 2.

A post processing step is necessary to remove the noise present during segmentation. For this, morphological operation is used. By the dilation operation, the boundaries will be expanded, and the small holes in the image will be filled. Output of post processing step is shown in Fig 3.

Fig. 2 Segmented Output

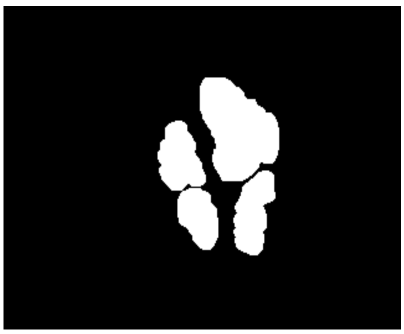

Fig 3. Output of post processing

2A. Preprocessing

Echocardiographic videos are converted to frames using matlab. Then RGB to gray scale convesion is performed.Fig 4 indicate a detailed flow diagram of the work.

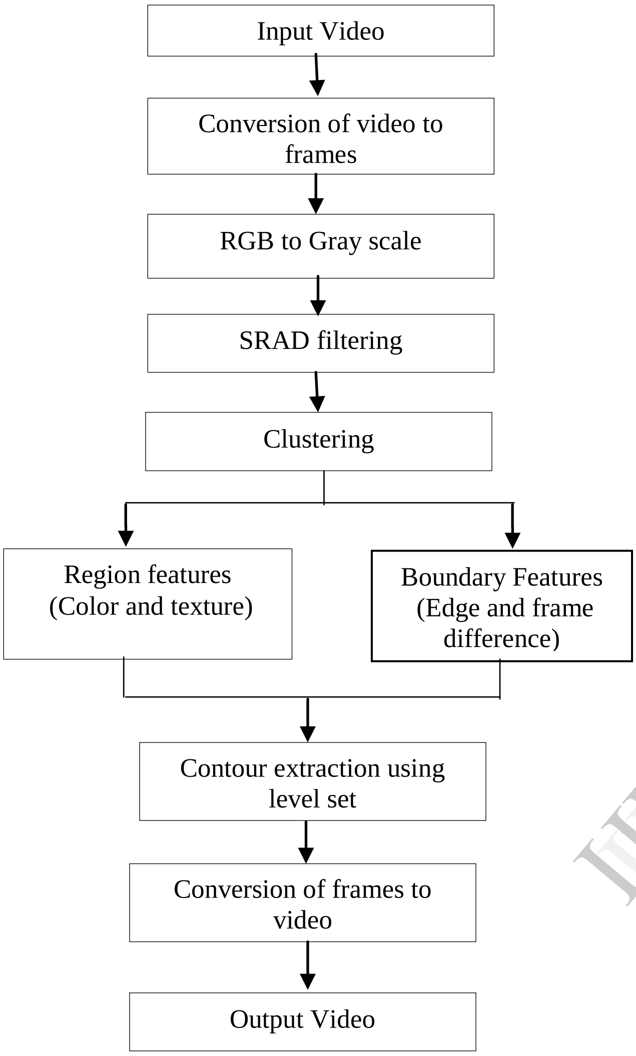


Fig 4. Detailed flow diagram of the work

Ultrasound images are highly affected by speckle noise. Two distinct processes constitute echo formation: Specular reflection and scattering. Reflection is the interaction between sound waves and objects larger than the pulse wavwlength and scattering means the interaction between sound waves and objects smaller than the pulse wavelength. The overlapping of the scattering echos results in speckle. To remove the speckle noise, Speckle Redusing Anisotropic Diffusion(SRAD) filter is used.

2B. Method

After preprocessing, the pixels with nearly same values are grouped together by k means clustering. Here, a cluster size of 20 is used. Then region and boundary features are captured. Region feature can quickly and roughly locate objects, where as boundary features provide more accuracy. Region feature include color and texture. Boundary feature include edge and frame difference.

The clustered image is first converted to a binary image. For this, a threshold value of 30 is used. Then the connected components in the binary image are found out. The area of these connected components are identified and the components within a particular range of area is selected which indicate the approximate location of heart chambers. Texture features include contrast, correlation, homogeneity etc. For finding out the texture features, the Gray Level Co-occurrence Matrix (GLCM) of the input image is computed and the value of the texture features are calculated. A more efficient texture descriptor is the Local Binary Pattern (LBP). It thresholds a circular neighbourhood of pixels with the value of the center pixel.

Edges of the image are found out using prewitt edge detector. Frame difference means the difference between current frame and the previous frame. It is calculated using the equation,

$$D(x)=I_n(x) \quad -I_{n-1}(x) \qquad (4)$$

Region feature image and boundary image are then combined together. Connected components in this image are identified and bounding box is constructed for the connected components. With the help of bounding box, the heart chambers can be extracted more accurately. Level set segmentation is used to get the segmented output. Segmented output is shown in Fig.5


Fig 5. Segmented Output

Each connected component inside the bounding box is considered individually and level set algorithm is applied. Then the output frames are converted back to video.

## III. CONCLUSION

Two methods for extracting the four cardiac chambers from echocardiographic images are discussed. The first method used phase symmetry approach for removal of noise and for capturing low level features. In the second method, region and boundary features are found out seperately and then they are combined together. Segmentation algorithm used in both cases is level set segmentation. Comapring the two methods, it is found that the second method is more automatic and provide more accurate results.

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