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Generalized Transformed Hough: Segmentation of Contours in Angiographic Images

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Abstract

The morphologic and functional study of cardiovascular system is of vital importance because problems related to this system are one of the main causes of mortality in the world. It is important to mention that the left ventricle (VI) is the most susceptible to suffer severe damage, in diseases, such as arterial hypertension, mellitus diabetes or arteriosclerosis. This article presents a new methodology directed to segmentation of left ventricular contours, in angiographic images by using Generalized Hough Transform (TGH). It is important to obtain the ventricular edge, because analyzing processes of systole and diastole end, it is possible to calculate parameters of the cardiac functionality as the end-diastolic volume, end systolic volume, ejection fraction, cardiac output, Hyperkinéticos, Hypokinéticos segments, and normal; in this work we focus only on the removal of the same. For the system implementation, it was used some technics such binarization contrast enhancement, ordering points, filtering, mathematical morphology, b-spline and the TGH, that improved the ventricular visibility contour, highlighting data of interest, eliminating or reducing the effect of present structures such as ribs, catheter and segmented automatically the ventricular contour. The system was validated using 10 studies of angiography, obtained in the Instituto Autónomo Hospital Universitario of the Universidad de los Andes (I.A.H.U.L.A.), Merida, Venezuela. The percentage of generalized error performing the comparison of the manual segmentation and automating segmentation was 3.54%+_ 0.2 taken as a basis the Pearson correlation coefficient. Throughout the work demonstrates the functionality and applicability of the technique for the detection of ventricular edge in angiographic images. In future works is expected to supplement this analysis with the calculation of the descriptors of the cardiac functionality.

Keywords: *houg, contours, angiographic*

1. Introduction

The morphological and functional assessment of the heart is of vital importance, because the cardiovascular damage (CVD) is one of the main causes of mortality in the world [1]. Of the four cardiac chambers, the left ventricle (VI) is more susceptible to suffer severe damage, in diseases such as hypertension, diabetes mellitus and atherosclerosis. In the emergence of a ventricular dysfunction the VI must cope with an overload of blood due to a high pressure, so that physiologically tends to suffer a hypertrophy. If it persists the stress the ventricle just by suffering a dysfunction, which with the passage of time, becomes chronic and irreversible. At this point, the function of the myocardium is compromised and the contractile ability of the heart has just lost forever [2].

At the clinical level, the analysis through images is typically performed in visual form, which generates an assessment which is imprecise about the ventricular function. The introduction of computer-assisted techniques has increased the need to develop efficient algorithms for the treatment of cardiovascular imaging, with the purpose of obtaining accurate results [3]. Under this context you want to use a methodology based on the widespread transformed Hough (TGH), which in initial work only allowed detect regular forms such as lines, circles, etc.; with time is extended its applicability to forms not predictable or irregular (of there its name). This algorithm is based on a contour map and thanks to a prior knowledge of how to search for (table R), it is possible to select the corresponding edge in this case to the left ventricle.

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With the foregoing, the purpose of this article is to design and implement a software platform that allows the removal of the contour ventricular, enabling future, the quantification of indicators of the cardiac functionality such as ejection fraction, cardiac output, etc.

2. Description of the System

The X-Ray angiography is a widely used modality in the evaluation of the cardiac function. To view the heart with this modality the patient is subjected to an intervention called cardiac, during which the VI is filled with a contrast material radio-opaque. The acquisition of images can be done in two planes (considering the right anterior oblique view (OAD) 30° and the left anterior oblique view (OAI) 60°). The acquisition time average is around 8 to 10 s, covering 7 to 9 cardiac cycles. The distribution of the injected contrast media is considered optimal around the second or third cardiac cycle [4].

The equipment used for the acquisition and display of the study of angiography is the so-called INNOVA 2000, built by General Electric and that has the following features: has a solid-state Digital Detector Revolution, fully digital images show a field of view of 20.5 cm x 20.5 cm., sequences of images are recorded at 30 frames per second, with a resolution of 512 x 512 pixels and each one of them is represented with 256 gray levels [5]. Tables and Figures are presented center, as shown below and cited in the manuscript.

3. Widespread Transformed Hough

The TGH is defined as a transformed that allows to detect curves not analytical, i.e. that detects the contour of irregular shapes in objects. In Figure 1 you can see that the fundamental data to obtain an irregular contour based on TGH, are: angulations (α, Φ) and the distance r.

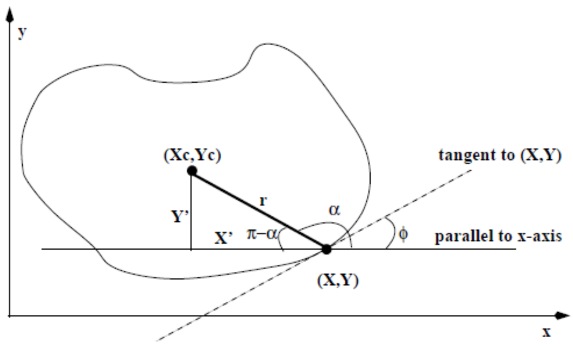

Figure 1. Graphical representation of the TGH

Where:
Xc, Yc define the center of mass of the shape.
r = radius from the center of mass to a point (X,Y).
A = angle formed by the radio, with respect to a horizontal line parallel to the x axis.
Φ = angle formed by the tangent line, with respect to a horizontal line parallel to the x axis

To mathematical level, it is possible to represent the center of mass of the figure, as follows:

X_C=X rcos(α) (1)

〖_C=AND rsen(α) (2)

The settlement formed by ri, αi, Φi, is called table R.

This table, is a settlement that contain values of radii, angles of different images, these values are related to a point on the object that is being processed, this table R, is the basis for building the TGH. For more information refer to [6, 7].

4. Methodology

The methodology used in the present investigation, is based on two large blocks, the first of them consists in the generation of the model of adjustment or pattern (Table R), and the second in the detection of the ventricular contour through the model.

4.1. Construction of table R

Initially, through an interactive tool, it is proceeded to demarcate, by the specialist, the ventricular contour. These coordinates are stored, with the purpose of generating a binary image (0s and 1s), where only are present the object of interest (VI) and the fund. The result is presented in Figure 2.

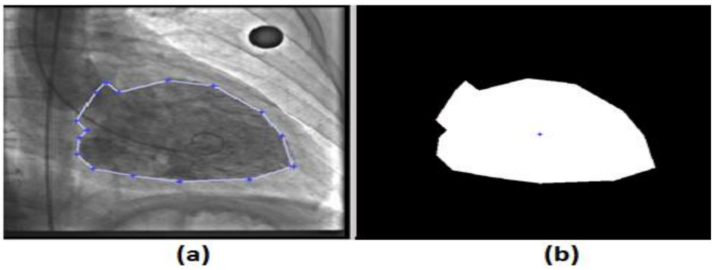

Figure 2. (a) Selection of the ventricular contour by the specialist. (b) Binary mask generated and detection of the centroid or center of masses

Then, it was implemented an algorithm that allowed the detection of the ventricular edge, next to the particularity that the points or coordinates that make it up are sorted, either in the clockwise direction or vice versa. The result is presented in Figure 3.

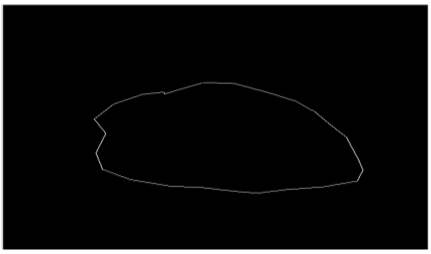

Figure 3. Final contour of the prototype

As explained in section 3, to generate the table R, it is necessary to calculate the corresponding values for α, Φ and r respectively. The procedure used on the contour prototype (Figure 3), for the search of these parameters is the following:

4.1.1. Calculation of r

It is doing plotting straights, from the center of mass of the prototype (centroid), to each one of the points of the contour of the prototype (see Figure 5). Subsequently proceeded to estimate its algebraic distance and finally stores its value in the table R.

4.1.2. Calculation of α

As is illustrated in Figure 1, to obtain this angle, it is necessary to generate horizontal straight to each point of the ventricular contour (see figure 6). Performing this procedure, only lack calculating the slope of each one of the segments and use them in the equation.

$$\alpha = \tan^{-1}\left(\frac{(m1 - m2)}{(1 + m2 \cdot m1)}\right) \tag{3}$$

Where m1 represents the pendent of radius R and M2 the corresponding to the horizontal segment. Finally stores its value in the table R.

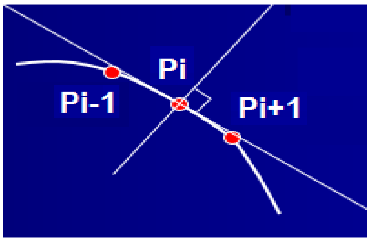

Figure 4. Selection of the reference points and its closest neighbors

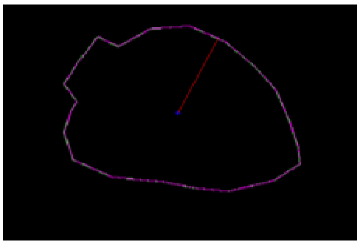

Figure 5. Demarcation of the straight line r, for a point of ventricular contour

The points mentioned above, are compounds so space, to be an image for a pair of X and Y coordinates, represented as follows: Pi (Xi, Yi), Pi 1 (Xi 1, Yi 1) and PI-1 (XI-1, Yi-1).

The tangential components to this point of reference Pi, are possible to calculate them through the equation (4).

$$(t_X\, ,t_Y)\ \approx \frac{(d_X\, ,d_Y)}{\sqrt{d_X^2+d_Y^2}} \tag{4}$$

Where d_X y d_Y, are calculated of the following way:

$$= X_{i+1} - X_{i-1} \tag{5}$$

$$d_Y = Y_{i+1} - Y_{i-1} \tag{6}$$

Then, with the purpose of generating the corresponding tangent line (interpolation), applies the equation (7).

(X,Y) i·(S_n (-t_Y),S_n t_X) (7)

Where (X,Y) are the coordinates of the center point or analysis, i = ….-2,-1,0,1,2,…… and Sn is a constant chosen heuristically.

Finally, taking built straight lines tangent and horizontal, for each point of the contour, it is possible to obtain the angle values φ. The methodology used for this purpose is the same applied in the section 5.1.2, and its value is stored in the table R.

In Figure 5, it is possible to highlight the way as outlined the straight r. For its part, Figure 6 shows a segment expanded the contour and the stroke of the radio r, the corresponding tangential straight (violet lines) and horizontal (green lines) respectively.

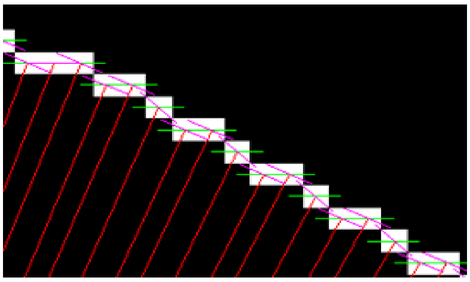

Figure 6. Stroke of the tangential and horizontal components

4.2. Detection of Ventricular Contour through the Model Developed (Table R)

To achieve this fundamental objective is to convert the image from a job in a contour map, where it is possible to compare the structure of the table R, with the different forms present in the image (ribs, catheter, abdomen, ventricle, etc.) and that way select them all the corresponding to the ventricular edge; purpose of the TGH. The procedure to follow will be described below:

4.2.1. Pre-processing

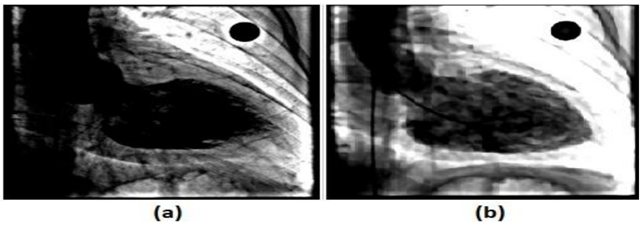

Figure 7. (a) Enhanced Image. (b) anti-aliased image

As is appreciable in Figure 2(a), an image of angiography, presents a considerable amount of noise and therefore it is important to perform a conditioning process or improvement of the information. To this end, it was first implemented a contrast enhancement by window and level, which sought opacificar in a better way the area of interest (VI), followed by a filter smoother [8]. The result of this procedure is illustrated in Figure 7.

Taking a better view of the data, the next step is to generate an image contours or only edges, which allows us to use the information collected in the table R; for that task, is used the algorithm of Canny[9], which is based on the calculation of the derivative. The result it is possible to appreciate in Figure 8.

Finally, and as mentioned previously, the purpose of this phase is to remove the ventricular contour with the least amount of noise, that is to say with the minimum amount of structures outside it; therefore applied mathematical morphology, using filtering by areas, detection of continuity, etc. The image obtained is presented in Figure 9.

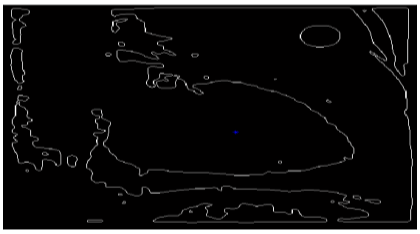

Figure 8. Result obtained using the CONTOUR DETECTOR

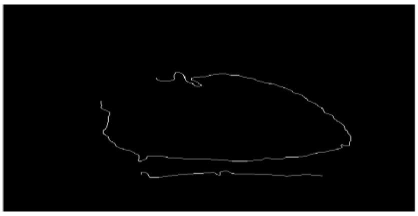

Figure 9. Use of mathematical morphology to the job picture

4.2.2. Implementation of the TGH

Figure 11. Fill ventricular contorn

5. Results and Validation

For the analysis of results, we selected the studies and the images as explained in section 4. It is important to highlight that for each study (different patient), it is necessary to create a table R.

To demo level of segmentation reached, will be presented with 3 of the 12 frames, used in this project. It chose one of each study to exemplify the variety in the data and contours.

In Figure 12, illustrate the original images and where it is intend to detect the contour ventricular. Overlaps in the same way the stroke made by the specialist, with the purpose of carrying out the process of validation.

For its part the Figure 13, presents the contour detection obtained through the TGH. Detailed procedure showed throughout the article and that presents good results.

Similarly in Figure 14, refilling and enclosure of the contours obtained, with the aim to quantify the detection process. Finally, Figure 15 performs the overlay on the original images of the edges detected, through the TGH, to display mode in the best way the results obtained.

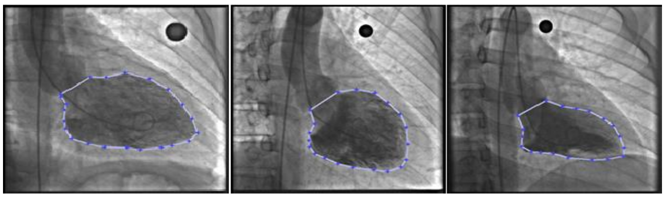

Figure 12. Initial studies and where in addition overlaps the stroke of the ventricular contour carried out by the specialist

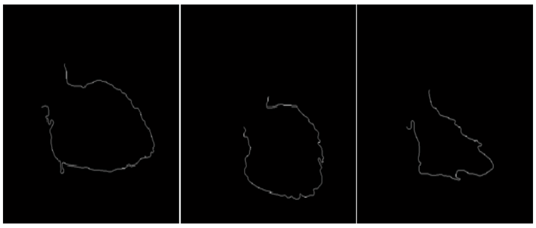

Figure 13. Contours detected through the TGH

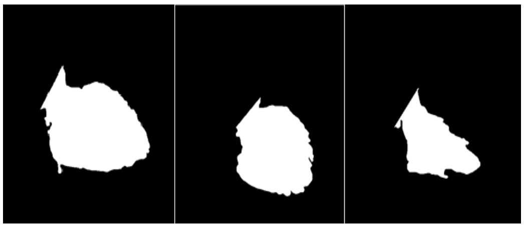

Figure 14. Enclosure and filling of contours

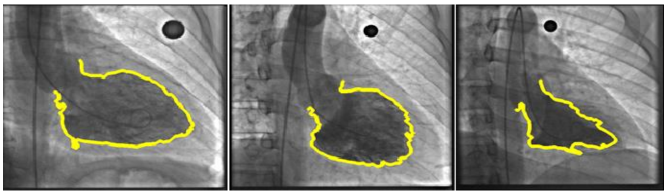

Figure 15. Overlap the contours detected, on the original image

A quantitative level, in Table 1, shows the percentages of error, obtained from the validation process. This estimate was made based on the equation (8).

$$\%Error= ((Sec.Manual-Seg.TGH))/(Sec.Manual)\cdot 100 \quad (8)$$

Where compares the manual segmentation (specialist) and the obtained with the TGH. These percentages were divided in final diastole, final sistole and transition 3 and 7. These transitions are images that are selected between sistole diastole and End. For this research, the areas were measured in pixels. It is important to highlight that the best results were obtained in the transition 7 of Study 1, where the estimated value was 0.65%. The percentage of total system error was 4.56%.

6. Conclusions and Future Work

The image segmentation ventriculographics, based on the TGH, allows exploring new results that support the development of support tools, specialists. The methodology raised, allowed to overcome the challenges presented by the images of this type, as are: low contrast and noise in the image, low details of contour, etc. This was achieved thanks to the techniques of preprocessing used, as are: filter medium, contrast enhancement, detectors of contours, binarization and ordering of points. On the other side, it was demonstrated that by means of the TGH, it is possible to segment images of the heart, achieving an average error of 4.56%. The table R, as analysis structure, generalizes great part of the contours that are presented in the image processing ventriculographics. Finally it is important to highlight that the selection of images for the selection of patterns, are fundamental for the good functioning of the TGH, because if there are mistakes in the selection of the data, at the time you want to perform a new analysis of contours, the results will not be the most relevant and therefore the error from the system will increase. In relation to future works, is expected to complement the part of removing the left ventricular contour, with phase of quantification of the different descriptors of the cardiac function (volume beat, fraction of ejection, expense cardiac, etc.), for this is necessary, select images in systole and diastole end of the cardiac cycle, approaching the border to a revolution ellipsoid. In the same way it would be very interesting to carry out a comparative analysis of different techniques of segmentation as the growth of regions, models so active, etc.

7. Contributions

The main contribution of this article is set out in the pre-processing, since the transformed as such this very well defined. In this sense was very important to analyze the noise present (ribs, catheter, etc.), the texture of the image contrast injected to display the cavity, etc. The result was the achievement of techniques which include the contrast enhancement by window and level, smoothing the pixels of the image and above all the mathematical morphology implemented, that generated as a result a contour map suitable for use the TGH.

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