Area and Volume Calculation of Necrotic Tissue regions of heart using Interpolation

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Abstract—**This paper attempts to develop an improved tool, which would read two dimensional(2D) cardiac MRI images and compute areas and volume of the scar tissue. Here the computation would be done on the cardiac MR images to quantify the extent of damage inflicted by myocardial infarction on the cardiac muscle (myocardium) using Interpolation.**

Keywords— **Scar tissue, Cardiac MR, Image post processing, Interpolation**

I. INTRODUCTION

Magnetic Resonance Imaging (MRI) is a noninvasive modality that helps physicians to diagnose and treat medical conditions. MRI scanner uses powerful magnetic field, radio frequency pulses and a computer to produce detailed images of organs, soft tissues, bones and virtually all other internal body structures [1], [2]. Fig.1 shows a Cardiac MRI image. The images are usually reviewed on a computer monitor [3] or films that can be printed.

Cardiac MRI gives the images of the heart and major blood vessels in still as well as in beating condition. These pictures help doctors to treat people with heart problems. In the event of heart attack due to severe artery block, affected portion of the heart muscles might become dead resulting in a scar. Using contrast (a type of dye) injection these dead parts will be seen as bright segments in the MRI scan. The analysis of these images is mostly qualitative at the moment which could be semi quantitative with the presently available tools. However, the exact quantification of the scar tissue with reference to normally functioning myocardium is not possible. There are a few groups in different universities of Europe and USA working on this issue. Search for reliable automated image software are under development [4]. This paper is an attempt in that direction.

Figure 1. *Cardiac MRI image*

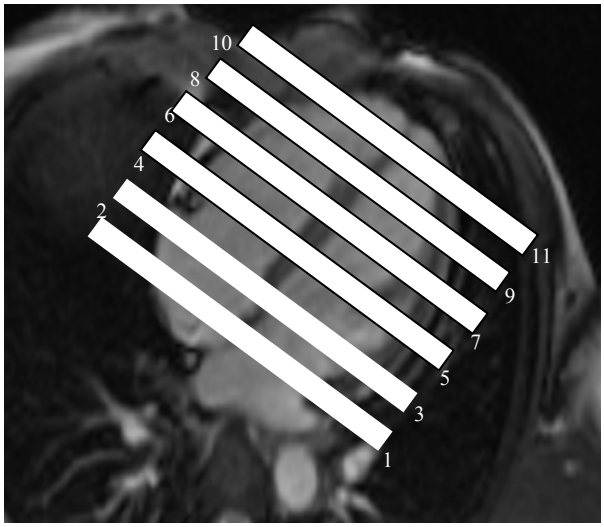

Figure 2. *Five slices of left ventricle of heart. All five slices are of 8 m.m thickness. There is also some gap(white rectangular portions) between each slice which are of 7.2 m.m thickness. The Front view of gaps are numbered as 1, 3, 5, 7, 9, 11 and the front view of slices are numbered as 2,4 ,6, 8, 10.*

II. THE SCAN

The department of Imaging Sciences & Interventional Radiology at Sree Chitra Tirunal Institute for Medical Sciences and Technology uses Siemens 1.5 T Avanto scanner for MRI. This paper aims to delineate the volumetric extent of the scar tissue affecting the left ventricular myocardium (heart muscle) computed with the aid of interpolation based image post processing for them.

During the cardiac MRI the sections of the heart could be made in various planes. The radiologists slice the heart along short axis in to various numbers of slices which are normally five in number encompassing the complete left ventricle. Needless to say, there would be gap also in between the slices (Fig. 2).

These images are acquired before and after giving the contrast. The scar tissue or the necrotic tissue is seen as white or bright areas (Fig. 3). The 'quantity' of damage (Necrotic tissue) level is indicated by volume of the entire Necrotic tissue.

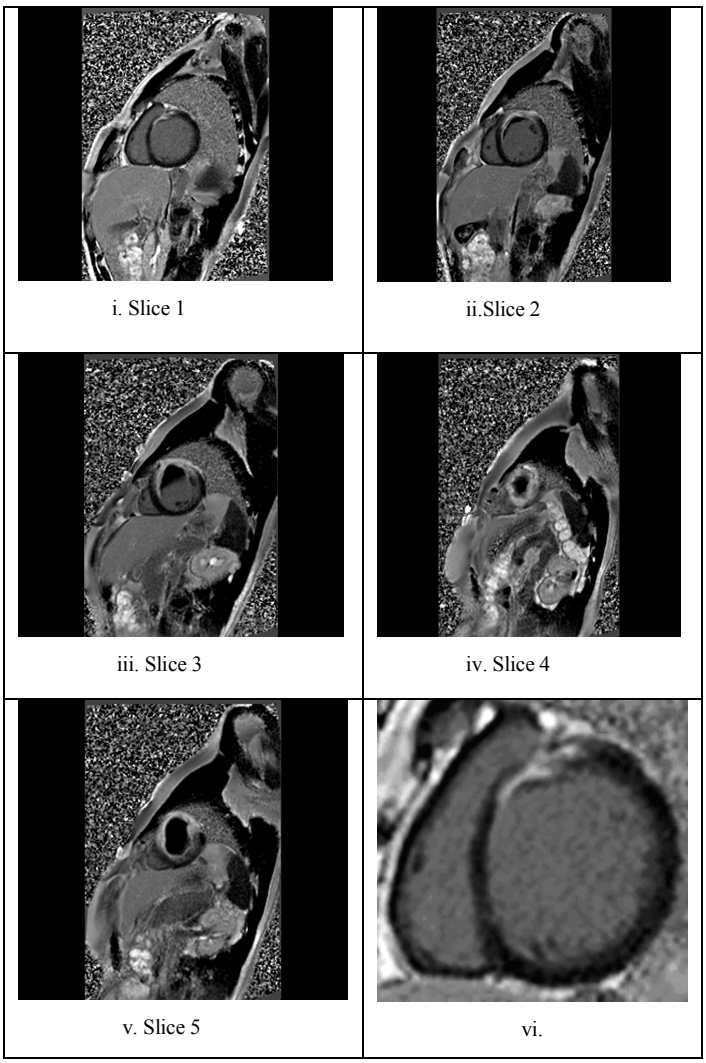

Figure 3. *i to v shows the five slices of left ventricle heart and vi shows the zoomed image of Figure 3.i*

III. STEPS IN PROPOSED METHOD

A. Extraction Of White Portions

White portions are extracted with the help of threshold based calculations [5]. A threshold value is found and all the pixels above that threshold value are extracted. The pixels with this particular threshold are considered as necrotic tissue region.

B. Area Calculation

Area of white portions are found in three ways

i) Finding the total number of pixels in the extracted white region.
ii) Rotating the image 33^o and taking the number of white pixels .
iii) Rotating the image 45^o and taking the number of white pixels.

For reduction of computation errors and increasing the accuracy all the three values are taken and the average of these is considered as the area of the white portion of the viewing side of the slice. The above method was used to find the area of all the viewing sides (numbered 2, 4, 6, 8, and 10 in Fig. 2) of all slices. Area of the hidden sides (numbered 3, 5, 7 and 9 in Fig.2) of all the slices are found using interpolation. The areas on slice number 1 and 11 are discarded. In Table I, X represents the distance of sides from the starting. Y represents the computed area of the white regions of the corresponding slices.

C. Area Calculation For The Gaps

The area of sides 3, 5, 7, and 9 (Fig.2)are found using interpolation.

1. Area calculation using Lagrange's interpolation [6].

The X values represent the distance to sides numbered 2, 4, 6, 8, 10 from the side 1 and Y values are the respective areas of sides read directly from the slices. The area of necrotic tissue on side 3 is found by interpolation. Then areas of sides 2, 3, 4, 6, 8 and 10 are used to find area of side 5 by interpolation and so on. These interpolated values along with the directly read values are given in Table 2.

2. Area calculation using Newton's divided difference interpolation formula [6], [7].

Here also input values are taken from Table 1. Using values of sides 2, 4, 6, 8 and 10, the area of side 3 is calculated. For calculating area of side 5, values of sides 2, 3, 4, 6, 8 and 10 are taken and so on.

TABLE I : AREA OF WHITE REGIONS

Side No	X	0^o rotation	33^o rotation	45^o rotation	Y
2	7.2	1612	1615	1614	1614
4	22.4	1850	1853	1849	1850
6	37.6	2553	2549	2550	2550
8	52.8	3240	3238	3235	3237
10	68.0	4214	4215	4213	4214

TABLE II : AREA USING LAGRANGE AND NEWTON'S INTERPOLATION FORMULA

Side No	X	Y (Area using Lagrange's)	Y(Area using Newton's)
2	7.2	1614	1614
3	15.2	1621	1622
4	22.4	1850	1850
5	30.4	2209	2209
6	37.6	2550	2550
7	45.6	2912	2912
8	52.8	3237	3237
9	60.8	3667	3666
10	68.0	4214	4214

3. Area calculations using Newton's forward, Gregory-Newton's Backwards and Stirling's interpolation formulas [6].

Here input values are taken from Table 1. Newton's interpolation formulas are used only for interpolation near the beginning and the end of the table. Area of side 3 is found using forward interpolation formula and side 9 is found using backward interpolation formula. These two formulas are not applicable to interpolation near the central values (middle values of the table). To get more accurate results for these values, Stirling's formula is used. Area of side 5 and side 7 are found using this method (Table 3).

D. Volume Calculation.

The volume of any arbitrary object can be obtained using the principle of Cavalieri[8] .The formula is described as follows

$$A = \Sigma P \text{ x } a(p) \quad (1)$$

$$V = A \text{ x } d = \Sigma P \text{ x } a(p) \text{ x } d \quad (2)$$

A - area

V - volume

ΣP - total number of test points

$a(p)$ - areal equivalent of one test point

d - thickness of slice.

The volume of the object is estimated from the total area and the mean distance between slice faces. The volume extraction formula of Cavalieri cannot be implemented as such in this study , because the thickness of the slices and gaps are different. So a refined Cavalieri formula is suggested.

$$V = Asd1 \text{ x } d + Asd2 \text{ x } k \quad (3)$$

V - the volume of Necrotic tissue regions in the heart,

$Asd1$ - areas of non-hidden sides of slices

d - thickness of slice,

$Asd2$ - areas of hidden sides of slices

k - thickness of gap.

The areas of slices on both sides of gaps are used to compute the volume for necrotic cells within gaps (Table IV).

TABLE III : AREA USING NEWTON'S FORWARD BACKWARD AND STIRLING'S INTERPOLATION FORMULA

Side No	X	Y (Area)
2	7.2	1614
3	15.2	1622
4	22.4	1850
5	30.4	2094
6	37.6	2550
7	45.6	2912
8	52.8	3240
9	60.8	3696
10	68	4214

TABLE IV : VOLUME OF NECROTIC TISSUES CALCULATED BY MODIFIED CAVALIERI FORMULA

Lagrange's Interpolation Values	Newton's Interpolation Values	Using table 3 values
182643.2	182664.8	182052.8

IV. CONCLUSION

Based on threshold values the necrotic tissue regions of visible slices are extracted. The areas of missing necrotic tissue regions are found with the help of Lagrange's interpoaltion Newton's interpolation, Newtons forward, Netons backward and Stirlings formulas. A modified Cavalieri equation is used to find the volume of slices having same thickness seperated by uniform gaps. This tool will be helpful in 2D and 3D Medical Image Processing.

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