UNIVERSITÉ DE BOURGOGNE

MSC COMPUTER VISION

MEIDCAL IMAGE ANALYSIS

Myocrdial Infarct Core and Gray Zone Segmentation in CEMRI Images

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May 21, 2015

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1 Introduction

This report presents the work aimed at quantifying the extent of tissue heterogeneity in the infarct periphery as well as infarct core. Infarct region which is supposedly uniform tissue bed also comes with heterogeneous border of the dead tissues among the healthy ones. An Algorithm [1] has been implemented in MATLAB with an user interface to segment the infarct core and the heterogeneous periphery, also called the gray zone. The algorithm requires ceMRI images where necrotic myocardium tissues can be delineated.

2 The Algorithm

The algorithm requires markers to create regions of interest. These ROI will be used to create thresholds to segment the subjects. The algorithm follows as:

- Epicardial(in Cyan) and Endocardial(in green in figure 1) borders are to be created by a trained observer. For the sake of development and testing, we have used our knowledge to create the regions.
- ROI(in Blue) is planted in remote myocardial region among the healthy tissues.
- ROI(in Red) is planted in hyperenhanced region.
- Peak, Mean and Standard deviation of the remote region is calculated.
- Then this peak remote SI is defined as the lower threshold of the abnormal myocardium.
- From the hyperenhanced region(in red), peak is calculated whose 50% is the upper threshold for the grayzone.
- The infarct core is defined as the region $>$ Peak SI of the hyperenhanced region.

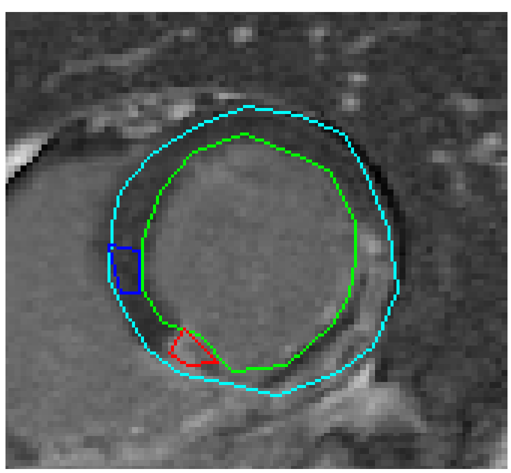


Figure 1: ROIs: Epicardial border(in Cyan), Endocardial border(in Green), Remote myocardial region(in Blue), and hyper-enhanced region(in Red)

3 FULL WIDTH HALF MAXIMUM

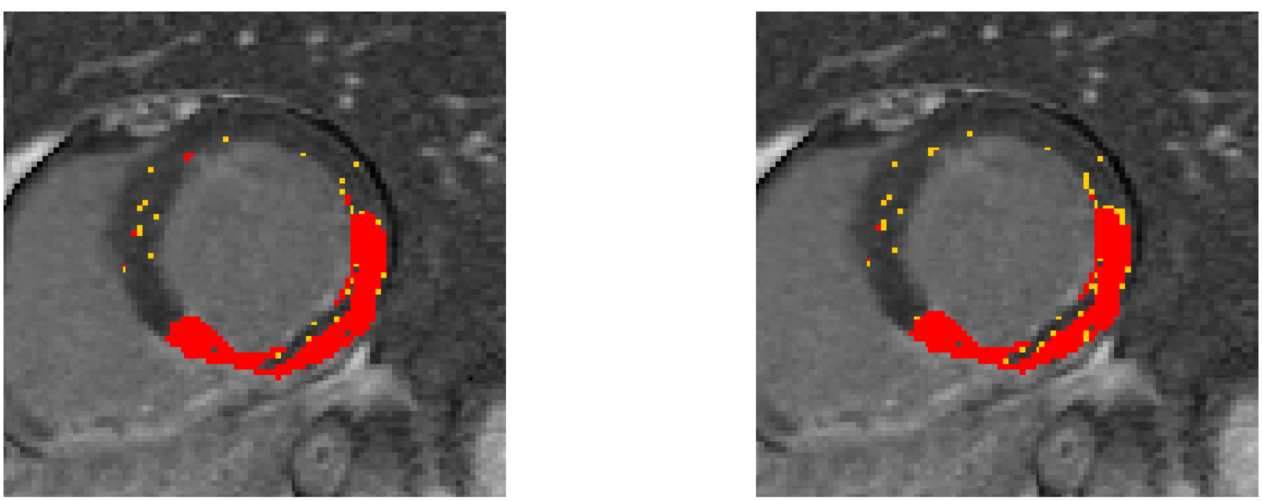
Full width half maximum criterion has be cited in many literature associated with the segmentation of myocardial MRI images. This statistical approach is reproducible in semi automatic manner and delivers good results [2].
The method generally requires user click in a hyperenhanced region. This selected pixel will be used as a seed point that grows in its neighborhood as long as the FWHM criterion is in check. Ultimately, the point grows into the whole infarct core. The algorithm implemented here[1], is a simple version of this technique. This version simply takes the maximum of the selected hyperenhanced region and assumes the whole area of hyperenhanched region is contiguous so that multi-pass region growth can be avoided to keep low computation cost. So a simple criterion is presented as:

$$core = 0.5 \times MaxSI \tag{1}$$

This criterion will be the lower threshold for the infarct core as well as the upper threshold for the gray zone. The result is shown in 2a. The relationship between FWHM and standard deviation has been shown in appendix 1.

4 N-Standard Deviation

We have also evaluated the segmentation with the n-standard deviation technique 2b. A region was selected in remote myocardium and its mean μ and standard deviation σ were calculated. The infarct core was set to be the region above 2,3,4,5 and 6 σ from the μ. In 2b, the gray-zone was defined between 2σ to 3 σ above the μ of remote region.



(a) simplified FWHM (b) between 2-3 σ

Figure 2: Segmented region: Infarct core(in Red); Grayzone(in Yellow)

5 Application Interface

The application has multiple functions from reading DICOM, contrast the images if needed, manually segment main myocardium left ventricular zones, save the segmentation (for each slice and for all slices) to be used later.

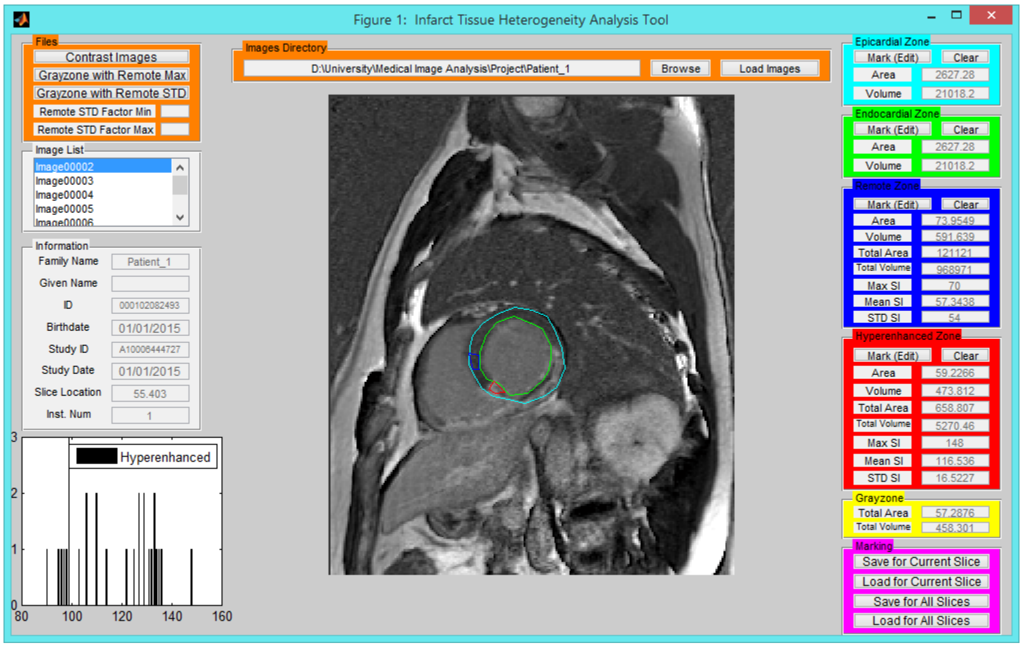


Figure 3: Main Application Window

The main functionalities are detailed as follows

- Load Multiple DICOM images, browse through them.
- Display patient information stored in the DICOM image files like Family Name, Given Name, ID, ... etc.
- Change the image contrast - if needed - using MATLAB built in contrast adjusting tool **im-contrast**
- Manually segment myocardium zones with multiple colors
- Edit segmentation and clear for each zones
- Save the manually segmentation in .m files to be loaded and used later.
- Automatic segment core infarct zone and gray zone using two implemented algorithms.
- Showing area and volume for all manually and automatic marked zones.

6 User Manual

To use the application, the user can follow the following steps

- Browse to the images folder using **Browse** button.
- Load the images using **Load Images button**.
- Change the current loaded image contrast - if needed - using **Contrast** button and also **Adjust Data** button in the **Adjust Contrast** displayed dialog.
- Mark zone - and edit if already marked – for current slice only using each **Mark(Edit)** button.
- The user can clear any marking using **Clear** button.
- The user can execute the calculation and show the gray-zone using **Compute Grayzone with Remote Max** to compute the gray zone using the remote maximum intensity.
- The user can execute the calculation and show the gray-zone using **Compute Grayzone with Remote STD** to compute the gray zone using the remote intensity standard deviation.
- The user can save marking for current image only and load it again when you close the application using **Save for Current Slice** and **Load for Current Slice**.
- The user can save marking for current image only and load it again when you close the application using **Save for All Slices** and **Load for All Slices**.
- The histogram axes only display histogram of Hyperenhanced marked zone.

7 Calculating Area and Volume

The application is able to calculate Area and Volume for every marked zone by the user once marked. and also the resulted remote, hyperenhanced and grayzone once calculated, for each slice the area and volume is displayed on text fields labeled by **Area** and **Volume**. and for calculated images they are displayed in text fields labeled by **Total Area** and **Total Volume** for each corresponding zone. This is done by the following:

1. Area is calculated by multiplying the marked **total area in pixels** by **PixelSpacing** field obtained from DICOM slice information.

$$Area = marked\_area \times pixelspacing(1) \times pixelspacing(2)$$

2. Volume is calculated by multiplying the previous calculated **Area** by **SliceThickness** field obtained from DICOM slice information.

$$Volume = Area \times SliceThickness$$

As an example, for image result obtained by simplified FWHM and standard deviation algorithm with 2σ and 3σ as factors the calculated area and volume

	Simplified FWHM		2σ to 3σ	
	Area (mm^2)	Volume (mm^3)	Area (mm^2)	Volume (mm^3)
Remote Zone	121121	968971	121108	968865
Hyperenhanced Zone	658.807	5270.46	634.57	5076.56
Gray Zone	57.2876	458.301	94.7449	757.959

8 Limitation

Problems with most of the semi-automatic method is the intraobserver/intereobserver variation. These methods do require ROIs to be initiated by a user. FWHM, however, has been reported to demonstrate reduced intereobserver variablity. This method still is based on statistical method and reproducibility has been left for the future studies in [1].

9 Future Work

The application could be enhanced in the future by implementing any of the following

- Convert the contrast enhancement process from manual to automatic
- Implement a Region growing algorithm for grayzone segmentation and compare the result with the current two implemented algorithms

10 APPENDIX

10.1 Relation between FWHM and SD

Let us consider μ and σ be the mean and standard deviation of a Gaussian model. Then the gaussian distribution $f(x)$ can be written as:

$$f(x) = \frac{1}{\sqrt{2\pi\sigma}} \times \exp\frac{-(x-\mu)^2}{2\sigma^2} \tag{2}$$

For half maximum, i.e. $\frac{1}{2}f(\mu)$,

$$\frac{1}{2}f(\mu) = \exp\frac{-(x-\mu)^2}{2\sigma^2} \tag{3}$$

$$ln\frac{1}{2} = -\frac{-(x-\mu)^2}{2\sigma^2} \tag{4}$$

$$(x-\mu)^2 = 2\sigma^2 \times \ln 2 \tag{5}$$

$$x = \pm\sigma\sqrt{2\ln 2} + \mu \tag{6}$$

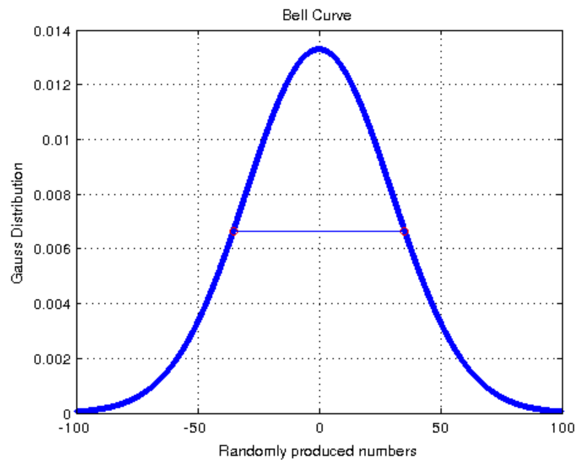


Figure 4: Half of the maximum in the red dots

References

[1] André Schmidt, Clerio F. Azevedo, Alan Cheng, Sandeep N. Gupta, David A. Bluemke, Thomas K. Foo, Gary Gerstenblith, Robert G. Weiss, Eduardo Marbán, Gordon F. Tomaselli, João A.C. Lima, Katherine C. Wu, "Infarct Tissue Heterogeneity by Magnetic Resonance Imaging Identifies Enhanced Cardiac Arrhythmia Susceptibility in Patients With Left Ventricular Dysfunction"

[2] Luciano C. Amado, Bernhard L. Gerber, Sandeep N. Gupta, Dan W. Rettmann, Gilberto Szarf, Robert Schock, Khurram Nasir, Dara L. Kraitchman,João A. C. Lima,"Accurate and Objective Infarct Sizing by Contrast-Enhanced Magnetic Resonance Imaging in a Canine Myocardial Infarction Model"