An Intensity Based Statistical Approach for Left Ventricular Localization and Identification of End-Systolic and End-Diastolic Images from Cine Cardiac MRI

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Introduction: A critical component in computing quantitative diagnostic metrics, such as ejection fraction, as well as, image segmentation and registration is the accurate identification of the end-systolic (ES) and end-diastolic (ED) frames in cine MRI. Localization of the LV is also important, to assist further analysis (ie., myocardial segmentation). Currently, these tasks are performed in a manual, semi- or fully-automated fashion. Fully-automated methods are desirable since they can eliminate manual labor and inter- and intra-observer variability. Most methods rely on measuring the area of the blood pool in the LV chamber, but they are computationally intensive, susceptible to noise, and require prior localization and segmentation of the LV. An image-driven statistical method is presented that utilizes cross-correlation (1), to detect ES and ED from cine MRI acquired from canines under control conditions. The purpose of this work is to develop a fully automated, computationally efficient, post-processing method for reliable LV localization and identification of ES and ED frames from cine cardiac MR images.

Methods: Experimental Setup and Imaging: Short-axis cine cardiac MR images were acquired on Siemens 1.5T scanner from three canines that were sedated and mechanically ventilated. ECG-gated and breath-held SSFP acquisitions were prescribed over the mid-ventricle following scout scans at various temporal resolutions (T_{Res}:7-153ms). Scan parameters: voxel size=1.2x1.2x6mm^3; flip angle=60^o; TR/TE=3.5/1.8ms. Image Processing: Each cine set was denoted as I(x,y,t), where x,y are pixel locations (NxM) and t denotes 1,…,F phases. Each image was smoothed by convolution with a Gaussian filter (width=10 and sigma=1). The normalized cross correlation was computed between all images, giving an FxF matrix C(i,j), (i,j corresponds to image pairs). The i,j corresponding to the minimum of C are the ES,ED images, since they are uncorrelated in the heart region (high motion). It is assumed that there was no patient movement for the duration of the scan. Using the same principle as in (2), the LV chamber can be localized by finding the temporal variation of I(x,y,t), as matrix V (NxM). V was then denoised using a Gaussian and binarized (Otsu's method). The centroid of the largest connected component was chosen as the LV center. The proposed identification method was compared against LV blood volume segmentation methods. For this application a seeded-region-growing method (4) was chosen for segmentation instead of level-set-active-contours (3), since it proved more robust to noise and the limited spatial resolution of the cine MRI images. Data Analysis: Cine images with varying temporal resolution (T_{Res}) were tested and additive-white-Gaussian-noise was introduced to demonstrate robustness. The seed location for the seeded-region-growing method (SRGM) was manually set inside the ventricle for each image. Average number of frames away from the true ES, ED images (manually chosen) was used as the performance metric. For each noise level, 40 trials were performed and the results were averaged.

Results: Figure 1(A) shows an image with added noise. Figure 1(A – D) demonstrate the performance of the proposed method when the whole image is used (B), and when a ROI around the heart is manually chosen (C), compared to the SRGM (D). Figure 1(E) shows the Euclidean distance between the centers found using the proposed and the reader delineation of all cine images.

Discussion & Conclusions: Pre-selection of an ROI, necessary with other methods, does not offer any significant advantage. SRGM underperformed in cases when image noise or T_{Res} was high (14ms and 24 ms), did not always yield a unique global maximum and minimum, and was not robust against the appearance of papillary muscles, thus hindering the identification of ES and ED. The proposed method reliably identifies the cardiac phases and localizes the LV, in an efficient manner (~10 times faster than SRGM), without the need for parameterization (SRGM requires the seed and the determination of the growing threshold). It can be easily extended to 4D MRI and can be incorporated in image analysis software (5).

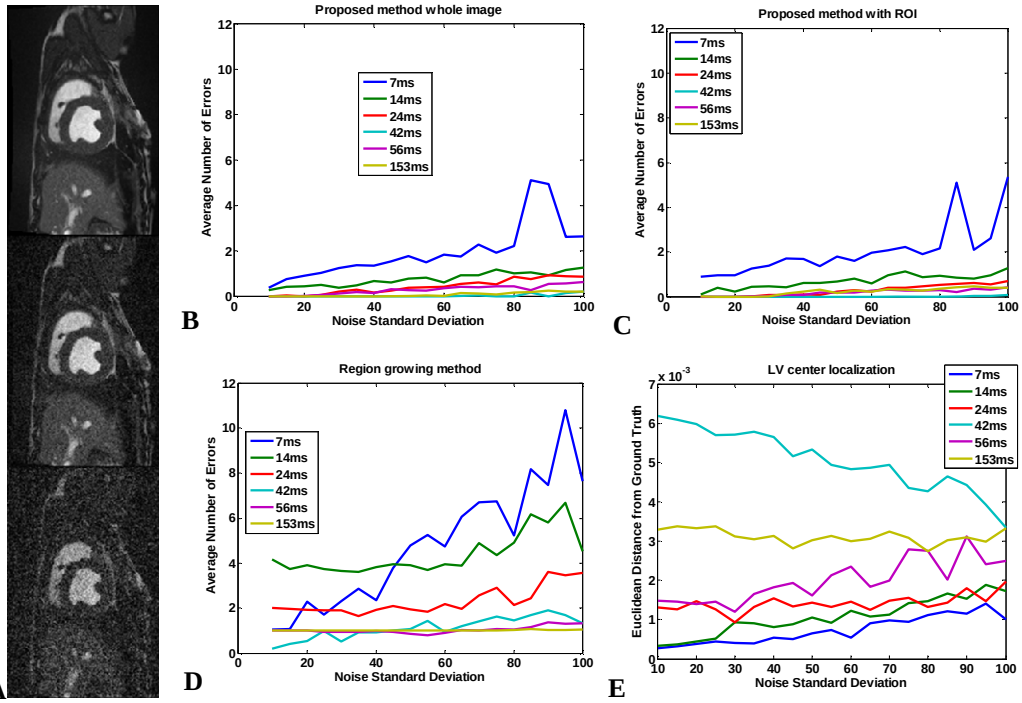

Figure 1

A: An image with various levels of noise: left no noise; middle and right additive zero mean noise of 40 and 100 standard deviation, respectively.

B and C: Accuracy of the proposed method, as measured by the average number of errors, for different noise levels and for a number of different T_{Res}, when the whole image is used (**B**), and with an ROI that encompasses the heart (**C**). Observe that the performance is similar to A, illustrating that there is no advantage in selecting an ROI, thus demonstrating that the proposed method can be used in the whole image, without needing an ROI.

D: Accuracy of the SRGM.

E: Accuracy of the proposed method in finding the center of the LV tested for different noise levels, and T_{Res}. The accuracy is measured as the Euclidean distance from the ground truth provided by an observer. Notice that the y-axis is scaled at 10^{-3} increments.

References: (1) Kachenoura et al. *EMBS 2007* pp. 4504-4507 (2007); (2) Cocosco et al. *JMRI* **28**(2):366-374 (2008); (3) Osher & Paragios *Geometric Level Set Methods in Imaging Vision and Graphics* (2003); (4) Shapiro & Stockman *Computer Vision* (2001); (5) Rasband *ImageJ* http://rsb.info.nih.gov/ij/ (1997-2008).