MOTION-CORRECTED STRAIN CALCULATION FROM LONG-AXIS MRI STRAIN-ENCODED (SENC) IMAGES

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Introduction:

Myocardial strain is an important measure used for assessing regional function, which could help in detecting myocardial infarction and other vital properties of the myocardium. MRI Strain-Encoding technique (SENC) introduced by [1] produces strain values during the cardiac cycle; however, due to the deformation (in-plain motion) of the myocardium, a tracking algorithm must be applied prior to calculating the strain. As SENC images suffer from low signal-to-noise ratio (SNR), common tracking algorithms fail. This intrigued us to develop an unsupervised automatic algorithm that overcomes this by exploiting the SENC information. In this work, we compare strain values measured by three different methods: 1) using a fixed region throughout the cardiac cycle ; 2) manually tracking the myocardium by an expert observer; and 3) automatically tracking the myocardium with the proposed algorithm.

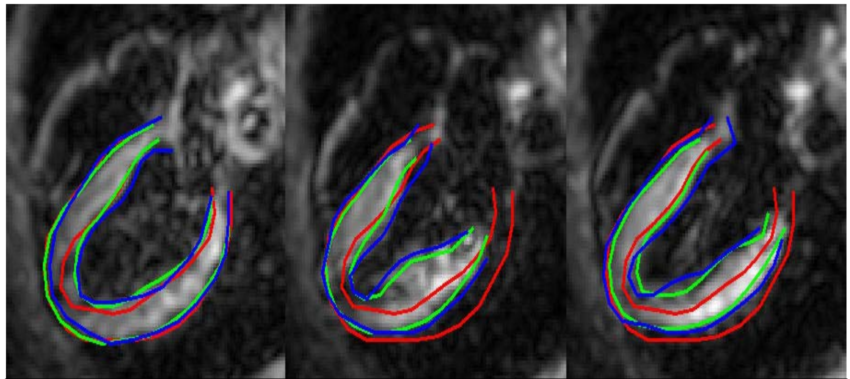

Figure 1: Different segmentation through the cardiac phase. Static in RED, manual segmentation in Green, and automatic segmentation in Blue.

Tracking Method

The proposed method uses the following algorithm (described as steps):

1. Using SENC images calculate the average strain value throughout the cardiac cycle for each pixel.
2. Pixels with average strain value less than 5% are marked and removed from further processing.
3. A threshold is independently applied to each frame to produce a binary image. Morphological operations are then applied to the stack of these binary images to determine two or three regions of interests: LV freewall, septum, and the RV freewall if applicable.
4. For each region of interest in every frame we apply an area threshold followed by morphological operations to detect the myocardium contour and skeleton.
5. In every frame several points from the contour points are selected then smoothed twice. First in space using splines, then smoothed through time by polynomial interpolation to obtain the final contour.

Experiments and Results

Figure 1 shows our automatic contour (marked in blue) outlining the myocardium with great agreement to the manual contour (in green). Figure 2 compares strain values for a LV Mid-wall segment calculated from the manual, static and automatic contouring. Note that the Static segmentation error is large during systole because the erroneous strain of the background is measured (see red contour in figure 1). In order to compare strain values, we divided the myocardium into three segments (endocardium, midwall, and epicardium). Moreover, each segment was divided into five regions. Considering our manual segmentation to be the gold standard, we defined static and automatic errors as the difference between strain values calculated from the respective contours and the strain calculated from the manual segmentation. Figure 3 shows average strain error versus average automatic error for the 15 regions of the myocardium. Note the significant decrease of the error in the LV freewall segments (R1, R2). However, since the motion of the apex (R3) and the septum (R4, R5) is minimal, both errors are approximately the same.

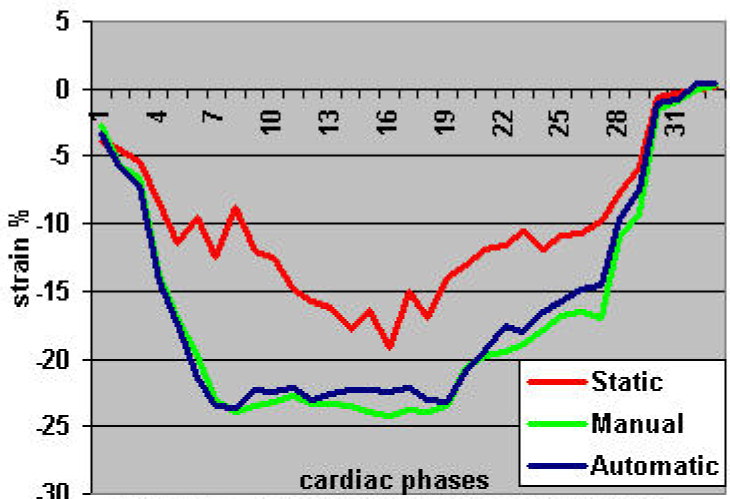

Figure 2: Cardiac Strain values for LV mid wall segment calculated from three different segmentation

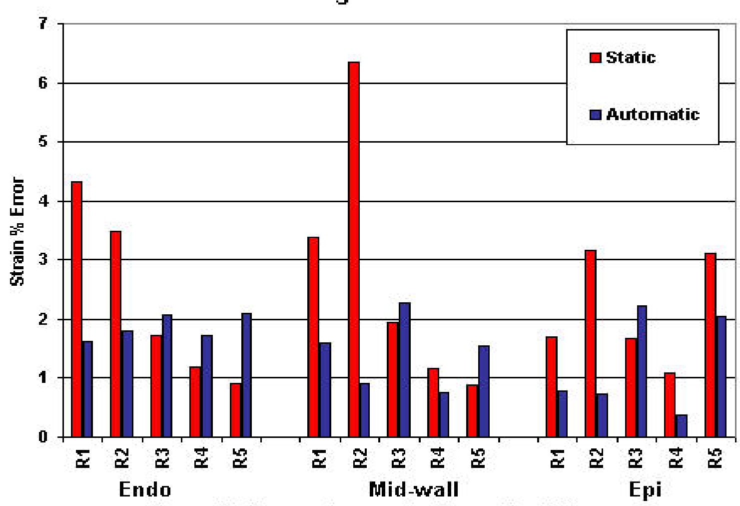

figure 3: Comparing strain Errors for different segments

Conclusion

Strain measured from SENC images are currently extracted from fixed regions, which introduce large error especially in the LV freewall. In this work, we developed a novel algorithm to automatically detect and track the motion of heart wall in long-axis SENC images. We showed that strain values calculated from our algorithm are acceptable and close to strain values calculated from the manual segmentation.

References:

[1] Nael F. Osman, Imaging longitudinal cardiac strain on short-axis images using strain-encoded MRI, Magn. Resn. Med. 46: 324-10 (2001).

Acknowledgments:

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