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Efficient Generation of Dynamic Cardiac Phantoms

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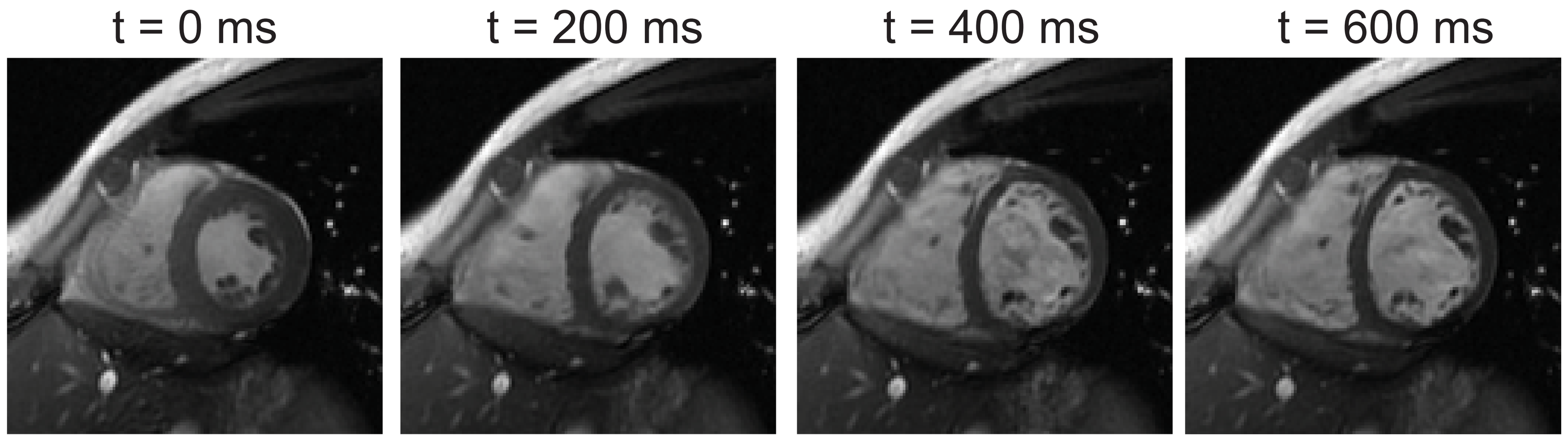
Objective

In the field of image processing and compression, researchers will often use test images called phantoms to evaluate the performance of their image reconstruction algorithms. Phantoms are digital images made of geometric shapes that usually model the structure and/or motion of typical images that are being processed by these algorithms. They are invaluable to researching magnetic resonance imaging (MRI) due to the recent insurgence of algorithms that intend to speed up the MR scanning process with constrained reconstruction algorithms such as compressed sensing. To address this I created a pipeline for generating anatomically correct cardiac phantoms modeled after existing datasets.

Methodology

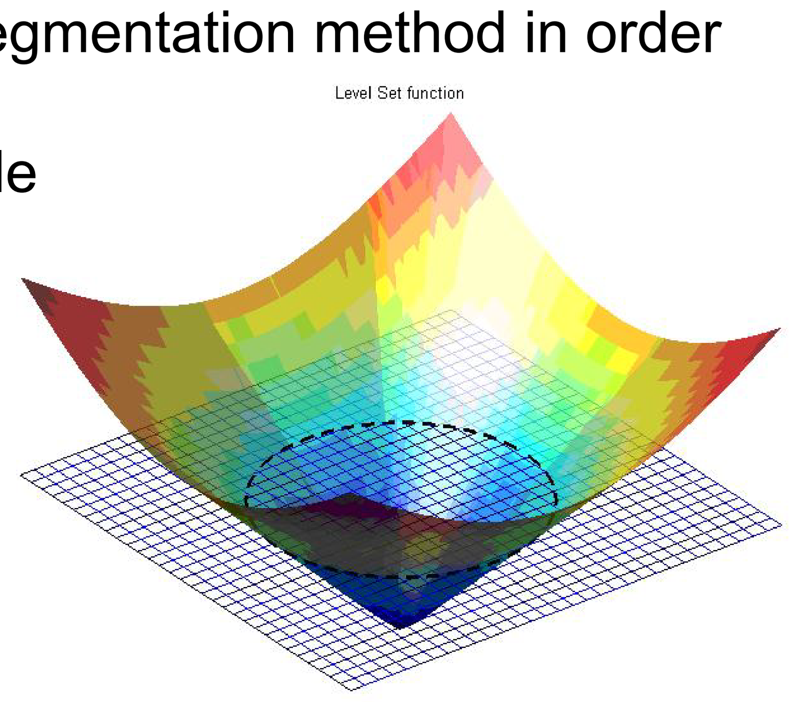


The first step of this pipeline is to manually select key frames from the original video.The key frames should show some kind of progression from one state to another (systole to diastole).

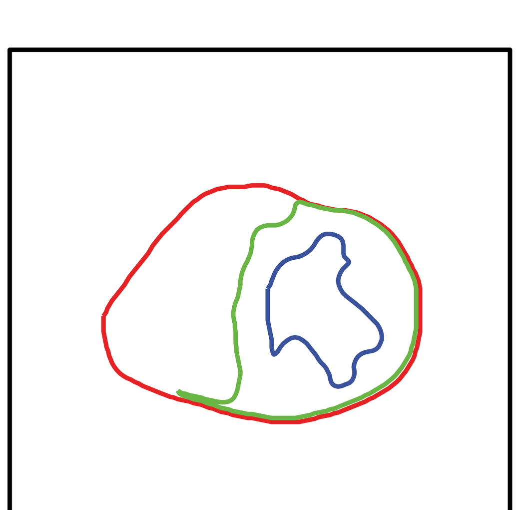
Segmentation

A mask must be manually drawn around the region of interest (ROI), in this case the boundaries of the entire heart, so that there is less data for the algorithm to process. It isn't necessary to segment every area in the image since we only need the heart.

I used a Chan-Vese level set segmentation method in order to segment the LV, RV and myocardium [1]. Level set is able to track how an object or shape evolves over time by using a region growing method in the gradient of the image.

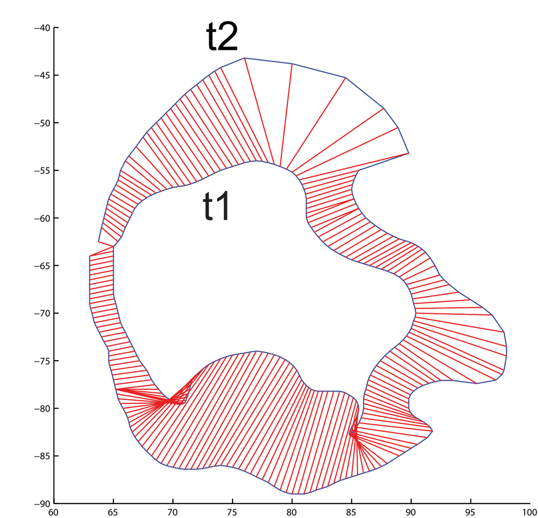


Interpolation

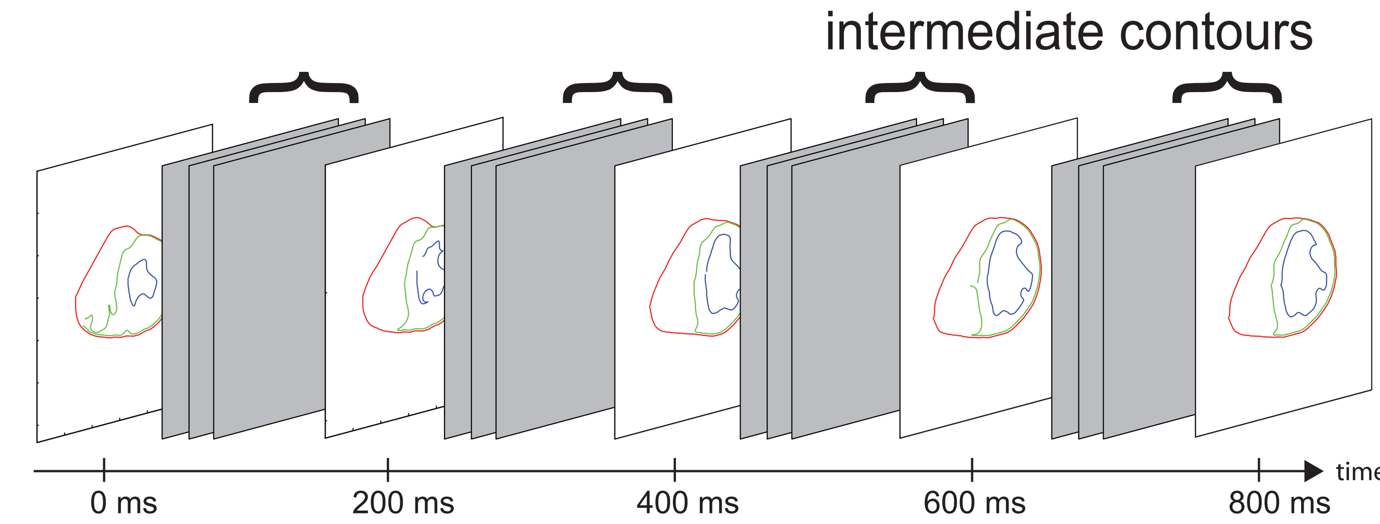


Since we only have several key frames, we must estimate frames in between in order to create a smooth video. The dynamic time warping algorithm [2] allows us to morph a contour in one frame into the corresponding contour in another.

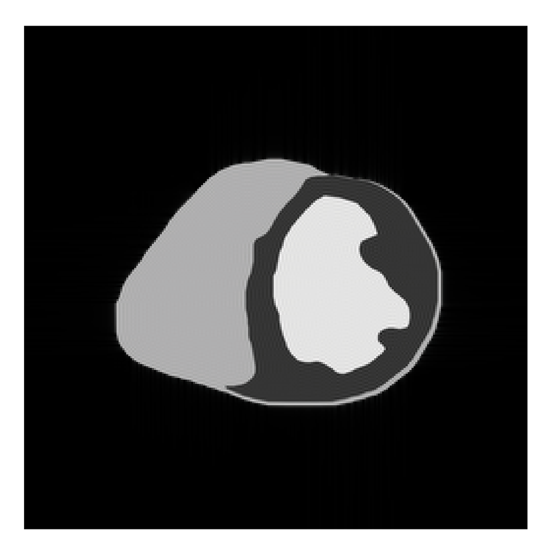
Interpolation, cont.



Dynamic time warping works by measuring "similarity" between waveforms t1 and t2 and draws relationship lines between similar points. Using these lines new intermediate contours can be drawn along those lines.

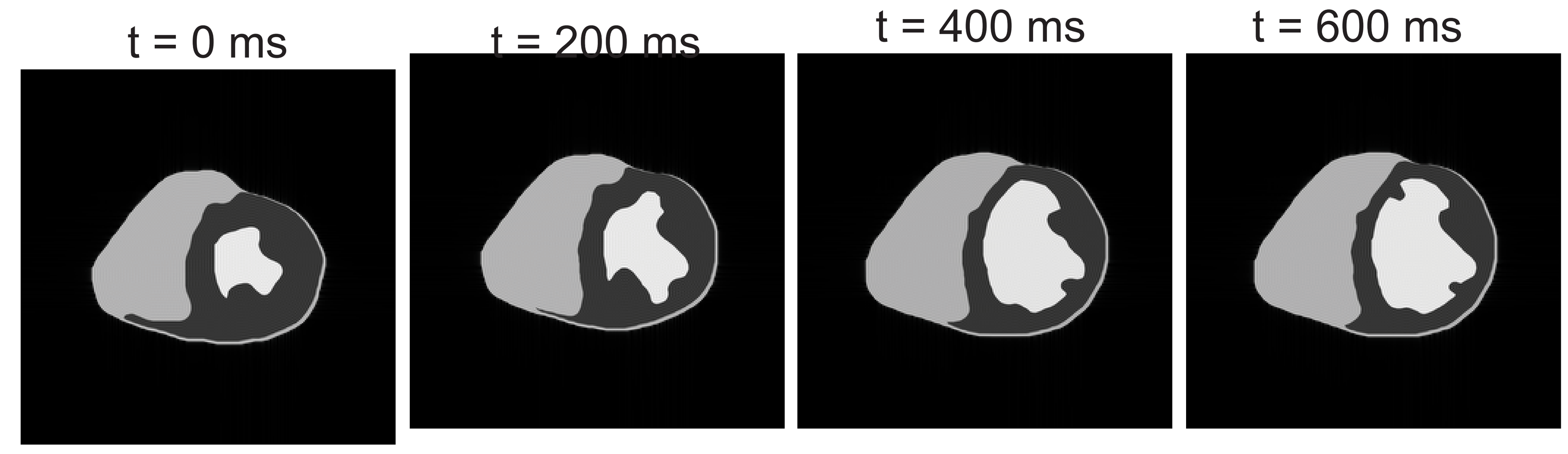


Visualization



With all of our interpolated frames containing each contour, we can now process them using the Polygon Fourier Transform [3], which allows us to create the phantom images at any arbitrary resolution that we would like.

Results



The pipeline creates a fairly anatomically and dynamically correct cardiac phantom. There are still certan problems with this method however. It is hard to capture the papillary muscles inside the LV because they come into contact with the heart walls, and then leave making segmentation a harder problem.

Future Research

- Collaborate with cardiologists in order to make sure we incorporate most clinically important features in the phantom
- Improve segmentation method to segment papillary muscles seperately from myocardial tissue
- Try different forms of dynamic time warping, current one makes inaccurate assumptions about heart anatomy (change in volume)
- Most importantly, incorporate MRI acquistion characteristics - such as multiple coil images

References

[1] Sethian, J.A., "Level set methods", Cambridge University Press, 1999.
[2] Vintsyuk, T.K., Kibernetika, Vol. 4, pp. 81–88, Jan.-Feb. 1968
[3] McInturff, et al., IEEE Trans. Antennas Propag.: 39: 1441-1443, 1991