COMPUTER-AIDED PERFUSION QUANTIFICATION OF MYOCARDIAL CONTRAST ECHOCARDIOGRAPHY

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Abstract

Myocardial contrast echocardiography (MCE) uses microbubbles as contrast agents to image myocardial perfusion. Myocardial perfusion analysis can aid in the diagnosis of coronary heart diseases. However, current analyses mostly rely on human visual assessments which are subjective and unreliable since MCE is noisy and highly variable. The project aims to use image processing techniques and quantitative methods to reduce human error and improve the diagnostic accuracy of MCE analysis.

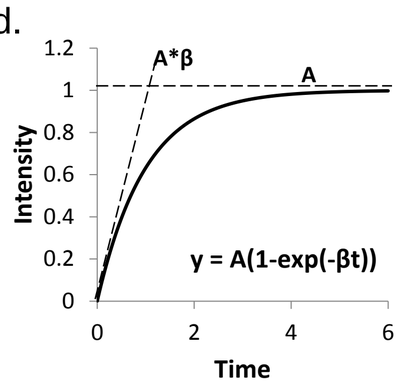
Background

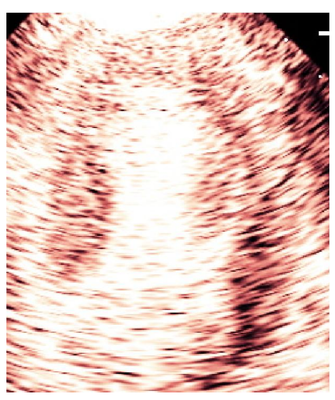
The perfusion quantification of MCE is based on the bubble destruction and replenishment method [1]. Microbubbles are first administered as a continuous infusion. Then, bubbles are destroyed within the myocardium with a high energy ultrasound pulse. A low energy ultrasound is then used to obtain a series of images of the heart over time. The myocardial reappearance of the bubbles on the images allow myocardial blood flow to be quantified.

The bubble reappearance can be modelled by the intensity-time curve:

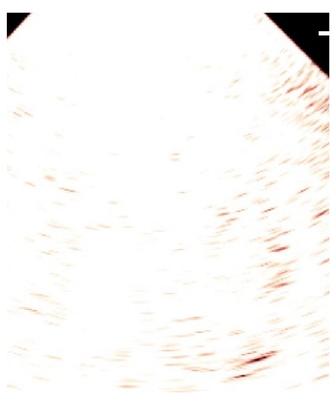
Intensity = A(1-exp(-βt))

where A ∝ blood volume, β ∝ bubble velocity, A*β ∝ myocardial blood flow. These perfusion indices provide diagnostic cues to diseases.

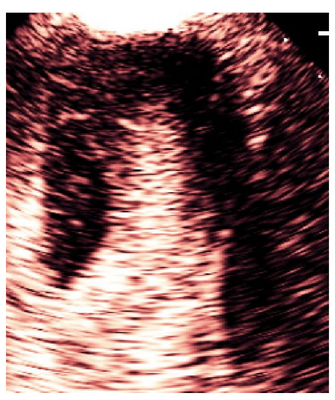




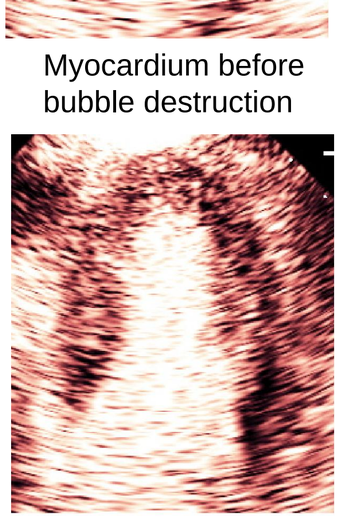
Myocardium before bubble destruction



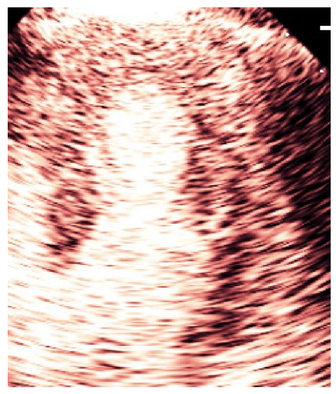
Bubble destruction by high energy pulse



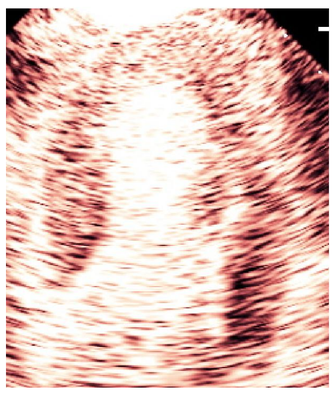
Immediately after bubble destruction



0.59s after bubble destruction



1.77s after bubble destruction



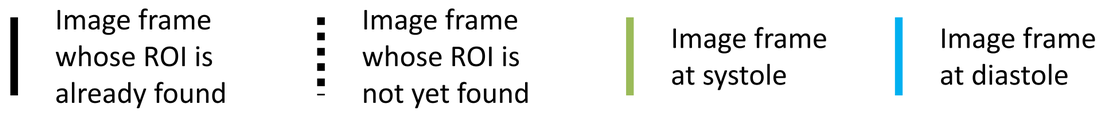
5.31s after bubble destruction

Project directions

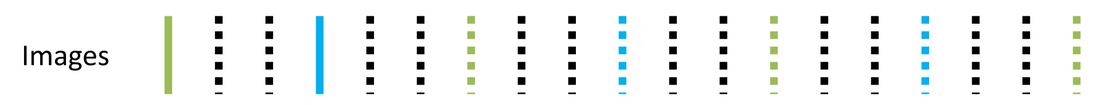
- Image processing and enhancement prior to quantification
  - Automatic segmentation and motion tracking of the myocardium
  - Artefacts correction and removal (eg. tissue attenuation, nonlinear artefacts)
  - Log signal decompression
- Improvement to quantification
  - Computation of other perfusion indices besides A, β (eg. Time-to-peak intensity, endocardium-epicardium ratio, coronary flow reserve)
  - Other intensity-time model based on ultrasound imaging physics (eg. S-shaped model: linearisation of video echo signals to overcome the log-compression of the imaging instrument, and, the spatial distribution of the transmit-receive ultrasound beam)
  - Using machine learning techniques to extract useful features and characteristics about the intensity profile curve of the healthy and abnormal myocardial regions and learn a classifier for future prediction

Myocardial motion tracking

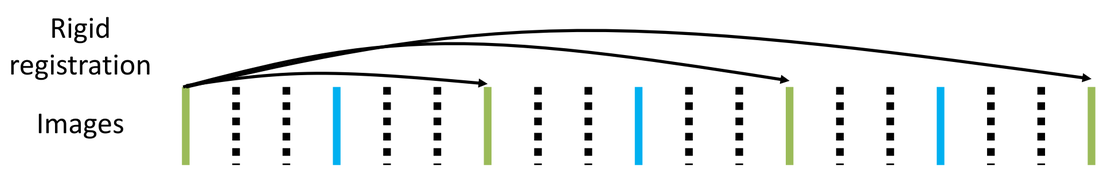
Automatic motion tracking of the myocardium is a first step before quantification. This is currently done using non-rigid b-spline registration.



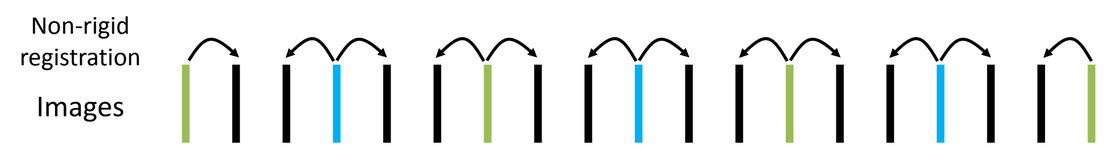
1. Select two image frames (reference) which occur at the end-systole and end-diastole of a cardiac cycle respectively. Manually delineate their myocardium ROI.



2. Rigidly register the reference systolic frame to all other systolic frames. Apply the found transformations to the ROI of the reference frame to find the ROIs of the other systolic frames. Do the same for diastolic frames.

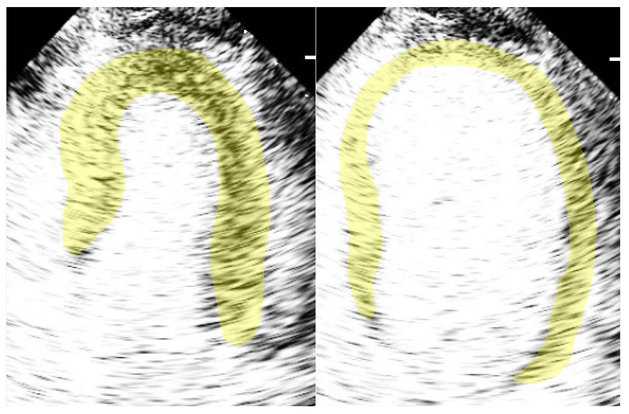


3. Perform non-rigid b-spline registration between each systolic/diastolic frame and its neighbouring frames. Apply the found transformations to the ROIs of the corresponding systolic/diastolic frames to find the ROIs of all other frames.



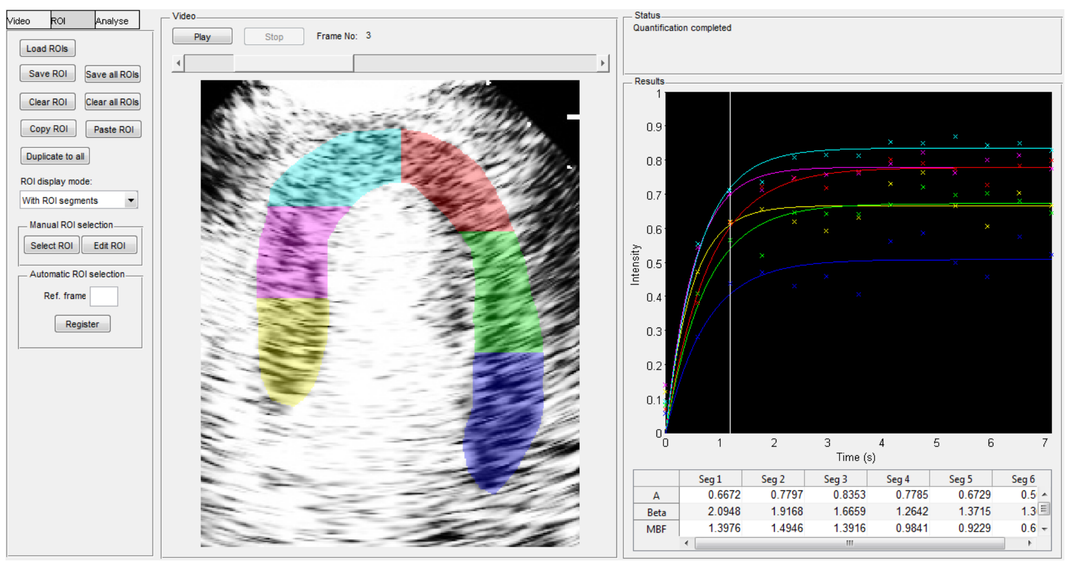
4. Average all the ROIs of frames that occur at the same point in a cardiac cycle.

Results: The mean Jaccard Index between the manually-drawn and the computer-predicted myocardium ROI is 0.88 for triggered sequence (rigid motion only) and 0.72 for real time sequence (rigid + non-rigid motion). Myocardium ROI found by registration algorithm at systole (left) and diastole (right).



Software

The final product of the project is a software that can help clinicians quantify perfusion in MCE sequences and identify abnormal myocardial regions with perfusion defects.



[1] K. Wei, A. R. Jayaweera, S. Firoozan, A. Linka, D. M. Skyba, and S. Kaul, “Quantification of myocardial blood flow with ultrasound-induced destruction of microbubbles administered as a constant venous infusion,” Circulation, vol. 97, no. 5, pp. 473–483, 1998.