2010 Research Proposal

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Abstract

This document groups together papers of interest and highlights those which are potentially relevant to *in vivo* studies of the heart, such as studies that distinguish between a healthy heart and a diseased one based on its different physical attributes. The document then describes a plan for inventing new methods based around stress analysis, applied to data acquired from just a 3-D slice of the heart with rectangular boundaries predefined for an MRI scanner to pick.

1 Overview

Analysis of the heart is a problem which is principally associated with biological factors that require knowledge of anatomy, but the problem can be simplified by pre-processing, alternative visualisation paradigms, and occasionally an automated classification of common groups. In this work, the problem gets narrowed down such that only a portion of the heart is dealt with. The key goal is to perform an analysis of human heart images while overcoming its different types of movements which blur tagging and make it increasingly difficult to study the anatomy.

We are attempting to exploit a novel approach whereby an isolated portion of the heart is captured for standalone analysis[1] as the shape of this portion is changed, over time.

DICOM-formatted datasets are to be analysed using calculations of stress (e.g. strain rotation, principal strains, and maximum shear strain), which can be derived by isolating and segmenting the data along the different axes.

2 Existing Literature

The proposed approach needs to be explored in the context of recent papers including those whose authors choose to work with non-rigid registration (see Isola *et al.* [1] from 2010) and/or simple tagging. Isoda *et al.* [2] have only just published an article which looks at three-dimensional phase-contrast MRI and results include an experiment that deals with the cardiac phase.

Last year's review of shape models for 3-D image segmentation [3] may be worthwhile for extracting the signal from larger images, but given the distinctly dark background captured when isolation is applied at the scanner, there ought to be simpler ways to achieve the same effect and obtain similar segmentation. A paper from Zhuang *et al.* [4] covers cardiac MRI for segmentation of the heart without human intervention. It does not deal with the problem of motion and real-time (or 'off-line') tracking of parts of the heart (4-D), though.

Motion caused by respiration is studied in [5]. Many papers on tracking exist and half a year ago there was a speckle-tracking echocardiographic study into myocardial deformation at the University of Hong Kong [6].

Other authors who had studied myocardial strains over a decade earlier [7] more recently looked at what they described as a "non-invasive method for assess-

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[1] The MRI equipment allows new protocols to achieve this selection.

ing regional myocardial" [8] (paper from 2003).

Cardiac tagging was done in Johns Hopkins University last year. It was tissue tagging [9] with cardiovascular magnetic resonance (CMR). More experimental work on CMR tagging (from 2008) can be found in [10] where mice hearts are studied. A paper from Wei *et al.* also considered CMR tagging by experimenting on mice [11]. Methods involved "[i]n vivo myocardial function was evaluated by 3D CMR tagging in mdx mice." More material on CMR tagging [12] "introduce[s] a standardized method for calculation of left ventricular torsion by CMR tagging and [determining] the accuracy of torsion analysis in regions using an analytical model." Delling *et al.* [13] looked at CMR and explained: "We sought to assess the correlation between mitral valve characteristics and severity of mitral regurgitation (MR) in subjects with mitral valve prolapse (MVP) undergoing cardiac magnetic resonance (CMR) imaging." Some less relevant papers on the subject may include [14, 15] on CMR tagging.

The problem of tracking parts of the heart is a complicated one and a particular group has proposed "a novel dynamic model, based on the equation of dynamics for elastic materials and on Fourier filtering." [16]

To some groups, robotic "intervention on the beating heart" is said to be a worthwhile route of exploration as well [17]. This one study on pig hearts [18] — like [6] — considers speckle-tracking. There is also lot about HARP, including a paper from last year [19]. Lastly, *Cardiac Imaging* has this broad new survey from 2010 [20].

3 Data

Experimental data is to be acquired at the hospital using a 3–Tesla (or less) clinical MR system with a specially-tailored protocol that separates a particular region of interest inside the heart (see Figure 1 for illustration). Which cubic region it will be remains to be decided, yet evidently, the acquired data needs to contain several different parts of the heart, e.g. the ventricles. Data is transported in DICOM format and sets can be either temporal or simply different slices taken at a given moment in time, if not analogous phases.

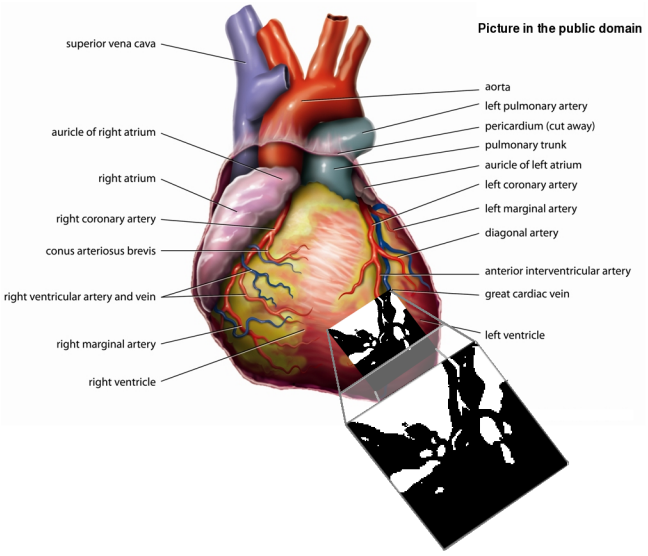

Figure 1: Extraction of a 3-D slice from the heart for strain analysis of the box/cube

4 Method

An exploration around strain analysis may be required in order to devise a new algorithm based on a 'triple sandwich' approach, wherein acquisition of images of the human heart have clippings/occlusions in three dimension such that only a small cube is isolated for analysis or some form of tagging.

To use a figure from Kurt Gramoll of the University of Oklahoma (Figure 2), for a given element such as the one shown in Figure 1, stresses along the four sides are denoted by subscripts xy and yx (in 2-D). Ways exist for calculating different types of stresses based on different parameters, including angles in some cases.

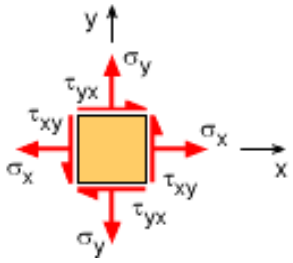

Figure 2: Sign convention for stress element (image from Kurt Gramoll)

5 Experimental Framework

Within the context of this investigation, no statistical analysis is expected to be required (nor pragmatic) because of the small number of subjects, possibly just one, initially. It is hoped, however, that by looking at several different instances acquired at the same site there will be room for studying the variation in shape of a preselected region and thus a characteristic type of expansion, shearing, tapering, or a more complex combination of factors which strain analysis can account for. Initial code has been written to deal with the raw data itself, yet it remains to be determined which method to use for 3-D segmentation and which calculations to perform on the segmented data. The aim is to decide on measures which are meaningful and distinguishable. Implementation of a prototype is expected to be a trivial task in MATLAB and GNU Octave. Some peripheral tools are written in C and automation coded in Bash (e.g. for data conversions).

6 Timeframe and Possible Extensions

At an existing pace of 50 hours per month, it is expected that a working prototype will be available within a month and further experimentation – including write-ups – possible within two months. There is room for experimental expansion and handling of larger sets of data can be an opportunity for statistical analysis too. This, however, changes the nature of the approach and transforms it into one where strain get parameterised, then dealt with in hyperspace rather than in real space which is easy to perceive and reason about.

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