A Tracking Algorithm for Three Dimensional Tags in Cardiac MRI

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Introduction

Tagged MRI offers the possibility to trace tissue deformation by creating planes of MR signal decrease throughout the measured object [1]. This results in dark stripes in the images, referred to as *tags*. In subsequently acquired time series the tag planes bend out of shape according to the motion of the imaged tissue. Retrospective tracking of the tag surfaces then enables reconstruction of the deformation process. Although actually only the intersection points of tag planes created in three independent directions, coincide with object material points, tags are commonly created in one or two dimensions. This is due to the insufficient tag accuracy, which does not only fade with time, but also decreases with the increase of directions in which the tags are created. Thus, more sophisticated numerical tools are of necessity, to come up with the benefits of 3D tags.

The vast variety of existing tag tracking algorithms can be classified by two fundamentally different approaches: Discrete methods are based on tracking the tags as intensity-minima and involve the development of a model for the intensity profile of the tag-lines, e.g. [2]. Alternatively, the tag lines themselves can be segmented using e.g. morphological operations [3]. To circumvent the problem of thermal noise and image artifacts a variety of active geometry methods, e.g. [4], have been introduced. While discrete methods pose the difficulty of assigning the objects extracted from the image to the according tag planes, active geometry models are inherently prone to fail when deformations are large.

The study presented suitably combines discrete and continuous methodologies with combinational logics so as to benefit from their assets, while leveling out their weaknesses. The resulting tag tracking algorithm specifically targets 3D tags, which are poor in resolution, due to the scanning modality, but potentially provide more information on the tissue deformation than 2D tags.

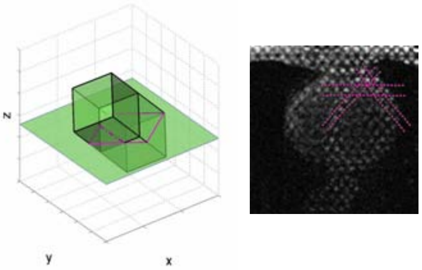

Fig.1: Left: Volumes and tag lines (pink) as created by the three surfaces of the oblique tag planes. Right: Resulting image.

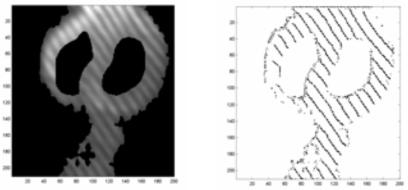

Fig.2: Left: 3D filtered image with respect to one tag direction. Right: Local minima found by profile analysis. (Initial time frame)

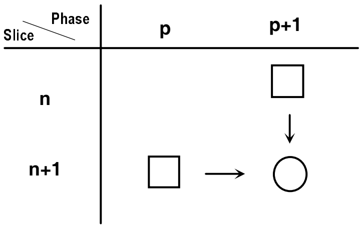

Fig.3: Composition of template incorporating information from previous phase and previous slice

Material & Methods

Data: Tagged 3D Cine data of the beating heart were acquired using a Siemens Vision scanner at 1.5T. Tags were produced in three orthogonal directions, but rotated 45° with respect to the z-axis and 45° with respect to the y-axis of the imaging frame (Fig.1) in order to prevent vanishing of tag planes parallel to the imaging plane. 13 timeframes were obtained over the whole heart cycle, where each time frame consisted in 50 slices of 2mm thickness with no overlap, reconstructed resolution of 512x320 pixel and a FOV of 320x200mm.

Preprocessing: The tagged MRI data were filtered using 3D directional Gauss filters with respect to the three tag directions. For each of the resulting data set the local minima of the projection at 90° to the concerned tag direction were extracted (Fig.2). The minima found in each image were connected to objects and labeled accordingly. The first time frame of the original data was analyzed by means of Fourier transformation in order to determine the initial tag plane positions and according tag lines for each image.

Algorithm: The core algorithm consists in the alternation of basically two routines. First, the tag lines are deformed according to minima objects found in the surrounding. Logical combination arguments with respect to the known tag arrangement are the key in this procedure. Subsequently, the resulting taglines are corrected to sub pixel level using energy minimization [5]. To consider spatiotemporal dependency, the template for the consecutive time frame of the following slice is composed by appropriate merger of the result from the previous phase of the same slice and the same phase of the previous slice (Fig.3).

Results & Discussion

By using the algorithm outlined above, it was possible to track 3D oblique tags for all three directions in slices near the apex up to the 10th time frame. For higher time frames the tag resolution in the images was too poor.

Considering these results, the application of discrete and continuous image processing methodologies incorporating combinatorial logics as described above is expected to succeed in the analysis of 3D tagged MRIs acquired at high magnetic field, which provides higher spatial resolution and tag contrast maintained over a longer period of time. Once the tag planes are extracted, the intersection points can be calculated to estimate the cardiac motion. Transferring the results into an appropriate mathematical model will then permits computational availability as well as visual reproduction of the heart motion.

Conclusion

Estimation and evaluation of the myocardial mechanics is of major importance for understanding and predicting heart diseases. By generation of a heart contraction model, visual examination is enabled. The construction of the former affords precise information about the regional cardiac contractility. Provision of a 3D tag algorithm for oblique tags offer the possibility to consider 3D tags in cardiac MRI experiments and benefit from their informational content. Access to novel and preciser methods in the reconstruction and analysis of the heart motion is given. The expected improvements in spatiotemporal resolution will fundamentally contribute to the development of a standardized mechanical heart model for clinical use.

References

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