Tagged cardiac MR images analysis

A. HISTACE, L. HERMAND, C. CAVARO-MENARD
LISA UPRES EA 2168, 69 avenue Notre Dame du Lac 49100 Angers - France
aymeric.histace@univ-angers.fr

Abstract : The noninvasive evaluation of the cardiac function presents a big interest for the diagnosis of cardiovascular diseases. Cardiac tagged MRI allows the measurement of anatomical and functional myocardial parameters. This protocol generates a dark grid which is deformed with the myocardium on short-axis frames in a time sequence. Tracking the grid allows the displacement estimation in the myocardium. The work described in this paper aims to automate the grid tracking and the myocardial contours detection on short-axis time sequences. With regard to the grid tracking, the method we developed uses an active contour model and gives more satisfying results than those of previously reported methods (our method is less sensitive to noise and to discontinuities near the cardiac cavity). Endocardial and epicardial contours detection is entirely automated and correct, whereas previous published works always used manual contours detection in cardiac tagged MR images analysis.

1 Introduction

The non invasive assessment of the cardiac function is of major interest for the diagnosis and the follow-up of cardiovascular pathologies. Whereas cardiac MRI only allows to measure anatomical and functional parameters of myocardium, tagged cardiac MRI makes it possible to evaluate the intra-myocardial displacement and thus, allows to analyse the regional contraction of the myocardium (detection of potential contractible areas within the infarcted area). The acquisition protocol used by tagged MRI displays a deformable dark grid which sticks to the contraction of myocardium (fig.1) on the images of a temporal short-axis (SA) sequence. The follow-up of this grid makes possible the evaluation of the intra-myocardial displacement.

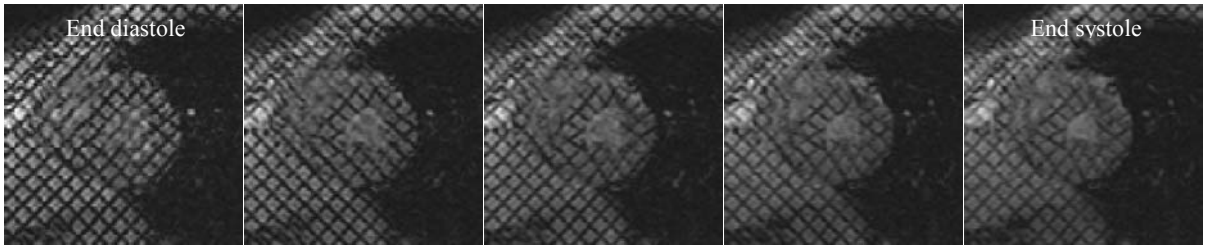

Figure 1 : SA axis tagged MRI

The aim of our study is first to automate the follow-up of the grid, and secondly to automate the detection of the myocardial boundaries on temporal SA axis sequences.

Many studies concerning the follow-up of the grid of tags on SA images use active contours (snakes) [Amini98] [Radeva97] [Stuber98] [Urayama00] [Young95]. The common disadvantages of all these methods which minimise energy to calculate the distortion of the active contour are their sensitivity to the noise and to tags fading, their bad adaptation when tags are very close to the myocardial contours, the difficulty in following the grid when the distortion of the tags from an instant t to an instant t+1 is too important. The only study dealing with automatic detection of endocardial and epicardial boundaries and developed by Guttman [Guttman94] was carried out on acquisitions radially tagged. After tests, this method turned out to be unadapted to our images.

2 Methods

2.1 Location and follow-up of the grid of tags

The follow-up of the grid of tags that we have implemented is based on a grid of active contours (B-Snakes) which allows us to move only the intersection points and to integrate regularity properties (definition of an internal energy), with a parametric and continuous modelling. The B-Snakes grid is built with spline-cubic interpolation between the points of interpolation, which are also the points of intersection. An active contour model (snake) allows to follow the grid of tags in the temporal sequence by moving the interpolation points by a minimisation of energy. The energy E associated to the grid is expressed as the summation of an internal energy E_{intern} which guarantees the regularity of the whole grid [Urayama00], and of an image energy E_{image} whose aim is to have a coherent attraction from the grid of splines to the grid of tags. To assure the resistance of the follow-up of the grid to noise and to the discontinuities of the cardiac cavity, we have defined a term of the image energy ($E_{intensity}$) which is based on a filtering in the Fourier's area. Indeed, the visualisation in the Fourier's area shows several pics, which correspond to the frequency of tags (fig.2b). A filtering in this area, which keeps only the characteristic pics of the grid, and the return to the image area through FFT, is an effective method to obtain specific information of the grid.

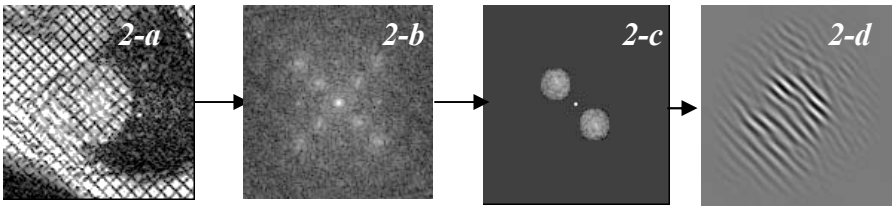

Figure 2 : a)tagged MRI, b) FFT, c) FFT+mask, d) Second Derivative of the inverse FFT: Image I1 135° Grid (resp. I2 45°)

So, $E_{intensity}$ can be noted as follows : $E_{intensity} = \sum_{i,j}\left(I_s(i,j) + \int I_1(\alpha_{i,j}(u))du + \int I_2(\beta_{i,j}(v))dv\right)$

where I_S=I1+I2, $\alpha_{i,j}(u)$ spline arc centered on (i,j) and directed at 45°, $\beta_{i,j}(v)$ spline arc centered on (i,j) and directed at 135°

2.2 Location and follow-up of the myocardial boundaries

The properties observed on a temporal tagged MRI sequence, like the fast erasure of tags in the cardiac cavity (due to blood circulation), lead us to locate and follow endocardium in a different way from epicardium. Nevertheless, the two developed methods have a common point : they both involve the use of an "approximate location", obtained by a transformation in polar coordinates (centred on the centre of the cardiac cavity) (fig.3).

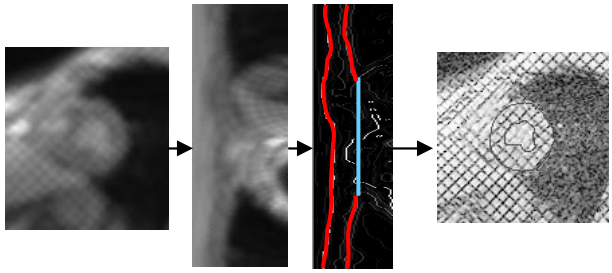

Figure 3 : Approximate detection of the boundaries (that we have developped): a) Erasure of tags, b) Transformation in polar coordinates, c) The endocardial contour and the part of the epicardial contour near lungs are detected by the "Shift XOR" method. The epicardial contour is completed by a linear interpolation, d) Result

This approximate location of the myocardial boundaries allows the initialisation of the follow-up of the epicardial contour modelised by a spline (the energy of the image is based

on a gradient filtering after the erasure of tags through a morphological close), and the region growing of the cardiac cavity where the tags disappear for the endocardial contour.

3 Results

3.1 Location and follow-up of the grid of tags

The follow up of the grid of tags is correct within the myocard on the first seven images of the sequence. Outside the myocard, the internal energy assures a good regularity of the grid (fig.4).

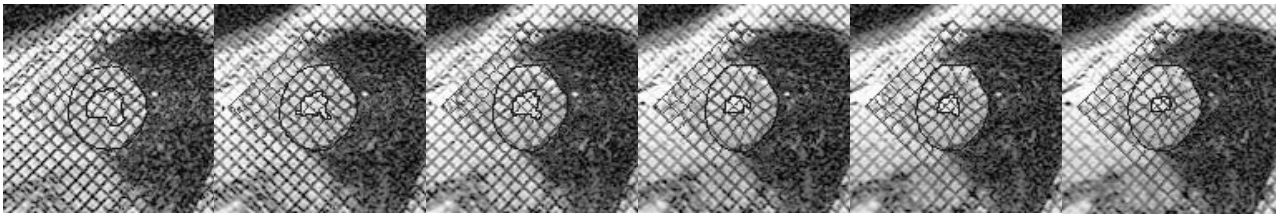

Figure 4 : Results of the follow-up of the grid of tags and of the contours

3.2 Location and follow-up of the myocardial boundaries

As shows the figure 4, the detection of the endocardial contour is satisfactory. Nevertheless, the use of segmentation based on the use of a region growing in our developed method shows its limits when it is applied to noisier images, in which the tags disappear and so, in which the intensity of the myocardial pixels becomes very similar to those of the cardiac cavity.

The distortion of the epicardial contour is more limited than the endocardial one. Its follow-up during the sequence is then easier and so correct in its visible part near the lung. Near the septum (on the left of the images), the results obtained are coherent.

4 Conclusions

The method we have developped for the follow-up of the grid of tags uses an active contour model and gives more satisfying results than those presented in the literature (our method is more resistant to noise and to the discontinuities due to the cardiac cavity). The detection of the endocardial and epicardial boundaries is fully automated and satisfying, whereas the literature always involves manual detection during the analysis of the tagged MRI images. It is now possible to use these results to develop a 3D modelling of the myocardium.

Medical specialists will now have to evaluate these results on pathological images during a clinic validation.

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