TAGGED CARDIAC MRI : A NEW DIFFUSION APPROACH TO INCREASE THE ROBUSTNESS OF THE DETECTION AND THE FOLLOWING OF THE GRID OF TAGS

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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 the analysis of 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) and Long-Axis (LA) sequence. The follow-up of this grid makes possible the evaluation of the intra-myocardial displacement.

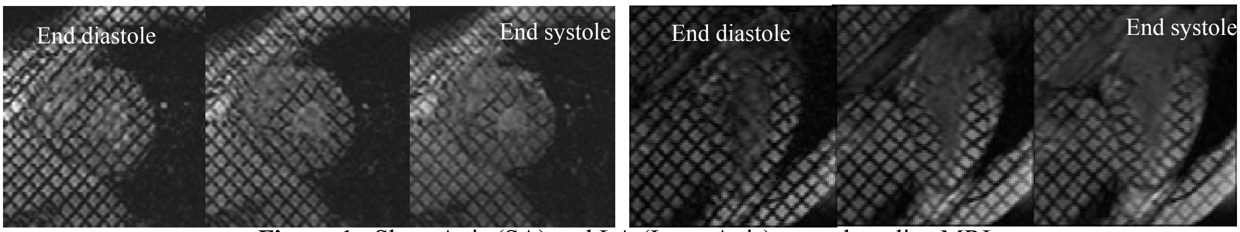

Figure 1 : Short Axis (SA) and LA (Long Axis) tagged cardiac MRI

In [Histace02], we presented a new detection method based on the use of a grid of active contours which was associated to a particular energy calculated in the spectral domain. This method allowed us to obtain a satisfying detection and following of the grids of tags, and resolved the problems of usual approaches (sensitivity to noise and to tags fading, bad adaptation when tags are very close to the myocardial contours, difficulty in following the grid when the distortion of the tags from an instant t to an instant t+1 is too important). Nevertheless, this method appears to need a precise estimation of the weights (α, β, χ, and δ) given to each attraction energy (cf. Eq.1).

$$E_{total} = \alpha.E^{extern}_{alignment} + \beta.E^{extern}_{spacing} + \chi.E^{\text{intern}}_{Spectral} + \delta.E^{\text{intern}}_{contraction} \qquad (Eq.\ 1)$$

For example, a 5 % variation of the weight χ given to the spectral energy leads to an imprecise detection. Moreover this parameterisation is also very dependant of the studied sequence. As a consequence, we propose in this article an amelioration of the past method, by building a new internal energy based on the restoration of the grids of tags at the optimal scale. This new approach leads us to introduce a new formalism called Extreme Physical Information (EPI) which allows us to present an original equation of diffusion totally adapted to the restoration of tagged MRI.

2 Methods

For our study, the extraction of the tag information is made by a curvature detection based on the local calculation of the Hessian matrix and of its eigen values at an optimal scale. The determination of this optimal scale leads us to establish a particular model of anisotropic diffusion [Perona90] coming from a larger generic variational formalism applied to low-level image processing. This formalism based on the principle of EPI, recently developed by Frieden [Frieden98], has for fundamental result the following diffusion equation (cf. Eq.2) [Courboulay02] :

$$\frac{\partial I}{\partial t} = \frac{1}{2}\left(\vec{\nabla} - \vec{A}\right)\left(\vec{\nabla} - \vec{A}\right)I + \Phi I \qquad I(x,y,0) = I_0(x,y) = \text{Initial Image} \qquad \textit{(Eq. 2)}$$

where Φ is a scalar potential and ***A*** a vectorial one which can be adapted to our specific application. This equation has two advantages; first, we can take into account an *a priori* information on the pattern to be restored making a judicious choice for ***A***, secondly it assures us the best incertitude/imprecision compromise all along the scheme process, which is a fundamental problem in image restoration.

In order to applied this technique to the restoration/diffusion of tagged MRI, we make the following choice for ***A*** and Φ (Eq. 3):

$$\vec{A} = \left(|\nabla I|\cos(\theta), |\nabla I|\sin(\theta)\right)^t, \; \Phi I = \lambda\left(I - I_0\right) \qquad \textit{(Eq. 3)}$$

The choice made for ***A*,** defines the anisotropic property of the process and allows us to take into account the pattern to be restored (the grid of tags) by choosing the appropriate values for θ (45°, 135°, 225°, 315° which are the principle direction of the grid)(cf. fig. 2). The expression of Φ allows to obtain a final solution which is a good approximation of the initial image.

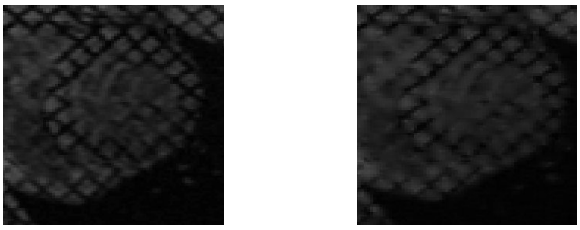

Figure 2 :Original and restored image

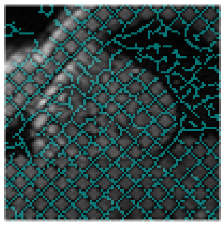

Figure 3 : Energy image (curvature detection)

3 Results

The results of the curvature detection on the restored image (cf. fig. 3) used as a new energy in replacement of the spectral and contraction ones, allow us to obtain a detection of the grids of tags which is as satisfying as this obtaining with the past method, but this new approach appears to be more robust (a 25% variation of the weight given to the new energy does not alter the results) and allows us to use it without any changes of parameters on different sequences (cf. fig. 4).

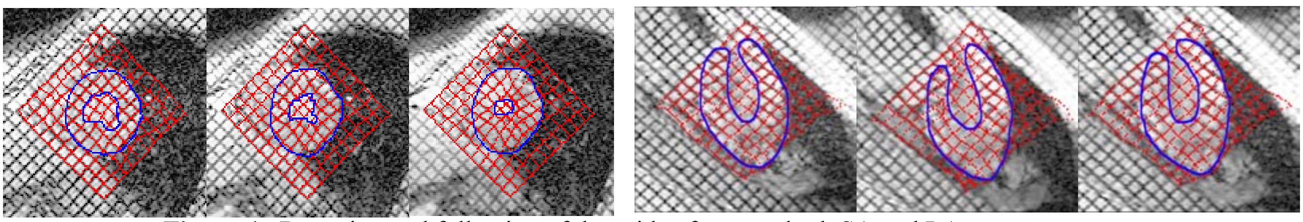

Figure 4 : Detection and following of the grids of tags on both SA and LA sequences

4 Discussion and Conclusion

The method that we have developed allows us to ensure a better stability of the detection which is a real advantage compare to the past approach, for which the lack of reproducibility makes difficult the implementation of the process in routine. A clinical validation of the results is now beginning.

References

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