AUTOMATIC MULTIMODAL REGISTRATION OF GATED CARDIAC PET, CT AND MR SEQUENCES

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Abstract: In this paper, we present an automatic multimodal registration method applied to gated PET, CT and MR images. CT images acquired on the same device as the PET ones are used to merge the anatomical MR and functional PET images. The registration process is divided in two steps: a 3D structure registration and a grey-levels registration. This approach enables global then local transformations. The structure registration uses a 3D biventricular heart model initialized on CT and MR data to define an optimal rigid transform. This global registration is then refined with the grey-levels step based on mutual information and free form deformations.

Keywords: Image registration, Medical applications, Cardiac sequences

1. INTRODUCTION

Cardiovascular diseases, in particular cardiac insufficiency, are exponential growing diseases. The different therapeutic options include chemicals drugs, revascularization surgery or heart transplant. Non-invasive evaluation of cardiac function is a major point for diagnosis and follow up of ischemic diseases in order to choose and adapt the better treatment. The complementary natures of Magnetic Resonance (MR) and Positron Emission Tomography (PET) imaging provide to cardiologists significant information about myocardial viability evaluation after infarction. In one hand, PET imaging is a gold standard for ventricle function evaluation and in the other hand, MR imaging gives a detailed anatomical image and is also a reference method for evaluating the both ventricle function (left and right). X-ray Computed Tomography (CT) imaging is a very high detailed anatomical modality and can also give complementary information about the coronary artery tree. Thus, registration and merging of these images lead to a more informative image.

In cardiac viability studies, a mental registration of the information from different imaging modalities is routinely performed by clinicians. Automatic registration, based on image processing, is therefore expected to offer better accuracy, reproducibility and to save time. Registration of cardiac images is a complex problem because of the mixed motions of the heart and the thorax structures. Moreover, as compared to the registration of brain images, the heart exhibits much fewer accurate anatomical landmarks and the images are usually acquired with lower resolution. A review of cardiac image registration approaches can be found in (Makela *et al.*, 2002). Anyway, these methods used a transmission PET image where we use a more detailed CT image. Moreover, theses methods only merge av-

[1] PhD financed by General Electric Healthcare.

erage PET images to end-diastole MR images since they don't use gated PET data.

We present an automatic method to register MR, PET and CT images gated to Electrocardiogram (ECG). Registration is the first step before image merging. We use a registration framework introduced in (Camara Rey, 2003): Anatomical information are incorporated into the registration process. The registration is divided in two steps. The first one is a 3D structure registration. The rigid transformation thus obtained initializes the second step that is a grey-level based registration. In our application, this approach is necessary because images are gated to ECG. It leads to a great amount of data. The 3D structure registration uses a 3D biventricular heart model that allows to reduce the computing time during the grey levels registration by reducing the deformation space. Thus, we take into account anatomical information.

In the following section, we present more precisely images modalities used for this application. Next, we describe the automatic registration method. The fourth section shows the results that we comment.

2. MULTIMODAL IMAGING OF THE HEART

The left ventricle ensures alone 80% of the cardiac function. Radiologists are then interested in the follow up of this part of the heart. and use a lot of different views to observe human body. For our application, we use two of them (short axis and axial directions) represented on Figure 1.

2.1 PET imaging

Positron Emission Tomography (PET) is a nuclear medical imaging technique which produces images of functional processes in the imaged organ. ^{18}F-FDG emission PET is used for studies about myocardial viability. The spatial resolution of PET images (about 3-4 mm) is low compared to MRI or CT (about 1 mm) and so don't allow a precise location of tissues alterations. CT images are now used to perform attenuation correction because of better resolution compares to a transmission PET image.

2.2 CT imaging

X-ray Computed Tomography (CT) is a medical imaging method with a very good spatial and temporal resolution. Because of this, the CT offers very good anatomical images. In heart imaging, CT images don't provide any functional information, but registered and merged to a PET image lead to a functional and anatomical image.

2.3 MR imaging

Magnetic Resonance Imaging is used to distinguish pathologic tissue (such as a tumor) from normal tissue. While CT provides good spatial resolution, MRI provides comparable resolution with far better contrast resolution. In heart imaging, MRI is used to study the myocardial perfusion and viability and permits the calculus of ventricular function parameters such as left ventricle fraction ejection, end diastolic and end systolic volumes or left ventricle mass.

2.4 Image acquisitions

All images used in this study were acquired in the Angers Hospital. PET-CT data were scanned on a General Electric Discovery ST. MR data were scanned on a 1,5 T General Electric Signa Horizon LX 9.1. The images are gated to ECG. Acquisition parameters are given in table 1. The General Electric Advantage Workstation device registers and merges directly PET and CT images. It also reformats the acquired axial slices to short axis slices.

	PET	CT	MR
Size	128×128	512×512	256×256
Number of Slices	47	335	12
Slice Thickness	3,27 mm	1,2 mm	8 mm
Field of View	circular 50 cm	circular 50 cm	rectangular 460×345 mm^2
Slice View	axial	axial	short axis

Table 1. Acquisition parameters for PET, CT and MR images.

3. AUTOMATIC CARDIAC REGISTRATION

In viability studies, mental registration of the information from theses different imaging modalities is routinely performed by clinicians. Automatic registration is expected to provide more informative images and to save time by assuring accuracy and better repeatability.

Bases of image registration can be found in (Brown, 1992; Glasbey and Mardia, 1998). For medical image registration, more information can be found in (Maintz and Viergever, 1998; Thompson and Toga, 1998; Thompson and Toga, 2000; Hill *et al.*, 2001; Pluim *et al.*, 2003). Image registration between source image (noted S) and target image (noted T) consists in the determination of the optimal transformation $\hat{\varphi}_{\boldsymbol{\theta}}$ that leads $S^{\varphi} := \varphi(S)$ similar to T (Brown, 1992) :

$$\hat{\varphi} = \arg\max_{\boldsymbol{\theta}} C(S^{\varphi_{\boldsymbol{\theta}}}, T) \qquad (1)$$