A fully integrated framework for inline post processing of MR data in real time without user interaction

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Introduction

Various MRI exams require post processing of the resulting images to extract desirable clinical information, e.g. the determination of quantitative cardiac function requires contour drawing on cardiac cine images along epicardial and endocardial borders for the determination of ejection fraction. Usually these processing steps are undertaken on a stack of images that are aligned along specific image dimensions. For instance, individual images typically need to be arranged by the cardiac phase to evaluate cardiac function [1] or by echo times to calculate relaxation times [2] of different tissues. These processing steps are typically performed offline after the image acquisition, frequently on a separate workstation using a dedicated post processing software program, which requires some degree user interaction. The process of data transfer and analysis is time consuming and often requires a highly trained user and therefore limits the use of quantitative approaches in clinical routine.

In this work, a framework is presented that is fully integrated in the image reconstruction software of a clinical scanner providing a generic approach to buffer and apply image analysis algorithms on multi dimensional images, presenting the result inline, immediately after the scan without the need for user interaction. As a first application, this framework was used to register multi-slice cardiac perfusion images to reduce the required user interaction for quantitative or semi-quantitative analysis.

Material and Methods

MRI images typically utilize a number of dimensions such as lines, columns, slice number, cardiac phase, and repetition. Depending on the clinical application, images are buffered in specific dimension and need to be available for processing that may consist of several consecutive algorithm steps. Thus, a generic image buffering technique was fully integrated in the image reconstruction environment of a clinical scanner (Siemens MAGNETOM Avanto, Erlangen, Germany). The framework was applied for the motion registration of free breathing cardiac perfusion data and tested on healthy volunteers.

Image Buffering

The pipeline architecture (PARC) framework of the scanner's image calculation environment (ICE, Siemens, Erlangen, Germany) provides the option to store and retrieve arbitrary data. A processing framework consisting of a modular functor chain was implemented, where the first image reconstruction module (buffer functor) saves images and image header information in the PARC environment (Fig. 1). This functor is supporting all available 16 dimensions such as slices, phases, repetitions, etc. and can be configured to accommodate a specific application, in this example cardiac perfusion images. The subsequent processing functors retrieve the buffered images to apply a specific algorithm.

Image Registration

For quantitative or semi-quantitative analysis of cardiac perfusion images, registration is necessary to minimize the errors due to respiratory motion.

The current implementation consists of rigid body registration (register functor), using a previously determined bounding box (find heart functor) for each slice position [3]: Each individual time frame is registered with respect to a reference image for each slice.

Volunteer study

The successful implementation and performance of the algorithm was tested in healthy volunteers, who were asked to breathe freely during the perfusion scan using a standard clinical protocol.
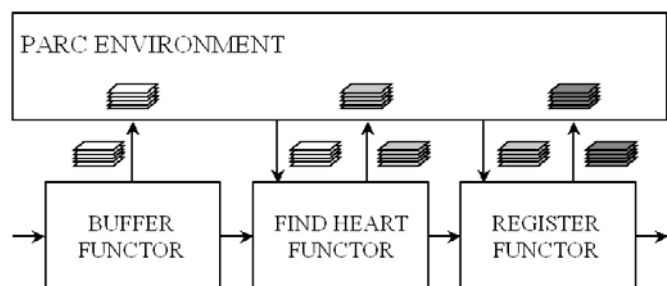

Figure 1: Integrated modular image analysis framework. An initial functor buffers generic image data in the pipeline architecture (PARC) framework of the image calculation environment (ICE). For feasibility testing, two processing algorithm steps required for analysis of cardiac perfusion data have been implemented: (1) Localizing the left ventricle and (2) automated registration of individual frames.
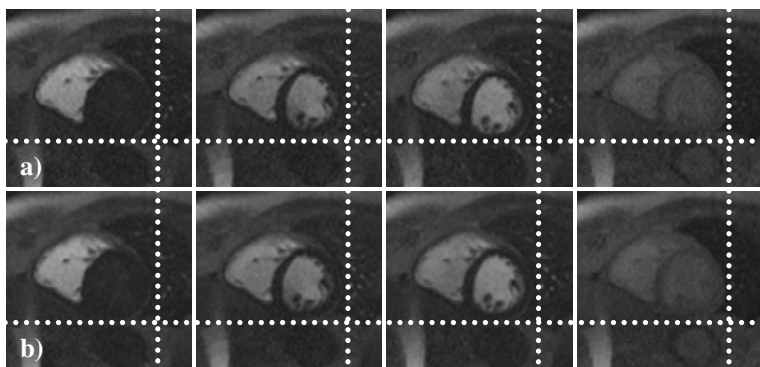

Figure 2: Integrated inline registration of perfusion images of healthy volunteers. The image reconstruction framework saves the original images (a) and generates registered (b) in the database.

Results

The current implementation generates a set of three image series in DICOM format that contain (1) the original image data, (2) the registered images and (3) the reference images with an overlay indicating the bounding box which contains the left ventricle. No user interaction was required to obtain the registered perfusion images. Fig. 2 shows typical free-breathing perfusion images (a) and their registered and filtered counterparts (b). The left ventricle was successfully found in all volunteers on the short axis images and correctly registered.

Discussion

The current implementation allows an easy extension of the algorithm chain to add functors for further analysis. The calculation of semi-quantitative parameter maps such as up-slope or time-to-peak are highly desirable for analysis of first pass perfusion images and could be a next step. Calculation of parametric bulls eye maps (e.g. AHA 16 segment model) may help to expand the use of quantitative cardiac perfusion in clinical routine. Due to the modular approach of the framework the described modules can be also applied to other applications such as segmentation for LV functional imaging, or the generation of relaxation maps, where image registration is also desirable for increased accuracy.

References

[1] Bi X. *et al*. Proc Intl Soc Magn Reson Med **14**: 2163 (2006)
[2] Messroghli DR *et al*. Radiology **238**(3): 1004-12 (2006)
[3] Sun Y *et al*. Proc. Medical Image Computing and Computer-Assisted Intervention: 903-910 (2004)