Spatial Segmentation Based on the Signal Time Activity of Dynamic Cardiac Images During Intracoronary Infusion of Gd Contrast Agent

C. Nikou[1], N. G. Galatsanos[1], and N. V. Tsekos[2]
[1]Computer Science (IPAN), University of Ioannina, Ioannina, Greece, [2]Radiology, Washington University, St. Louis, MO, United States

INTRODUCTION: Image segmentation of anatomical and functional MRI is an important and well studied area [1]. In most applications semi-automated/semi-quantitative segmentation with manually traced region-of-interests are sufficient for extraction of diagnostic information [2]. However, certain applications would be highly benefited by automated segmentation to speed processing, reduce the work load and potentially provide higher resolution extracted segments. In addition to traditional applications like in first pass perfusion [2], such approach would be important in the emerging MR-guided cardiac interventions (e.g. [3]). In such procedures, segmentation of certain areas (as example locally perfused myocardium) can be identified on-the-fly and overlayed on anatomical or functional images to generate multi-parametric/multi-dimensional maps for planning and guiding an intervention. In this work we propose a method that segments cardiac tissue based on the time evolution during the infusion of Gd-based contrast agent.

METHODS:

Segmentation: The proposed segmentation method is based on the assumptions that (1) pixels representing tissue with similar blood flow/perfusion properties should have similar signal intensity time-evolution, i.e., the "activity curves" and (2) spatially adjacent pixels should have a larger probability to belong to the same cluster. Gaussian mixture model-based clustering [5] takes into account spatial information using a Bayesian formulation. It relies on a data-based likelihood term modeling the probability of obtaining a certain pixel intensity and a term imposing spatial smoothness in the neighborhood of a pixel. Let the observed data be $\mathbf{g}=[g_1, g_2 \cdots g_k]$ where k is the temporal index and $g_m(i,j),\ i,j=1,2,\ldots N$ the spatial indexes. With this assignment, the data points $\mathbf{g}(i,j)=\left[g_1(i,j), g_2(i,j) \ldots g_k(i,j)\right]^T \in R^k$ having similar intensity characteristics and being close in space are grouped into the same cluster. The algorithm has two steps: at first, Principal Component Analysis (PCA) reduce the dimensionality of the data [4]. This is achieved by projecting the data onto the directions of the eigen-vectors of the largest eigen-values of the data covariance matrix $\mathbf{R}=\sum_{i,j=1}^{N}\mathbf{g}(i,j)\cdot\mathbf{g}(i,j)^T$. The dimensionality of the data is reduced, since the first 10% of the largest eigen-values capture over 99% of the variance of the data. The next step is clustering the features of the reduced space by a spatially variant Gaussian mixture model [5].

In Vivo Studies: Evaluation of this method was performed on dynamic cardiac images collected during the intracoronary (IC) infusion of Gd-DTPA into the main Left Coronary Artery. In vivo studies were performed on pigs (n=3) instrumented with an intracoronary catheter in the left main placed through a carotid access under x-ray fluoroscopy for direct IA infusion of Gd-DTPA. Dynamic imaging of the CE coronary arteries was performed with non-triggered SMIR-prepared [6] thick slab GRE sequence (TR/TE/α = 2.7/1.42/35°; FOV = 147x147 mm; slice = 50mm; matrix = 96x96).

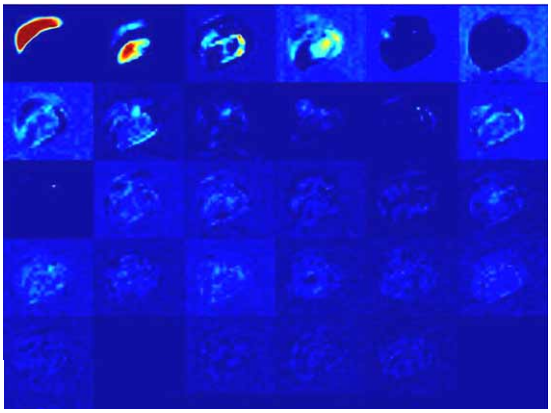

Figure 1

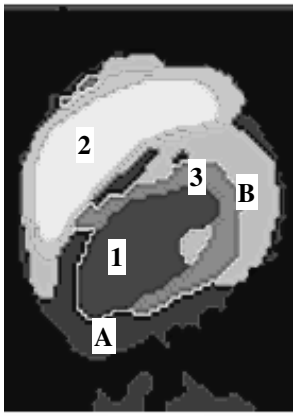

Figure 2

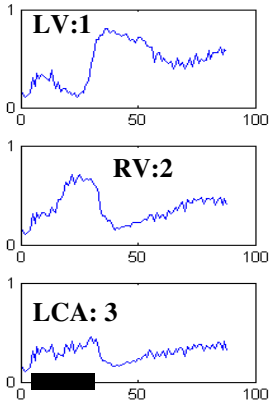

Figure 3

RESULTS: Figure 1 shows the eigenvectors of the data covariance matrix in descending order (from top left). Figure 2 shows the resulting segmentation and Fig. 3 the activity-curves obtained as spatial averages of selected segments (the bar is the period of slow Gd infusion). Note the different time evolution of the LCA, right ventricle (RV) and the reft ventricle (LV) accurately representing the passage of the agent first through the LCA, the RV and finally the LV. The algorithm successfully segmented out anatomies based on their activity curves despite using non-triggered images. Note that first is highlighted the anterior, septal and apical myocardium (A), which is perfused by the LCA at this animal, and then the basal and lateral walls (B), and to less extend. We are developing this method for extraction of segmentation masks for on-the-fly identification of perfused beds during intracoronary infusion of Gd agent and superimpose them on scout and CINE images for use with catheter maneuvering for applications such as alcohol septal ablation. Other applications include functional brain MRI and generating maps sensitive to small SI changes for monitoring thermotherapies.

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