Frank B. Sachse
Gunnar Seemann (Eds.)

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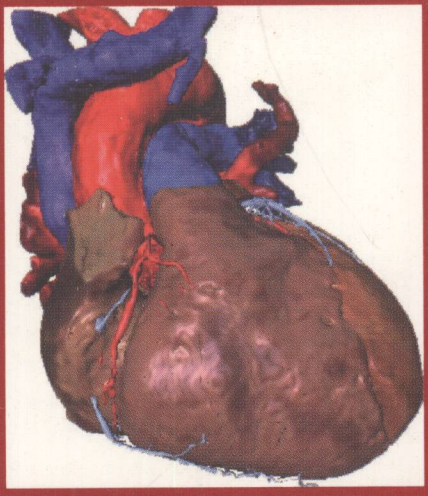

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Preface

Functional imaging and modeling constitute important research approaches to gaining insights into the physiology and pathophysiology of the human heart. Applications of these approaches are promising to support clinical diagnosis and therapy of cardiac diseases, which are the most common cause of death in the western world and a major health problem in Asia.

The series of international conferences on "Functional Imaging and Modeling of the Heart" (FIMH) aims at integrating the research and development efforts in the field of cardiovascular imaging, image analysis and modeling. The main goal is to encourage collaboration between scientists in signal and image processing, imaging, applied mathematics, biophysics, biomedical engineering and computer science, and experts in cardiology, radiology, biology and physiology.

Previous FIMH conferences were held in Helsinki (2001), Lyon (2003), and Barcelona (2005). The 4th FIMH conference was the first outside Europe and took place at the University of Utah, Salt Lake City, USA, on June 7–9, 2007.

These proceedings present peer-reviewed contributions to the FIMH 2007 conference from Asian, European, North American and New Zealandian research groups. Their contributions cover topics of imaging and image analysis, electrophysiology, electro- and magnetocardiography, structure mechanics, and anatomical modeling. The contributions describe both experimental and computational studies. Several contributions are closely related to the clinical application of imaging and modeling approaches.

We would like to thank all authors for their excellent contributions to the FIMH proceedings, all members of the scientific committee for their invaluable efforts during the review process, and all members of FIMH steering committee for their outstanding scientific and organizational guidance.

June 2007

Frank B. Sachse
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Local Wall-Motion Classification in Echocardiograms Using Shape Models and Orthomax Rotations

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Abstract. Automating the analysis of left ventricular (LV) wall motion can improve objective prediction of coronary artery disease. A new method for classifying LV wall motion using shape models with localized variations was developed for this purpose. These sparse shape models were built from four-chamber and two-chamber echocardiographic sequences using principal component analysis and orthomax rotations. The resulting shape parameters were then used to classify wall-motion abnormalities of LV segments. Compared with the shape model before rotation, higher classification correctness was achieved using significantly less shape parameters. The local variations exhibited by these shape parameters correlated reasonably with the location of the segments.

1 Introduction

Coronary artery diseases are a major cause of death in the western world. Detection of wall-motion abnormalities of the left ventricle (LV), widely accepted as predictors for these diseases, is therefore of great clinical importance. To improve the diagnostic quality of the detection, current visual analysis methods should be automated. The goal of this study is to evaluate a new automated classification approach to detect local wall-motion abnormalities, using point-distribution models with localized variations.

Point-distribution models, or shape models, are parametric representations of a set of shapes. First applied to face analysis, these models have since then been used in various medical image processing contexts, especially segmentation [1],[2]. Shape models are often built using Principal Component Analysis (PCA), which maximizes the variance of the input data. This results in models with global variations. In our previous work, PCA shape models of the LV endocardial borders were used to classify wall-motion abnormalities [3]. Clear correlations were found with respect to global clinical parameters (e.g. LV volume), as well as to local parameters (e.g. visual wall-motion scores). However, relatively many shape modes were needed to classify these *local* wall-motion scores, because *global* shape parameters were used. We therefore hypothesize that models with local variations should be able to predict local wall motion using less shape modes.

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Several methods for building more localized shape models have been proposed, including independent component analysis [4] and various sparse PCA methods [5],[6]. Recently, Stegmann et al. [7] suggested a method using orthomax rotations, which is particularly attractive due to its computational feasibility in high-dimensional spaces. The applicability for localized classification was mentioned in that paper, but has not yet been investigated.

To determine whether localized shape models can improve classification of local wall-motion abnormalities of the left ventricle, shape models were constructed using PCA and rotated according to the orthomax criterion. Classification correctness, the number of shape modes needed, and cluster representation were studied, for different proportions of retained variance. The position of the local variations exhibited by the shape modes was compared with the location of the classified segment.

2 Methods

2.1 Shape Modeling

Shape models of the LV endocardial contours were constructed using full-cycle 2D+time (2D+T) echocardiograms. By modeling the complete cardiac cycle, typical motion patterns associated with certain pathologies were included. More details of the model can be found in our previous work [8].

Each 2D+T shape was represented as a vector $\mathbf{x}$, consisting of landmark coordinates in a number of cardiac phases. Shape models describing the main variations in a patient population were built using PCA:

$$\mathbf{x} = \bar{\mathbf{x}} + \mathbf{\Phi}\mathbf{b} \ , \tag{1}$$

where $\bar{\mathbf{x}}$ denoted the average shape, $\mathbf{\Phi} = (\phi_1|\ldots|\phi_p)$ the $n \times p$ matrix of orthogonal shape eigenvectors or modes, and $\mathbf{b}$ a vector of shape coefficients. Each shape could be seen as a point $\mathbf{b}$ in a p-dimensional parameter space spanned by the p orthogonal eigenvectors. Any new shape could be approximated in this PCA space using the pseudoinverse ($\mathbf{\Phi}^{-1}$) of the eigenvector matrix:

$$\mathbf{b} \approx \mathbf{\Phi}^{-1}(\mathbf{x} - \bar{\mathbf{x}}) \ . \tag{2}$$

To obtain a more compact model, k eigenvectors with the largest eigenvalues λ_i were kept, so that only a proportion f of the total variance $V = \sum_{i=1}^{p} \lambda_i$ was retained:

$$\sum_{i=1}^{k} \lambda_i \geq fV \ . \tag{3}$$

2.2 Orthomax Rotations

Orthomax rotations were applied to the PCA shape models to produce models with localized spatial variations [7],[9]. Orthomax rotations are reparameterizations of the PCA space so that the resulting Orthomax PCA (OPCA) space has