Sunway Academic Journal 2, 77–83 (2005)

SEARCH OF DYNAMIC MAGNETIC RESONANCE IMAGES USING ACTIVE SHAPE MODEL

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ABSTRACT

This paper focuses on segmenting dynamic magnetic resonance (MR) images of the human heart stored in a database. Heart MR images are dynamic, as the size and shape of a person's heart vary in time. Active Shape Model segmentation was used to segment dynamic images of the heart. The input data is a points file of a set of random points. This method is economical since points of all the frames need not be placed in the points file for search. Segmented dynamic images of an organ such as a heart would help physicians to better understand certain medical conditions. The novelty of this approach is that it allows automatic segmentation of thousands of dynamic MR images in the database, visualization of the shape variation and retrieval of similar cases of interest from the image database.

Key words: Magnetic resonance imaging (MRI), shape model search, database image storage and retrieval, medical image search.

INTRODUCTION

In recent years, technological advances have led to many reliable medical imaging techniques such as computed tomography and magnetic resonance imaging (MRI). MRI has been shown to be effective in diagnostic imaging, which is concerned with detection, localization, and tissue characterization. The number of medical images accumulated for diagnostic purposes in hospitals is colossal. For example, the radiology department of University Hospital of Geneva produced 12,000 images a day in 2002 (Muller et al., 2004).

Due to the large collection of medical images, analyzing them to search for images that are relevant to certain medical conditions is time consuming without automation. Research is widely conducted using visual features such as color, texture and shape in addition to text annotation to interpret image contents. Fully automated segmentation of images into objects is still an unsolved problem. In addition, Muller et al. (2004) have highlighted that the current image search and interpretation techniques have still not solved the semantic gap and sensory gap; medical expertise is required to reduce these gaps.

Within humans, structures such as brain and bone can be static as they only vary in shape from one individual to another. Organs such as heart and lungs are dynamic as their shapes change during contraction and expansion within an individual; also, they vary from

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one person to another. Searching for static images having matching segmented content is complicated. Similar searching for dynamic images is even more challenging and complicated.

The shape-based algorithm as introduced by Cootes et al. (1994) is able to segment dynamic images such as of the heart, thus reducing the semantic gap and the complexity of segmentation. Segmenting dynamic images accurately will help physicians to find similar cases of complications and to diagnose conditions. In this method, the input data is a points file of randomly selected points. This is economical since points of all the frames need not be specified. The shape based algorithm depends on the energy minimization principle. Once a rough direction is defined it will settle on the minimum energy as defined by the boundary of all the frames, which can amount to thousands. It can shrink and wrap on the region of interest, such as the heart. This novel approach allows the search for objects of interest in MR images stored in databases and visualization of the temporal variation of the shape.

The purpose of this research is to identify the object in the region of interest in a given set of MR heart images based on a model created from a training set. The MR images were obtained from a local hospital, preprocessed, scanned and stored in a database. The objects in the region of interest chosen can differ depending on the type of disease. We wish to model the shape variation of the heart and use the resulting model to interpret MR images in the database.

PREVIOUS WORK

Many different techniques have been introduced for searching medical images in order to retrieve, from the image management systems, images and records that have similar if not exact content (Rui et al., 1999). A few of these techniques use semantic keywords or content-based search using color, texture or shape; the latter is more complex than using key words attached to images (Eakins and Graham, 1996; Vujovic and Brzakovic, 1998).

The segmented gray-level MR image encodes the brightness level observed at each point in a scene using a value usually in the [0,255] range. Edges are image contours and corners of the image correspond to sharp points on image edge contours. Detection of edges and corners can help in image feature matching. Rigid templates and correlation can be used in image interpretation. However, the biological objects often do not share an exact rigid shape and are inherently variable in shape. Therefore, a flexible model has to be used to allow for some degree of variability in the shape of the imaged object (Sclaroff and Pentland, 1994).

Kass et al. (1987) presented a simple and general two-dimensional (2D) image processing deformable model called “snakes.” Although popular, “snakes” was not reliable in identifying a particular class of object to the exclusion of other strong image structures (Cootes et al., 1994). The Active Shape Model (ASM) employs statistical models of shape. The model can deform based solely on statistical analysis of the training set, allowing a compact and specific description of the shape variation. ASM is used to interpret 2D MR images based on the shape variation of the objects in the region of interest (Cootes et al., 1994).

The shape model is created from the mean and covariance of the *x* and *y* coordinates of points that lie on the boundaries of samples of the object. Sampling the grayscale profile along the normal to each of the points that define a sample boundary creates the grayscale model. ASM models of the shape of image sequences allow search, recognition, measurement and classification of objects. Statistical analysis of objects allows explicit description of their shape variation, resulting in Active Shape models, which can deform to realistic shapes (Cootes et al., 1994). Therefore, the ASM approach is adopted as the segmentation method in this research.

MODELING TECHNIQUE

The region of interest or object modeled in MR heart images is the heart. The heart ASM model is used to classify MR heart images stored in the database. Software tools used to conduct this study are Microsoft Windows 2000, Matlab version 5.3, ASM Toolkit (ISBE, 1999) and Microsoft Access 2000. Image modeling and classification involve image acquisition, modeling segmented MR images, creation of heart shape model and classification of matching images as shown in Figure 1.

Image Acquisition

A set of 27 MR transverse-slice heart images of a healthy male was used for this study. The heart is chosen as it is a dynamic organ and the variation in shape of the heart model from one MR image to another can be tracked through a sequence of MR heart images.

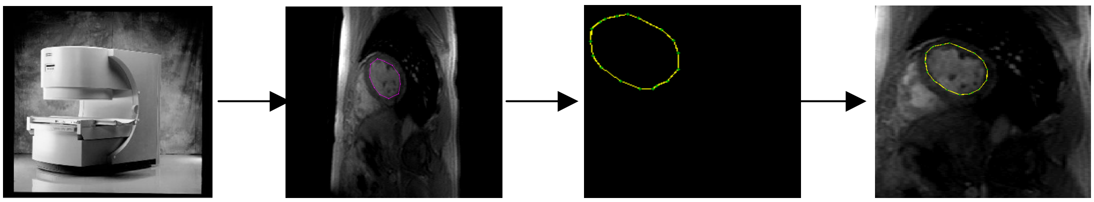

Figure 1. Image modeling and search methodology

Modeling MR Heart Images

A subset of 10 MR images was selected from the database to build a shape model. Modeling the MR images was carried out by labeling points along the strong edges of the heart shape in the images. Each image was labeled with 15 landmark points, making the shape explicit. Good search performance of the model depends on the accuracy and consistency of the labeling (Cootes et al., 1994). These points were stored in a points distribution file.

The shape model data file was created to keep track of the location of images, model file, parts file and points file. The parts file keeps track of the number of points marked. The points file keeps track of the coordinates of the marked points in order to search for the shape variation in a given MR image. The second panel of Figure 1 shows the labeled heart shape.

Heart Shape Model

Active Shape Models are statistical models of the shapes of the objects in the region of interest in a given MR image. Each object in the training image set is represented by a set of 15 labeled landmark points, which is consistent from one shape to the next. Each shape is represented by a vector **x** of landmark points coordinates: $\mathbf{x} = (x_0, y_0, x_1, y_1, \ldots x_n, y_n)^T$.

The movement of the landmark points together with the shape variation is described by the linear deformation modes and is represented by the eigenvectors $\mathbf{p_t}$ of the covariance matrix. The associated eigenvalue $\boldsymbol{\lambda_t}$ is equal to the variance in each linear deformation mode. Each shape **x** of the training set is computed as a weighted sum of eigenvectors $\mathbf{p_t}$ and the mean $\bar{x}$:

$$\mathbf{x} = \bar{x} + \mathbf{Pb} \qquad (1)$$

where $\bar{x}$ is the mean of the aligned training MR image set,

$\mathbf{P} = (\mathbf{p_1}\ \mathbf{p_2}\ \mathbf{p_3} \ldots \mathbf{p_t})$ is the matrix with the eigenvectors as its columns, and

$\mathbf{b} = (b_1\ b_2\ b_3 \ldots b_t)^T$ is a vector of weights for shape parameters.

Equation (1) is used to calculate the shape parameters that are approximated using the mean shape and weighted sum of deviations from the modeled landmark points scattered around the region of interest in the training sets. By varying the value of **b**, new shapes that are similar to the training set can be generated for the heart model (Cootes, 2001). The third panel in Figure 1 shows the heart model created.

Classification of Matching Images

The ASM static search is an iterative refinement of the heart model poses (rotation θ, translations t_x and t_y, scale s) and shape parameter **b**. Starting from a specified pose (region of interest), the MR image was searched for instances of the specified heart model. Upon completion, the final model pose was returned, along with a vector of shape parameters which describe the model shape. This allowed the search and classification of images with the same shape class as defined by the model. The remaining 17 MR images in the database were classified using the same method. The classified images were automatically added to the training set to further refine the model.

RESULTS AND DISCUSSION

A simple database was created to store MR heart images and models, a subset of a patient's diagnosis report and the type of treatment given. Twenty-seven MR heart images were stored in the database. Prototype software was developed to link ASM Toolkit with the database as in Figure 2.

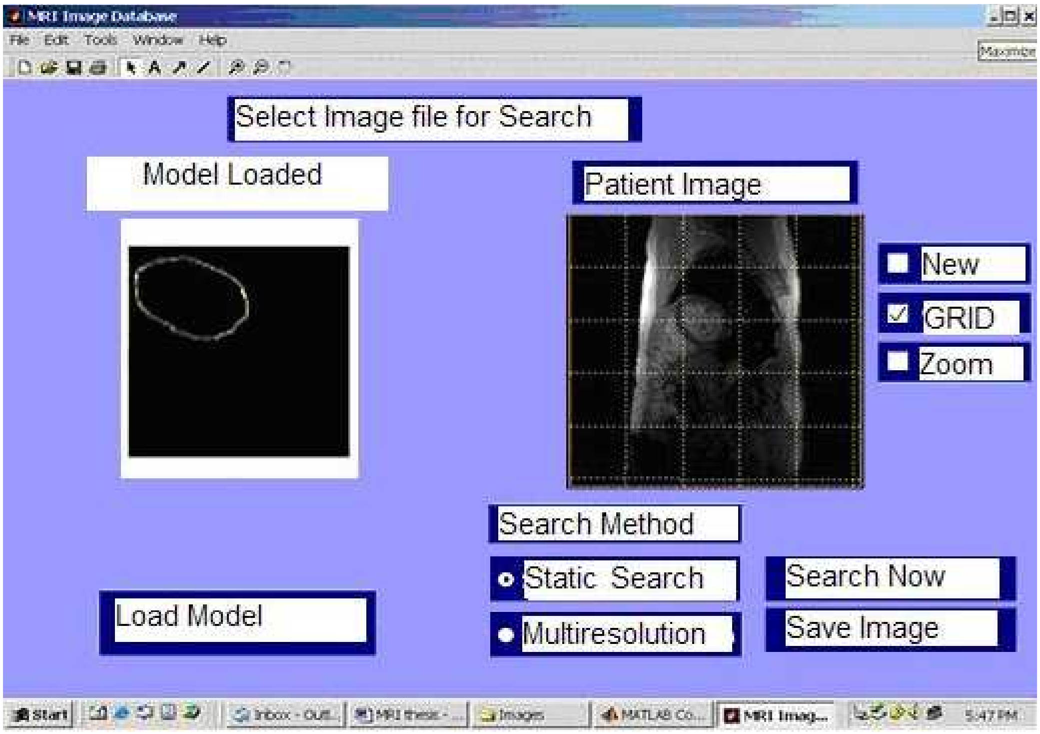

Figure 2. Prototype developed to search the MR images from a database

The heart model created was loaded into the prototype software to classify the new heart images using the iterative search method. Initially, the iterative search makes larger steps, quickly finding a rough estimate of the region of interest. As the search progresses, the steps become smaller allowing for a refined fit. All the seventeen images were successfully classified using this method. Figures 3, 4 and 5 show the iterations of search performed using the model.

The MR heart images were linked to patient records and once the model fitted into the region of interest of a selected MR image, the related medical records of the patient were retrieved and displayed by the prototype. Using the prototype, the Active Shape Models can be indexed to interpret different shape classes of MR images and to retrieve relevant records from the database.

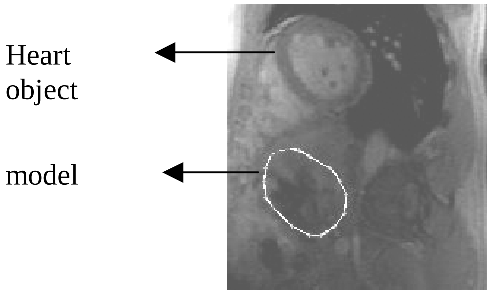

Figure 3. Initial stage of the iterative search

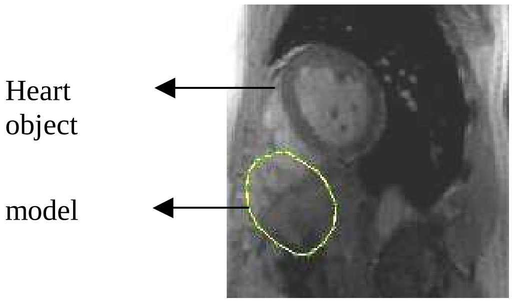

Figure 4. After a few iterations

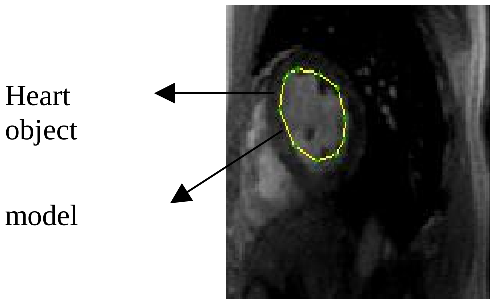

Figure 5. Fitting of the model with the heart object

CONCLUSION

In this study, we have focused on the dynamic heart ASM model of a healthy male and used the resulting model to interpret other MR heart images in the database. Once defined, such models can be used to classify and index the thousands of images and patient records in a database. This approach can be extended to study the MR images of other dynamic organs. The semantic gap (loss of information through image representation) may not be a problem as medical expertise is used in creating a new model. Future work would include studying the efficiency of this method in storage and retrieval of matching images from large database systems in hospitals. This would require the following applications: easy database connection, three-dimensional (3D) modeling and Augmented Reality (AR). However, these features would require high-end processors and graphics cards.

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