Medical Image Analysis Assignment 4

Statistical Shape Models

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Introduction

In this assignment we are going to do shape analysis and create a shape model. The shape model will be used to segment kidneys in renal scintigraphy images. The purpose of this assignment is to develop a shape model and use this model to improve the segmentation process. We will develop a shape model based on a number of segmented kidneys. This model will be based on points sampled along the contour of the kidneys.

Description of theory and Results

Scintigraphy:

Scintigraphy is an imaging technique where the decay of a radioactive substance is measured with a gamma camera. In renal scintigraphy the radioactive substance is 99mTc, Technetium. To get an image of the kidneys, this radioactive substance is attached to a biological molecule called dimercaptosuccinic acid (DMSA) which accumulates in the kidneys. This substance, 99mTc-DMSA, is injected into the patient's blood flow and the images are acquired after 2–3 hours. Then you get an image where in most cases only the kidneys are visible (the urinary bladder can sometimes show up in the images too).

The uptake of 99mTc-DMSA is normally homogeneous but if the patient has scars, these can be seen as wedge-shaped regions with lower uptake.

Because of this it is practical to use a shape model when segmenting the kidneys, since for example it's common for an edge detector to fail to include the scars if they are located close to the edge of the kidney.

Shape model

To create a shape model you need manual segmentations of organ. The segmentations and coordinates of the landmarks are given in the data.

In the first task, we need to resample these landmarks to 14 equally spaced landmarks. We use linear interpolation and arc-length to resample the even distributed landmarks.

There is a function available in MATLAB called interparc using arc-length to interpolate a set of points along some curve in space and create a new set which is uniformly spaced along the same curve.

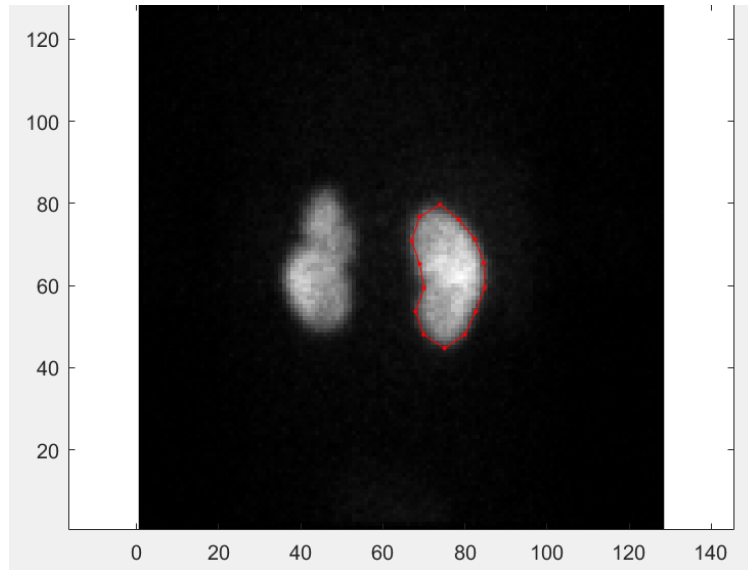The resampled contour and landmarks are shown as below.

Figure 1: Sampled landmarks

In the second task, we need to model the shape of a kidney from given manual segmentations. First, we need to remove the scale, translation and rotation. It can be done by aligning the shapes using Procrustes analysis. The steps are as below.

1. Align each shape to the first
2. Calculate the mean of the transformed shapes (by calculating the mean value for each point)
3. Align the mean shape to the first (to guarantee convergence)
4. Align each shape to the mean shape
5. Update the mean shape
6. Iterate 3 to 5 until convergence (i.e. the mean shape does not change significantly from the previous iteration)

The aligned shapes are plotted in figure 2 and it can be verified from the figure that the translation, rotation and scale are eliminated.

After aligning the shapes calculate the covariance function of the points and the corresponding eigen-values and eigen-vectors in order to obtain a shape model.

The covariance function is calculated by calculating the difference with respect to the mean shape for each transformed shape. The 2n x 2n covariance matrix is then calculated using the formula from the lecture on shape models.

$$S = \frac{1}{M} \sum_{i=1}^{M} \mathbf{dX}^i (\mathbf{dX}^i)^T$$

The corresponding eigen-values and eigen vectors are then calculated using the MATLAB function eig which takes the covariance matrix as input and produces a diagonal matrix of eigenvalues and a full matrix whose columns are the corresponding eigenvectors. The eigen-values and eigen-vectors are then ordered decreasingly. The eigenvectors corresponding to the highest eigenvalue describes the most likely principal variation. They are plotted in figure 3.

Figure 2: Aligned shapes

Figure 3: Eigen-values
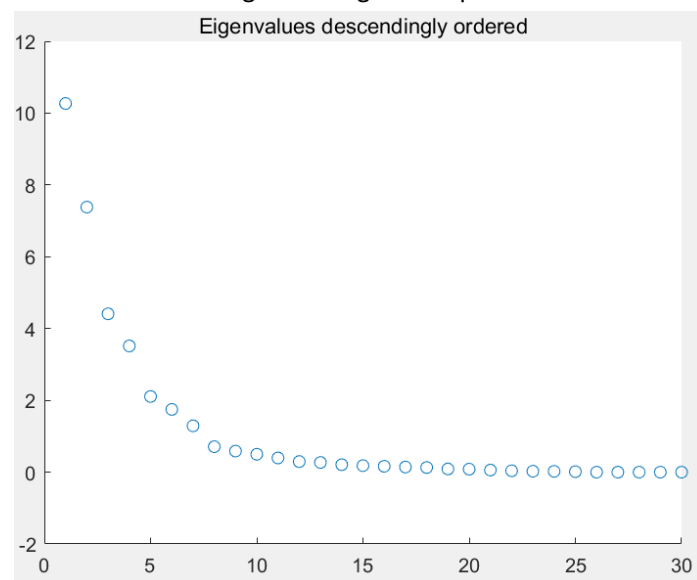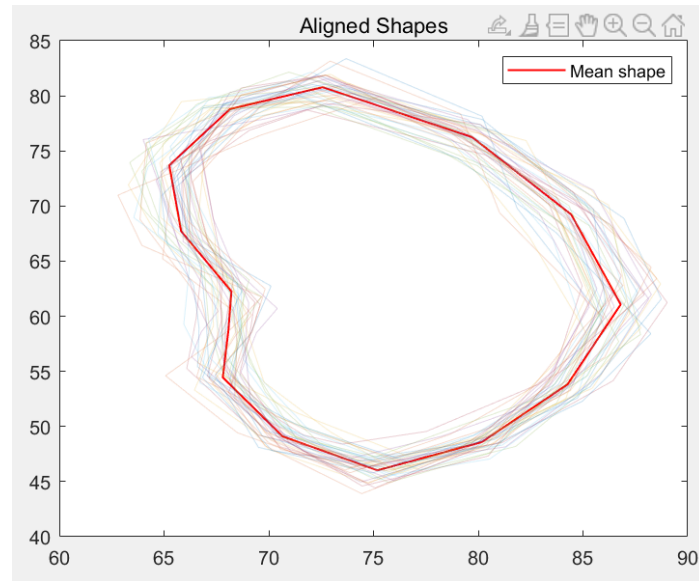
Usually, the first principal modes describe the most relevant and most likely principal variations in the training set and the last modes only capture noise in the training data.

To determine how many modes that are suitable for our shape model, we can either look at the geometric appearance of each mode and select the relevant one, or we can determine how much energy we want to preserve in the shape model. For example, we can select the first t models that preserve 95% energy. In our case, I choose the first four modes. They are shown in figure 4 below.
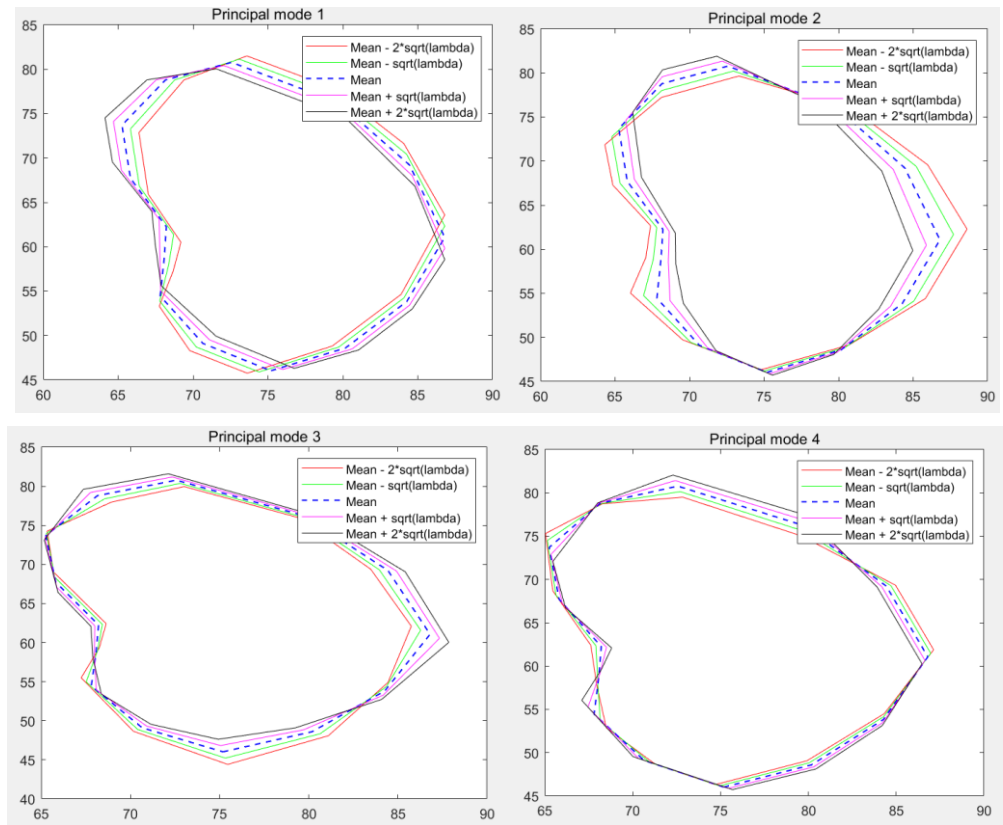
Figure 4: Principal modes