H-020

# Proposal of Eigen-organ Method for Location Detection of Multi-Organs in Three Dimensional Medical Images

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## 1. Introduction

To support doctors who suffer from large amount of images by the scanners, in recent years, multi-organ multi-disease Computer Aided Diagnosis (CAD) system has become a popular topic [1]. In these systems, location detection of organs is an important step for the following tasks, such as precise segmentation of organs and detection of lesions.

Template matching is a basic tool for the location detection [2][3]. It involves determining the similarities between a given template and windows of the same size in an image and identifying the window that produces the highest similarity measure. Different similarity measures have been used in template matching, such as sum of absolute difference, cross-correlation coefficient, geometric distance, mutual information, invariant moments, and etc. However, most of these similarity measures only match the image to the average template and the variance in the image is ignored. So the matching accuracy may greatly descend when the target has large variance.

Eigen-face approach [4] is widely used in the recognition of human faces and can deal with the variance of image. Noticing its good performance in 2D images, we transplanted it and proposed an eigen-organ approach for location detection of organ in volumetric medical images [5]. In this paper, we extend the eigen-organ approach for the locations detection of multi-organs in 3D CT abdomen image based on probabilistic atlas.

## 2. Method

Our approach contains two types of matching, both of which are based on eigen-spaces derived by means of PCA. One is the matching of individual organs and the other is the evaluation of location relationship among all target organs. The main process could be described as follows:

First, we construct both the "local eigen-organ spaces" for each target organ and the "global eigen-organ space" for the organs' spatial relationship. A set of probabilistic atlas images for each target organ is also generated. During the matching procedure, VOIs from abdomen CT image are projected into the local eigen-organ space. Then the difference between the original VOI and its reconstruction from the local eigen-organ space is calculated. In the difference calculation, it is divided by the probability of existence of target organ at corresponding location. By extracting the local minimum difference, a set of candidate locations for each organ is selected. Next, it projects each possible combination of organ's candidate locations into the global eigen-organ space and computes the difference between original combination and its reconstruction. The location combination, which gives minimum difference, is detected as the corresponding locations of the target organs.

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### 2.1 Construction of Local Eigen-organ Space

Ten types of local eigen-organ spaces are constructed from the training 3D abdomen CT images, which are normalized and transformed by rigid registration. These spaces are constructed for liver, spleen, left-lung, right-lung, left-kidney, right-kidney, abdominal aorta, heart, pancreas and inferior vena cava. For each training image, a labeled image is created manually. We can easily derive the probabilistic atlas for each organ from these labeled images. According to the organ label, each organ is picked out from the abdomen image and a set for training images each of which includes an organ is generated. At the same time their spatial locations in the original abdomen image are also recorded for the preparation of creating the global eigen-organ space.

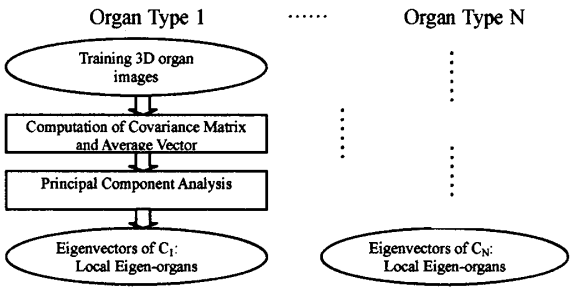


Fig.1 Flowchart of constructing the local eigen-organ space

Based on the Fig. 1, we construct the local eigen-organ spaces by the training samples according different organ types. For current organ type, each of the training organ r is treated as a high dimensional vector, whose dimension is equal to the total voxel count of current organ type. Similar to the eigen-face method, we apply PCA to these samples and find the eigenvectors as the local eigen-organs of the corresponding organ type.

### 2.2 Construction of Global Eigen-organ Space

Using the spatial location information of all kinds of organs in each original abdomen image, we can construct the global eigen-organ space. We have K types of organs in the abdomen image and the centers' coordinates of these organs are indicated by ($L_{1x}$, $L_{1y}$, $L_{1z}$), ($L_{2x}$, $L_{2y}$, $L_{2z}$), ..., ($L_{Kx}$, $L_{Ky}$, $L_{Kz}$). We treat these spatial coordinates as one point in K×3 dimensional space and construct a global eigen-organ space from the distribution of training data in this space. The rest work of construction is same as the procedure in constructing local eigen-organ space.

### 2.3 Location Detection by Local Eigen-organs

After constructing eigen-organ spaces, the first loop of matching procedure can be started. First of all, we can define a threshold for skipping VOIs which have low possibility (range from 0 to 1) to contain the target organ. We use a probabilistic atlas of different organ type to do this task. The atlas is generated by the spatial existence probability of each type of organ. For

example, a location in liver region will have a higher value in probabilistic atlas of liver than other locations. VOIs from 3D abdomen CT are projected into each kind of local eigen-organ spaces. Next we reconstruct the VOI from the spaces and record the difference between the original VOI and its reconstructions. Then, we continue with the same process for next VOI. After each possible location has been scanned, the probabilistic atlas of corresponding organ is used again as weight parameters to the corresponding difference value. After the atlas information is applied, difference maps of each type of organ for the test image is generated. Then we select the local minimum locations from each difference map as the candidate locations for the corresponding organ.

### 2.4 Location Detection by Global Eigen-organs

To refine the true locations of organs from the candidate locations detected by local eigen-organs, we project every possible combination of different organs into the global eigen-organ space. As this space contains the relative location information among target organs, the true combination of locations should generate the minimum difference after reconstructing from the space. So we still compare the difference between the combination of different organ locations and its reconstruction from global eigen-organ space. Finally the combination with minimum difference is output as the locations of organs in the test image.

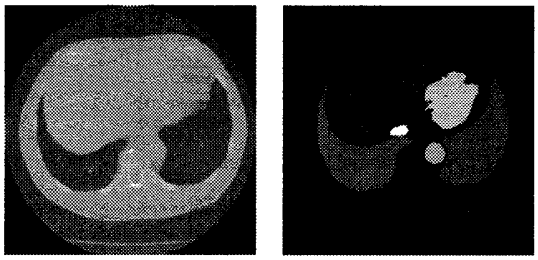

Fig.2 Left: a slice picked from one of the volumetric abdomen CT images. Right: its corresponding slice of the labeled image. Regions of liver, lung, and etc. are indicated by different labels

## 3 Experiments

### 3.1 Materials

We have five 3D abdomen CT images. They are normalized by the location of the top of diaphragm and kidneys. Their volumetric size is 512×512×(154~216). For computational convenience, we rescaled them to 85×85×100. We use all these images as the training set for construction of eigen-organ spaces and then evaluate the performance of proposed approach by same samples. We use ratio of coincidence as evaluation standard. It is defined by the ratio of intersection between volume at calculated location and that at true location, to their combination.

Comparing Fig.3.1 Fig.3.2 and Fig.3.3, we find matching accuracy is greatly improved by applying the probabilistic atlas. A slight improvement is also achieved after refining the candidate location by the global eigen-organs. By adjusting the threshold for atlas, computation time can be reduced from around 2 hour (disable the threshold) to about 2 minutes (threshold=0.9) with little influence of output accuracy.

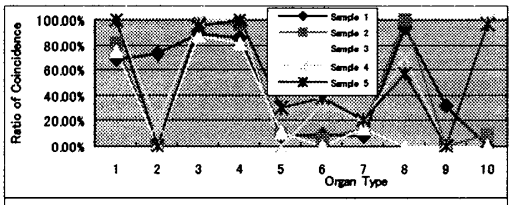


Fig.3.1

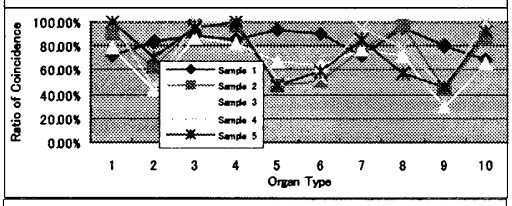


Fig.3.2

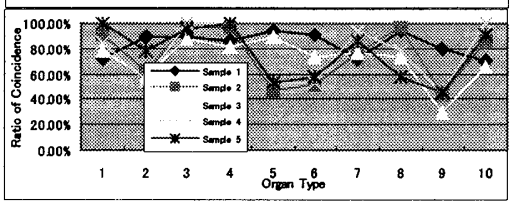


Fig.3.3

Fig.3.1 shows ratio of coincidence if the location of minimum difference is treated as matched location after detection by local eigen-organs. The average ratio is *44.53%*. Fig.3.2 shows the ratio after applying the atlas parameters. The average ratio is *75.41%*. Fig.3.3 shows the final ratio after location detection by global eigen-organs. The average ratio is *76.49%*.

## 4. Conclusions

Our proposed approach focuses on the principal components of the training image and ignores the trivial information. It combines both individual organ features and the entire abdomen spatial features together to generate a synthetic optimized matching result. We expect the proposed approach to be applied in pre-processing the locations of organs in multi-organ multi-disease CAD systems.

## Reference

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