# Image Registration Method for Chest MDCT Images Based on 2-D Finite Element Method

**Takuji Ogimoto, Tohru Kamiya**
*Department of Mechanical and Control Engineering, Kyushu Institute of Technology, 1-1 Sensui-cho, Tobata-ku, Kitakyushu-shi, Fukuoka, 804-8550, Japan*

**Takatoshi Aoki**
*University of Occupational and Environmental Health, 1-1, Iseigaoka, Yahatanishi, Kitakyusyu-shi 807-8555, Japan*

**Abstract**

Multi detector-row computed tomography (MDCT) device has been used for early detection of lung cancer. However, there is concern that an increase in the burden on doctors will be caused by improvements in CT performance. Therefore, developing a computer aided diagnosis (CAD) reduces the burden on doctors. A temporal subtraction (TS) technique is one of the CAD systems and it is the subtraction operation of the current image and the previous one of the same patients that emphasizes temporal changes. In the TS image, when the position of the current image and the previous image are misaligned, subtraction artifacts are remained. In this paper, we propose a registration method based on the 2-D finite element method (FEM). In our proposed method, to improve the high computed cost that is the biggest problem of the FEM, we introduce the 2D FEM registration. We applied this method to 31 series MDCT image sets which was obtained previous and current from the same subjects and evaluated. As a result, full width at half maximum (FWHM) of 28.0, artifact to lung volume ratio of 5.77% and computational time of 140 sec were obtained.

*Keywords*: Computer Aided Diagnosis System, Temporal Subtraction Technique, Non-Rigid Image Registration, Finite Element Method.

## 1. Introduction

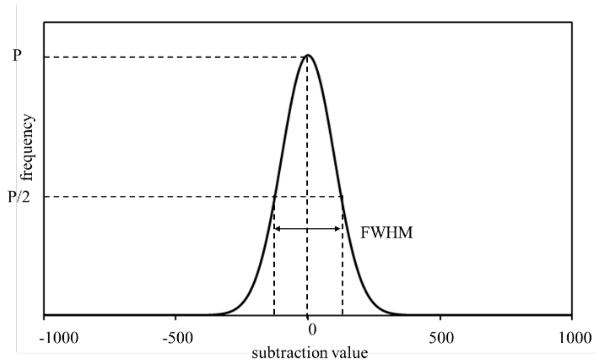
In recent years, multi detector-row computed tomography (MDCT) of the chest device has been used for the early detection of lung cancer. Chest MDCT images can detect lung cancer at an earlier and more curable stage than routine chest radiography. However, while MDCT images can be obtained in a short period of time and have a high resolution, there are problems that the frequency of CT scans and the number of images increase. To solve these problems, computer aided diagnosis (CAD) has been attracting attention. The results of the analysis by the CAD system are provided to the radiologists as a "second opinion" [1]. By using the CAD system, it is expected to shorten the time required to make a diagnosis and eliminate the variability in diagnosis by doctors. In this paper, we propose a registration method for the generation of temporal subtraction (TS) images from CT images of the chest, which is a CAD system. A TS technique is the subtraction operation of the current image and the previous one of the same patients and emphasizes temporal changes [2]. The TS technique can emphasize interval changes such as new lesion shadows and shape changes in the current image by removing the normal structures (blood vessels, bones, muscles etc.) that appear in both images that do not change much over time. Such a technique has been shown to be effective in detecting nodular shadows by physicians in a clinical evaluation experiment [3].

In general, subtraction artifact in TS images is a normal structure that remains in the temporal subtraction image without being erased by the differencing process. Also, artifacts can be caused by misalignment between current and past images. Misalignment is caused by various factors such as the photographic equipment and the photographic environment. Therefore, we can obtain a subtraction image in which the normal structure is removed and only the abnormal structure is emphasized by deforming the previous image to the current image and computed the difference between the two images. Such an image registration technique is necessary to generate the TS images.

In this paper, we propose a registration method for reducing the subtraction artifacts on TS image by using the finite element method (FEM). In a previous study [4], to reduce the computational cost (processing time and memory) required for the FEM registration use other simple alignment methods [5] for generating a temporal difference image. After that a local matching technique was performed on to the high-density regions (i.e., abnormal regions or subtraction artifacts) on the TS images. In this paper, to further reduce the computational cost compared to the previous studies, we applied 2-D FEM to each slice instead of 3-D FEM to reduce the computational cost. This can be expected to reduce the processing time and to generate highly accurate TS images. In our experiments, we apply the proposed method to chest MDCT images and verify its effectiveness in terms of both positioning accuracy and calculation time.

## 2. Proposed Method

Our proposed method consists of three major phases: create an initial temporal subtraction image, mesh of triangle elements, 2-D FEM registration for final subtraction image. Flow is shown in Fig 1. In the first phase, extract the regions to be aligned using the temporal subtraction technique. In the second phase, create the mesh for FEM for the extracted regions. In the final phase, 2-D FEM registration is performed.




### 2.1. *Initial temporal subtraction image*

Itai et al. [5] proposed a method based on voxel matching technique for creating a temporal subtraction image. In this study, to reduce the computational time, we made an initial subtraction image based on voxel matching technique. In general, when we implement the FEM technique on the image for registration, it required computational time. To avoid this problem, we performed the FEM technique on the initial subtraction areas.

### 2.2. *Creating the mesh of triangle elements*

We set the region of interest (ROI) around the detected regions on initial temporal subtraction image that meets the conditions. The conditions are the subtraction value is 200 over and volume is over 50mm$^3$. We installed node point at equal intervals and created tetrahedron elements by using Delaunay triangulation [6].

### 2.3. *Creating the final subtraction image*

Ferrant et al. [7] proposed a registration method using FEM. They expressed potential energy E as:

$$E = \int_{\Omega} \sigma^T \cdot \epsilon d\Omega - \int_{\Omega} [I_1(x+\delta(x)) - I_2(x)]^2 d\Omega. \qquad (1)$$

where $\Omega$ is the body on which one is working, $\sigma$ is the stress vector, $\epsilon$ is the strain vector, $I_1$ is deformation image, $\delta$ is displacement vector, and $I_2$ is current image, respectively.

From principle of minimum potential energy, they sought minimum of this function by solving $\frac{\partial E}{\partial \delta} = 0$. Eq. (1) then becomes:

$$(\boldsymbol{K}+\boldsymbol{G})\boldsymbol{\delta}=\boldsymbol{P}. \quad (2)$$

Matrix $\boldsymbol{K}$, $\boldsymbol{G}$, and $\boldsymbol{P}$ are defined as follows: $\boldsymbol{K}=\int_{\Omega} \boldsymbol{B}^T\boldsymbol{D}^T\boldsymbol{B}\, d\Omega$, $G=\int_{\Omega} \boldsymbol{N}^T\, \nabla \boldsymbol{I}_1^T \nabla \boldsymbol{I}_1 \boldsymbol{N} d\Omega$, and $\boldsymbol{P}=\int_{\Omega} (I_1-I_2)\nabla \boldsymbol{I}_1 \boldsymbol{N} d\Omega$ ; where $\boldsymbol{B}$ is strain displacement function, $\boldsymbol{D}$ is D matrix, $N$ is shape function. By solving Eq. (2), the displacements of all nodes are determined and the displacements inside the elements are determined. Then we obtained warped images. We performed FEM registration on a slice by slice to reduce the computational cost.

## 3. Result

In this paper, we evaluated the performance of the image registration method using the 2-D FEM. Two experiments were conducted. Experiment 1 confirmed the effectiveness of the method using synthetic data. In Experiment 2, previous and current chest CT of the same subject were set as a set and registration processing was performed.

### 3.1. *Quantitative evaluation on synthetic data*

We confirmed the effectiveness of the method using synthetic data. The previous image is rotated by 5 degrees to become the current image, and the previous image is warped and registered to create the temporal subtraction image.

As the evaluation method, Full Width at Half Maximum (FWHM) and subtraction artifact to lung volume ration were used. FWHM represents the spread of the histogram and smaller values of FWHM indicate fewer artifacts. The offset width is 71. An example of a concentration histogram is shown in Fig. 2.

In the experiment, we applied this method to 31 cases. As a result of the experiment, FWHM: 12.1, artifact to lung volume ratio: 2.70%, cost time: 22sec were obtained. Table 1 shows the result.

### 3.2. *Quantitative evaluation on real data*

The previous and current chest CT of the same subject was set as one pair and the registration process was performed. We applied the proposed method to all 31 pairs and found the result. From Table 2, FWHM: 28.0, artifact to lung volume ratio: 5.77%, cost time: 140 were obtained.

## 4. Discussion and conclusion

In this study, we proposed a 2-D FEM registration. The result of the 2-D FEM registration method was obtained with FWHM: 28.0, artifact to lung volume ratio: 5.77%, cost time: 140sec. Table 2 shows the result of the previous method [4] and the proposed method. From the Table 2, the value of FWHM and artifact to lung volume ratio for the previous method and the proposed method is almost the same, and the proposed method reduces computational time. Therefore, the proposed method improved cost time without decreasing registration accuracy.

The previous method performed 3D-FEM registration and has high registration accuracy. So, we need to develop a more accurate registration method.

In this paper, we developed the registration method for chest MDCT images based on 2-D FEM. Our proposed method has three phases which are temporal subtraction technique, creation of the mesh of triangle elements, and registration based on 2-D FEM. We evaluated our method by FWHM and artifact to lung volume ratio, and cost time and obtained. Furthermore, the result

| | FWHM | Artifact to lung volume ratio [%] | Cost time [sec] |
|---|---|---|---|
| Previous method [4] | 28.1 | 5.70 | 228 |
| Proposed method | 28.0 | 5.77 | 140 |

Table 2 Experimental 2 result

FWHM:28.0, artifact to lung volume ratio: 5.77%, and cost time: 140 sec was obtained.

(a)previous image(b)rotated image (c)output image

Fig. 3 Experimental result: rotated image

(a)previous image (b)current image (c)output image

Fig.4 Experimental result

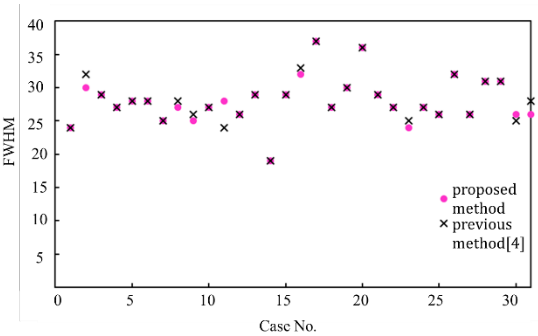



Fig. 5 Experimental 2 FWHM result

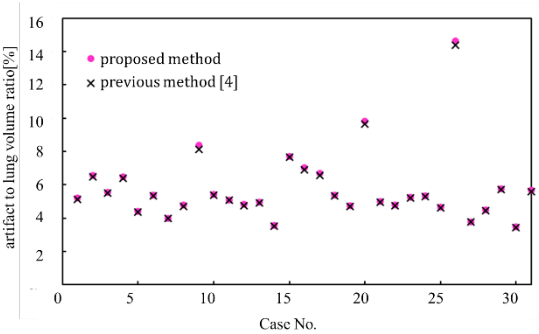



Fig. 6 Experimental 2 artifact to lung volume ratio result

Table 1 Experimental 1 results

| | FWHM | Artifact to lung volume ratio [%] | Cost time [sec] |
|---|---|---|---|
| Previous method [4] | 12.1 | 2.68 | 45 |
| Proposed method | 12.1 | 2.70 | 25 |

## References


1. K. Doi, Current status and future potential of computer-aided diagnosis in medical imaging, *British Journal of Radiology*, Vol. 78, pp. S3-S19, 2005.
2. A. Kano et al., Digital image subtraction of temporally sequential chest images for detection of interval change, *Medical Physics*, Vol. 21, No.3, pp.453-461, 1994.
3. T. Aoki et al., Temporal Subtraction Method for Lung Nodule Detection on Successive Thoracic CT Soft-Copy Images, *Radiology*, Vol. 27, No. 1, pp. 255-261, 2014.
4. S. Yamada et al., Three-dimensional non-rigid registration of thoracic CT image based on finite element method, Joint International Conference on Soft Computing and Intelligent Systems (SCIS) and International Symposium on Advanced Intelligent Systems (ISIS), pp. 1-6, 2014.
5. Y. Itai et al., Development of A Voxel Matching Technique For Substantial Reduction of Subtraction Artifacts in Temporal Subtraction Images Obtained from Thoracic MDCT, *Journal of Digital Imaging*, Vol. 23, No. 1, pp. 31-38, 2010.
6. L.P. Chew, Constrained Delaunay triangulations, *Algorithmica*, Vol. 4, No. 1, pp. 97-108, 1989.
7. M. Ferrant et al., 3D Image Matching Using a Finite Element Based Elastic Deformation Model, Lecture Notes in Computer Science, Vol. 1679, pp. 202-209, 1999.