SELECTED PAPER

Computer-Assisted System for Detecting Infiltration of Gastric Cancer

Hiroyuki Watabe[1], Toshiya Nakaguchi[2], Toshiyuki Natsume[3], Hiromichi Aoyama[3], Hiroshi Kawahira[4], Ahmed Afifi[5] and Norimichi Tsumura[5]

[1]Department of Information and Image Sciences,
Faculty of Engineering, Chiba University
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan

[2]Department of Medical System Engineering,
Graduate School of Engineering, Chiba University
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan

[3]Department of Frontier Surgery,
Graduate School of Medicine, Chiba University
1-8-1 Inohana, Chuo-ku, Chiba 260-0856, Japan

[4]Research Center for Frontier Medical Engineering,
Chiba University
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan

[5]Department of Informatics and Imaging Systems,
Graduate School of Advanced Integration Science, Chiba University,
1-33 Yayoi-cho, Inage-ku, Chiba 263-8522, Japan
Phone/Fax: +81-43-290-3296 E-mail: watabe@chiba-u.jp

Abstract

It is strongly required to determine the occurrence of infiltration between the stomach and neighboring organs from only information prior to surgery such as a computed tomography (CT) scan. In this study, we propose a new quantitative index to indicate the infiltration of gastric cancer by analyzing two CT images of the patient in different poses. The quantitative index of infiltration is obtained by calculating the relative movement of the stomach to the pancreas. To calculate this index, we perform three-step registration. Next, a displacement map around the pancreas and stomach is derived. To assist the diagnosis, the displacement map is illustrated with intensity and superposed onto the CT image. The proposed method was applied to eleven subjects and the efficacy of the proposed index was confirmed.

1. Introduction

Gastric cancer is one of the most serious diseases in Japan. The problem is that advanced gastric cancer infiltrates peripheral internal organs, causing the stomach to adhere to neighboring organs. In order to treat gastric cancer, it must be excised by a surgical operation. Because the procedure in this operation is determined by the occurrence of adhesion between the stomach and neighboring organs, the surgeon needs to establish this before surgery. It is, however, very difficult to detect infiltration from only advance information such as CT or magnetic resonance imaging (MRI) scans. Hence, the surgeon is frequently required to change the procedure in the surgery after opening the abdominal cavity. To overcome this problem, we propose a new quantitative index to indicate the infiltration of gastric cancer by analyzing two CT images of the patient in different poses. The quantitative index of infiltration is obtained by calculating the relative movement of the stomach to the pancreas. To calculate this index, we perform three-step registration. Next, a displacement map around the pancreas and stomach is derived. To assist the diagnosis, the displacement map is illustrated with intensity and superposed onto the CT image.

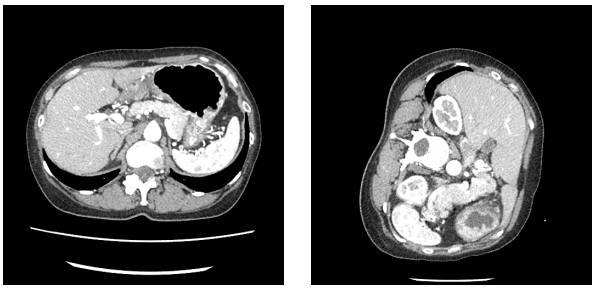
2. Proposed Method

2.1 Overview of the proposed method

In this study, two CT scans are taken of the patient in different poses. one in the supine position as shown in Figure 1(a) and the other in the lateral position as shown in Figure 1(b). Since the pancreas is one of the retroperitoneal organs, it hardly moves even if the patient changes from the supine to lateral position. On the other hand, since a normal stomach that has not infiltrated the pancreas can move easily, it moves significantly when the patient changes position. This means that by calculating the relative movement of the stomach to the pancreas, a quantitative index of infiltration can be obtained. To obtain this index, we perform three-step registration. Each step is implemented by utilizing the Insight toolkit [1]. Next, a displacement map around the pancreas and stomach is calculated. To assist the diagnosis, the displacement map is illustrated with intensity and superposed onto the CT image. Fig. 2 shows a flowchart of the proposed method.

2.2 Three-step registration

First step: The first step roughly registers the truncal position of the CT images taken at two positions using a marker-based registration method [2]. The markers are defined as the bifurcation points of the central artery, which are detected semiautomatically by analyzing an angiographic CT image. To obtain the markers, the central artery is extracted by the region growing method.



(a) (b)

Figure 1: Two CT scans taken of the patient in different poses: (a) Supine position, (b) Lateral position

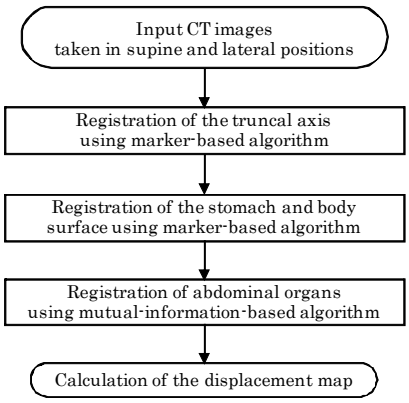
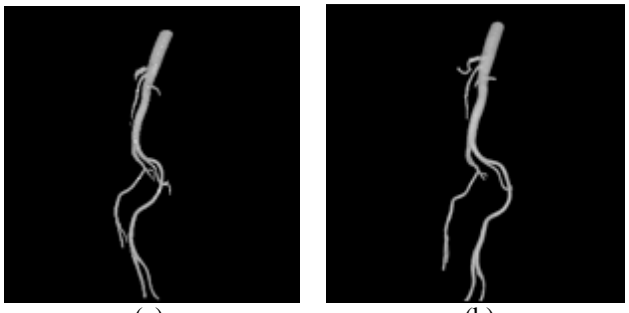


Figure 2: Flowchart to calculate the displacement map

The seed points are determined manually. Figures 3(a) and 3(b) show examples of a three-dimensionally reconstructed central artery. After that, the thinning of the extracted central artery is performed [3]. Figures 4(a) and 4(b) show rendered images of a three-dimensionally reconstructed and thinned central artery. Finally, the bifurcation points are determined using a 3×3×3 filter. The bifurcation points can be found by detecting the points with three or more branches extending outwards. Figures 5(a) and 5(b) show the bifurcation points of the central artery. Because the bifurcation points are not determined definitively, the correspondence of the bifurcation points between the supine and lateral positions is determined manually.

Second step: After the registration of the truncal axis in the first step, the second step of registration is performed at each slice. This step registers the luminal contour of the stomach and the body surface from the two CT images using the marker-based registration method. The markers used to register the stomach are defined as shown in Figure 6. The center point of the black line in Figure 6 is defined as the centroid of the gastric lumen. The gastric lumen is extracted by the region growing method and the seed points are determined manually. A marker on the contour of the gastric lumen is placed at the intersecting points of the black lines in Figure 6 and the contour. Supposing that the Y axial direction in the image is 0°, then the lines are drawn every 30 degree from 0° to 360°. In the same way, the markers on the body surface are defined by placing the center point of the line at the center of the image. A line is drawn every 10°. The white points in Figure 7 represent the markers used to register the luminal contour of the stomach and the body surface. The corresponding points are determined by the angle of the line.

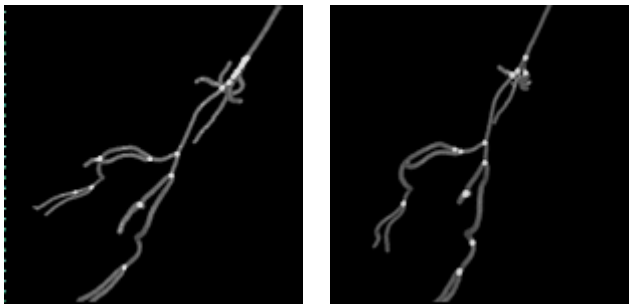


(a) (b)

Figure 3: Central artery extracted by region growing: (a) Supine position, (b) Lateral position

(a) (b)

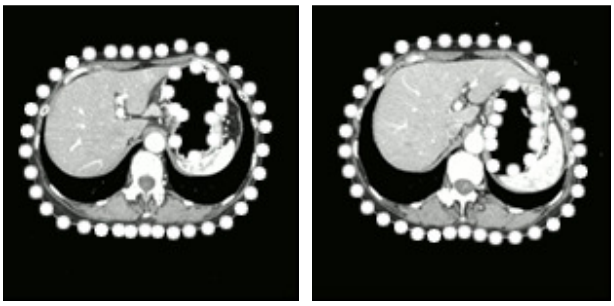
Figure 4: The thinning of the central artery is performed and then morphological dilation is performed: (a) Supine position, (b) Lateral position



(a) (b)

Figure 5: Bifurcation points of central artery: (a) Supine position, (b) Lateral position

Figure 6: Method of deciding Markers used for registering the gastric lumen.



(a) (b)

Figure 7: Placement of markers to register the gastric lumen and the body surface: (a) Supine position, (b) Lateral position

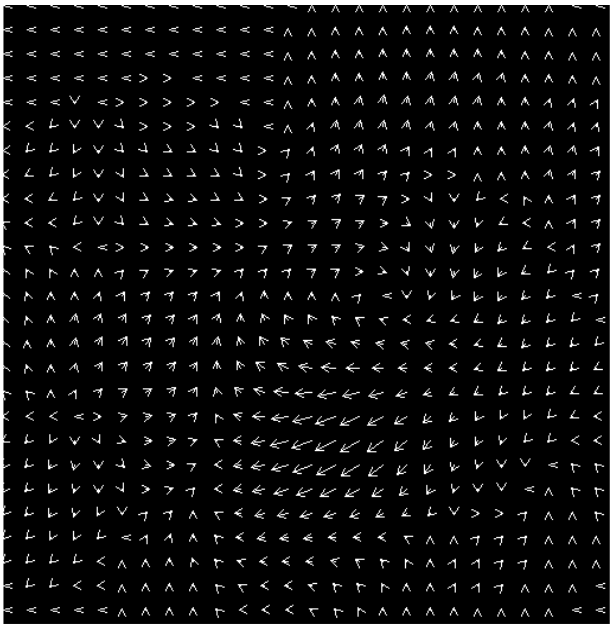


Figure 8: Displacement map represented by vectors

Table 1: Experimental results

Case #	Displacement of pancreas (mm)	Displacement of stomach (mm)	Difference in displacement (mm)	Matching
1	11.240	9.389	1.851	TP
2	9.175	10.747	-1.573	TP
3	9.820	6.797	3.023	TN
4	6.164	5.318	0.846	TP
5	10.540	8.393	2.147	TN
6	9.879	6.416	3.462	TN
7	12.439	9.322	3.116	FN
8	5.453	4.040	1.413	TP
9	8.889	10.071	-1.182	TP
10	4.069	3.213	0.856	FP
11	6.701	6.222	0.479	FP

Third step: The third step finely registers each abdominal organ in two CT images by using the image difference. The image difference is calculated by the mean square error of the window area. After the third step of registration, a displacement map can be obtained as shown in Figure 8 and illustrated as described earlier.

3. Experiments

By performing the three-step registration, the relative movement of the pancreas to the stomach can be obtained, which is expected to indicate the presence of infiltration. Figures 9 and 10 show the displacement map and the results of registration. Figure 9(h) shows that the displacement (represented by intensity) around the pancreas is larger than that around the stomach. This means that in the case shown in Figure 9 there is no evidence of infiltration. In contrast, Figure 10(h) shows a case in which the pancreas is displaced as much as the stomach. This means that infiltration is suspected to have occurred in the case shown in Figure 10. The proposed method was applied to eleven cases and the results are listed in Table 1. Calculating the difference in displacement between the pancreas and stomach, the criterion is experimentally given as 2mm, which means that when the difference in displacement is less than 2mm, the stomach is suspected of infiltration. Using this criterion, we investigated the efficacy of the proposed index in comparison with autopsy reports by a doctor. We obtained eight cases (73%) of correctly determined infiltration (TP+TN), two cases of false positive (FP) identification and one of false negative (FN) as shown in the right column of Table 1.

4. Conclusions

In this study, we have proposed the use of a displacement map and a new index to determine the infiltration of gastric cancer for assisting the diagnosis before the surgery. The displacement map was calculated by the three-step registration of two CT images. From the comparison with autopsy reports, we confirmed that by using the proposed displacement map, the relative movement of each organ is obtained easily and can be used to detect infiltration. In the future, we need to improve the accuracy of the registration and investigate the clinical efficiency of this method by considering more cases.

References

[1] L. Ibanez, W. Schroeder, L. Ng and J. Cates: The ITK Software Guide, Kitware, Inc., 2003.

[2] R. Sprengel, K. Rohr and H. Stiehl: Thin-plate spline approximation for image registration, Eng. Med. and Biol. Soc., Vol. 3, pp. 1190–1191, 1996.

[3] T. Saito and J. Toriwaki: A sequential thinning algorithm for three dimensional digital pictures using the Euclidean distance transformation, Proc. 9th Scandinavian Conf. Image Analysis, pp. 507–51, 1995.

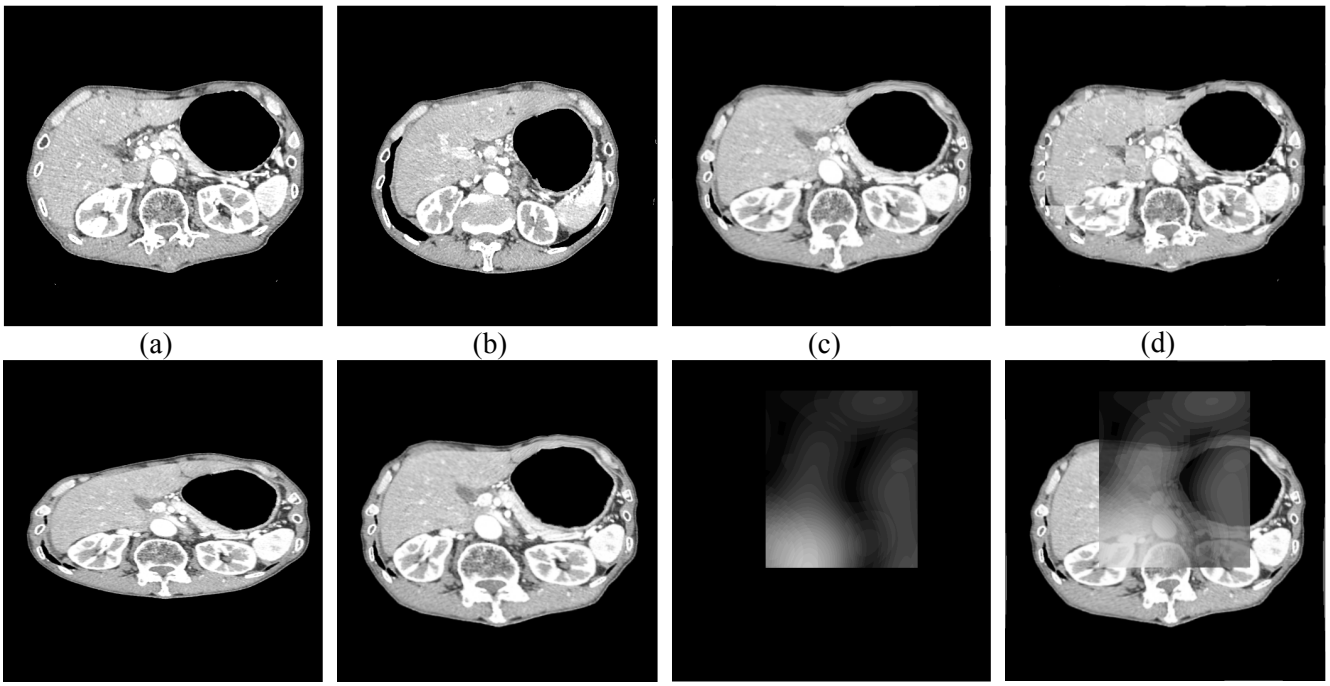


Figure 9: Results of three-step registration and the displacement map (slice number 86 in case #10): (a) CT image taken in supine position, (b) CT image taken in lateral position, (c) Result of the third step of registration, (d) Checkerboard comparison of (b) and (c), (e) Result of the first step of registration, (f) Result of the second step of registration, (g) Displacement map around the pancreas and stomach, (h) Displacement map superposed onto (f)

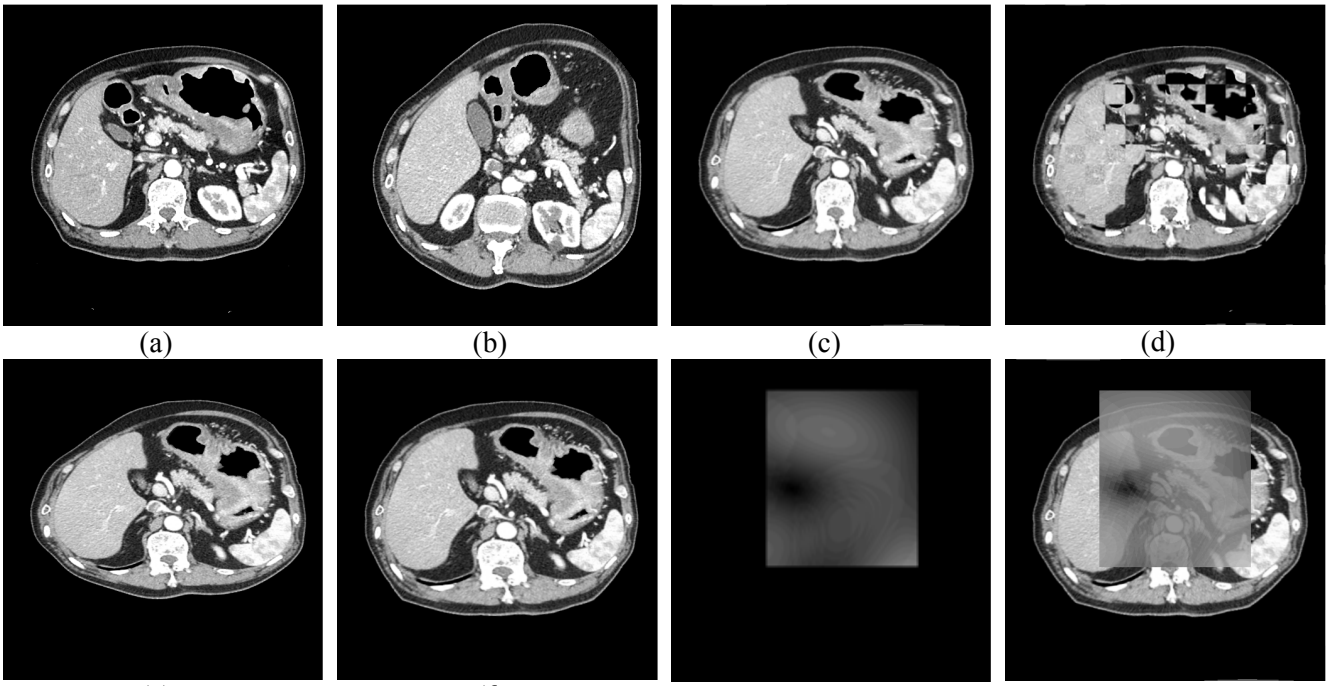


Figure 10: Results of three-step registration and the displacement map (slice number 92 in case #9): (a) CT image taken in supine position, (b) CT image taken in lateral position, (c) Result of the third step of registration, (d) Checkerboard comparison of (b) and (c), (e) Result of the first step of registration, (f) Result of the second step of registration, (g) Displacement map around the pancreas and stomach, (h) Displacement map superposed onto (f)