The Development of Pancreatic Cancer CAD System for CT and US Images

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Abstract— **The pancreatic cancer is extremely fatal. Due to limitations of anatomic location and condition, physicians are hard to make precise diagnoses of patients from traditional ultrasound (US) or CT images. The purpose of this study is to develop a computer-aided diagnosis (CAD) system for pancreatic tumor by the selected features from CT and US images. In this study, the following steps are included: (1) Segment images by applying GVF SNAKE; (2) Select features by applying t-Test; (3) Identify normal tissues, adenocarcinoma tumors, pseudo tumors, cystic tumors, and pseudo cyst by SVM and SOM for CT and US images, respectively. (4) Finally, totally diagnosed 69 US images and 136 CT images were used to evaluate system performance. In order to improve this system, different numbers of features were selected in three different stages for CT and US images. The results show this CAD system has the best performance to identify all images by applying 2 features (Area, NRL_MA) and 4 features (l_Average, g_Entropy, c_Entropy, Area) in US images and contrast injected CT images, respectively. Moreover, the tumor area is the most important morphological feature for tumor classification in US images and the adenocarcinoma tumor has lower value of "Entropy" in contrast injected CT images. In most cases, the performance (sensitivity, specificity, and accuracy are higher than 0.9) of this developed system is good enough for clinical study. However, US CAD system and CT CAD system have better performances on identifying tiny pancreatitis tumors and cystic tumors, respectively. We suggest physicians to diagnose tumors by the aid of US CAD system, and diagnose cysts by CT CAD system; consequently, reduce cost and improve the diagnostic accuracy.**

Keywords— **Pancreatic cancer, Ultrasound images, CT images, CAD system, Image processing.**

I. Introduction

Pancreas is an important organ in digestive system; however, owing to the physiological location, it is hard for physicians to diagnose. In addition, different kinds of pancreatic tumors, its fatality, severity, treatment effect are all different; what's more, the patients with pancreatic cysts are more predisposed to pancreatic cancers. Nowadays, abdominal ultrasound (US) and computed tomography (CT) are the most two common ways for physicians to make diagnosis.

According to the prior research, the pancreatic tumors in CT images tend to have the distinguishable textural features in both CT images with and without contrast injection, which may allow us to reduce the contrast injection for patients. On the other hand, the morphological features are a lot distinguishable in US images, which tend to be regarded as a criterion for identifying malignant tumors from benign tumors by the surface area and the edge roughness [1]. In general, morphological features are a lot significant than textural features when classifying images.

In this study, we utilized some image processing technologies to reduce the errors of image segmentation; besides, improved the diagnostic performance of the system; furthermore, reduce the probability of injection contrast for patients.

II. Materials and methods

The database had total 205 pathologically proven digital images of pancreas. It included 69 US images (13 normal tissue, 18 Adenocarcinoma tumor, 6 Pancreatitis pseudo-tumor, 23 Cystic tumor, and 9 Pancreatitis pseudo-cyst), 68 CT images (6 normal tissue, 12 Adenocarcinoma tumor, 3 Pancreatitis pseudo-tumor, 16 Cystic tumor, and 31 Pancreatitis pseudo-cyst), and 69 injected contrast medium CT (IcmCT) images (6 normal tissue, 10 Adenocarcinoma tumor, 6 Pancreatitis pseudo-tumor, 13 Cystic tumor, and 33 Pancreatitis pseudo-cyst) were used to develop and evaluate this CAD system, respectively. The image format and resolution of each US image was 24 bits and 640×480 pixels; each CT image was 8 bits and 512×512 pixels.

The proposed image processing flowchart in this study was shown in Figure 1. First of all, we separated our flow chart into CT images and US images, inspecting pancreatic tumors by CT and US CAD systems, respectively. In order to save time for system operation, an experienced physician has manually extracted the region of interest (ROI) sub image in an US or CT image with/without image processed. Each step is described as follow:

(1)Preprocessing: We utilized median filter and histogram equalization to get rid of the noises in CT images and US images, respectively. In consequence, we are able to gain some information that we can't get it from the original images [2].

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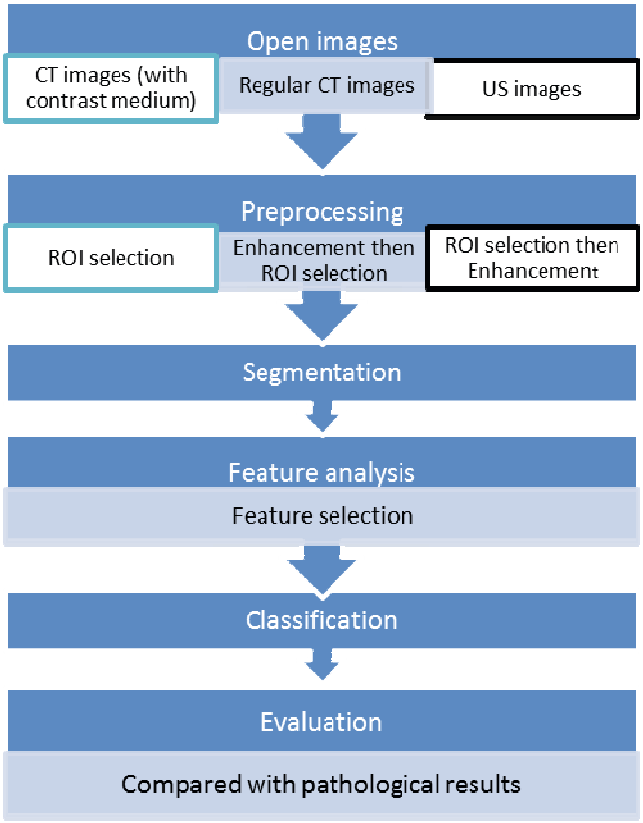

Fig.1 Proposed system development flowchart

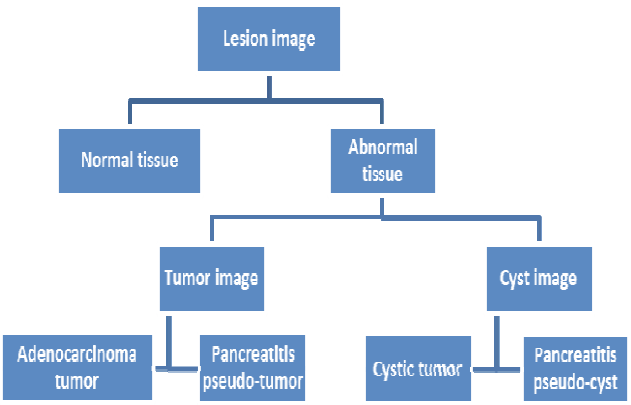

Fig. 2 Proposed image classification flowcharts

(2) Image segmentation: The Gradient Vector Flow Snake method was used to segment the tumors images and also avoids the edge discontinuousness as well as contours noises; in consequence, get the features of tumors [3].
(3) Feature analysis: According to our prior research, figure out the significant features in both CT and US images by applying t-test is an effective approach for identifying different kinds of tumors. In this study, we categorized pancreas tumors into adenocarcinoma tumor; pancreatitis pseudo-tumor, cystic tumor, and pancreatitis pseudo-cyst (see Figure 2). And the statistically effective features ($p < 0.05$) were selected and tested for image classification.
(4) Classification: Support Vector Machines (SVM), Self-Organizing Map (SOM) were used for classifying tumors in CT images and US images, respectively. In addition, there are three stages in our classification such as (1) stage 1: identify the tumors from the normal tissues; (2) stage 2: identify the cysts from the tumors; (3) stage 3: identify the adenocarcinoma tumors from pancreatitis pseudo-tumors, and the cystic tumors from the pancreatitis pseudo-cysts.
(5) Evaluation: Finally, system was test and evaluated by using train set and test set method and comparing with pathological results of patients. When it comes to system evaluation, Kappa value must be more than 0.4 which is reliable. Moreover, we also compared the results of CT images with/without contrast injection, in order to provide the information which may lead to reduce the needs of injecting medical contrast medium into patients.

III. Results and Discussion

A. Results for CT CAD system

First of all, we separated CT images into CT images with contrast injection and CT images without contrast injection, and ROI was picked shown as Figure 3 and 4. In this study, we utilized features as l_Average, c_Average, g_Entropy, c_Entropy, Area, Lesion_Entropy, and Lesion_Mean to identify the tumors in the CT images with contrast injection. It turned out that Accuracy is 0.9354, shown in Table 1[4].

On the other hand, we utilized l_Average, g_Entropy, c_Entropy, Area to identify tumors in CT images, it turned out that accuracy is 0.9677, shown in Table 2. And the time cost to classify an image in different Stages is shown in Table 3.

In three different stages, the features of l_Average, g_Entropy, c_Entropy, Area should be taken into account first. Lower l_Average means the edge of tumor is smoother; furthermore, the tumor is more likely to be benign.

On the contrary, the edge of tumor is rougher; the tumor is more likely to be malignant. Besides, Entropy means the variety of the grayscale; physiologically, it shows the structures of our body. To a certain extent, Entropy can tell the tumors from the normal tissues. In general, the normal tissues tend to be with lower entropies, and different kinds of tumors are with various entropies as well. In addition, Area means the surface area of a tumor which is a helpful criterion for telling a tumor, as shown in Table 4.

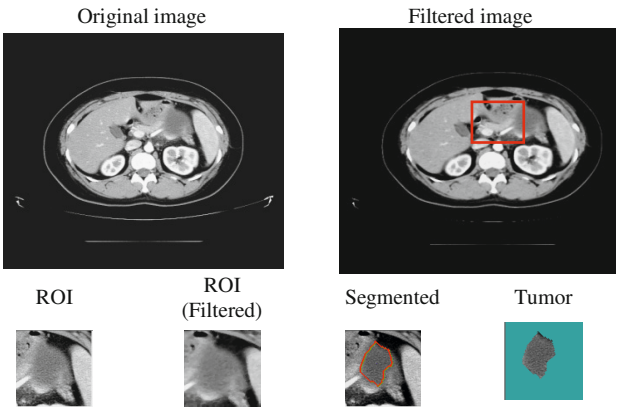

Fig. 3 The ROI of CT images without contrast injection

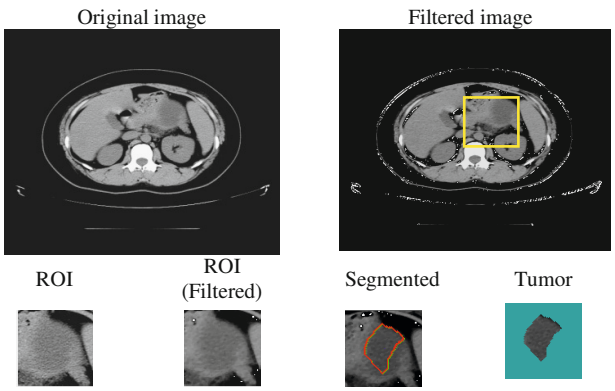

Fig. 4 The ROI of CT images with contrast injection

Table 1 System evaluation on CT images with contrast injection

	Accuracy	Sensitivity	Specificity	Kappa
Stage1	1	1	1	1
Stage2	0.96	0.87	1	0.91
Stage3(Tumors)	1	1	1	1
Stage3(Cysts)	0.95	1	0.94	0.89

Table 2 System evaluation on CT images without contrast injection

	Accuracy	Sensitivity	Specificity	Kappa
Stage1	1	1	1	1
Stage2	0.93	0.71	1	0.79
Stage3(Tumors)	1	1	1	1
Stage3(Cysts)	1	1	1	1

Table 3 Single cycle time of SVM classification

CT images	with contrast injection	without injection
	Single cycle time(sec)	
Stage 1	13	12
Stage 2	12	11
Stage 3	11	10

Table 4 Significant features for CT images

Features	Contrast injection	Max	Min	Mean
***I*_Average**	With	87.94	17.23	28.0
	Without	88.20	18.36	27.96
***g*_Entropy**	With	9.09	6.77	7.26
	Without	9.05	6.69	7.18
***c*_Entropy**	With	9.15	6.75	7.29
	Without	9.12	7.29	7.23
Area	With	23683	811	2511
	Without	23693	1023	2537

B. Results for US CAD system

Secondly, we disposed US images by means of histogram equalization to enhance the contrast of the US images, shown in Fig 5. Accordingly, we separated US images into US images with preprocess and without preprocess as well.

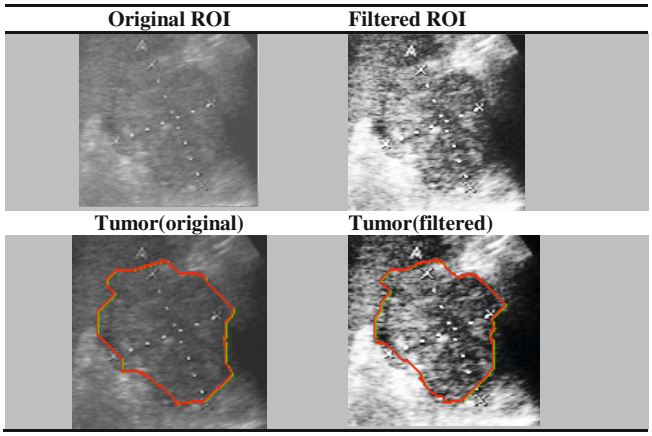

Fig. 5 The result of preprocessed US image

Table 5 Significant features for US images

Stage	Features						
1	Ori.	Area	Circu.	Mean	M.A	R.I	Skew
	Pre.	Area	Circu.	Mean	M.A	R.I	
2	Ori.	Area	Circu.	S.D.	M.A	R.I	
	Pre.	Area	Circu.	S.D.	M.A	R.I	
3 (tumors)	Ori.	Area	Circu.	M.A	R.I		
	Pre.	Area	Circu.	M.A	R.I		
3 (cysts)	Ori.	Area	Mean	S.D.	M.A		
	Pre.	Area	Mean	S.D.	M.A	R.I	

Table 6 System evaluation on US images without preprocess

	Accuracy	Sensitivity	Specificity	Kappa
Stage1	0.957	0.964	0.923	0.862
Stage2	0.946	0.958	0.938	0.891
Stage3(Tumors)	0.875	0.889	0.833	0.684
Stage3(Cysts)	1.000	1.000	1.000	1.000

Table 7 System evaluation on US images with preprocess

	Accuracy	Sensitivity	Specificity	Kappa
Stage1	0.942	0.964	0.846	0.810
Stage2	0.929	0.917	0.938	0.854
Stage3(Tumors)	0.917	0.944	0.833	0.778
Stage3(Cysts)	1.000	1.000	1.000	1.000

After that, we utilized 5, 5, 4, and 4 features in stage1, 2, 3(tumors), 3(cysts), respectively, shown in Table 5. It turned out that the evaluation of US images with and without preprocess are shown in Table 6 and 7. Moreover, it takes 40, 32, and 27 sec in stage 1, 2, and 3, respectively.

In 3 different stages, the features of Area, Circularity, Mean-Area, and Roughness-Index should be taken into account first. According to the clinical experience, a tumor with larger surface area is more likely to be a malignant tumor, vice versa. Besides, a benign tumor tends to be well-rounded, i.e. the circularity should be approximately 1; furthermore, a benign tumor tends to be smooth, i.e. the roughness-index should be as lower as possible. In consequence, our research result definitely matches the clinical experience.

C. Comparison for different modality

Compared the result of CT and US CAD system, their preprocessing process and significant features are not similar, due to their different imaging process.

In 3 classification stages; by comparison, the evaluation of CT CAD on stage2 (tumors and cysts) is a little lower than US CAD system, the overall evaluation, however, both CT and US CAD system are acceptable, shown in Table 8.

According to the physician's advice, it is better to use US images for telling the tiny lesion; on the contrary, it is better to use CT images for telling the tumors with the larger scale.

Table 8 Comparison of CT and US CAD system

Stage	Image types		Sens.	Spec.	Acc.	Kappa
1	CT	with	1	1	1	1
		without	1	1	1	1
		US	0.911	0.846	0.899	0.695
2	CT	With	0.87	1	0.96	0.91
		with-out	0.714	1	0.93	0.79
		US	0.91	0.846	0.92	0.85
3 (tumors)	CT	With	1	1	1	1
		without	1	1	1	1
		US	0.88	0.83	0.87	0.68
3 (cysts)	CT	With	1	0.94	0.95	0.80
		without	1	1	1	1
		US	0.95	1	0.96	0.92

The result of our research matches the clinical experience; therefore, we suggest physicians to use US for identifying the solid tumors; on the other hand, to use CT for identifying cysts in order to both reduce the waste of medical resource and make the diagnosis more precisely.

IV. Conclusion

In this study, a CAD system is developed for enhancing images and providing doctors with reliable features as well as information. Textural and morphological features were utilized to analyze pancreas CT images; furthermore, we enhanced the images by preprocess for the sake of reducing the probability of injecting contrast for patients. We also figured out that the morphological features in US images are more significant than the textural features. According to our result, there are both 4 features are significant in CT and US images.

With the CAD systems that we developed, physicians are able to make diagnoses more precisely and avoid misdiagnoses; moreover, to combine the other kinds of medical images in the future to improve the medical quality is possible in the near future.

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References

[1] Jenn-Lung Su, The Development of CAD system for Pancreatic Tumors, NSC Projects Final Report, 2010, NSC99-2221-E-033-040.

[2] Sha-Kang Mou, Digital Image Processing, Pearson Education, Taipei, 2003: 373-385.

[3] Krit Somkantha, Nipon Theera-Umpon, and Sansanee Auephanwiriyakul, "Boundary detection in medical images using edge following algorithm based on intensity gradient and texture gradient features," *IEEE Transactions on Biomedical Engineering*, 2011, 58(3): 567-573.

[4] Yu Guan-Wen Chen, The Development of Computer-Aided Diagnosis System for Pancreatic Tumor Recognition, *Master Thesis*, Department of Biomedical Engineering, CYCU, Chung-Li, 2015.

[5] Yu-Chieh Hsu, The Development of Computer Aided Diagnosis System for Pancreatic Tumor Recognition in Ultrasound Images, *Master Thesis*, Department of Biomedical Engineering, CYCU, Chung-Li, 2015

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