Medical Image Processing and Computer-Aided Detection/Diagnosis (CAD)

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Abstract

Computer-aided detection/diagnosis (CAD) is emerging as an innovative interdisciplinary technology for medical service. The traditional concept of automated computer diagnosis is encountered with a significant barrier because computerized medical systems cannot fully replace human doctors with the comparable level of performance. By contrast, CAD is becoming widely adopted in clinical work because it offers complementary computing power to enhance doctor's competence for medical examination. 4 state-of-the-art CAD technologies were presented in the special session of medical image processing and CAD at ICCH 2012 as reported in this short paper. Those technologies will be briefly introduced here to show the current trend of development of CAD and to demonstrate how CAD helps in medical care.

1. Introduction

Computer-aided detection/diagnosis (CAD) is emerging as an innovative interdisciplinary technology for medical service. The traditional concept of automated computer diagnosis is encountered with a significant barrier because computerized medical systems cannot fully replace human doctors with the comparable level of performance. By contrast, CAD is becoming widely adopted in clinical work because it offers complementary computing power to enhance doctor's competence for medical examination.

With the development of medical imaging processing technologies, the role played by CAD in medical care become more and more important. 4 state-of-the-art CAD technologies were presented in the special session of medical image processing and CAD at ICCH 2012 as reported in this short paper. Those technologies will be briefly introduced in section 2~5 to show the current trend of development of CAD and to demonstrate how CAD helps in medical care of arteriosclerosis, pancreas diseases, lung diseases, and other systemic diseases.

2. Carotid 4D-shape Reconstruction

Early detection of arteriosclerosis is very important because arteriosclerosis sometimes causes cerebral infarction, myocardial infarction, and angina pectoris. In order to diagnose arteriosclerosis, three dimensional observation of the inner wall of carotid artery is very effective. Furthermore, four dimensional visualization of carotid artery including three special axes and one temporal axis is expected to give more information related to arteriosclerosis because carotid artery has systaltic movement [1, 2].

2.1 Recordings

The ultrasonograph used for this experiment is the SonoAce PICO, produced by Medison Co. Ltd., Japan. A linear type probe (7.5MHz) for ultrasonic waves is firmly set on an electromotive slider (EZS3D010M-K) controlled by a linear motion controller (ESMC-K; ORIENTAL MOTOR Co., Ltd.). It is placed on the right side of the carotid artery of a subject to capture a B-mode minor axis cross-section image. The B-mode image is also outputted from the video output terminal of the ultrasonograph. The image is subsequently sent to the computer as IEEE1394 (i.Link/DV) digital data after it is captured by the DV converter (ADVC-300; CANOPUS Co., Ltd.) as a video image. The size of the recorded video images is 540 pixels in the horizontal direction (x-axis) and 420 pixels in the vertical direction (y-axis) and 120 frames in the temporal direction (t-axis). The resolution of the video images is 0.0713 mm/pixel specially and 30 frames/s temporally. Such recording is performed for every z points with 2 mm interval among 50 mm of measurement width, including the branching parts; z-axis is defined as the orientation along with carotid artery running.

2.2 Subjects

The subject chosen for this study was 22-year-old man. The chin of subject positioned at the fixed setting. The probe was set on the upper part of the carotid artery. The subject was requested to maintain that position with only normal breathing allowed. However, the subject refrains from both conscious salivation to swallowing and even the slightest muscular movement during 4(s) for capturing images.

2.3 4D Reconstruction method

4D-data denoted as I(x,y,z,t) from the all obtained video images I(x,y,t) for each z point are reconstructed. In the reconstruction, the t-axis was adjusted such that the first diastolic point in the systolic movement of carotid artery was set to be the origin (t=0). The measurement was performed for z=0,2,4,…, 58 (mm).

The x-, y-axes was adjusted such that tissue surrounding carotid artery fitted most property among the video images I(x,y,t) at each z point because fixation of probe might be imperfect or the subject might move slightly. Furthermore, one dimensional interpolation was performed along z-axis because I(x,y,t) is anisotropic data, that is, the resolution in the z-axis is very low compared to those in the x-, y-axes. The inner wall of carotid artery in the 4D-data I(x,y,z,t) at each t is detected, then the surface of the carotid artery was represented as many trigon patches to applying a surface rendering technique.

2.4 Results

Figures 1(a) and 1(b) show the estimated carotid surfaces at a diastolic phase, i.e., t=0, and a systolic phase, respectively. Carotid artery has the shape that common carotid artery branches into both inner and outer carotid arteries. Figures 1 represent such the branching carotid shape very well.

Furthermore, it is shown that the diameter of the carotid artery at a diastolic phase is small, and otherwise the diameter of that at a systolic phase is large. In order to inspect inner carotid surface, the cleaved visualization of carotid surface is useful. Figures 1(c) and 1(d) show the cleaved carotid surface at a diastolic and a systolic phase, respectively. If there are some plaques, they could be observed the plaques in these figures, though there are no plaques actually because the subject is 22 years old healthy man.

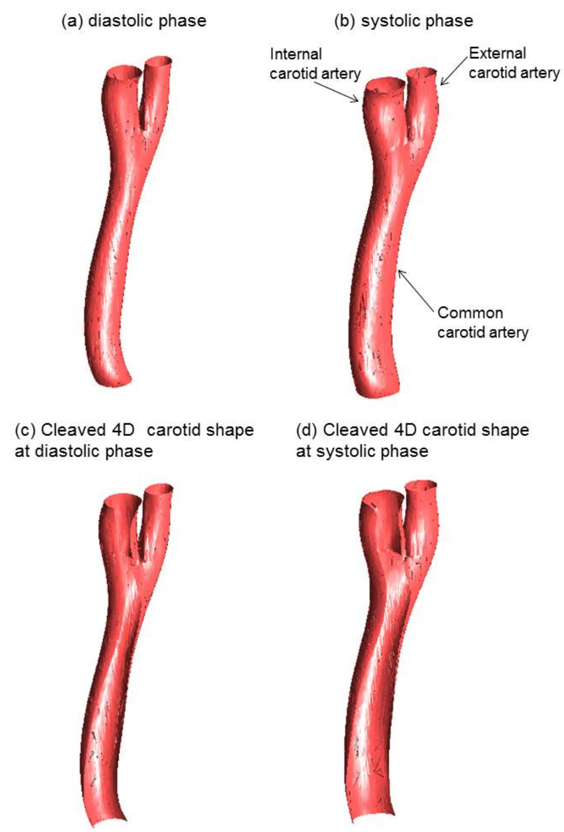

Figure 1 4D carotid shape at the diastolic and systolic phase.

3. Modeling and Classification of Pancreas

3.1 Method

This research proposes a pancreas modeling and classification method based on statistical shape model (SSM) and fractal tensor with the theoretical basis of computational anatomy, fractal theory and tensor theory. The proposed method mainly consists of three parts: (1) Pancreas modeling based on the level set method guided by the SSM; (2) Fractal apparent modeling of pancreas based on the generalized N-dimensional principal component analysis (GND-PCA) and the fractal theory; (3) Construction of the classifier for the pancreas diseases diagnose.

There are four parts in the modeling of pancreas: (1) Segmentation pancreas accurately from many groups of abdomen medical images based on human-computer interaction method under the direction of a doctor, and construct training samples; (2) Normalized the training samples; (3) Construct the statistical shape model of pancreas based on the PCA method, and generate average shape and mode that can indicate individual specificity; (4) Serve the average shape as the zero level set, and conduct image segmentation based on the level set method to obtain the pancreas region.

During the construction of pancreas fractal apparent model, the fractal features are extracted, shape features and texture features from an image to construct generalized high order tensor; then, fractal apparent model is constructed based on the GND-PCA approach.

In the part of construction for the pancreas disease classifier, theories of fisher, SVM and ACO-SVM are used to construct pancreas disease classifier, and a final classification is implemented based on the voting method.

3.2 Results

Experimental data is 60 sets abdominal CT image obtained from a large hospital in Shenyang of China, among them, 40 sets are served as training sample and 20 sets are acted as test sample. The training sample consists of 20 sets of normal data and 20 sets of abnormal data, while the test sample is composed of 10 sets of normal data and 10 sets of abnormal data.

A pancreas segmentation based on the level set method guided by the SSM conducted to improve the segmentation accuracy. The segmentation result is shown in Fig. 2.

Figure 2. The result of pancreas segmentation

In order to improve the classification performance, the GND-PCA approach is firstly used to construct the fractal apparent model and to obtain features; then, the theories of fisher, SVM and ACO-SVM are used to construct classifiers respectively for conducting an initial recognition; lastly, a voting is conducted to the three classifiers to get a final recognition result. The abnormal pancreas classification result is shown in Fig. 3, which shows that the performance of ACO-SVM classifier is obviously better than that of the fisher classifier and the SVM classifier, and the classification performance is further improved by fusing and voting operation to the classifiers.

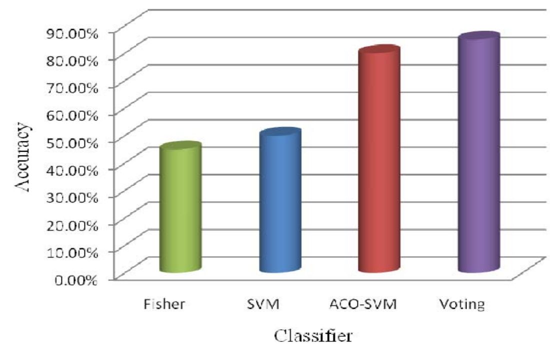

Figure 3. The results of pancreas classification

4. Quantitative Imaging in Diffuse Lung Diseases

Computer-aided diagnosis (CAD) algorithms using three-dimensional thoracic CT images have been developed. There are two targets in the development of CAD algorithms for pulmonary diseases. One is CAD for localized pulmonary diseases. In this target, CAD for pulmonary nodule detection is important and many algorithms are published. The other is CAD for diffuse lung diseases. This target includes many kinds of diseases and variety of texture patterns. In the CAD for diffuse lung diseases, morphological and functional viewpoints are important.

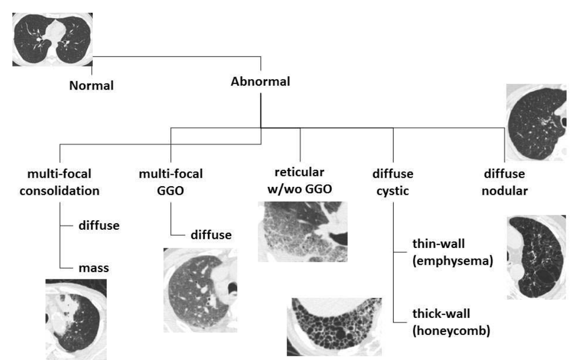

Figure 4. The patterns of diffuse lung diseases to be classified.

However, number of published algorithms for this is smaller than that for localized pulmonary diseases. Here, CAD algorithms are proposed using thoracic CT images for especially diffuse lung diseases. By use of the proposed CAD algorithms, it will be expected that the radiologists will be able to obtain quantitative imaging in diffuse lung diseases, and also obtain objective and quantitative information about them, and use this information as a second opinion. Also, the proposed CAD algorithms are expected to contribute the clarification of the diagnostic logic and the improvement of the diagnostic accuracy for the diffuse lung diseases for which imaging diagnosis is difficult. Fig. 4 shows the patterns of diffuse lung diseases to be classified. Fig.5 shows the classification process.

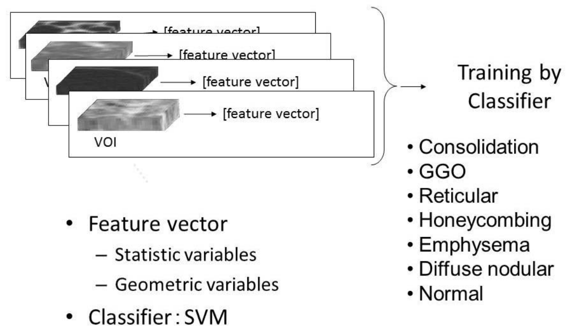

Figure 5. Classification Process

5. Systemic diseases found in panoramic radiography

Findings of panoramic radiography that plays a very important role in clinical dentistry include clinical information on not only dental conditions but also radiographic signs that are especially suggestive of possible systemic diseases. For example, decrease in the mandibular cortical thickness is one of radiographic signs of osteoporosis [3]. Calcifications within the carotid artery, that may indicate the potential for arteriosclerosis, can be observed on panoramic radiography [4]. Radiopacity of maxillary sinus is one of the abnormality signs such as maxillary sinusitis [5]. Supplemental screening of systemic diseases on routinely-used panoramic images in dentistry has a potential to detect asymptomatic patients. However, it is not easy for general dental practitioners to pay careful attention to such signs. Therefore, the aim of this study was to develop a computer-aided detection (CAD) system that detects radiographic signs of pathology on panoramic images and to present a new screening pathway by cooperation of dentists and the CAD system.

5.1 Method

The overview of the proposed CAD system is illustrated in Fig.6. The screening pathway via dental clinics with CAD system is illustrated in Fig.7. Computerized schemes for detecting three radiographic signs related to osteoporosis, arteriosclerosis, and maxillary sinusitis were implemented in the CAD system. The details are described in the references of [6-11].

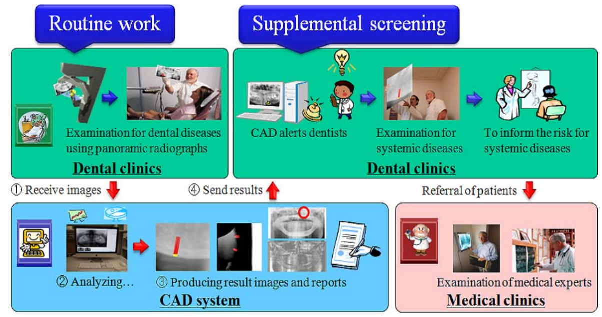

Figure 7. New screening pathway via dental clinics with CAD system.

5.2 Results

The performance evaluation of the proposed CAD system showed the sensitivity and specificity in the identification of osteoporotic patients were 88.5 % and 97.3 %, respectively, and those of the maxillary sinus abnormality were 89.6 % and 73.6 %, respectively. The detection rate of carotid artery calcifications that suggests the need for further medical evaluation was approximately 93.6 % with 4.4 false-positives per image. To validate the utility of the new screening pathway, preliminary clinical trials by using the proposed CAD system were conducted. To date, 223 panoramic images were processed and 4 asymptomatic patients with suspected osteoporosis, 7 asymptomatic patients with suspected calcifications, and 40 asymptomatic patients with suspected maxillary sinusitis were detected in the proposed initial trial. We found that development of the algorithm that reduces the image-quality variation in panoramic images is needed to improve the performance of the proposed CAD system. The preliminary trial to demonstrate the clinical usefulness by use of the PACS (picture archiving and communication systems)-CAD system was conducted. 100 cases selected at random were processed, and the following suspected cases were detected by dental radiologists that checked the result images on the PACS-CAD system: (i) 3 cases with suspected osteoporosis; (ii) 2 cases with suspected carotid artery calcifications; and (iii) 4 cases with suspected maxillary sinusitis. The seamless integration of image viewing, CAD analysis and reporting in a computer were achieved. Dental radiologists estimated that the PACS - CAD system may be useful in interpreting panoramic images.

In summary, it was suggested that our new screening pathway (Fig. 7) could be useful to identify asymptomatic patients with systemic diseases. Development of the CAD system available on multiple platform such as a software of personal computer, a function of the dental PACS system, and an

Application Server Provider (ASP), is currently in progress. Commercialization of our project will be expected through the use of state-of-the-art information and communication technology (ICT), especially together with the collaboration of CAD technology with telemedicine system for dentists.

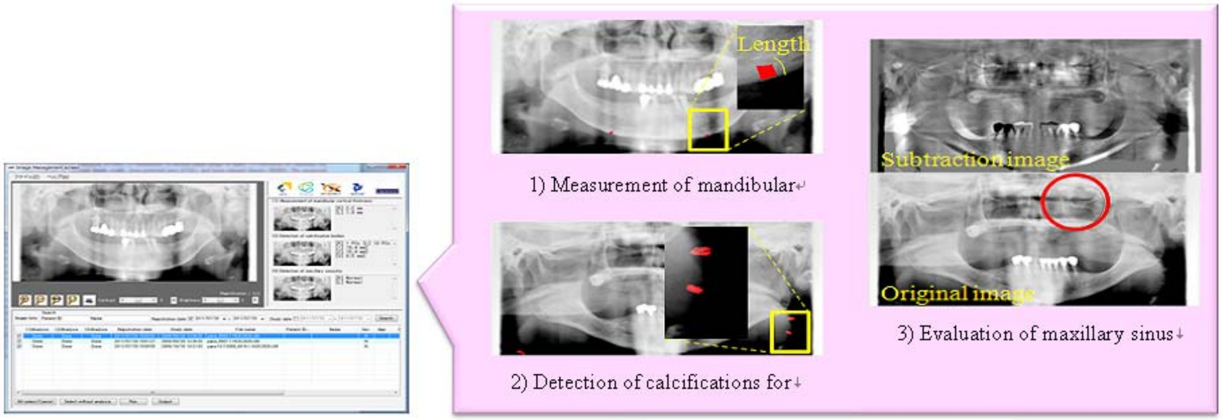

Image management screen   Three CAD schemes

Figure 6. Overview of the proposed CAD for panoramic radiogpahy

6. Conclusions

The presentations given in the special session of medical image processing and CAD at ICCH 2012 covered the latest research and technology development in different areas, which will have long-term significant impact and immediate beneficial to the community on the medical care of different diseases. These applications will not only increase efficiency and productivity in the business environment, but also enhance the health service for the public.

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References

[1] K. Ito,"3D echography," Japanese Journal of Clinical Radiology, 41: 1415–1422 (1996).

[2] S. Kume, S. Hibino, M. Kobayashi, J. Kanazawa, T. Shima, M. Nishida, K. Yamane, C. Mihara, K. Hiramatsu, A. Toyota, "Usefulness of three-dimensional ultrasonography in obstructive diseases of the carotid artery," Neurosonology, 17: 5–9 (2004).

[3] A.Taguchi, "Triage screening for osteoporosis in dental clinics using panoramic radiographs," Oral Dis, 16: 316-27 (2010).

[4] E.Ertas and Y.Sisman, "Detection of incidental carotid artery calcifications during dental examinations: Panoramic radiography as an important aid in dentistry," Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 112: e11-7 (2011).

[5] E.Imaizumi, "Clinical study on the detection of maxillary sinus disease by means of panoramic and waters' projections," Kyushu-shika-gakkai-zasshi, 44: 597-614 (1990).

[6] H.Fujita, T.Hayashi, T.Sawagashira, et al., "Effect of screening for systemic diseases using panoramic radiographs: The new role of preventive care in dentistry," 97th Scientific Assembly and Annual Meeting of Radiological Society of North America 2011 (RSNA 2011), Education Exhibits, LL-INE1185-WEA (2011).

[7] T.Hayashi, T.Matsumoto, T.Sawagashira, et al., "A new screening pathway for identifying asymptomatic patients using dental panoramic radiographs," Proc of SPIE Medical Imaging 2012: Computer-Aided Diagnosis, 8315, 83152K-1 - 83152K-7 (2012).

[8] T.Matsumoto, T.Hayashi, T.Hara, et al., "Automated scheme for measuring mandibular cortical thickness on dental panoramic radiographs for osteoporosis screening,"

Proc of SPIE Medical Imaging 2012: Computer-Aided Diagnosis, 8315, 83152L-1 - 83152L-6 (2012).
[9] C.Muramatsu, T.Matsumoto, T.Hayashi, et al., “Automated measurement of mandibular cortical width on dental panoramic radiographs,” International Journal of Computer Assisted Radiology and Surgery, in press.
[10] T.Sawagashira, T.Hayashi, T.Hara, et al., “An automatic detection method for carotid artery calcifications using top-hat filter on dental panoramic radiographs,” Proc of the 33rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 6208-6211 (2011).
[11] T.Hara, S.Mori, T.Kaneda, et al., “Automated contralateral subtraction of dental panoramic radiographs for detecting abnormalities in paranasal sinus,” Proc of SPIE Medical Imaging 2011: Computer-Aided Diagnosis, 7963: 79632R-1 - 79632R-6 (2011).