A Robust Medical Image Recognition System Employing Edge-Based Feature Vector Representation

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Abstract. The medical image recognition system based on a robust edge-based feature vector representation, called Projected Principal-Edge Distribution (PPED), has been developed. The robust nature of the PPED vector representation has been demonstrated in the cephalometric landmark identification, expert dentists' practice. In contradistinction with the previous works for the optimization of the PPED, the feasibility of the system has been demonstrated by applying to 26 cephalometric landmarks with 250 head films and the ones with the degradation. The system has been successfully applied to not only the cephalometric landmarks on the hard tissue but also the ones on the soft tissue without tuning the algorithm. The robust nature of the system against the degradation in the X-ray films has also been demonstrated.

1 Introduction

There has been considerable interest in the development of human-like expert systems that can assist professionals or replace a certain part of the professionals' work, especially in the medical area. In the cephalometric landmark identification which is one of the most important expert procedures in diagnosis, a dentist is requested to identify a number of predefined anatomical points as shown in Fig. 1. For this, the edge tracing technique [1], the spatial spectroscopy technique [2], and the neural network with genetic algorithm [3] were developed. The recognition performance by the edge tracing technique is very sensitive to the quality of head films and easily degraded by X-ray exposure conditions. And the other two techniques utilized probability distribution information, paying high computational costs. In addition, the recognition performances were not very satisfactory.

Our approach is based on the template matching technique. Although it is computationally very expensive and takes a lot of time on general-purpose MPUs, very powerful maximum-likelihood search VLSI hardware systems, called *associative processors*, have been developed in our laboratory in both digital [4] and analog technologies [5].

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With these chips, the template-matching processing is carried out almost cost free due to the parallel architecture with vast on-chip memories.

To represent images in a format compatible with the associative processors, *Projected Principal-Edge Distribution* (PPED) has been developed. (It was previously called *Principal Axis Projection* (PAP) [6].) In the PPED vector representation, human perception of similarity is very well reproduced in the vector space while substantially reducing the vector dimension. The robust nature of PPED image representation has been demonstrated by applying it to binary pattern recognition [7] and the cephalometric landmark identification [6,8,9]. In our previous works, only small X-ray image database was utilized and only three cephalometric landmarks (Sella, Nasion, and Orbitale) on the hard tissue (the bone tissue) were examined in order to optimize the algorithm. The recognition performance has not been tested for other cephalometric landmarks including the ones on the soft tissue. The soft tissue landmarks are very difficult to identify due to their very faint images [10]. (See the white markings on Fig. 1) Even expert dentists have to carefully adjust the contrast on the display screen for identification.

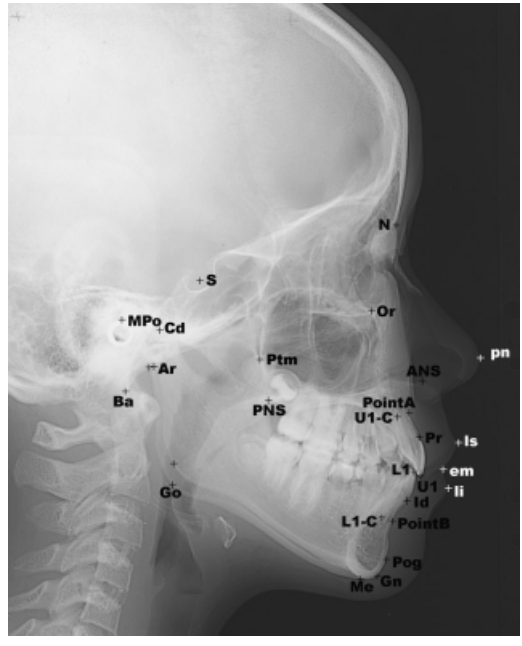

Fig. 1. Cephalometric landmarks. The landmarks on the soft tissue are indicated by the white markings.

The purpose of this paper is to demonstrate the feasibility of our medical image recognition system in a practical environment. The performance has been tested for 26 cephalometric landmarks using a total of 250 head X-rays taken from the retention files in the university hospital. To be more practical, it has been also applied to the cephalometric landmarks on the soft tissue. In addition, the robust nature against the degradation of X-ray images has been examined.

2 Projected Principal-Edge Distribution (PPED)

In this section, one of the most important techniques in the image recognition system, edge-based feature vector generation algorithm, is discussed. Figure 2 (a) illustrates the outline of the Projected Principal-Edge Distribution (PPED) vector representation procedure (formerly called Principal Axis Projection (PAP)) by taking the landmark L1 (the toe of the lower anterior tooth) as an example. The input image (64x64 pels) is firstly subjected to pixel-by-pixel 5x5 spatial filtering with threshold operation to determine whether an edge really exists or not. The median value of intensity variance distribution is utilized as the threshold value to normalize the contrast of an image and eliminate local intensity variation. Feature maps containing edge presence information as binary flags are generated for principal directions: horizontal (H); vertical (V); +45-degree (+45); and –45-degree (-45). The two-dimensional bit array in the feature map is reduced to a 1D array of numerals by projection in the edge direction, for instance, horizontal edge information is projected onto the vertical axis and edge information in other directions are operated in the same way. Then the projected data sets of numerals are subsequently connected as a series and smoothed to form a feature vector. The details of the PPED processing are described in Ref. [11].

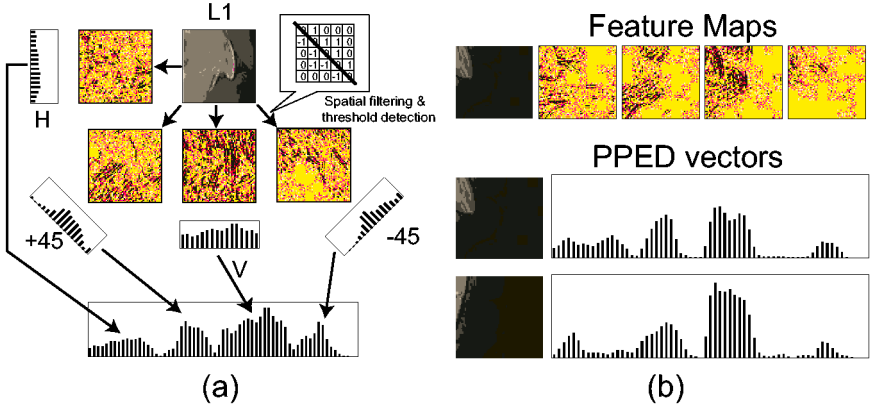

Fig. 2. (a) PPED image representation algorithm (b) Feature maps and PPED vectors for li (the most anterior point of the lower lip).

The feature maps and PPED vectors for the landmark li (the most anterior point of the lower lip) patterns on the soft tissue are presented in Fig. 2 (b). In the feature maps, it is seen that very faint edge information is successfully detected. While generally cephalometric landmark images vary a lot from patient to patient, they are pretty close to each other in the PPED vector space. This feature of PPED image representation is very suitable for the template matching processing on the associative processors.

3 Experimental

Two hundred and fifty X-rays (800x600 pels) were taken from the retention files at the Department of Orthodontics, Osaka University and utilized for experiments. 100 films were used for template generation and other 150 films were used for recognition tests. Fifteen template vectors were generated from the 100 head films by the Generalized Loyd learning algorithm, as shown in the results in Ref. [8]. Twenty-six cephalometric landmarks including the cephalometric landmarks on the soft tissue were employed as recognition targets. A 64x64 pels area was taken from a head film as an input image, and was transformed to a PPED vector. The input image was then matched with the template vectors in the PPED vector space. The template having the minimum dissimilarity (the Manhattan distance was utilized as the measure.) was selected as a winner pattern and the dissimilarity value was recorded. By pixel-by-pixel scanning the input image in a test head film, cephalometric landmarks were identified as the minima of dissimilarity. In addition, macro vision search [9] was also applied to some cephalometric landmarks. In this technique, the recognition processing was carried out in the low resolution in order to utilize more surrounding information and locate the correct position roughly before the high-resolution search. All the recognition results were confirmed by an expert dentist to verify the feasibility of the image recognition system.

4 Results and Discussion

The performances of all cephalometric landmark identifications are demonstrated in Fig. 3. While the same image recognition algorithm was applied to many kinds of cephalometric landmarks, not only the landmarks on the hard tissue but also the very faint landmarks on the soft tissue (pn. ls. em, li) were successfully identified. However, there are some landmarks for which the system did not show the good performances (MPo, Ba, Gn, Go, Ar, and Cd).

The result of applying macro vision search to the recognition of the landmark Gn (the most posterior inferior point at the angle of the mandible) is shown in Fig. 4 (a). While a false result is demonstrated in the simple search, the correct point is identified in the macro vision search. This result is achieved through eliminating local details and utilizing more surrounding information in the macro vision search. The recognition performances for the landmarks (MPo, Ba, Gn, Go, Ar, and Cd) are also shown in Fig. 4 (b). All the recognition performances except MPo have been improved by introducing the macro vision search technique.

As for MPo (the most superior surface of the ear rod), by increasing the number of head films for template generation from 100 to 150 including 50 additional head films, it is seen that the recognition performance was improved to 72%. It is because MPo has much more variations from patient to patient than the other landmarks and a lot of samples for template generation were needed.

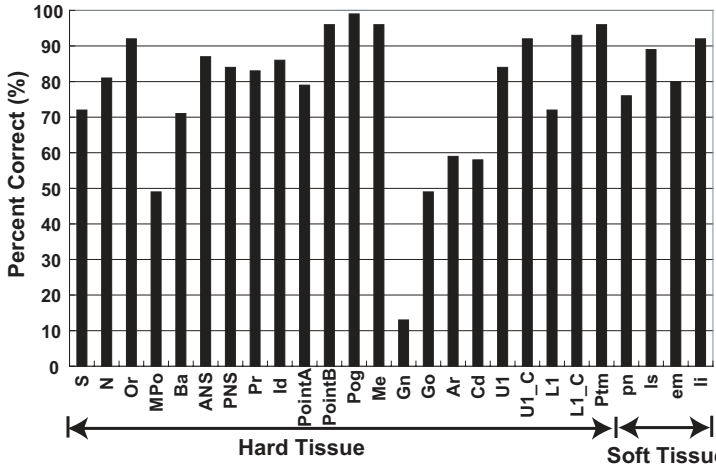

Fig. 3. Overall recognition performances.

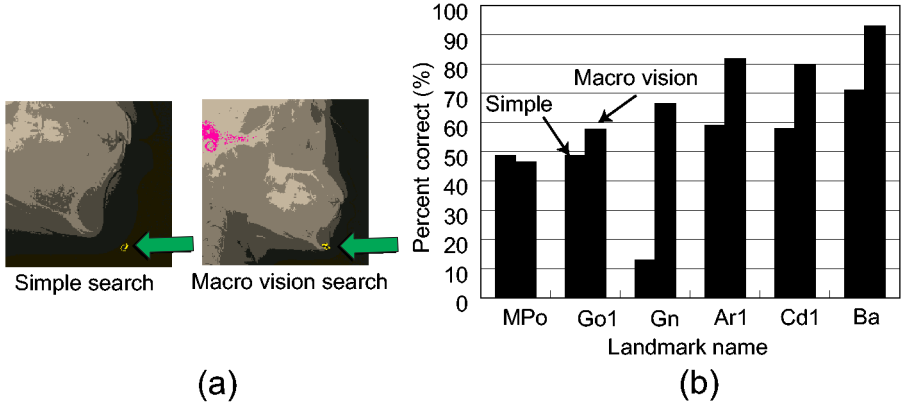

Fig. 4. (a) Recognition results of Gn and (b) recognition performances for several landmarks by macro vision search.

The same algorithm was also applied to the X-ray images showing degradation, as displayed in Fig. 5 (a). The degraded image has a lot of vertical line noise generated by taking X-ray picture in an improper condition. However, the robust recognition performance for the landmark Me has been demonstrated in Fig. 5 (b) against the degradation in head film images.

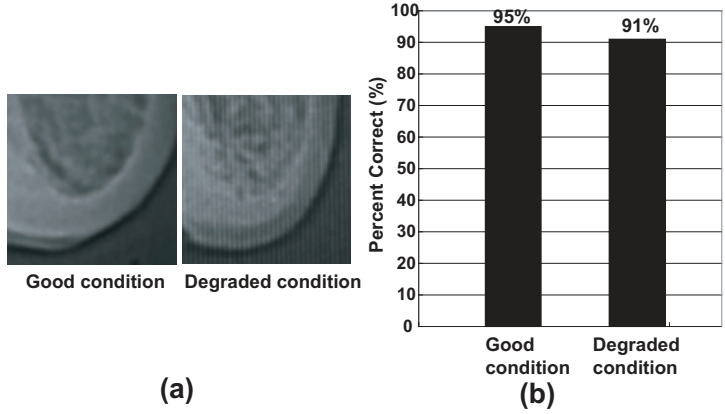

Fig. 5. (a) X-ray images (Good and Degraded) and (b) recognition performances of Me against the degradation in the quality of head film images.

5 Conclusion

The feasibility of the medical image recognition system based on PPED vector representation has been demonstrated by applying to 26 cephalometric landmarks with 250 head films and the ones showing the degradation. The same algorithm has been successfully applied to not only the cephalometric landmarks on the hard tissue but also the ones on the soft tissue without tuning the algorithm.

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References

1. Levy-Mandel, D., Venetsanopoulos, A. V., Tsotsos, J. K.: Knowledge-Based Landmarking of Cephalograms. COMPUTERS AND BIOMEDICAL RESEARCH 19, 1986, pp. 282-309.
2. Rudolph, D. J., Sinclair, P. M., Coggins, J. M.: Automatic Computerized Radiographic Identification of Cephalometric Landmarks. American Journal of Orthodontics and Dentofacial Orthopedics, Feb. 1998;113, pp. 173-179.
3. Yen-ting, C., Kuo-sheng, C., Ja-kuang, L.: Improving Cephalogram Analysis through Feature Subimage Extraction. IEEE Engineering in Medicine and Biology Magazine, Vol. 18, No. 1, 1999, pp. 25-31.

4. Ogawa, M., Ito, K., Shibata, T.: A General-Purpose Vector-Quantization Processor employing Two-Dimensional Bit-Propagating Winner-Take-All. Digest of Technical Papers of 2002 Symposium on VLSI Circuits, p.p. 244-247, Honolulu, June 13-15, 2002.
5. Yamasaki, T., Shibata, T.: Analog Soft-Pattern-Matching Classifier Using Floating-Gate MOS Technology. 14th Conf. Neural Information Processing Systems: Natural and Synthetic, 2001 (NIPS*2001), pp. 1131-1138, Vancouver, Dec. 2001.
6. Yagi, M., Adachi, M., Shibata, T.: A Hardware-Friendly Soft-Computing Algorithm for Image Recognition. 10th European Signal Processing Conference (EUSIPCO 2000), pp. 729-732, Tampere, Finland, Sept. 4-8, 2000
7. Yagi, M., Shibata, T.: A Human-Perception-like Image Recognition System based on PAP Vector Representation with Multi Resolution Concept. 2002 IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP 2002), Vol. I, pp.1041-1048, Florida, May 13-17, 2002.
8. Yagi, M., Shibata, T., Takada, K.: Optimizing Feature-Vector Extraction Algorithm from Grayscale Images for Robust Medical Radiograph Analysis. Fourth International Conference on Multimedia and Image Processing (IFMIP 2002), Vol. 13, pp.251-257, Orland, June 9-13, 2002.
9. Yagi, M., Shibata, T., Takada, K.: Human-Perception-like Image Recognition System Based on the Associative Processor Architecture. XI European Signal Processing Conference (EUSIPCO2002), Vol. I, pp. 103-106, Sep. 3-6, 2002 Toulouse, France (2002).
10. Mostafa, Y. A., EL-Mangoury, N. H., Salah, A., Rasmy, E. M.: Automated Cephalographic Soft-Tissue Analysis. JCO / Sept. 1990, Vol. XXIV No. 9.
11. Yagi, M., Shibata, T.: An Image Representation Algorithm Compatible with Neural-Associative-Processor-Based Hardware Recognition Systems. IEEE Transactions on Neural Networks. (To be published)