Cancer Cell Discrimination by

Power Spectral Density Function

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Abstract

An improved method of digital image analysis required in basic medical science for diagnosis of cells was proposed. The object image was the thyroid gland cell image, and the purpose was automatic discrimination of three classes cells by difference of chromatin patterns. This paper uses the power spectral density (PSD) function of the Fourier transform (FT) as the feature parameter in the transform domain, the result of which was compared with generally used feature parameters in spatial domain. The features of nucleus are extracted from microscopic images. The generally used 11 feature parameters are extracted in the spatial domain for comparison. As for the experimental result, average recognition rate of 63.08% was obtained by applying single parameter of 16 feature parameters at a time. The discrimination rate of 90.27% was obtained by PSD function of FT.

Keywords: Cancer Cell Discrimination, Pattern recognition, PSD of FT

1 Introduction

Pattern recognition technique has attracted considerable attention in the recent years. This is mostly due because it plays an important role in human visual perception and provides information which is used in recognition and interpretation. Pattern recognition has a wide variety of applications in medical image, remote-sensing, geology, and robotics. [1]

This paper deals with the cancer cell recognition that calls attentions to the pathologists. The object cell images were thyroid gland cells image that diagnosed as normal cell, follicular neoplastic cell, and papillary neoplastic cell, respectively In this paper, features are extracted in the nucleus instead of DNA which include the main features of cell. Experiment for discrimination was carried out by microscopic image. Because the microscopic image is more clear than ultrasonic echography. We use the PSD function of FT as a feature parameter for discrimination of cancer cell.

2 Clinical cytology and thyroid gland cells

  The clinical cytology is the inspection method of detecting the cancer cells by analyzing the microphotographs of cells in medical image processing. Cells are taken from the internal organs of human body and check for the existence of cancer cells. It is a necessary inspection method of detection of the various types of cancers for early diagnosis and treatments. Because of the treatment of the large amount of data in a short period of time, the automation of recognition of cell is also necessary. The clinical cytology is making an observation on cells and diagnosing the cells by morphological features. Since it has to handle a large amount of object in a short period of time, it has been used single parameters only. [2]   The samples used in the experiment of this paper are provided by department of pathology of medical school in Chonnam National University, Korea. They are microscopic images of thyroid gland cells taken by surgical operation and are diagnosed as normal, follicular neoplastic and papillary neoplastic, respectively. 93 frames (13 frames of normal, 40 frames of follicular neoplasm, and 40 frames of papillary neoplasm) of medical sample images were used and the total 1,822 nuclei (normal: 191, follicular: 879, papillary: 752) were used in the experiment. After dying by Papanicolaou technique, images of samples of each class were obtained by microscope and captured by camera. Size of object image was 512 × 512 with 8-bit resolution of gray-leveled value. Actual size of sample image was 102.4μm.
  The intraluminal colloid is pale staining and has scalloped borders in follicles with active secretory function and is densely eosinophilic in inactive ones. In old age, it tends to be broken up in globular formations. It is variably PAS-positive and alcianophilic, depending on the types and relative amounts of carbohydrate components present. [3]   Its microscopic appearance is extremely variable, ranging from well-formed follicles to a predominantly solid growth pattern. Poorly formed follicles, cribriform areas, or trabecular formations may be present, sometimes in combination. Focal or extensive cytoplasmic clear changes can occur. The reason for the peculiar appearance of the papillary cancer nucleus remains unknown; some theories have proved wrong - the nuclei are not hypodiploid ; the clearing is not caused by cytoplasmic invagination. In addition, in papillary cancer these nuclei often appear crowded, overlapping one another.

Ultrastructural studies of these nuclei have shown a finely dispersed chromatin, a highly folded nuclear membrane, and a paucity of nuclear pores. Another feature noted by electron microscopic studies and found as a prominent diagnostic clue in cytologic preparations is the presence of intra nuclear cytoplasmic invaginations. [4]

Figure 1 shows the typical nucleus of thyroid gland cells. The size of papillary neoplastic cell is biggest and the size of follicular neoplastic cell is smaller than other types. And the shape of normal and follicular neoplastic cell is round but the shape of papillary neoplastic cell is irregular. The texture pattern of nucleus of each class is different each other.
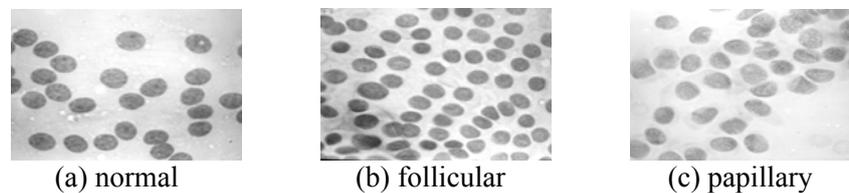

| (a) normal | (b) follicular | (c) papillary |

Figure 1. Typical nucleus of thyroid gland cells

3 Cancer cell discrimination

The configuration of experimental system that was used in this paper is as follows. The cell images were enlarged by microscope and the microscopic image was captured by camera and stored in computer memory. [5][6]

At first, images are enlarged by microscope stored in computer memory. Then, the gray level histogram is calculated to select a threshold value. Then, classify the nucleus from background by applying proposed region segmentation algorithm to the thresholded image. After segmentation, calculate the features by 16 feature parameters. And calculate the PSD function of Fast Fourier Transform(FFT).

The preprocessing of large volumes of data into a suitable form will be very helpful for more accurate pattern recognition. A two-dimensional image is a very good example of problems with a large data set. Generally, the preprocessing of an image can be carried out in one of two domains: the spatial domain and the transform domain. When an image is processed in the spatial domain, the processing of digitized image is carried out directly either by point processing or by neighborhood processing. But, if an image is to be processed in the transform domain, the digitized image will first be transformed by Discrete Fourier Transform (DFT) or FFT. Processing will then be carried out in the transform domain. When the processing is completed, an inverse operation of the FFT (IFFT) will be carried out on to transform the result back to the spatial domain.

A feature of image is a distinguishing primitive characteristic or attribute of an

image. Some features are natural in the sense that they are defined by the visual appearance of an image, while others are artificial result from specific main pulations of an image. Natural features include the luminance of a region of pixels and textural structure of regions. Examples of artificial features are amplitude histograms and spatial frequency spectra of image. Features of image are of major importance in image segmentation and classification. Image features are calculated by feature parameters.

The objective of the parameter selection of the feature parameter is to reduce the dimensionality of the measurement space to a space suitable for the classification algorithms. During the process of feature parameter selection, only the salient features necessary for the discrimination process are retained so that classification algorithm can be implemented on a vastly reduced feature space.

We must extract the feature of texture to analysis the nuclear pattern. The image function in the spatial domain can be expressed in following function in frequency domain.

$$f(x, y) \leftrightarrow F(u, v) = f(r, \phi) \tag{1}$$

The two-dimensional distribution function of PSD can be expressed as

$$|F(u, v)|^2 = |F(r, \phi)|^2 \tag{2}$$

where

$$F(r) = \oint_\phi |F(r, \phi)|^2 d\phi, \quad 0 \le \phi \le 2\pi \tag{3}$$

and

$$F(\phi) = \int_0^\infty |F(r, \phi)|^2 dr \tag{4}$$

Equation can be express in discrete image function as

$$|F(n)|^2 = \sum_{(i,j) \in N} |F(i, j)|^2, \quad N = \left[(i, j) : \left[(i^2 + j^2)^{0.5} \right] = n \right] \tag{5}$$

The normalized one-dimensional distribution function of PSD for extract the feature parameter is following

$$DF(n) = \frac{\displaystyle\sum_{(i,j) \in S_n} |F(i, j)|^2}{\displaystyle\sum_i \sum_j |F(i, j)|^2} \times 100, \quad S_n = \left[(i, j) : \left[(i/a)^2 + (i/b)^2 \right]^{0.5} = n \right] \tag{6}$$

where a, b : scale factor, [   ] : nearest neighbor integer

The look-up table was constructed by calculating the total mean of each class. The reason of construction of look-up table of each class is to get the standard value of each class for discrimination. In this paper, the total number of frames of

input images was 93 and total number of nucleus was 1822. The experiment of recognition is carried out by computing the distance between the value from the look-up table of each class and nuclear information from the nucleus.

4 Simulation Results

Figure 2 shows the experimental sample results of each class. And table 1 shows the summary of recognition rates in each class by applying the proposed feature parameter and generally used 11 morphological feature parameters.[6]
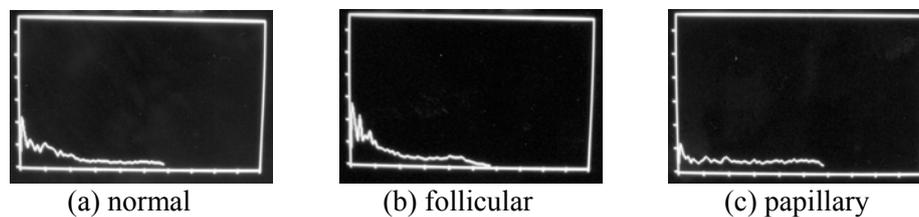

(a) normal (b) follicular (c) papillary

Figure 2. One-dimensional distribution function of PSD

Table 1 shows that, the parameters of denseness (DS), nuclear x-size (SX), and absolute value (AV) gave high recognition rate (around 79%) for all classes. Recognition of nucleus by average of x-size and y-size (MS), valid rate (VR), and the ratio of perimeter versus average of x-size and Y-size (RP) were effective on follicular cells but not for normal or papillary cells. The standard deviation of gray level of nucleus (SD) gave high recognition rate (around 80%) for all class. Other parameters did not give high enough recognition rate for all class (around 40%).

Table 1. Summary of discrimination rate

class parameter		normal		follicular		papillary		total	
		freq.	%	freq.	%	freq.	%	freq.	%
No.	Symbol	191	100	879	100	752	100	1822	100
1	AR	64	33.51	814	92.61	399	53.06	1280	70.25
2	SX	84	43.98	828	94.20	541	71.94	1453	79.75
3	GM	61	31.94	372	42.32	321	42.69	754	41.38
4	AP	117	61.26	201	22.87	328	43.62	646	35.46
5	AC	110	57.59	282	32.08	316	42.02	708	38.86
6	SD	101	52.88	771	87.71	585	77.79	1457	79.97
7	AV	96	50.26	747	84.98	608	80.85	1451	79.63
8	MS	14	7.33	818	92.94	49	6.52	880	48.30
9	DS	101	52.88	739	84.07	612	81.38	1452	79.69
10	VR	23	12.04	797	90.67	318	42.29	1138	62.46
11	RP	102	53.40	768	87.37	553	73.54	1423	78.10
12	PSD	169	88.48	798	90.78	690	91.76	1657	90.94

The experimental result was follows. The best recognition rate obtained by single parameter method was 79.97% for generally used feature parameters. The second is 79.75%, which was by nuclear X-size. The worst was 35.46%, which was obtained by averaged power of nucleus (AP). Average recognition rate obtained by applying 11 feature parameters was 63.08%. As examined above, the recognition rate of each parameter was not high enough for automatic recognition. However most feature parameters gave high recognition rate for some class. Discrimination rate obtained by two-dimensional PSD function of Fourier transform was 90.94%. It was improved at least 10.97%.

5 Conclusion

The focus of this paper is the discrimination of cells into normal and abnormal cells. The object cells image used in this paper was microscopic image of thyroid gland cells. A new technique for discrimination of cells image that uses two-dimensional PSD function of Fourier transform was proposed.

As for the experimental result, average recognition rate of 63.08% was obtained by applying single parameters. PSD function of Fourier transform obtained discrimination rate of 90.94%. As a consequence of using the PSD function of Fourier transform proposed in this paper the discrimination rate was improved by at least 10.97%.

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