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Accurate segmentation of leukocyte in blood cell images using Atanassov's intuitionistic fuzzy and interval Type II fuzzy set theory

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ABSTRACT

In this paper automatic leukocyte segmentation in pathological blood cell images is proposed using intuitionistic fuzzy and interval Type II fuzzy set theory. This is done to count different types of leukocytes for disease detection. Also, the segmentation should be accurate so that the shape of the leukocytes is preserved. So, intuitionistic fuzzy set and interval Type II fuzzy set that consider either more number of uncertainties or a different type of uncertainty as compared to fuzzy set theory are used in this work. As the images are considered fuzzy due to imprecise gray levels, advanced fuzzy set theories may be expected to give better result. A modified Cauchy distribution is used to find the membership function. In intuitionistic fuzzy method, non-membership values are obtained using Yager's intuitionistic fuzzy generator. Optimal threshold is obtained by minimizing intuitionistic fuzzy divergence. In interval type II fuzzy set, a new membership function is generated that takes into account the two levels in Type II fuzzy set using probabilistic T co norm. Optimal threshold is selected by minimizing a proposed Type II fuzzy divergence. Though fuzzy techniques were applied earlier but these methods failed to threshold multiple leukocytes in images. Experimental results show that both interval Type II fuzzy and intuitionistic fuzzy methods perform better than the existing non-fuzzy/fuzzy methods but interval Type II fuzzy thresholding method performs little bit better than intuitionistic fuzzy method. Segmented leukocytes in the proposed interval Type II fuzzy method are observed to be distinct and clear.

1. Introduction

Segmentation is an important step medical image processing which is used for extracting different objects in an image. Especially for pathological images, segmentation is very much essential. In pathological studies, blood cell parameters such as erythrocytes (red blood cell), leukocytes (white blood cell), and platelets are very essential to detect many diseases such as anemia, leukemia, cancer and any other infections. Out of these blood parameters, leukocyte plays an important role in human immune system. The family of leukocyte is comprised of eosinophill, basophill, neutrophill, lymphocytes, monocytes. The five types of leukocytes can be distinguished by their cytoplasmic granules, staining properties of the granules, size of cell, the proportion of the nucleus to the cytoplasmic material, and the type of nucleolar lobes.

Leukocyte counting and the type of leukocyte are essential in order to detect diseases. Conventionally medical experts visually count the cells but it is time consuming. Today, automated techniques are carried out to perform medical image diagnosis. But still accurate counting is difficult. So, for more accurate diagnosis, fuzzy or intuitionistic fuzzy or Type-II fuzzy set are being explored (Fig. 1).

Many authors suggested different techniques for image segmentation. But studies on pathological image segmentation are few. Segmentation should be accurate in leukocyte segmentation as the shape of the leukocytes should be preserved in order to detect the disease depending on the number and type of leukocytes present in the blood cell. Liao and Deng (2002) segmented white blood cells. In this work, they thresholded the blood cells and then applied morphology and finally shape detectors to find the shape. Piuri and Scotti (2004) initially separated the leucocytes from the others blood cells and then extracted morphological indexes and finally classified the leucocytes. Scotti (2005) identified Leukemia using morphological method. They first separated the leukocyte from other blood cells and used morphological indexes and then classified the cells. Ghosh et al. (2010) suggested automatic leukemia recognition using fuzzy divergence (Chaira and Ray, 2003a,b). They proved that membership function from Cauchy distribution shows better result. Textural approach to leukocyte recognition using GLCM matrix was suggested by Sabino et al. (2004). Ramoser et al. (2008) had given an idea of leukocyte segmentation and classification in blood smear images. They used some features that are related to cytoplasm and nucleus properties. The features used are color, shape of the nucleus, and finally SVM classifier is used to

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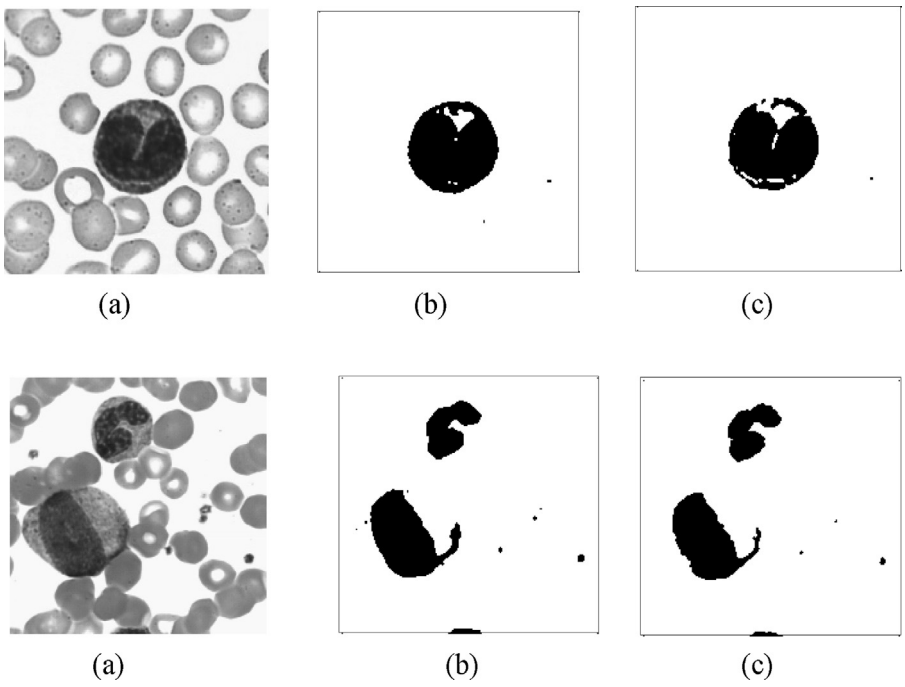

Fig. 1. (a) Original image, (b) thresholded using Sugeno generator, (c) thresholded using Yager generator.

classify the images. Wu et al. (2008) segmented colored WBC images using Otsu's approach (Otsu, 1979) and HSI color model. Adolla et al. (2008) provided a review on cell segmentation techniques. Chan et al. (2010) proposed leukocyte nucleus segmentation and nucleus lobe counting method. They extracted the leukocyte region from blood smear images and developed a leukocyte recognition system. The number of lobes increases when there is leukemia, liver disease, cancer, vitamin B12 deficiency, etc.

But there is hardly any work using intuitionistic fuzzy set or Type II fuzzy set theory. Intuitionistic fuzzy set theory considers two uncertainties – membership and non-membership degree. As selection of membership function is user defined and it varies from person to person, so some kind of hesitation exists while defining the membership function. Membership function may be Gaussian, Gamma, triangular and so on. Due to this hesitation, hesitation degree is considered and so the non membership degree in intuitionistic fuzzy set is not the complement of the membership degree as in fuzzy set rather less than or equal to the complement of the membership degree.

In Type II fuzzy set, the membership function in Type I (ordinary) fuzzy set is considered as 'fuzzy'. The membership function is considered to lie in an interval range with upper and lower membership levels and so it may be termed as interval Type II fuzzy set.

In this paper, an automatic leukocyte segmentation method from pathological blood cell image (abnormal and normal cell images) using both intuitionistic fuzzy set and interval Type II fuzzy set theory is proposed that preserves the shape if leukocytes in order to count different types of leukocytes for different disease detection. Modified Cauchy membership function from Cauchy distribution is used to find the membership function of the image. In case of intuitionistic fuzzy set, Yager's intuitionistic fuzzy generator is used to find the non membership function. Intuitionistic fuzzy divergence is used to find the optimum threshold value. In case of interval Type II fuzzy set, probabilistic fuzzy T co norm is used to form a new membership function using the two membership levels of interval Type II fuzzy set. Proposed Type II fuzzy divergence is used to find the optimal threshold. Experiment is conducted on several cell images where it is observed that the leukocytes are clearly detected.

The paper is organized as follows. Section 2 overviews the introduction to Intuitionistic fuzzy set. Section 3 writes about Cauchy distribution and the modified membership function derived from it. Section 4 details the procedure of leukocyte segmentation. Section 5 writes about the introduction of Type II fuzzy set. Section 6 details the procedure of segmentation using interval Type II fuzzy set. Section 7 discusses and displays the results and finally the conclusion is drawn in Section 8.

2. Introduction to Atanassov's Intuitionistic fuzzy set

A fuzzy set A in a finite set $X = \{x_1, x_2, \ldots, x_n\}$ may be represented mathematically as:

$$A = \{(x, \mu_A(x)) \mid x \in X\}$$

where, the function $\mu_A(x): X \to [0, 1]$ is measure of degree of belongingness or membership function of an element x in the finite set X and the measure of non-belongingness is $1 - \mu_A(x)$. An intuitionistic fuzzy set A in a finite set X may be mathematically represented as (Attanassov, 1999):

$$A = \{(x, \mu_A(x), \nu_A(x)) | x \in X\} \quad (1)$$

where, the functions $\mu_A(x)$, $\nu_A(x): X \to [0, 1]$ are respectively the membership and non-membership functions of an element x in a finite set X with the necessary condition

$$0 \le \mu_A(x) + \nu_A(x) \le 1$$

Stressing the necessity of taking into consideration a third parameter $\pi_A(x)$, known as hesitation degree that arises due to the lack of knowledge or the 'personal error' in assigning the membership degree, an intuitionistic fuzzy set A in X may be represented as:

$$A = \{(x, \mu_A(x), \nu_A(x), \pi_A(x)) \mid x \in X\}$$

with the condition

$$\pi_A(x) + \mu_A(x) + \nu_A(x) = 1 \quad (2)$$

It is obvious that $0 \le \pi_A(x) \le 1$, for each $x \in X$.