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SEGMENTATION ANALYSIS OF BLOOD CELL IMAGES

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Abstract. *In this article, blood cell image processing using fuzzy sets, Atanassov's intuitive fuzzy set analysis, cell distribution and segmentation analysis of blood components were studied and analyzed.*

Keywords: *intuitive fuzzy set, segmentation, cauchy distribution, leukocyte segmentation, fuzzy divergence.*

Color image segmentation is a problem in constant development because they provide more information than grayscale. In particular, it provides special support for several purposes, such as the analysis of biomedical images. Analysis of images of blood cells is an important task in pathological laboratories to identify diseases such as infections, bleeding, leukemia, anemia or inflammation. In cell imaging, the shape and number of white blood cells, called leukocytes, are important features for diagnosing leukemia. Accurate segmentation of leukocytes remains a key issue. Therefore, an automatic method of leukocyte segmentation using fuzzy sets was developed. Such sets provide a flexible mathematical framework for dealing with uncertainty in images and uncertainty. These sets take into account not only the degree of membership, but also the degree of membership uncertainty. The HSV color space is used to model the image and only the color component is considered. In this processing, the similarity is measured between each point of the image and a fixed point. This point is obtained using fuzzy mathematical morphology. Disadvantages of the method: the information in the image is lost, the similarity is measured between the points (the colors of the neighbors are not calculated due to this), the computational cost of the method is very high due to the use of uncertain mathematical morphology. To eliminate these, you can use the RGB field and the K-means clustering algorithm to select a fixed pixel.[1][2][3]

Color model. RGB is the simplest representation system for controlling color images and is widely used in computer systems and hardware devices for displaying color images. The RGB space is a single codification, and all components represent the same concept, the saturation level of the primary color. One of the possible methods of processing color images is individual processing of images. In this model, the image is an independent image consisting of 3 primary colors: red (R), green (G) and blue (B). Individual processing of 3 planes allows obtaining meaningful information for segmentation. A color image is defined as follows:

A color image in the RGB color space is a function $f\ : D_f \subset R^2 \to R^3$ where D_f image domain $f\left(i,j\right)=\left(r_{ij},g_{ij},b_{ij}\right)$ $r_{ij},g_{ij},b_{ij} \in \{0,......., 255\}$. will be in between.[4][5]

Intuitive fuzzy sets. Intuitive fuzzy sets introduce uncertainty in the level of membership, which is called the degree of duality. It is known that the traditional fuzzy set theory determines the membership level for each element, and the membership level is classically calculated as one less than its value. After this idea, Atanasov introduced the concept of intuitionistic fuzzy set. Its purpose is to reflect that the degree of membership is not always equal to the degree of membership minus one, due to the existence of some ambiguities. Anatasov's intuitive fuzzy set is as follows:

Since images are considered fuzzy due to uncertain gray levels, advanced fuzzy set theories can perform well. The modified Cauchy distribution is used to find the membership function. In the intuitionistic fuzzy method, the non-membership values are obtained using Jaeger's intuitive fuzzy generator. The optimal bound is achieved by minimizing the intuitionistic fuzzy divergence. In the interval type II fuzzy set, a new membership function is generated that takes into account the two levels in the type II fuzzy set using the probability norm T. The optimal threshold is selected by minimizing the proposed type II fuzzy difference. Previously, fuzzy methods were used although these methods could not delineate multiple leukocytes in the images. Experimental results show that type II fuzzy and intuitionistic fuzzy methods perform better than existing fuzzy methods, but type II fuzzy delimitation method performs slightly better than intuitive fuzzy method. Recommendation it is observed that the segmented leukocytes of the II type with a fixed interval are clearly segmented.[4][5]

Segmentation is an important step in medical image processing, which is used to extract various objects in the image. In particular, segmentation is very important for pathological images. In pathological studies, blood cell parameters such as erythrocytes (red blood cells), leukocytes (white blood cells) and platelets, anemia, It is very important to detect many diseases such as leukemia, cancer and other infections. Among these blood parameters, leukocytes play an important role in the human immune system. The leukocyte family includes eosinophils, basophils, neutrophils, lymphocytes, and monocytes. The five types of leukocytes are cytoplasmic granules, granules It can be distinguished according to the characteristics of the cell, the size of the cell, the ratio of the nucleus to the cytoplasmic material, and the type of nuclear fragments. The number of leukocytes and the type of leukocytes are necessary for the diagnosis of diseases. Traditional medical professionals count the cells visually, but this is time-consuming is enough. Today, automated techniques are being implemented to perform medical image diagnostics. But exact calculation is still difficult. Therefore, fuzzy or intuitionistic fuzzy or Type II fuzzy sets are studied for more accurate diagnosis.

Many authors have proposed various methods of image segmentation. However, there are few studies on pathological image segmentation. In leukocyte segmentation, the segmentation must be accurate, because the leukocyte shape must be preserved to determine the disease according to the number and type of leukocytes present in the blood cells. Liao and Deng (2002) segmented white blood cells. In this work, they delimited the blood cells and then applied morphology to find the shape and finally applied shape detectors. Piuri and Scotti (2004) first separated leukocytes from other blood cells, then they extracted morphological indicators and finally classified leukocytes. Scotti (2005) identified leukemia using a morphological method. They first separated leukocytes from other blood cells and from morphological indicators used and then classified the cells. Ghosh et al. (2010) proposed automatic detection of leukemia using fuzzy divergence (Chaira and Ray, 2003a, Chaira and Ray, 2003b). They proved that the Cauchy distribution membership function gives better results. A textural approach to leukocyte recognition using the GLCM matrix was proposed by Sabino et al. (2004). Ramoser et al. (2008) suggested segmentation and classification of leukocytes in blood smear images. They were related to cytoplasmic and nuclear features used some features. The features used are color, kernel shape and finally SVM classifier is used to classify the images. segmented color WBC images using the Otsu approach (Otsu, 1979) and the HSI color model. Adolla et al. (2008) provided a review on cell segmentation techniques. Chan et al. (2010) provided a method for leukocyte nuclear segmentation and nuclear lobe counting. proposed. They extracted leukocyte regions from blood smear images and developed a leukocyte detection system. However, there is almost no work using intuitive fuzzy set theory or Type II fuzzy set theory. Intuitive fuzzy set theory solves two uncertainties - considers membership and degree of membership. Since the choice of membership function is user-defined and varies from person to person, there is some ambiguity in defining the membership function. Membership function Gaussian, Gamma, triangle, etc. Due to this duality, the degree of duality is considered, and therefore intuitively the degree of membership in a fuzzy set is less than the complement of the degree of membership.

In the type II fuzzy set, the membership function in the type I (normal) fuzzy set is considered to be "fuzzy". abnormal and normal cell images) an automatic leukocyte segmentation method using intuitive fuzzy set and intermediate type II fuzzy set theory is proposed, which preserves leukocyte shape to count different types of leukocytes. A modified Cauchy membership function from the Cauchy distribution is used to find the membership function of the image. If it is an intuitionistic fuzzy set, Jager's intuitive fuzzy generator is used to find the non-membership function. Intuitive fuzzy divergence is used to find the optimal threshold value. In an interval type II fuzzy set, the probability fuzzy T co norm is type II is used to form a new membership function using the two membership levels of the fuzzy set. The proposed type II fuzzy divergence is used to find the optimal threshold. The experiment is carried out on several cell images, where leukocytes are clearly identified.[4][5][6]

Atanassov's intuitionistic fuzzy set.

$X = \{x_1, x_2, ...x_n\}$ The unknown set A in the finite set can be expressed mathematically as follows. $A = \{(x, \mu_A(x)) \mid x \in X\}$ here $m_A(x)$ is the function: $X \to [0,1]$- the degree of relevance or the membership function $1 - m_A(x)$ measure of the element x in the finite set X is equal to the measure of non-relevance. An intuitively vague set A on a finite set X can be expressed as:

$A = \{(x, \mu_A(x), V_A(x)) / x \in X\}$ here $m_A(x), n_A(x)$ functions.

Cauchy distribution.

The Cauchy distribution has a probability density function defined as:

$$f(x; a, \gamma) = \frac{1}{\pi\gamma\left(1 + (x - a/\gamma)^2\right)}$$ Here "a" is the location parameter, g is the scale parameter.

For the standard Cauchy distribution g=1 and a=0, the distribution is:

$$f(x; 0, 1) = \frac{1}{\pi\left(1 + (x - a)^2\right)}$$ To find the membership values of an image, the distribution is modified according to the image requirement.

$\gamma = 1/\sqrt{const}, const = 1/(f_{\max} - f_{\min})$ here $f_{\max}$ and $f_{\min}$ maximum and minimum values of the image.

Leukocyte segmentation using intuitionistic fuzzy divergence.

Consider an image A of size M×N with maximum and minimum values recorded. The average value of the background and foreground regions is calculated for a certain boundary. Then, using the Cauchy membership function, the membership function at a certain boundary "t" separating the background and foreground region is written in the equation of the object (foreground) region as follows:

$$\mu(a_{ij}) = \frac{1}{1 + const \cdot \left(a_{ij} - m_0\right)^2} \quad \text{if, } a_{ij} > ta_{ij}$$

A fuzzy set of type II.

Type II fuzzy set (Mendel, 2007, Zadeh, 1975) is useful in the situation where the membership values are difficult to agree with the exact membership values. This is due to the appearance of some inaccuracies in the location, shape or other parameters. A Type II fuzzy set accounts for this uncertainty by considering another degree of freedom to better represent the uncertainty when the membership functions are uncertain.[7]

Segmentation Using Interval Type II Fuzzy Set.

In the segmentation problem, the T co-norm is used to generate a new membership function using two membership functions in the interval of type II fuzzy set. Before discussing segmentation, a brief introduction to the fuzzy T co-norm is provided.

AT co-norm $S[0,1] \to [0,1]$ is a kind of binary operations used in fuzzy logic and probability metric space. It represents union in fuzzy set theory. It is an associative, commutative and increasing function, and $S(0,x) = x$ is associative for all $x \in [0,1]$.

Intuitive fuzzy generator

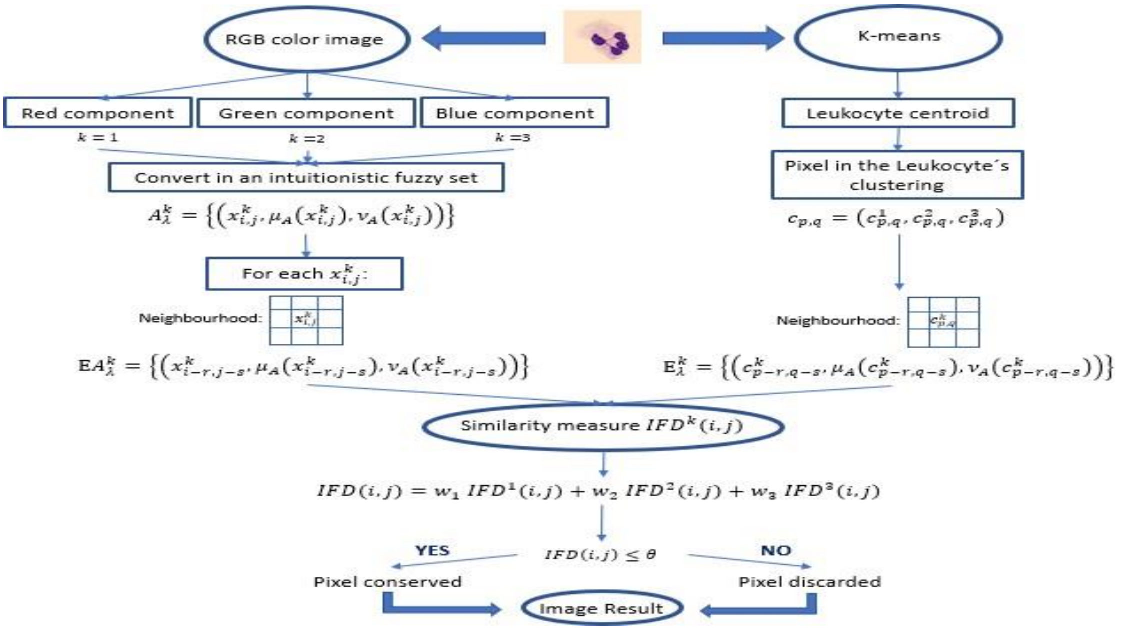
Intuitive fuzzy generators are used to construct the IFS and are defined as a function $\varphi : [0,1] \to [0,1]$ satisfying: $\varphi(x) \leq 1 - x \quad \forall x \in [0,1]$. Therefore, $\varphi(0) \leq 1$ and $\varphi(1) = 0$ The important intuitionistic fuzzy generator is defined by Sugeno, and the resulting IFS is given by:

$$A_\lambda = \left\{ \left(x, \mu_A(x), \frac{1 - \mu_A(x)}{1 + \lambda \mu_A(x)} \right) / x \in X \right\} \quad [8][9][10]$$

Intuitionistic fuzzy divergence

Intuitionistic fuzzy divergence (IFD) is a measure of the difference between two intuitionistic fuzzy sets. There are several definitions of IFD in the literature. It is used in this work due to the relevance of the degree of ambiguity in the definition. Let A and B be two IFSs, and their associated IFD value is:

$$IFD(A,B) = \sum_{2} 2 - \left[1 - \mu_{AB}(x_i)\right] e^{\mu_{AB}(x_i)} - \left[1 + \mu_{AB}(x_i)\right] e^{-\mu_{AB}(x_i)} + 2 - \left[1 - \mu_{AB}(x_i) - \pi_{AB}(x_i)\right] e^{\mu_{AB}(x_i) - \pi_{AB}(x_i)} - \left[1 + \mu_{AB}(x_i) + \pi_{AB}(x_i)\right] e^{-\pi_{AB}(x_i) - \mu_{AB}(x_i)}$$



RGB intuitionistic-based method

In this section, the proposed method is developed. This method first considers each component of a RGB image and model each of them as an IFS. Then a pixel from the image is selected as reference to compute the similarity and computes the IFD between a neighbourhoods of each element in the image and a neighbourhood of the pixel selected as reference. If the IFD is less or equal than a fixed value, the point is conserved, otherwise discarded. Figure 3 shows a block diagram of the proposed algorithm. The method to segment the images can be summarised in the following six steps:

1: The first step consists on deciding the color space that it will be used. In this case, RGB model is used for representing the color images. Therefore, let f be a color image, three components are extracted according to the red (R), green (G) and blue (B) components which they be denoted by k = 1, k = 2 and k = 3, respectively. It is important to notice that the proposed method could be used in others color spaces and this choice will depend on the image characteristics and the objective set in the segmentation.

2: In this step, the image is modeled as an IFS. Each component of the image has M×N dimensions. However, components are defined intuitively as fuzzy sets as follows:

The first coordinate x_{ij}^k represents the value of pixel (i, j) with k in the component $0 \le i \le M, 0 \le j \le N$ and $k = 1,2,3$. For example, for the red component $x_{ij}^1 = r_{ij}$, for the green component $x_{ij}^2 = g_{ij}$ and finally for the blue component $x_{ij}^3 = b_{ij}$ the second coordinate is the normalized value of the first. It is obtained by using the membership function:

$$\mu_A\left(x_{i,j}^k\right) = \frac{x_{i,j}^k}{255}$$

The non-membership function is applied to the value obtained in the above step. The non-membership function is calculated using a Sugeno-type intuitionist and the fuzzy generator is constructed as follows, where the chosen value of λ is equal to 0.5:

$$\vartheta_A\left(x_{i,j}^k\right) = \frac{1-\mu_A\left(x_{i,j}^k\right)}{1+\lambda\mu_A\left(x_{i,j}^k\right)}$$

Therefore, an intuitive fuzzy set for each component k is defined as:

$$A_\lambda^k = \left\{\left(x_{i,j}^k, \mu_A x_{i,j}^k, \frac{1-\mu_A x_{i,j}^k}{1+\lambda\mu_A x_{i,j}^k}\right) | \, 0 \le i \le M \cap 0 \le j \le N\right\}$$

3: The degree of ambiguity is calculated for each pixel of each component of the image:

$$\pi_A\left(x_{i,j}^k\right) = 1-\mu_A\left(x_{i,j}^k\right) - \frac{1-\mu_A\left(x_{i,j}^k\right)}{1+\lambda\mu_A\left(x_{i,j}^k\right)}$$

4: For leukocytes segmentation, a neighbourhood of a point of the object to be segmented is necessary to evaluate the similarity with the image to be analyzed. This neighbourhood is chosen instead of just one point because the leukocytes are, in general, a nonhomogeneous color object [10]. An example of this kind of images is later shown in Fig. 4. Therefore, a fixed pixel corresponding to the object to be segmented is selected and a neighbourhood of it is chosen. This selection is made using K-means. For this, a K-means algorithm is applied over the original image and three clustering are obtained, each one for leukocyte, cytoplasm and background, respectively. As the centroid corresponding to the leukocyte is not necessarily a pixel of the original image, an element of the clustering is chosen in order to guarantee that this point belongs to the image.So that's the point is defined by $c_{p,q}=\left(c_{p,q}^{1},c_{p,q}^{2},c_{p,q}^{3}\right)$, where p and q are the location of the pixel in the image. Using this point c as the center point, $D\times D$ size neighbor is selected. This neighborhood is seen as, and defined by Ec_{λ}^{k} $k=1,2,3$, an intuitively fuzzy set, just like us. From now on, the value of D is equal to 3. This value is chosen heuristically depending on the type of images we are working with.

5: At this stage similarity is considered. A_{λ}^{k} be an intuitive fuzzy set of colors. For each component, the image k is given by Eq.

A_{λ}^{k} and Ec_{λ}^{k} intuitive fuzzy set of and is the neighborhood k for each component. With each pixel of the original image $x_{i,j}$ $0\le i\le M, 0\le j\le N$, the following subset is considered Ec_{λ}^{k} in the same size, i.e. 3×3

$$EA_{\lambda}^{k}(i,j)=\left\{x_{i-r,j-s}^{k},\mu_{A}\left(x_{i-r,j-s}^{k}\right),\nu_{A}\left(x_{i-r,j-s}^{k}\right)/\,r,s\in\{-1,0,1\}\right\}$$

EA_{λ}^{k} and Ec_{λ}^{k} IFD between each element is calculated using the equation given above:

$$IFD^{k}(i,j)=\sum_{r=-1}^{1}\sum_{s=-1}^{1}2-\left[1-\mu_{Ac}\left(x_{i-r,j-s}\right)\right]e^{\mu_{Ac}\left(x_{i-r,j-s}\right)}-\left[1+\mu_{Ac}\left(x_{i-r,j-s}\right)\right]e^{-\mu_{Ac}\left(x_{i-r,j-s}\right)}$$

$$+2-\left[1-\mu_{Ac}\left(x_{i-r,j-s}\right)-\pi_{Ac}\left(x_{i-r,j-s}\right)\right]e^{\mu_{Ac}\left(x_{i-r,j-s}\right)-\pi_{Ac}\left(x_{i-r,j-s}\right)}$$

$$-\left[1+\mu_{Ac}\left(x_{i-r,j-s}\right)+\pi_{Ac}\left(x_{i-r,j-s}\right)\right]e^{-\mu_{Ac}\left(x_{i-r,j-s}\right)-\pi_{Ac}\left(x_{i-r,j-s}\right)}$$

being $\mu_{Ac}\left(x_{i-r,j-s}\right)=\mu_{A}\left(x_{i-r,j-s}\right)-\mu_{A}\left(c_{p-r,q-s}\right)$ and $\pi_{Ac}\left(x_{i-r,j-s}\right)=\pi_{A}\left(x_{i-r,j-s}\right)-\pi_{A}\left(c_{p-r,q-s}\right)$

Finally, a weighted average is calculated:

$IFD(i,j)=\omega_{R}\times IFD^{1}(i,j)+\omega_{G}\times IFD^{2}(i,j)+\omega_{B}\times IFD^{3}(i,j)$ Where $\omega_{R}+\omega_{G}+\omega_{B}=1$

6: In this step, a decision is taken. If the similarity measure IFD is less or equal than a fixed value, denoted by θ, then the point $x_{i,j}$ is conserved; else discarded. The value of θ is heuristically chosen. As a consequence, the segmented leukocytes image is obtained, i.e., for all i and j,

$0\le i\le M, 0\le j\le N$

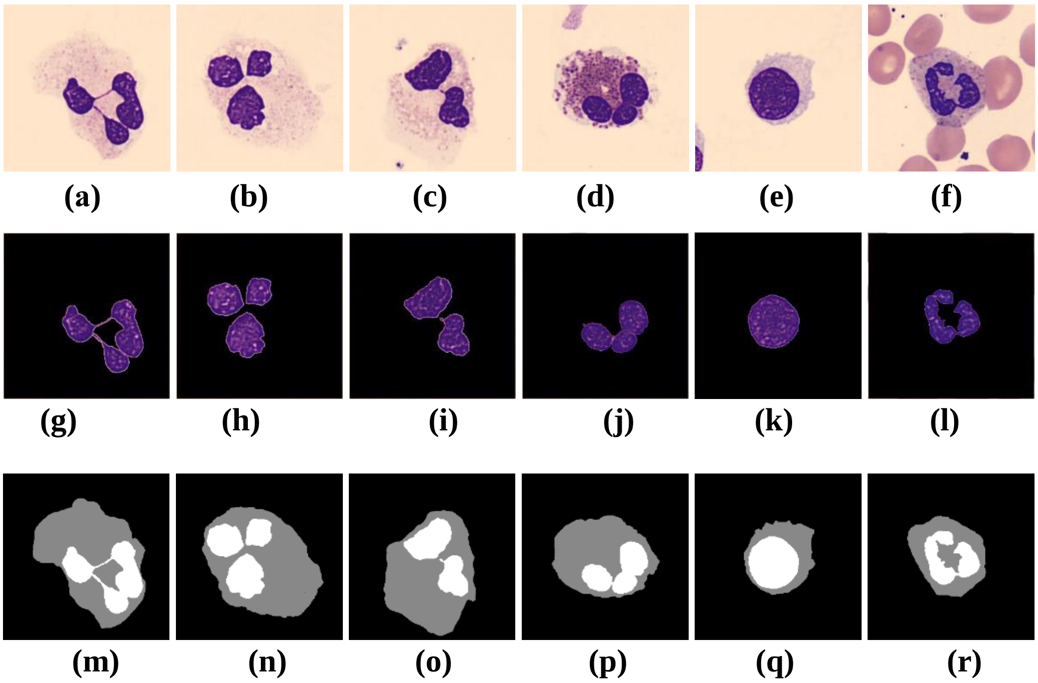
If $IFD(i,j)\le\theta\Rightarrow \mathrm{Re}\,sult^{k}(i,j)=x_{ij}^{k}$

If $IFD(i,j)>\theta\Rightarrow \mathrm{Re}\,sult^{k}(i,j)=x_{ij}^{k}$

where $\mathrm{Re}\,sult^{k}(i,j)$ represents the component k of the result image to pixel (i,j),with $k=1,2,3$ Combining the component, the final image is obtained as follows:

$$\mathrm{Re}\,sult(i,j)=\left(\mathrm{Re}\,sult^{1}(i,j),\mathrm{Re}\,sult^{2}(i,j),\mathrm{Re}\,sult^{3}(i,j)\right)$$

Results. In this section, some experiments are conducted to show the results of the application of the proposed method. The images used have been taken from the CellaVision blog. This dataset consists of one hundred 300 × 300 color images.



a–f Original pictures. g–l Getting the segmentation in the recommended way. m–r Segmentation given by experts.

Cell images are usually purple in color and may include many red blood cells around white blood cells. Also, the region associated with the nucleus and cytoplasm was manually segmented by an expert.Preliminary results show good behavior for color segmentation. This is the first approach to this methodology and some more studies and experiments are needed to define the segmentation.[4][6][7][8][10]

Conclusion. In this work, a new method of segmentation of leukocytes based on intuitive fuzzy sets color image was analyzed. K-means clustering algorithm is used to select a neighborhood and then measure the similarity between the analyzed image and this neighborhood. The similarity measure was used as a tool to segment the objects in the image. As we can see in the results, the performance of the proposed algorithm is high.

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