Blood Sample Image Analysis by Color Concentration and Pixel Density Features

Roman Melnyk¹, Illya Kozhukh², Yuriy Kalychak²

¹ Professor of Software Department, Lviv Polytechnic National University, Ukraine, Lviv, S. Bandery street 12, ramelnyk@polynet.lviv.ua
² Assistants of Software Department, Lviv Polytechnic National University, Ukraine, Lviv, S. Bandery street 12, maestrodirk@gmail.com

Abstract – The method for the image color concentration and pixel density features extracted from the image intensity segments is considered. The features of cumulative histogram, color perimeter’s length and color concentrations are calculated. These image features were taking for detection of blood cells – neutrophils – among platelets.

Keywords – color concentration, pixel density, intensity segments, blood cells detection

I. INTRODUCTION

The main objects to elaborate in images are local and global image intensity, color histograms, relative location of colored regions, their shape, wavelet- or Fourier-function coefficients etc. Nowadays there are a lot of works dedicated to the algorithms of image features extraction. In particular, methods (J. R. Smith, S.-F. Chang., 1996; H. Nezamabadi-pour, E. Kabir, 2004; T. Gevers et al., 2006) contain the object regions, block color histogram and invariant factors, algorithms (F. Mokhtarian, S. Abbasi, 2002; A.K. Jain, A. Vailaya, 1996,) utilize the main objects of attention and their quantitative characteristics.

The color concentration features and its component could find an application for material surface analysis, in searching and classification procedures on the preliminary steps of image filtering.

II. COLOR CONCENTRATION FEATURES

We can calculate an image and the cumulative histogram

\[ V = \sum_{i=1}^{n} V(i) \]
\[ V_F(s) = \sum_{i=1}^{n} V(i) \]  \hspace{1cm} (1) (2)

where \( V \) is the overall number of image pixels, \( V(i) \) is the intensity frequencies, \( V_F(s) \) is the accumulating frequency for the given intensity, \( n \) is the number of cumulative histogram intervals, \( s, i \) are the interval numbers (intensity value). Some values of the cumulative histogram we accept as an image feature vector for its retrieval and effectiveness comparison.

We can not distinguish the images presented on Fig. 1 by the cumulative histogram, because they have the same number of black pixels.

Fig.1 Images with equal numbers of black pixels

So, we propose another two image features to retrieve them from databases: perimeter’s length and color concentration.
For every binary image first or second region of color area could be presented as

\[ S_1(i) = V_F(i), \quad S_2(j) = S_i - S_1(i) \]

where \( S_i \) - full image square.

For three colors we have

\[ S_1(i) = V_F(i), \quad S_2(j) = V_F(j) - V_F(i), \]

\[ S_3(j) = V_F(j) - V_F(i), \]

where 1, 2 - color numbers, i, j - color intensity numbers. We denote the color concentration as

\[ K(i) = S_i(i) / L(i) \]

where \( L(i) \) is a figure’s perimeter.

For a binary image the perimeter’s value is a sum of edge length and external border values. The corresponding concentration components of black pixels and concentration itself for the images presented in Fig. 1 are:

\[ S_1(i) = 32, L_1 = 32, 64, 128 \]

\[ K(b) = 1, K(b) = 1/2, K(b) = 1/4 \]

We also present the more precise formula for the k-th color concentration

\[ K(i) = [S_k(i) \cdot 4S_k(i)] / L_k(i) \]

where coefficient \( 4S_k(i) / L_k(i) \) indicates how the perimeter’s length of real color region of the picture is different from a perimeter of the hypothetical square with the side value \( S_k(i) \). We assume that the color concentration of a quadrature is maximal.

Let us consider two formulas (3-4) for color concentration of the black quadrates on Fig. 2. The quadrates have correspondently the side sizes 1x1, 2x2 and 3x3. So, by the formula (3) we have color concentration values \( K=1/4, 1/2 \) and 3/4. And by the formula (4) \( K=1, 4 \) and 9.

In the first case dependence from the size is linear and in the second case - quadratic. So, the formula (3) is suitable for figures with comparatively close areas. The formula (4) is closer to economical category of resource concentration - the more capital and less the owners - the greater capital concentration. The formula declares: the greater difference from quadrates the less color concentration. To confirm it the 4-th rectangle square on Fig. 2 is 9 , side sizes 2x 4.5 . So, the color concentration feature is 9*4*3 /13=8.3 i.e. smaller than 9 of third quadrature.

### III. PIXEL DENSITY FEATURES

The colour image is being converted into the grayscale one. The value of pixel intensity is calculated from the equation of its relative filling by the percentage of the white color (0-255).

Let us divide the image intensity space into n fragments by the horizontal planes XOY with an interval (intensity fragmentation step) \( d = 255/n \).

There are three classes of segment features to be distinguished: the distributed features by intensity, the distributed features by pixel coordinates and the mixed distributed features. We call them distributed since by them parts of the image intensity surface as well as the whole image are characterized.

During intensity fragmentation the volume of fragments and segments are calculated. The intensity segment is formed by combining fragments from the first to the s-th one with a downward movement (Fig.1b) and its volume is calculated respectively:

\[ V_S(s) = \sum_{i \in S} V_F(i) \]

\[ V_S(s) \] is the volume of s-th segment, \( V_F(i) \) is the volume of i-th fragment, S, F are the indices to denote segments and fragments.

To the distributed features by intensity we refer the mathematical expectation and standard deviation of the values of the image volume segments (the last n-th segment is the whole image):

\[ \bar{V}_S(s) = 1 / s \sum_{i \in S} V_S(i) \]

\[ E^2(V_S(s)) = \sum_{i \in S} (V_S(i) - \bar{V}_S(s))^2 \]

\( \bar{V}_S(s) \) is the mathematical expectation for the volumes of s segments, \( E^2(V_S(s)) \) is the standard deviation of the segments volume (from the first to the s-th one).

Segments contain a large number of pixels. For these the distributed features of pixel coordinates are determined the mathematical expectation of the segment pixel coordinates:

\[ \bar{x}(s) = 1 / k_s \sum_{i \in X(s)} x_i, \quad \bar{y}(s) = 1 / k_s \sum_{i \in Y(s)} y_i \]

\( x_i, y_i \in X(s), Y(s) \)
and variance of segment pixel coordinates:

\[ E^2(s) = \frac{1}{k_s} \cdot \sum_{x \in X(s), y \in Y(s)} (x - \bar{x}(s))^2 + (y - \bar{y}(s))^2 \]  

\[ s \] is the number of pixels in the segment, \( \bar{x}(s) \), \( \bar{y}(s) \) are coordinates, \( X(s), Y(s) \) are the sets of the segment pixels coordinates, \( E^2(s) \) is the variance of pixel coordinates in the segment.

The following refer to the mixed (both coordinates and intensity are taken into account) - the flat density of segment pixels:

\[ G(s) = \frac{k_s}{S_f(s)} \]  

Where \( S_f(s) \) is the figure area that covers the segment pixels determined as the area of a rectangle or a circle containing pixels, for example:

\[ S_f(s) = 9 \cdot p \cdot E^2(s) \]  

IV. EXPERIMENTS

One of the tasks for blood analysis is detection of neutrophils among platelets (fig.3). By histogram or cumulative histogram we could not detect these cells and to calculate their quantity.

\[ \text{Fig.3 Blood samples with platelets (a,b) and neutrophils (b)} \]

So, we apply two image features – color concentration and pixel density - to confirm or to deny neutrophils presence. Two curves on Fig.4 are the color concentration functions for two blood samples from fig.3. The chart beginning from the less values of intensity indicates the dark cells. The other chart indicates an absence of neutrophils in the blood sample.

\[ \text{Fig.4 Color concentration of two images: with and without neutrophils} \]

Two curves on Fig.5 are the pixel density functions for two blood samples from fig.3. For the image with neutrophils the chart has strong maximum on beginning of intensity axis indicating by it the dark cells. The other chart has no any features which indicate on neutrophils in the blood sample.

\[ \text{Fig.5 Pixel density of blood samples: with and without neutrophils} \]

**Conclusion**

Two distributed features of image obtained from cumulative histogram, object perimeter and intensity segments have been suggested. They are tested to detect the blood cells having dark colors among those having more light colors. Even if a number of interesting cells is small enough the proposed features help to detect them. So, the developed software can be used in automated systems of blood analysis.

**REFERENCES**


