Medical-Laboratory Algorithm WTH-MO For Segmentation of Digital Images of Blood Cells: A New Methodology for Making Hemograms

Ana Carolina Borges Monteiro [1], Yuzo Iano [2], Reinaldo Padilha França [3], Rangel Arthur [4]

[1, 2, 3] *Department of Communications* (DECOM), State University of Campinas – UNICAMP, Campinas, Brazil.
[4] Faculty of Technology (FT), State University of Campinas – UNICAMP, Limeira, Brazil.
monteiro@decom.fee.unicamp.br, yuzo@decom.fee.unicamp.br, padilha@decom.fee.unicamp.br, rangel@ft.unicamp.br

***Abstract* – Inter-disciplinarity has been responsible for solving several problems in the medical areas, being that many of which are derived from the use of engineering techniques. One problem that affects a large part of the world's population is the difficulty of access to health, often caused by a lack of financial resources. One of the most requested medical tests due to its ability to detect a wide range of diseases is the hemogram. However, this methodology is often inaccessible due to its cost, which for disadvantaged populations can be seen as high. Based on this, the present study aims to develop an algorithm for the segmentation of digital images of blood smears, which is capable of detecting and counting erythrocytes, leukocytes and platelets simultaneously, with high accuracy and low cost. The algorithm was developed in the Matlab software environment, based on the Watershed Transform, Transformed Hough methodologies and operations methodologies. The hybrid algorithm was named WHT-MO. The experiments were conducted using 10 digital blood smear images. The results showed high accuracy (90% and 100%) in the detection of the three cell types. Therefore, the WHT-MO algorithm demonstrates that the hemogram can be performed using a simple computer, dispensing with the need to acquire high-cost hematological equipment, which directly impacts the final price of the examination for patients. In addition, high accuracy demonstrates that it is possible to perform the hemogram at a reduced cost without loss of quality and reliability.**

Keywords - Hybrid Algorithm, Segmentation of Digital Imaging, Blood Cells, Morphological Operations, Hough and Watershed Transforms

I. INTRODUCTION

In the last decades, many problems of the medical areas have been solved through techniques from Engineering. This interdisciplinarity resulted in automated methodologies that today are indispensable to the medical routine, such as computed tomography, magnetic resonance, myography, electrocardiogram, echocardiogram and laboratory equipment of clinical analysis[1].

Clinical analyzes are a branch of science responsible for performing laboratory tests using biological materials such as urine, feces, and blood. The results of these analyzes are responsible for directly impacting 70% of the medical decisions, because through them it is possible to identify etiological agents and indicate the best treatment [2]. In this context, the most requested laboratory examination is the hemogram. This methodology is responsible for qualitatively and quantitatively analyzing blood cells. This test is subdivided into 3 parts called erythrogram, leukogram and platelet, which analyze erythrocytes, leukocytes and platelets respectively [2] [3].

The erythrocytes are biconcave disc-shaped anucleated cells with a diameter of about 7μm. These cells are responsible for transporting gases through the body, through the connection of oxygen and carbon dioxide to 4 iron molecules present inside the red blood cells. The erythrocytes are produced within the bone marrow of long bones and are released into the bloodstream on the order of 4.0 to 6.0 x 10^6 per mm 3 of blood. These values are variable according to the age and sex of the patients. The increase in the production and release of these cells can be seen as a strong indication of polycythemias, while the decrease can be seen as indicative of genetic anemias, anemia, or internal or external hemorrhages [2] [3] [4].

Leukocytes cells of rounded shape and with presence or absence of granules and lobular segmentation depending on their subtype. These cells are subdivided into neutrophils, basophils, eosinophils, monocytes and lymphocytes, which are responsible for the body's defense cells against external agents such as viruses, bacteria, allergic processes, intestinal parasites, among others. These cells are produced in the bone marrow and released in the amount of 4,000 to 11,000 leukocytes per mm3 of blood. The increase in these values may indicate the presence of infections and/or inflammations. Exacerbated values are seen as strongly indicative of leukemia. The decrease in the amount of leukocytes is generally linked to treatments based on chemotherapy or sedentary lifestyle [2] [3] [4].

The platelets are small round-shaped cells, having a diameter of 1.5 to 3 μm, being produced and released in the range of 150000 to 300000 per ml of blood. These cells work in partnership with internal and external coagulation factors in order to contain bleeding through the formation of a platelet buffer. The reduction in the amount of platelets

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allows the appearance of internal hemorrhages, whereas the increase is directly related to the formation of intravenous thrombi [2] [3] [4].

These cells can be analyzed by two methodologies: manual hemogram or automated hemogram. Both methodologies are dependent on the collection of 4 ml of peripheral blood collected through venipuncture. The manual hemogram is the oldest methodology, being dependent on health professionals for the processes of centrifugation, counting and making blood smears. This process presents a low cost, however, it can become an exhaustive process, which can cause erroneous counts that negatively impact the medical diagnosis [2] [3] [4].

The automated hemogram is the newest methodology, originated in the 1950s by introducing impedance principle for cell counts. Since then this methodology has undergone several modifications and has given rise to a vast multiparameter hematological apparatus. These equipment are less dependent on the health professional, present a higher speed in the release of the reports, as well as greater accuracy and reliability. On the other hand, these methodologies present a high cost both for the acquisition of the equipment, and for its maintenance and reagents. This high cost is often incompatible with the reality of the populations of underdeveloped and developing countries [6].

A Objectives: To develop a digital image processing algorithm that is capable of detecting and counting red blood cells, leukocytes and platelets, directly impacting the reduction of the cost of blood tests, making it possible for the less favored populations to be accessible.

II. LITERATURE REVISION

In the late 1970s, Matlab software was created. While other computational languages mainly work as numbers one at a time, Matlab is able to operate on all matrices and commands. All Matlab variables are multi-directional commands, no matter what data type. Matlab is a tool capable of analyzing data, developing algorithms, creating models and applications and searching for a solution faster than traditional programming languages such as C/C ++ or Java [1].

Given its wide applicability, many authors over the past few years have used this tool for the purpose of detecting blood cells in digital blood smear images through various digital imaging techniques. In 2011, Kareem et al. Described the methodology for identifying red blood cells as well as its location on blades stained with Giemsa stain. The method was based on the structure and brightness of the components, since the Giemsa dye is able to stain the sample and assist in detecting the location of cells in the image [6].

In the year 2014, Sumeet Chourasiya and G Usha Rani used the Watershed and Hough Transforms to reduce noise and at the same time improve the image. In this way, it was concluded that the accuracy of the algorithm used depends on the camera used and the size of the objects to be captured [7]. As early as 2015, Nasreen and colleagues used digital images of blood cells in the RGB format. The segmentation of the images was performed in grayscale. The Otsu method, chose the limit to minimize the classes between the variance of black and white pixels. [8]. In the year 2017, Ghane et al., Segmented leukocytes from the pool of modified k-means and Watershed techniques. The study has 3 stages: (1) segmentation of leukocytes from a microscopic image, (2) extraction of nuclei from the cellular image and (3) separation of superimposed cells and nuclei [9].

In 2018, Golnaz Moallem *et al.* developed a new algorithm capable of segmenting and detecting overlapping red blood cells in digital blood smear imaging. Initially, the binarization of the image is performed, with the posterior location of the cell center by means of clustering adaptable to medium changes. Finally, the Gradient Vector Flow (GVF) technique was used to detect erythrocytes. [10]

III. METHODOLOGY: DEVELOPMENT OF HYBRID ALGORITHM WTH- MO

The experiments were conducted using blood smears containing erythrocytes, leukocytes and platelets. The images were acquired on ope access platforms in the formats of "jpeg", "jpg" and "png". The algorithm modeling was implemented in Matlab® software, version 8.3 of 64-bit (2014a).

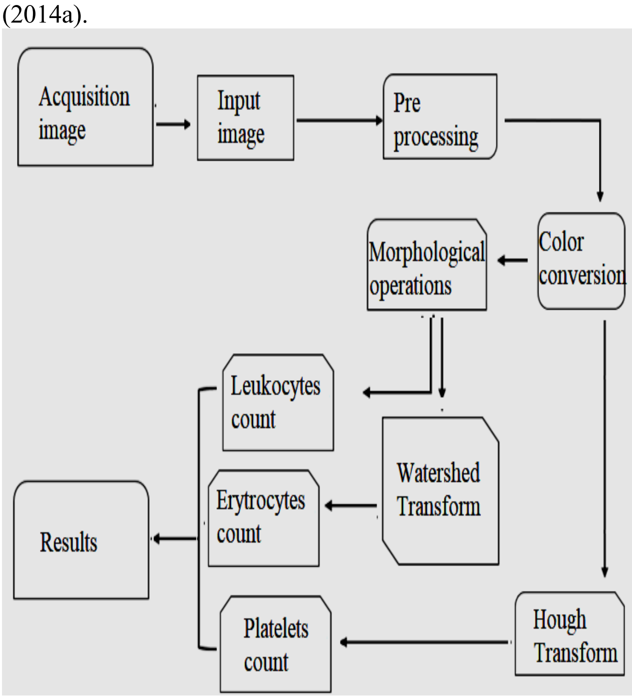

Figure 1. Diagram illustrating the logic employed in the development of the hybrid algorithm WHT-MO

There are many techniques of image segmentation, however, the focus of this study will be the Watershed (WT) and Hough (HT) Transform, and Morphological Operations

(MO), which will originate the WTH-MO hybrid algorithm. Leukocyte detection and counting will be based on Morphological Operations techniques, while erythrocyte counting and detection will be based on the Watershed Transform. Platelets will be detected and counted based on the Hough Transform. The WTH - MO algorithm is presented in figure 1.

After the images are entered, they will be submitted to pre-processing in order to correct possible problems arising from the moment of image capture. This can correct the brightness, contraction and sharpness of the image. The next step is to apply the technique of morphological operations for the detection and counting of leukocytes.

Considering that an image can be defined as a two-dimensional function $f(x, y)$; where f is the function that will define a grayscale image defined in $\Re^2 \rightarrow \Re$. In this context, B will be a planar structuring element such that $B \subseteq \Re 2$ and will be an image operator that will turn a grayscale image into another image according to some specific task. Where conceptually morphological operations consist of the following steps: dilation; erosion; opening; closure and reconstruction [11]. The morphological operations will be the basis for the development of a logic applied to the structural element in the input of an image creating an output of the same size.

Subsequently, the Watershed Transform interprets the images as surfaces, where each pixel corresponds to a position and the gray levels determine the altitudes. Thus, considering the distinct morphological characteristics between the blood cells, the Watershed Transform acts on the detection, labeling and counting of the erythrocytes contained in the image [12]. The segmentation of images by the Watershed Transform will be used as a pixel labeling process, where all the pixels belonging to the same homogeneous region will be marked with the same label. The labeling will consist of inserting a number on top of each cell and according to the order of count established by the methodology.

The Hough Transform will detect the platelets by detecting the border points in each cell, and draw a circle with that point serving origin and radius. It will also use a three-dimensional matrix, the first two dimensions being responsible for representing the coordinates of the matrix, which will increase each time the circle is drawn around the radii on each edge point. An accumulator shall keep the appropriate [13].

IV. RESULTS AND DISCUSS

After the images pass through the segmentation process through the WTH-MO hybrid algorithm, the detections and counts will be performed simultaneously, and the results of the red cell, leukocyte and platelet counts will be released separately, as can be seen in figures 2, 3 and 4, respectively.

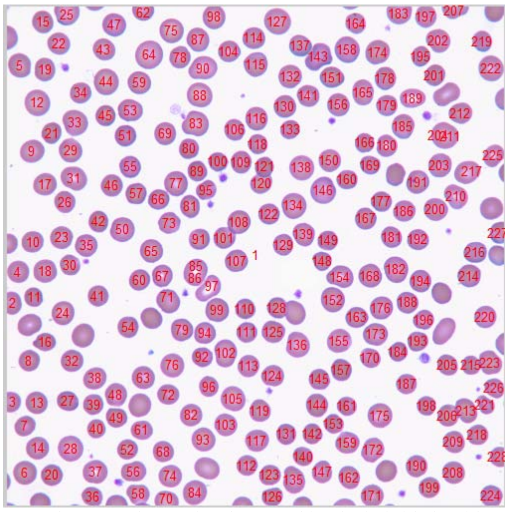

Figure 2. Erythrocytes detected and counted by the hybrid algorithm WTH - MO

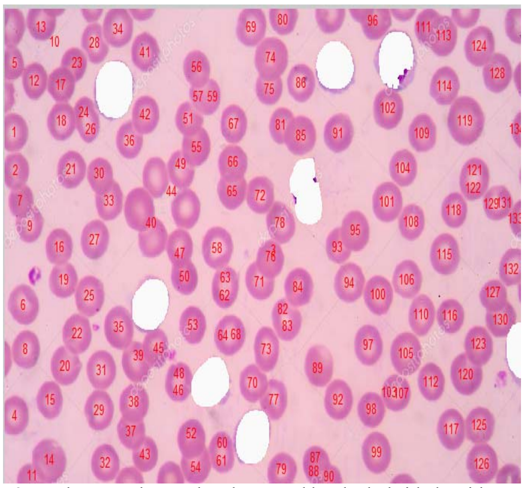

Figure 3. Leukocytes detected and counted by the hybrid algorithm WTH - MO

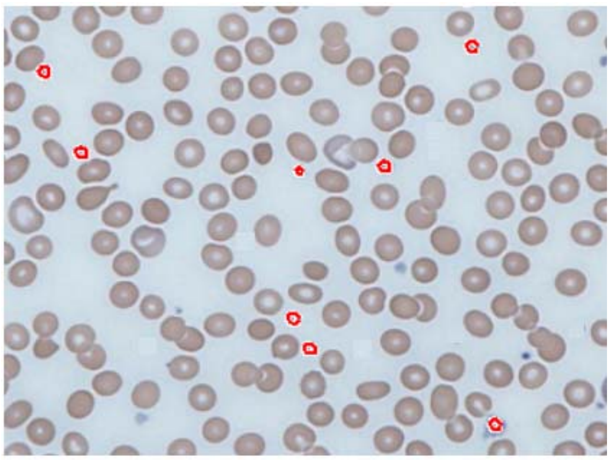

Figure 4. Platelets detected and counted by the hybrid algorithm WTH - MO

In order to determine the accuracy of the methodologies, the 10 digital images of blood smears were submitted to the WTH-MO hybrid algorithm. The total number of red cells, leukocytes and platelets detected and counted in digital blood smear images was 1667, 16 and 134. The results of these counts were compared to counts performed manually by a biomedical professional. The results are shown in Figures 1, 5, 6 and 7.

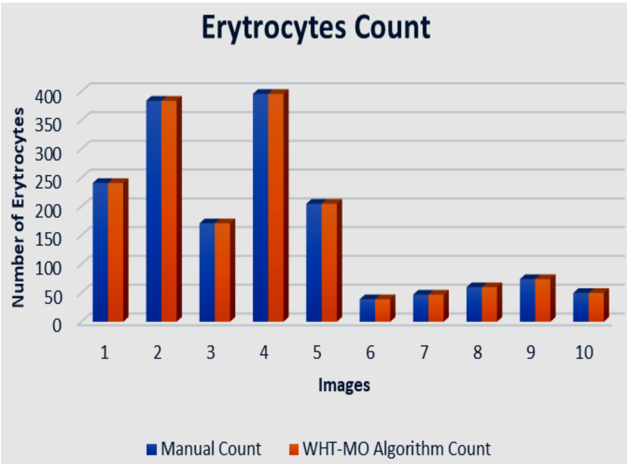

Figure 5. Comparison of erythrocytes counts by manual methodology and by WHT-MO methodology

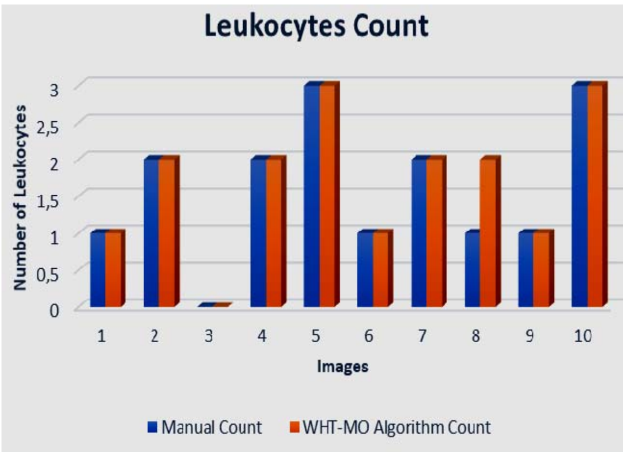

Figure 5. Comparison of leukocytes counts by manual methodology and by WHT-MO methodology

By means of the values obtained in the comparisons of the counts the accuracy values were obtained for the counts of red blood cells, leukocytes and platelets, which are expressed in 100%, 100% and 90% respectively

The accuracy of a methodology is one of the primary criteria for choosing a laboratory test. The greater the aquarium the greater the reliability that the methodology offers to the patient and the professional. Given the accuracy values obtained in the simulations with the hybrid algorithm WHT-MO, it is possible to note that this technique can directly aid in the accomplishment or confirmation of hematological reports with values that are not established in the medical literature.

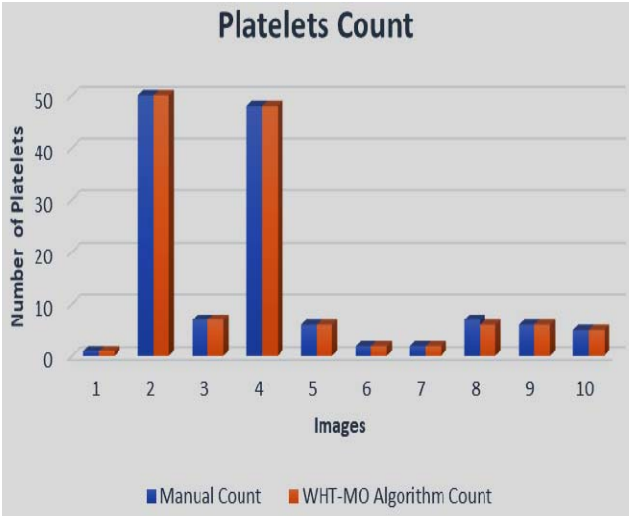

Figure 7. Comparison of platelets counts by manual methodology and by WHT-MO methodology

Laboratories with less demand for tests per day can adopt the WHT-MO methodology as a safe tool for the detection and counting of blood cells. On the other hand, laboratories with greater demand for tests per day can use the WHT-MO algorithm as a confirmatory methodology for the most altered reports. It is common in the laboratory medical routine that the hematological devices present failures in the reading of tests with more severe pathologies. When this happens the biomedical professional must make a blood smear and manually perform its reading under light microscopy. In addition to a tiresome methodology, this practice is subject to failures, since counts and detections depend directly on the professional's attention. Employing the WHT-MO methodology as a confirmatory method may bring greater reliability to medical reports, avoiding the issuance of reports with results that do not express the patient's actual health status and even prevent patients from being indicated for inadequate treatments.

Recently published papers [10], [14], [15], [16], [17] and [18] present the development and application of techniques based on digital image processing for the purpose of detecting and counting blood cells. All these methodologies only contain red blood cells, or leukocytes or both, neglecting platelet counts, which are an important part of the blood count. In light of the above, the hybrid methodology WHT_MO can be seen as the one closest to the laboratory medical reality, presenting a greater potential for application in everyday life.

V. CONCLUSIONS

The hybrid WHT-MO algorithm can be seen with a medical informatics methodology with great potential for blood cell counts in digital blood smear images, presenting satisfactory results for a daily medical laboratory.

The methodology developed brings benefits to patients in both reliability and low cost, as it eliminates the acquisition of high-cost hematological devices. The WHT-MO algorithm can also be used in laboratories with higher purchasing power as a tool for confirming hematological findings. Thus, it can be noted that the WHT-MO technique has wide applicability in the laboratory context.

Performing hematological examinations through digital images allow the exchange of information and greater interactivity among health professionals, since the image can be analyzed by several professionals and reduces the need for new blood collections, which for some patients is seen as a Nice little action.

Future work related to the WTH-MO algorithm includes data rate velocity tests as well as sensitivity and accuracy determination of the methodology. These actions tend to refine the methodology developed to the point of generating easy-to-use and low-cost software aimed at healing part of the deficiencies faced by the less favored populations.

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