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Online Rpi-Web-Server based Blood Cell Analysis for Fast Diagnosis and Monitoring of Disorders for Remote Stations

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ABSTRACT

Government of India had already undertaken various steps for developing health care stations at villages and remote places. But it is not possible to provide the expert physicians and doctors at these places. Government had appointed care takers and nurses at these places. In case of any emergency, proper care may not be possible in proper way. Some remote monitoring systems that can be used for remote assistance may be developed. Experts may remotely analyze the defined problems and may immediately suggest the solution that may be responsible to the saving of one’s life. We have developed a system that can perform the WBCs, RBCs and platelets count from the blood sample taken by caretakers. The microscopic images of blood sample are captured and then they are stitched using novel approach of Hybrid Ero-Dilation based circular stitching and processed for counting cells automatically with this system designed with Raspberry Pi. The results and samples are stored in to the system and can be remotely accessed with embedded web server. Embedded web-server is designed for the counting of WBC available in blood sample based on image processing. MATLAB code is designed and called into python for the execution with Raspberry pi processor. Web-server is designed and embedded into the Raspberry pi processor for accessing remotely from outside worlds.

Key words- Raspberry pi, embedded web-server, WBC, Classification, MATLAB to python.

1. INTRODUCTION

World health organization (WHO) has facing a challenges for getting and keeping health workers are rural and remote areas. The Ministry of Rural Development of the Government of India initiated the task of accelerating the social and economic development of rural India. Its focus is many on health with education, drinking water, housing and roads. Health issues are the major issues in remote places. Indian health ministry also initiated the steps towards the development of many health related techniques.

Available Remote monitoring systems mostly included blood pressure monitoring [1][2][3] It also included blood oxygen saturation monitoring [4][5] and blood glucose monitoring [6][7]. Remotely monitoring and counting of White Blood Cells (WBCs), Red Blood Cells (RBCs) and platelets are considered here as it requires frequently to be observed for diagnosis of many diseases.

Many doctors and many pathologists identify this problem. In the current era of automation, it becomes necessary to provide software-based solution to almost all problems. For the hematologist, subjective interpretation of blood smear become more difficult due to some ambiguity of cells, or due to traditional methods [8][9]. Assessment of blood smear also suffers from tiredness and capability of performing repetitive task of observing through microscope. May one of these reason attracted researchers towards computer aided procedures. Computer aided analysis of blood cells improves objectivity and reproducibility.

Large view microscopic tumor and blood cell structure analysis is required to identify the various diseases like cancer, ‘rouleaux’ formation, leukemia, malaria, psoriasis, AIDS and many more. Microscopic Video Mosaic Creation [10][11] and Mosaic Video Creation [12] (both the terms are different) are necessary to perform various medical related works. In medical field, mosaic can be used for thermo-graphic cancer cell/tumor identification in which thermal cameras can be used to create large view of human body to be projected [13].

A novel automated technique for providing a remote assistance for the analysis of blood sample is developed. It required making blood sample slide for microscopic visualization by the caretaker properly. The blood sample slide is required to be scanned by the proposed system for further automatic analysis. The proposed automatic system includes an Electronic Microscopic System (Bluetooth connected) that can capture the image of blood sample at 10X, 40X and 100X magnification. Microscope is slightly tuned to capture surrounding images i.e. connected overlapped microscopic images. Captured images are sent to the Raspberry pi based Controlling System using Bluetooth communication. The sample images are processed using python code for stitching of overlapped microscopic images. The stitched image (mosaic image) is cropped based on the predefined unit scale or size so that number of WBC can be identified and counted per unit sized sample. After cropping to the specific size of mosaic image, the BWC areas are identified and separated from RBC and platelets area. Identified WBC areas are then classified according to its different types. The same data is stored in to the database maintained into its memory in terms of number of WBC for specific class. The web page is designed for monitoring and visualization of the captured data. This web page is embedded into the web-server [14] developed into the flash memory of Raspberry pi board. IP of web-server Ethernet is mapped to external IP for accessing through internet using specified port. For the expert opinion, SMS will be sent to the expert for further immediate assistant.

2.METHODOLOGY

The proposed system includes two subsystems as 1) Electronic Microscopic System (Bluetooth connected) and 2) Raspberry pi based Controlling System. Electronic Microscopic System is designed to capture the electronic images of blood sample. Initial manual setting is required for 1st sample then it automatically focuses to the different positions for capturing surrounding microscopic images to be used for mosaic creation. Microscopic auto positioning is used for focusing along the centre position by x-y micro actuator systems that was controlled through Bluetooth by raspberry pi board. System includes electronics microscope with x-y control using steeper motors (micro actuators). The steeper motors are controlled with the steeper motor controller. Steeper motor controller is configured with Arduino controller that is connected to Raspberry pi Controller System through Bluetooth communication. The captured images are temporary stored into the SD card and also sent to the central controller (Raspberry pi based Controlling System) through Bluetooth. Arduino code called ArduinoMicroscopy.ino is developed for the controlling of the system. Algorithmic steps for ArduinoMicroscopy Algorithm are as given bellow.

1) Scan the keyboard for checking the key input
2) According to the x-position and y-position key pressed, move the corresponding steeper motor in clockwise or anticlockwise direction.
3) If Focus button is pressed (after manual proper focusing on slit of blood sample), captures the image (centre image).
4) Rotates the x-position and y-position steeper motors for capturing surrounding 8 images.
5) Displays the status of all images captured on the screen for manual verification.
6) After pressing Send button, send all the captured images to Raspberry pi board through Bluetooth.
7) Repeat the process from step 1) to step 6) for next scan.

Raspberry pi based Controlling System is configured with Bluetooth and internet connectivity through Ethernet to act specifically as processing device, controlling device and web-server. A novel approach of Circular Image Stitching Algorithm is developed (MATLAB code of function circularstitch.m) for stitching of multiple microscopic images using Strip Search Algorithm [11] to make a big high resolution microscopic mosaic image. Algorithmic steps for Circular Image Stitching Algorithm (function) are as given bellow.

1) Get central image (1st image) as an initial mosaic image.
2) Get 2nd image (next image) and find the overlapped portion with that of with the 1st image (mosaic image). Identify the seam line for overlapping portion using RANSAC algorithm [15].
3) Stitch the two images (1st and 2nd images) using strip search algorithm [11] using circular strips along seam line to create the mosaic image.
4) Get next image and find the overlapped portion with that of with the mosaic image. Identify the seam line for overlapping portion.
5) Stitch the two images (mosaic image and next image) using strip search algorithm [11] using circular strips along seam line to create the mosaic image.
6) Repeat the step 4) to step 5) for all remaining images to create the final mosaic image.
7) Return the function.

WBC-ANALYZE Algorithm is developed (MATLAB code of function wbcanalyze.m) for analysis of WBC in sample mosaic image. Algorithmic steps for WBC-ANALYZE Algorithm (function) are given bellow.

1) Crop the mosaic image for predefined size indicating unit sized sample.
2) Classify/identify the area/regions of WBC, RBC and platelets [16] in mosaic image.
3) Classify the WBCs by using mathematical image morphology [17].
4) Count the WBCs according to its type.
5) Create the database for it.
6) Send the database on web-server for internet access.
7) Return the function

Main MATLAB code (developed for controlling whole operation using various developed functions) is imported into the python code (stitch.py) for execution on Raspberry pi board. Route python code say Root Algorithm (root.py) is developed for controlling whole operation of raspberry pi system from the root like image stitching, WBC analyze and web-server operation. Web-server is installed in Raspberry pi and web page designed is embedded in to it for monitoring the required information from internet. Algorithmic steps for Root Algorithm are given bellow.

1) Initialize all the ports.
2) Initialize Bluetooth and Internet connections.
3) Initialize the web-server.
4) San the Bluetooth data.
5) If new data is arrived, initiate the processing.
6) Call the circularstitch.m function for stitching the images received from Bluetooth to create the mosaic image.
7) Call the wbcanalyze.m function for analysis of mosaic image to classify and count the various types of EBCs.
8) Created database is send to web-server storage location for monitoring purpose.
9) Send SMS to mobile of experts for further processing.
10) Monitor the reply from web page using web-server by capturing the dynamic text from experts.
11) Repeat the step 5) to step 10) if next data is received.
12) Repeat the step 1) to step 10) if system is rebooted.

2.1 Block Schematic for proposed models

Total system consists of two modules as Electronic Microscopic System (Fig. 1) and Raspberry pi based Controlling System (Fig. 2).

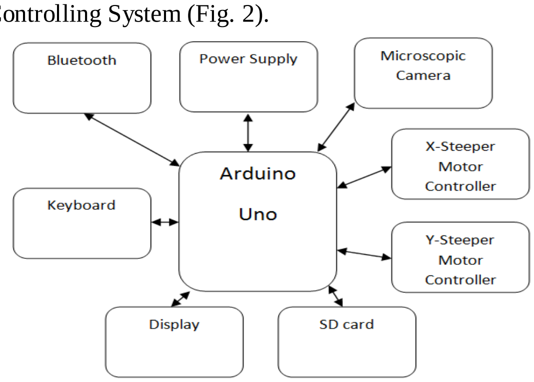


Figure 1: Block Schematic of Electronic Microscopic System

Electronic Microscopic System consist of various modules like Arduino-Uno module, SD card module, Bluetooth Module, Keyboard, Display module, Steeper control module and Camera Module. Using Arduino, embedded programming for accessing various modules becomes easy. Its interfacing also becomes simple. HC05 Bluetooth module is used it works on serial communication. Serial data can be sent through the Bluetooth module to the paired Bluetooth modules or device (to Raspberry pi board). Serial LCD display using Serial LCD I2C Module PCF8574 is connected to Arduino for reducing the interfacing lines. Micro SD card reader module is used for storing the images in databases. Push to on keys are interfaced to Arduino for sending different commands for particular operation of systems like x position, y position, Focus, Display and Send. OV7670 Camera Module is used for sensing the microscopic images from mechanical microscope whose slate is movable using two steeper motors in x and y directions respectively. L293D Motor Driver Shield is used for interfacing Arduino with steeper motor. It has two channels for the interface to two steeper motors.

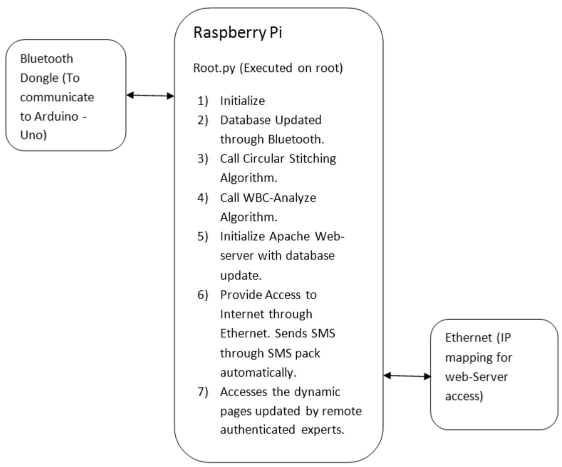


Figure 2: Block Schematic of Raspberry pi based Controlling System

Raspberry pi board is used for computing the required information from complex algorithms. Various communication protocols can be efficiently installed and can provide better communication through-puts. For proposed work, Bluetooth and Ethernet communications are required. Through Bluetooth, captured image data is received and processed for image stitching and for analysis of WBC. The computed outputs of both the algorithms are visualized on Webpage that is embedded in to the Apache Web-server installed into the flash of Raspberry pi board itself. To access the embedded web page, Ethernet IP is mapped to Global IP. Authenticated experts may access the published web page. It also sends the SMS to the particular mobile number using SMS pack. The response from web user (from authenticated experts) can be dynamically received through dynamic pages created by PHP.

2.2 Circular Image Stitching for Microscopic Images

Microscopic mosaicing requires horizontal or vertical stitching of video frames from microscopic camera, which is performed by novel stitching idea of Hybrid-Ero-Dilation process over the exact stitching boundary of the overlapped circular views of consecutive frames. Consecutive frames from the microscopic camera can be captured according to the logic of specific distance travel along the boundary of circular microscopic view for real time operation. For real time operation, during the travel span between the consecutive frames, their stitching operation should be performed. So, Hybrid-Ero-Dilation process along per-defined mask is considered for the stitching purpose. Wide view microscopic mosaic images are useful for preservation and analysis of distortable microscopic blood and body organs. Continuous scanning can provide large view mosaic-video frames for live time analysis of various deceases samples.

Microscopic views are circular in shape through many general microscopes as shown in Fig. 3 below. Combination of various frames of video taken from microscopic cameras in circular manner is called microscopic mosaicing. Image stitching along elliptical area is required for the microscopic mosaicing as shown in Fig. 4 below.

Figure 3: Circular viewing area of microscopic camera

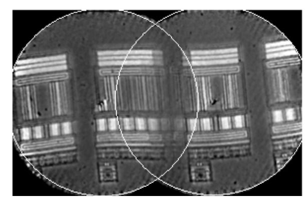


Figure 4: Elliptical stitching area during microscopic mosaicing with circular viewing area

Steps to obtain microscopic mosaic are as follows.

1. Obtain the clear view of the specimen under microscope by properly focusing the lens assembly. This is the starting point of the mosaic image.
2. The specimen is moved in required linear direction (X-direction) slowly.
3. With the linear motion of the slide, each new frame is checked with respective to the previous frame to determine the optimum stitching area.
4. As the slide moves, the length of the radical line between the current frame and the previous frame decreases. When the length reaches to a predefined length, the two frames, assume to be register previously, are stitched together along the overlapping region to obtain an image as shown in Fig. 5.

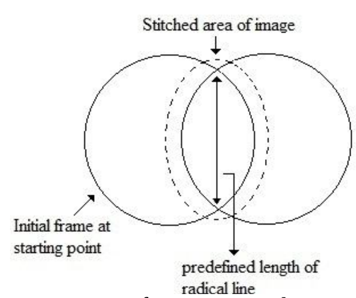


Figure 5: Determination of optimum overlapping for stitching

5. Repeat steps 2 to 4 to obtain the mosaic of surround images for complete view.
6. A mosaic with wavy will be obtain as shown in Fig. 5a and Fig. 5b, which is then cropped at the top and bottom to

remove the wavy edges of mosaic as shown in Fig. 6a and Fig. 6b below.

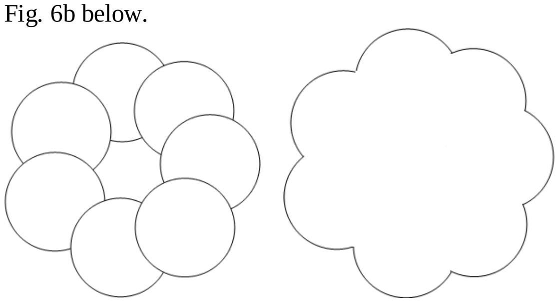


Figure 5a, b: Wavy mosaic formed after scanning surround of specimen under microscope

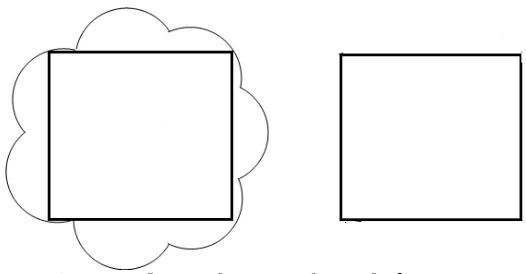


Figure 6a, b: Final mosaic obtained after Cropping

Thus, the height of the mosaic image thus obtained is equal to the length of the radical line.

2.3 Microscopic Circular View Stitching

Once the height of overlap area between the frames reaches the predefined length (that is equal to length of radical line), then two frames are stitched in the following manner:

1. New pixel values within the overlap area are calculated by averaging the values of corresponding pixels to be stitched as shown in Fig. 7.

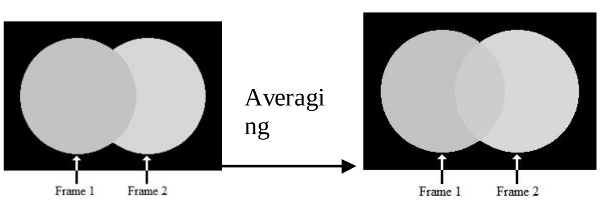


Figure7: Averaging of pixel values in overlapping region

2. The mask image for Hybrid-Ero-Dilation process is formed as follows:

   i. Mask image (black image) as in Fig. 8 of the size same as the overlapping image is considered.
   ii. The mask is created in this image along the overlapping location to create a final mask image as shown in Fig. 7.

Figure 8: Mask image obtained from step 2

3. The image from step 1 and mask from step 2 are then input to Hybrid-Ero-Dilation algorithm that is the combination of the erosion and dilation operation on images to remove the visible seams as shown in Fig. 9.

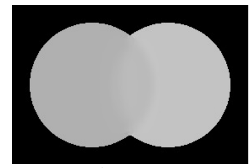


Figure 9: Illustration of Hybrid-Ero-Dilation Process

The averaging, dilation and erosion processes are repeated for all new frames that are stitched together.

2.4 Cell Region Identification

Based on the shape and size of cell, WBC, RBC and platelets are separated and marked by white, Red and yellow rectangle along the identified cell respectively. WBCs are having bigger shape and platelets are having smaller shape than RBCs, accordingly the thresholds are set and all the cells are classified.

At different magnification levels like 10x, 40x and 100x, the focus on bold slide may visualize the particular blood cells. At 10x level, WBCs can be focused properly. At 40x level, RBCs can be focused properly. At 100x level, platelets can be focused properly. So, we focused by the level of 40x for making combination of all the cells on one image.

2.5 Cell Counting and WBC Classification

In proposed algorithm, in unity sized image, the WBCs, RBCs and platelets are counted by the number of white rectangles, red rectangles and yellow rectangles formed respectively.

WBCs classification method includes the steps of WBC area cropping, Image segmentation, Image boundary detection and parameters extraction like pixel area, circularity, eccentricity and number of lobes [18].

2.6 Installation of Apache Rpi-web-server on Raspberry pi board

The various steps involved in installation are as follows.

1. Install the OS. Hook up the keyboard and mouse to the Pi and connect it to an HDMI monitor.
2. Check the network address.
3. Update your Pi and install Apache Web server.
4. Add PHP and MySQL.
5. Test Apache web server.
6. Start building your site.

2.7 Design Dynamic Web Page using html and PHP

Raspberry Pi can host a web page and all the content that may be published on it. A dynamic page is designed to display changing data such as data from Arduino system regarding to cell count and types and the changing time and date. A dynamic page that is capable of changing without you manually uploading files to it. It was done using a scripting language called PHP. To use PHP on the Raspberry Pi, it is needed to install PHP with module package for Apache. It is also needed to combine current HTML and PHP scripts and needed to make the text larger by using HTML tags.

3.EXPERIMENTAL RESULTS

Experimental set-up is shown in Fig. 10a and the sliding bed used to focus on various positions is shown in Fig. 10b. The proposed Electronic Microscopic System used is as shown in Fig. 11.

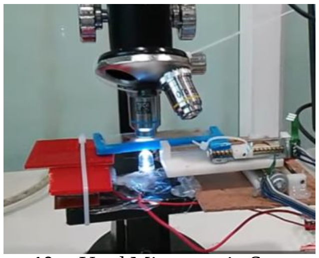


Figure 10a: Used Microscopic System

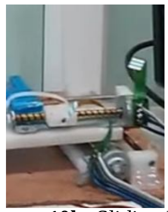


Figure 10b: Sliding Bed

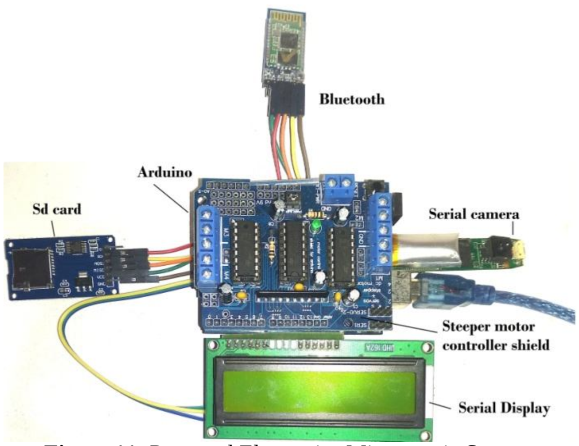


Figure 11: Proposed Electronics Microscopic System

Fig. 12 shows the microscopic images captured by microscopic system. Mosaic image produced by circular image Stitching Algorithm is as shown in Fig 13a. The mosaic image is cropped to get the final mosaic image (Fig. 13b).

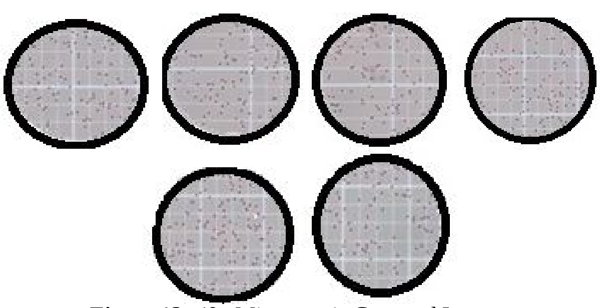


Figure 12: 40x Microscopic Captured Images

Figure 13a: 40x Microscopic Mosaic Image

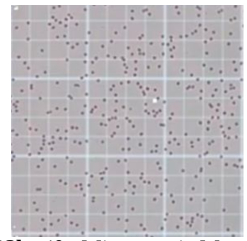


Figure 13b: 40x Microscopic Mosaic Image

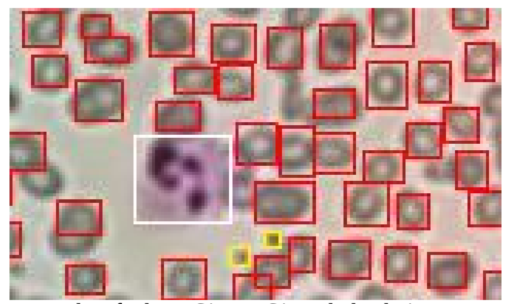


Figure 14: Identified WBC's, RBC's and platelet's Regions with 200x Mosaic Image

Identified WBC regions (Fig. 14) from various mosaic images are collected (Fig. 15) and are classified.

(a) (b) (c) (d)

Figure 15: Images from created mosaic

The following images show the output for each image in Fig. 15 at each step of proposed system.

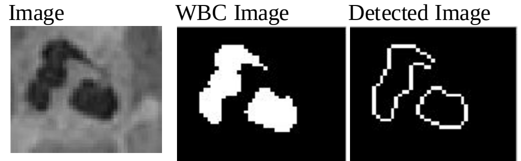
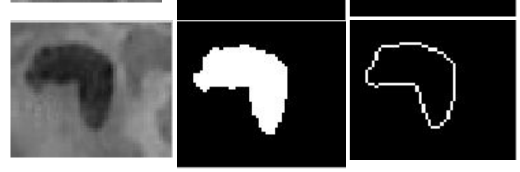
Image	Green channel Image	Segmented WBC Image	Boundary Detected Image
Figure : 15 a			
Figure : 15b			

Figure : 15c

Figure : 15d

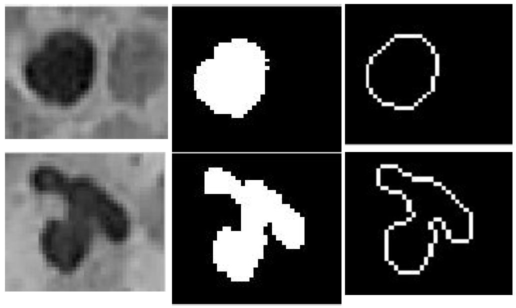


Fig. 16: Stepwise output of proposed system

Table 1: Results obtained from proposed algorithm

Image	Area (pixels)	Circularity	Eccentricity	Number of lobes
Fig.15 (a)	166	2.4009	0.9144	2
Fig.15 (b)	433	1.832	0.7860	1
Fig.15(c)	257	1.1125	0.5679	1
Fig.15 (d)	280	2.8136	0.5132	1

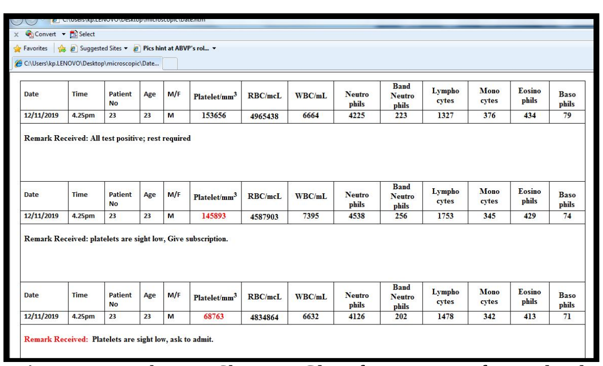
Using the result obtained from the proposed algorithm and the ranges obtained from the training dataset the unknown dataset images are classified as follows given in Table 2.

Table 2: Classification obtained from result for given images

Image name	Classification
Fig.15 (a)	Segmented Neutrophil
Fig.15 (b)	Monocyte
Fig.15 (c)	Lymphocyte
Fig.15 (d)	Neutrophil

As subjecting the proposed algorithm to given images, yield correct classification rate as 93% for different sub-type of WBC. Web Page (Fig.17) is showing classification data from blood sample taken on Dated 23 Dec 2019, 05.23 Pm. It also show the request (SMS) sent for further analysis to particular expert on Mobile Number 08275737890 and response received from expert against the request by system through dynamic pages on web-server.

A secure communication is more required to be added in the proposed system. IOT security [19, 20] may be utilized for more secure communication.



Convert Select

Favorites Suggested Sites Pics hint at ABVP's rol...

C:\Users\kp.LENOVO\Desktop\microscopic\Date...

Date	Time	Patient No	Age	M/F	Platelet/mm^3	RBC/mcL	WBC/mL	Neutro phils	Band Neutro phils	Lympho cytes	Mono cytes	Eosino phils	Baso phils
12/11/2019	4.25pm	23	23	M	153656	4965438	6664	4225	223	1327	376	434	79

Remark Received: All test positive; rest required

Date	Time	Patient No	Age	M/F	Platelet/mm^3	RBC/mcL	WBC/mL	Neutro phils	Band Neutro phils	Lympho cytes	Mono cytes	Eosino phils	Baso phils
12/11/2019	4.25pm	23	23	M	145893	4587903	7395	4538	256	1753	345	429	74

Remark Received: platelets are sight low, Give subscription.

Date	Time	Patient No	Age	M/F	Platelet/mm^3	RBC/mcL	WBC/mL	Neutro phils	Band Neutro phils	Lympho cytes	Mono cytes	Eosino phils	Baso phils
12/11/2019	4.25pm	23	23	M	68763	4834864	6632	4126	202	1478	342	413	71

Remark Received: Platelets are sight low, ask to admit.

Figure 17: Web Page Showing Classification Data from Blood Sample

4.CONCLUSION

Online cell analyzing system is successfully developed that can perform the WBCs, RBCs and platelets count from the blood sample. Only the manual assistance is required for the preparation blood slide. Prepared blood slide is needed to be scanned by proposed microscopic system. The captured images are stitched using a new approach of Hybrid Ero-Dilation based circular stitching to get big and high resolution mosaic images. RBCs, WBCs and platelets are identified and counted using root algorithm. WBCs are also classified into the sub categories and counted for further analysis. The results are stored on embedded web server and can be remotely accessed. Alert is provided to expert once the data is uploaded by the system for assistance. Expert may provide the remark on the web for corresponding samples that may be read by caretaker for further treatment or process. The proposed system is real time working and tested on many patients.

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