International Journal of Psychosocial Rehabilitation, Vol. 24, Issue 02, 2020
ISSN: 1475-7192

Detection of Rheumatoid Arthritis using Image Processing Techniques

[1]Mahesh Kumar A S, [2]Mallikarjunaswamy M S, [3]Chandrashekara S

ABSTRACT-- *Rheumatoid Arthritis (RA) is a kind of inflammatory disease.Main symptoms of RA are inflammation, swollen and joint pain especially early hours of the day. Inflammation starts at smaller joints of the body, in later stages inflammation spread to heart and other organs of the body. Therefore, detection of RA in early stages is very much essential.Different modalities are being used for the purpose of RA diagnosis notably radiography, ultrasound and Magnetic Resonance Imaging (MRI), even though X-ray is the best and effective tool in the assessment of joint damage and position changes. The gap between phalangeal bones in the hand finger is a vital parameter in the detection of RA using X-ray images, especially the metacarpal joint and proximal joint involved in the early stage of the RA. This work deals with development of the image processing technique which is helpful for RA detection. The image processing steps involves median filtering, background extraction, images subtraction, canny edge detection for segmentation and finally features extraction. The extracted feature reveals the significant difference between normal and abnormal (RA) image. Dataset include both normal and RA affected images.*

Key words- *Canny edge detection, Median filtering, Phalangeal bones, Rheumatoid arthritis, X-ray*

I. INTRODUCTION

Rheumatoid Arthritis (RA) is an autoimmune and chronic disease.Generally it results with inflammation, swollen, stiffness, joint pain and loss of functionality in the joints. The functioning of connective tissues, tendons, ligaments, cartilages and muscles affected in RA joints [1]. Initially, the smaller joints of the body affected by RA, such as joints of the finger, hand and wrist, in later stages it affects knee, feet, ankles, elbows, shoulders and hip [2].Human hand finger have different phalangeal bone like distal phalangeal, proximal phalangeal and metacarpal phalangeal, in between each phalangeal having a gap calledJoint space width (JSW). The JSWbetween the phalangeal bones is very much helpful inRA diagnosis at its early stages.Except thumb, human hand fingers have three joints notably distal interphalangeal joints (DIP), proximal interphalangeal joints (PIP) and metacarpophalangeal joints (MCP). The DIP joint is a joint between intermediate and distal phalangeal bone, PIP joint is a joint between proximal and intermediate phalangeal bone whereas MCP joint is a joint between metacarpal and proximal phalange bone. There are many factors influencing the RA include sex, family history, age, gender, habit of smoking and obesity[3]. RA is a kind of autoimmune disease, normally immune system of the body protect against foreign substances like bacteria and viruses. RA attack the immune system by creating inflammation, the resultant inflammation thickens synovium, which is present in and around the joints

[1] PES College of Engineering, Mandya, Karnataka, India, as.mahesh.ec@gmail.com

[2] JSS Science and Technology University, Mysuru, Karnataka, India.

[3] ChanRe Rheumatology & Immunology Center & Research, Rajajinagar, Bangalore, Karnataka, India.

Received: 02 Dec 2019 | Revised: 24 Jan 2020 | Accepted: 16 Feb 2020

of the body. Thicken synovium causes swelling and pain in the body [4].JSW evaluation process involvesdifferent phalanges of human hand shown in Fig1.

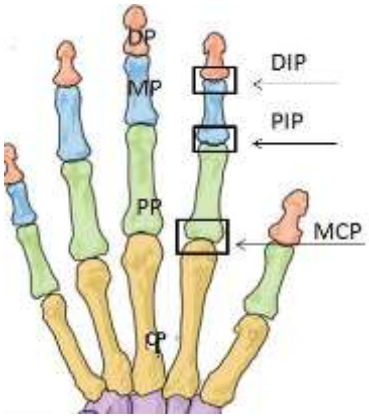


Fig1: Posterior view of the human hand anatomy.

Different modalities are being used for the purpose of diagnosis of RA problems viz., X-ray, MRI, ultrasound, bone scintigraphy and CT.X-ray is the best and effective tool in the assessment of joint damage and position changes in RA patients [5].RA radiographic changes arecartilage loss, and bone erosions in hand and wrist of the body. The changes in the JSW in each of the finger are the sign of RA [6 7].

II. LITERATURE REVIEW

In diagnosis of RA doctors suggest any one of the modalities test along with blood test based on the severity of the disease. X-ray hand images consider is the best and effective tool in the assessment of joint damage and position changes, but radiograph gives only two-dimensional (2D) visualization whereas MRI and ultrasonography gives three-dimensional (3D) visualization of RA affected joints. Radiographs consider being used as a supporting tool for RA diagnosis. Compared with other imaging modalities radiograph is an intrinsic advantage of super capacity of imaging the bone structures of the body. The conventional radiography generates significantdifference between bones and soft tissues. In the work of Huo et al [8]it is mentioned that advantage of conventional radiography is short exposure time (typically around 0.1 second for capturing) and superior spatial resolution (e.g.0.1 mm^2/pixel). X-ray equipment is relatively cheap and service available at almost all the hospital and clinic. The disadvantage of radiography imaging is the ionizing radiation involved during acquisition of image and 3D imaging is not possible with radiograph [8].TheRA hands radiographic images are examined by rheumatologist based on some features which are visible for naked eyes. There are several RA diagnosis methods based on the image processing techniqueincluding histogram equalization, Gaussian filter, edge detection and classification.Hall et al [9] presented a survey on different preprocessing and feature extraction techniques, process include gray level distribution for linearization,digital spatial filtering, and contrast enhancement done in the post filtering stage, detailed arterio-venous obtained for image subtraction. Finally features extracted were used for classification. Kumara et al [10] presenteda series of image processing operation like contrast enhancing followed by adaptive histogram equalization which increases the intensity level of input image, Gaussian filter used for the removal of random noise which is present in the image, edge detection is used for edge detection and region of interest is found out by masking. Bhisikar [11] presented

automatic analysis of RA based on statistical feature. Analysis process involves preprocessing, segmentation using active shape model, joint location detection done by local linear mapping and Gabor filter used to local texture feature. Subramoniamet al [12] used image segmentation algorithms for arthritis detection. Initially noise was removed from the image by using a median filter. Histogram calculated from the filter image,and thenregion growing algorithms were used for grouping purpose. After grouping is done, canny edge detection used for finding edges of the image.They located the periarticular space clearly.Mitta et al [13] proposed morphology technique for the arthritisdetection. Dilation and erosionmorphology operations used for image enhancement. Vinoth et al [14] introduced a method for arthritis detection, which involves steps like de-noising, histogram smoothing, finally edge detection segmentation. The Gray Level Co-Occurrence Matrix (GLCM) is one of the best techniques used in image analysis. GLCM can be used for extracting important features such as energy, entropy, homogeneity, correlation and contrast of a bone.Shimizu et al [15] introduced a method called super resolution for X-rays,effectively found cartilage thickness in arthritis.A radiography image has noise and low resolution.Initially they consider radiographic images of the arthritis patient and apply Total Variation (TV) regularization. TV regularization is an image denoising method,followed by a shock filter and a median filter. David et al [16]presented method using ultrafast doppler for arthritis detection. This algorithm calculates the JSW of metacarpophalangeal joint with ahigh accuracy.Morphological operations being used to find the distance between phalanges especially metacarpal phalanges and proximal phalanges bone in hand radiography images.

From this literature study it's clear that there is a need of simple and effective image processing technique for the RA diagnosis and classification.This work makes use of X-ray imageforprocessing and analysis because image acquisition requires shorter time, facility required for image acquisition is available in the most of the clinic and hospital and also cheapest among all other modalities.The objective is set to develop image processing technique to detect RA based on JSW.

III. METHODOLOGY

The X-ray dataset were collected from ChanRe Rheumatology and Immunology Center, Bangalore, Karnataka, India. Dataset include both normal and RA affected images. The images are processed in Matlab 2018b. Images are restricted to 128*128 sizes. The image processing stages involve operations like median filtering for smoothing, background extraction, images subtraction, canny edge detection for segmentation and finally feature are extracted. The extracted feature used for classification of normal and abnormal (RA) images.Theflow diagram shown in Fig 2 illustrates the steps involved in RA detection based on image processing using hand X-ray image.

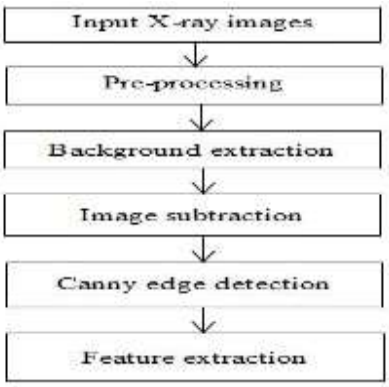


Fig 2: The image processing steps involved in detection of RA

3.1 Image processing phase

Images are undergone through series of image processing steps in order to quality enhancement of image and extract the necessary features for classification. The most important feature is obtained by calculating the distance between metacarpal phalangeal bone and the proximal phalangeal bone. Images are passing through median filtering for smoothing, background extraction, images subtraction, canny edge detection and feature extraction.Feature extraction play vital role in the classification of the images.The image processing operations are described as follows.

3.2 Median filtering:

Median filter is a non-linear filter using for the purpose of image smoothing. It is widely using in the application where the removal or reductionof noise by preserving edges of the image is necessary. The role of median filter is to remove or reduce noise, especially salt and pepper and impulsive noise by preserving the image edges. Such a removal of salt and pepper and impulsive noise by preserving the image edges gives better results in the later stages of the processing such as edge detection etc., It is a non-linear method of filtering in which the output pixel obtained by calculating the median of a pixel window selected for processing pixel[17].Fig. 3 illustrates median value calculation and pixel window consideration mechanism for calculating the median value to reduce noise.

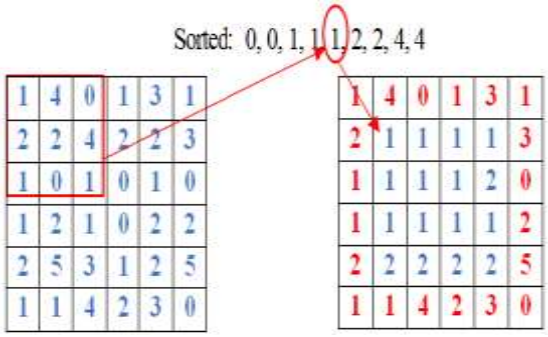


Fig3: Median filtering example using 3x3 sampling window

The median filter moves on each and every individual pixel and replaces it by the median of the neighboring pixel that surrounds it. The pixel which surrounds the reference pixel for replacement is called window or kernel [18]. The median value of the pixel is calculated by sorting out all the pixel value present in the considered window size into numerical order, and then replaces the pixels being considered with the median pixel.

3.3 Background extraction

Morphological operation is an image processing technique based on shapes and structure of the picture. Morphological operations are being used to apply structuring elements to input images by creating same size output. The basic morphological operations are enlargement and disintegration. Enlargement morphological operation used to add pixels to images while disintegration used to uproot pixels on articles limits. Both enlargement and disintegration depends on the size of the image.Dilation and erosion are the other set of morphological operation used in the image operation based on the structuring picture[19].The background extraction process is accomplished by image opening morphological technique. The image openings make use of erosion followed by dilation with the same structure element [20].

Erosion and dilation equations are given by $Erosion:$

$$[f \ominus g](x) = min_{u \in G}[f(x+u) - g(u)] \quad (1)$$

$Dilation:$

$$[f \oplus g](x) = max_{x+u \in F}[f(x+u) + g(u)] \quad (2)$$

Background extraction aims to find foreground detection, it helpful in the extraction of bone region in the X-ray image.

3.4 Image subtraction

Image subtraction is considered as basic tool for medical image analysis and preprocessing. Image subtraction extensively used in the tumor detection. Image subtraction takes two images as input and produces one image as output. Image subtraction operation is done by pixel subtraction operator. Subtraction operator performs pixel value subtraction of first image with pixel value of the second image. Image subtraction used to obtain new better quality image by subtracting input image from the background image[21].

$$S(i,j) = I(i,j) - B(i,j) \quad (3)$$

Where S, I and B represent the resultant subtracted image, input image and background image respectively. I (i, j), B (i, j) represent the corresponding input element value and background element value.Main importance of image subtraction is to leveling uneven portion of the images. Image subtraction is helpful in the detection of changes betweentwo images. Image subtraction improves connected component (blob) contents. These steps used to enhance the bone region of the X-rayimage. The subtracted image gives a more detailed structure image which was previously not visible in background image and also helps in leveling uneven section of an image.

3.5 Image adjustment

Generally image adjustment can be used to do modification in the contrast, hue, brightness, saturation, gamma and level in the image. Predominate use of image adjustment in pattern recognition and fingerprint recognition where contrast enhancement is needed. Image adjustment can be used to increase intensity and

enhance the quality of the image. Gamma contrast adjustment is the most common type of image adjustment function [21 22].Image adjustment used to fix an overexposure image to a required level and it improves the brightness and color correction wherever needed in the subtracted image.

3.6 Joint space width calculation

The process of dividing the digital image into multiple meaningful segments called as image segmentation. Canny edge detector is considered be one of the best currently used edge detectors because detection of true edges is more accurate and also it provides good noise immunity. Canny operators follows few steps to detect the edges, Smoothing, Finding gradients, large magnitudes, non-maximum suppression, Perform double thresholding and Final edge tracking by hysteresis [23 24].The calculation of JSW between phalangeal bones, finding of the edges is most important for calculation. This can be achieved by canny edge detection. Canny edge detection algorithm as follows

Gradients: Canny algorithms uses different filter to detect vertical, diagonal and horizontal edges in the blurred images. Edges getting mark due to larger magnitude of the gradients places in the images. Since it's very much essential to find gradient of the images, which is obtained by convoluting smoothen images with the derivative of the Gaussian filtering, both in the horizontal and vertical directions.

The formula can be used to find magnitude values as follows:

$$|G| = |Gx||Gy| \quad (4)$$

$$|G| = \sqrt{(G^2x + G^2y} \quad (5)$$

Where Gx and Gy are the gradient values in x and y direction respectively computed by canny algorithms.

Non maximum suppression: This technique very much essential to suppress all other noise present in the image also its helpful to find local maxima in the direction of the gradient. Find out the maxima in the direction of the gradient which is useful in minimize the false edges.

Double thresholding: Canny edge detection algorithms make use of double thresholding instead of single static thresholding value for the image. Double thresholding good in finding strong edges in the images. After the application of non-maximum suppression, almost all the pixels with real edges of the images even though few edges affected by noise and color variation. It is very much essential to filter out the noise by this stage this accomplished by selecting the low and high thresholding values for an image. From the selection of low and high thresholding values filter out pixel with weak gradient. Selection of threshold values depends on the content present in the input image.

Edge tracking by hysteresis: in this stage only the edges with strong gradients are consider by suppressing all the edges with weak gradients [25].

3.7 Removal of connected object

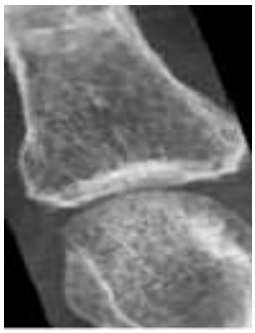
Soon after segmentation, unwanted components are removed from the segmented images. Removal of unwanted components from the segmented images is achieved by the Matlab function "bwareaopen" [26 27].Removal of connected object results with removal of unwanted components.

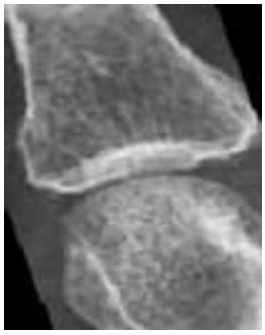
3.7 Feature extraction

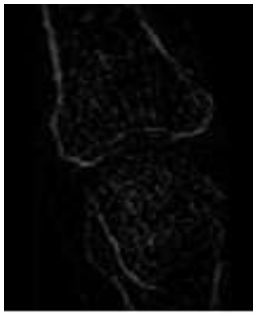
The space between phalangeal bones in the hand finger shows the clear distinguish in the classification of the images, especially the metacarpal joint and proximal joint involved in the early stage of the RA. Mean and standard deviation has been extracted. The extracted feature shows the clear distinguish between normal and RA image.

IV. RESULTS AND ANALYSIS

Mean and standard deviation has been extracted. The extracted feature shows the clear distinguish between normal and RA image. The results of median filter, background extracted, image subtracted and segmented images are shown Fig 4. Fig 4(a) shows the input X-ray image, 4(b) median filtered image, 4(c) background extracted image, 4(d)Subtracted image, 4(e) Segmented image and 4(f) Cleaned image.







(a) Input image(b) Median filtered image

(d) Subtracted image(c) Background image


(f) Cleaned image(e) Segmented image

Fig 4: Image processing results (a) Input image (b) Median filtered image) Background image (d) Subtracted image (e) Segmented image (f) Cleaned image.

The proposed method has been tested on X-ray images consists of both normal and abnormal images. The dataset consists of 10 normal and 15 abnormal images.Mean and standard deviation are calculated for both normal and abnormal images. The results show that for normal images mean value is less and more is the standard deviation compared to abnormal image. These results useful in the RA diagnosis process in the early stages. Thecalculated mean and standard deviation are for normal and abnormal imagesshown in Table1

.

Table 1: Calculated mean and standard deviation for normal and abnormal images

Case study no	Mean	Standard deviation	Results
1	2.58	6.07	Abnormal(RA)
2	1.74	6.24	Abnormal(RA)
3	2.34	6.27	Abnormal(RA)
4	2.25	6.27	Abnormal(RA)
5	1.85	6.36	Abnormal(RA)
6	1.85	6.37	Abnormal(RA)
7	1.95	6.62	Abnormal(RA)
8	1.84	6.87	Abnormal(RA)
9	1.82	6.87	Abnormal(RA)
10	2.07	6.95	Abnormal(RA)
11	1.84	6.95	Abnormal(RA)
12	1.87	6.21	Abnormal(RA)
13	1.76	6.15	Abnormal(RA)
14	1.76	7.07	Normal
15	1.97	7.07	Normal
16	1.88	7.08	Normal
17	1.32	7.08	Normal
18	1.34	7.13	Normal
19	1.74	7.02	Normal
20	1.3	7.03	Normal

V. CONCLUSION

An image processing based RA classification using hand X-ray has been presented in this work. This work gives new insights into the RA disease diagnosis. This work makes use of hand X-ray image for processing and analysis because image acquisition requires shorter time, facility required for image acquisition is available in the most of the clinic and hospital and also cheapest among all other modalities. Dataset included both normal and abnormal images (RA). The space between phalangeal bones in the hand finger helpful in the image classification, especially the metacarpal joint and proximal joint involved in the early stage of the RA. This workpresents the development of the image processing based RA diagnosis using hand X-ray images. It starts with median filter to remove the salt and paper noise and edge detection by using canny edge operator. After segmentation, mean and standard deviation is calculated for both normal and abnormal images. Based on the calculated values of mean and standard deviation of the hand radiography images have been classified as normal and abnormal images. This workis really helpful for the doctors in the early RA diagnosis process.The extracted mean and standard deviation values can be used to train any kind of machine learning algorithms for automatic classification of images.

VI. ACKNOELEDGEMENTS

Authors are grateful to ChanRe Rheumatology and Immunology Center, Rajajinagar, Bangalore, Karnataka, India for providing datasets for the research work.

REFERENCES

1. Vera, S., 2010. Finger joint modeling from hand X-ray images for assessing rheumatoid arthritis. Center de Visio per computador CVC Technical report, 164, pp.1-30.
2. Brown, J.M., Ross, E., Desanti, G., Saghir, A., Clark, A., Buckley, C., Filer, A., Naylor, A. And Claridge, E., 2017. Detection and characterization of bone destruction in murine rheumatoid arthritis using statistical shape models.Medical image analysis, 40, pp.30-43.
3. Sugimoto, H., Takeda, A. And Hyodoh, K., 2000. Early-stage rheumatoid arthritis: prospective study of the effectiveness of MR imaging for diagnosis. Radiology, 216(2), pp.569-575.
   Crowson CS, Therneau TM, Matteson EL, Gabriel SE. Primer: demystifying risk-understanding and communicating medical risks. Nat ClinPractRheumatol. 2007, pp181–187.
4. Huo, Yinghe, Koen L. Vincken, Désirée van der Heijde, Maria JH De Hair, Floris P. Lafeber, and Max A. Viergever. "Automatic quantification of radiographic finger joint space width of patients with early rheumatoid arthritis." IEEE Transactions on Biomedical Engineering 63, no. 10 (2016): pp. 2177-2186.
5. Schenk, O., Huo, Y., Vincken, K.L., van de Laar, M.A., Kuper, I.H., Slump, K.C., Lafeber, F.P. and Moens, H.B.B., 2016. Validation of automatic joint space width measurements in hand radiographs in rheumatoid arthritis. Journal of medical imaging, 3(4), p.044502.

6. Duryea, J., Jiang, Y., Zakharevich, M. And Genant, H.K., 2000. Neural network based algorithm to quantify joint space width in joints of the hand for arthritis assessment. Medical physics, 27(5), pp.1185-1194.
7. Huo, Y. H. Automated measurement of joint space width in early rheumatoid arthritis hand radiographs. Diss. Utrecht University, 2017.
8. Hall, E.L., Kruger, R.P., Dwyer, S.J., Hall, D.L., Mclaren, R.W. and Lodwick, G.S., 1971. A survey of preprocessing and feature extraction techniques for radiographic images.IEEE Transactions on Computers, 100(9), pp.1032-1044.
9. Kumara, M.L. and Prabakaran, N., 2015. Automatic detection of cartilage thickness for early detection of KOA.ARPN Journal of Engineering and Applied Sciences, 10(7).
10. Bhisikar, S.A. and Kale, S.N., 2016, September. Automatic analysis of rheumatoid arthritis based on statistical features. In 2016 International Conference on Automatic Control and Dynamic Optimization Techniques (ICACDOT) (pp. 242-245).IEEE.
11. Subramoniam.M, A Non-Invasive Method for Analysis of Arthritis Inflammations by using Image Segmentation Algorithm, 2015 International Conference on Circuit, Power and Computing Technologies [ICCPCT].
12. Mittal, A. and Dubey, S.K., 2012. Analysis of rheumatoid arthritis through image processing. International Journal of Computer Science Issues (IJCSI), 9(6), p.442.
13. M.Vinoth, B.Jayalakshmi, Bone Mineral Density Estimation Using Digital X-Ray Images For Detection Of Rheumatoid Arthritis, International Journal of Pharma and Bio Sciences ISSN 0975-6299, Int J Pharm Bio Sci 2014 July ; 5 (3) : (B) 104 – 121.
14. Shimizu, M., Kariya, H., Goto, T., Hirano, S. and Sakurai, M., 2015, October. Super-resolution for X-ray images. In 2015 IEEE 4th Global Conference on Consumer Electronics (GCCE), IEEE, pp. 246-247.
15. David Maresca, MickaelTanter, Ultrasound Micro angiography of the Metacarpophalangeal Joint using Ultrafast Doppler, Institute Langevin, ESPCI paristech, PSL Research University, UMR 7587 CNRS, U979 INSERM, Paris, France, 10.1109/ULTSYM.2014.0105.
16. Z. Wang, D., Wang, “Progressive switching median filter for the removal of impulse noise from highly corrupted images,” IEEE Trans. On circuits and Systems II: Analog and Digital signal processing , Vol. 46, no 1999, pp. 78-80.
17. Helwan, A., 2014. ITDS: Iris tumor detection system using image processing techniques. Int. J. Sci. Eng. Res, 5, pp.76-80.
18. H. Abdulkader, “ITDS: Iris Tumor Detection System Using Image Processing Techniques,” International Journal of Science and Engineering Research, 2014, pp.45-80.
19. Chokkalingam, S. P., and K. Komathy. "Intelligent assistive methods for diagnosis of rheumatoid arthritis using histogram smoothing and feature extraction of bone images." World Academy of Science, Engineering and Technology International Journal of Computer, Control, Quantum and Information Engineering 8, no. 5 (2014).
20. R. Gonzalez, and E. Woods, Digital Image Processing, 2cd ed. Prentice-Hall, 2002.
21. A. Boujelben, H. Tmar, M. Abid, and J. Mnif, “Automatic Diagnosis of Breast Tissue,” Advances in Cancer Management, doi: 10.5772/22565, 2012, pp. 258–2270.

22. S.S. Mokri, M.I. Saripan, M.H. Marhaban, A.J. Nordin, “Lung segmentation in CT for thoracic PET-CT registration through visual study,” in Biomedical Engineering and Sciences (IECBES), 2012 IEEE EMBS Conference on, Langkawi, 17-19, Dec. 2012, pp. 550 - 554,.
23. Saif, J. A., A. A. Al-Kubati, AbdultawabSaifHazaa, and Mohammed Al-Moraish. "Image segmentation using edge detection and thresholding." In The 13 th International Arab Conference on Information Technology ACIT, 2012, pp.10-13.
24. K. Adnan, E. Al-Zgoul, “Image Segmentation of Blood Cells in Leukemia Patients”. Recent Advances in Computer Engineering and Application, 2010 pp. 104–109.
25. K. Adnan, IBCIS: Intelligent blood cell identification system. Progress in Natural Science, (2008), doi: 10.1016, pp. 1309-1314.
26. M.O. Reza, M.F. Ismail, A.A. Rokoni, M.A.R. Sarkar, “Smart Parking System with Image Processing Facility,” I.J. Intelligent Systems and Applications, 3, DOI: 10.5815/ijisa.2012.03.06, 2012, pp. 41-47.