An Efficient Fuzzy Based Edge Estimation for Iris Localization and Pupil Detection in Human Eye for Automated Cataract Detection System

Aditya Dixit[1], Shashwat Pathak[2], Rahul Raj[2] CH Naveen[1], V.R Satpute[1]
[1] Department of Electronics and Communication Engg., Visvesvaraya National Institute of Technology, Nagpur, India
[2] Department of Electronics and Communication Engg., Motilal Nehru National Institute of Technology Allahabad, India

***Abstract*: Presently Digital Image Processing based automated diagnosis of medical images is very popular area of research. This technique cuts short the diagnosis time and produces results with high degree of accuracy with least variations in diagnostic opinion. For such applications, basic parameter mapping and evolving image processing techniques play a very crucial role. Automated Cataract detection through digital eye images requires circular pupil extraction from eye image. Conventional Hough transform fails to extract the circular pupil area due to presence of similar ring structure in Iris and in between region. This paper explains the distinct approach in iris localization and pupil extraction from eye images by extraction of edges using fuzzy logic approach resulting into effective edge estimation technique and later use of these inputs to circular Hough Transform for detection of both. The results of proposed approach has been compared on MMU1, UTIRIS, and IIT-Delhi eye biometric databases. Experimental results explain effective iris localization and pupil extraction with greater accuracy and lower computational time. Results show that the proposed algorithm can be effectively applied in automated cataract detection where circular regions: Iris Localization and subsequent pupil extraction are key to the detection methodology.**

Key-points- Gaussian filtering, Fuzzy Logic, Circular Hough Transform (CHT), Iris localization, Pupil Extraction

I. Introduction

Vision related problems arising from the eye disorders often leads to vision loss over a long period of time, if not treated satisfactorily and early, affecting the patient in both terms namely on-going medical expenses and through the high mental trauma of degrading vision [1]. The World Health Report regarding cataracts, updated in 2014, says that 285 million people are estimated to be visually impaired worldwide, out of those 39 million are blind and 246 have low vision [2]. Presently, cataract related blindness is major cause owing to increase in ageing population and shortage of required healthcare infrastructure in low and middle-income countries [3]. World Health Organization (WHO) defines cataract as clouding of the lens of the eye, which impedes the passage of light [4]. Modern Digital Image Processing techniques have enabled automated diagnosis and assisted the process of diagnosis in eye related diseases through machine learning,extraction and identifying the significant features from an eye image; e.g., detection of cataract can be accomplished by identifying the clouding in protein structure of eye lens by examining different image mapping parameters. Like, Retno Supriyanti et al. [5,6] proposed a new approach to detect the presence of cataracts based on digital image processing. The authors proposed the use of specular reflection analysis for cataract detection. Retno Supriyanti et al. [7] proposed the necessary specifications and guidelines to detect the presence of cataracts. As the eye lens lied in pupil region, therefore, for automatic cataract detection from simple digital eye image, faithful pupil extraction is the key point. The basic method for robust cataract detection algorithm [8] can be described in three steps: preprocessing, feature extraction, and decision making.

For iris localization and subsequent pupil detection various methods have been applied so far in the literature. C.H. Morimoto et al.[9] described a fast, low cost, simple and robust pupil detection technique which uses two infrared time multiplexed light sources synchronized with the CCD B/W camera frame rate. When the light source is placed off-axis with the camera optical axis (normal illumination), the camera is able to detect a dark pupil image, known as odd frame, while with the on-axis placement of the IR source, the light is reflected from the interior of the eye and camera is able to detect a bright pupil image, known as even frame. Xianmei Wang et al.[10] presented a new approach for pupil localization in multi-view eyeballs under ordinary light conditions. To address the issue of pupil localization, the author present an approach based on ASM (Active Shape Models) incorporating with analysis of regional gray information. Somnath Dey et al.[11] proposed a new scheme which is based on scaling and power transform. The author also uses the edge detection and circle finding to detect the boundary layer between iris and pupil. Scaling mitigates the search space significantly for pupil center and pupil radius whereas power transform minimizes the influence of irrelevant edges and performs the image thresholding. The experiment is performed on CASIA iris database. Theekapun Charoenpong et al.[12] enhanced the accuracy of pupil extraction method by using integrated method. Three techniques are used to eliminate the noise, present in extracted pupil image, which are K-mean clustering, black blob, and Mahalanobis distance. Pupil position is addressed by mean of gray value based on the assumption that the gray value of pupil is lowest. Saurabh Singh et al.[13] proposed a new approach for circular edge detection. A mathematical operation is operated using Hough transform to find the centre and radius of the pupil. After that on applying any of the edge detection gives us a ring. A.El-Zaart et al.[14] developed a new technique to extract the pupil part from an eye image, based on minimum and mean gray value of pupil. In this work, red RGB color layer image is used which is smoothed by smoothing filter initially to reduce the noise and color variation. The RGB image is converted to binary image using this threshold and removes all unnecessary components (eyelids, eyelashes) except large connected component.

Therefore, a robust, automated and reliable iris localization algorithm is of utmost importance for the accomplishment of automated cataract detection. Hough transform is the most popular choice for detection of circular iris and pupil, but it suffers from different noises due to change in surrounding pixel values and related entropies (figure 1.). A novel iris localization algorithm has been developed, tested and results have been shown in the following sections. This algorithm uses fuzzy based edge estimation as input for the CHT algorithm to produce reliable and faithful results. Section II describes the methods and materials, Hough transform based Iris localization has been discussed in section III. Section IV presents experiment results, conclusion and future scope concludes the paper with section V.

II. Methods and Materials

The following section explains the preprocessing methods required for iris localization and pupil detection in this approach. 2D-Gaussian filtering is performed to obtain a smoothened image. The gradient of the image yields horizontal detail component and vertical detail component of the image in order to define the membership functions of the fuzzy logic based edge estimation model.

A] Gaussian Filtering

Gaussian filtering is an effective technique in image processing, used for blurring or smoothing the image so as to reduce the noise content in the image and the smoothened image is useful in efficient edge extraction. The Gaussian filter output is weighted average of each neighborhood pixels and this average focused more to the center pixel values. This is an advantage of Gaussian filter over other evenly weighted average filters like mean filter and it contributes pleasant smoothing and effective edge preservation over other averaging filters. For image processing, a 2D Gaussian filtering is considered.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \quad (1)$$

In the proposed approach, Gaussian filtering is performed on a grayscale image with zero mean and with 0.7 standard deviation value for different databases.

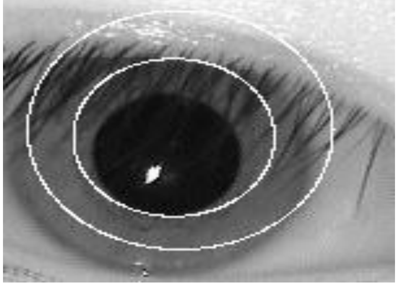


Figure 1. Incorrect detection using CHT due to noise.

B] Fuzzy logic based edge estimation

Edge estimation is of useful application in the area such as model recognition, and biomedical imaging. [15,16] Edge estimation traces the high-frequency elements present in an image. [17,18,19] The challenge lies in effective edge estimation for noisy images. As compared to other edge estimation techniques like Prewitt, Canny type edge detectors, fuzzy inference system based edge estimation has guided to better results. [20,21] Estimation of the edge using fuzzy membership function is a non-linear type of image enhancement technique. [22] It is important to define the fuzzy rules appropriately in order to extract correct edge information. Fuzzy membership functions are of great importance in a fuzzy inference system in-order to specify fuzzy rules. Fuzziness of fuzzy system is defined with the help of membership functions as they are primal components of a fuzzy system. The article [23] covers a detailed explanation of fuzzy sets and fuzzy membership functions.

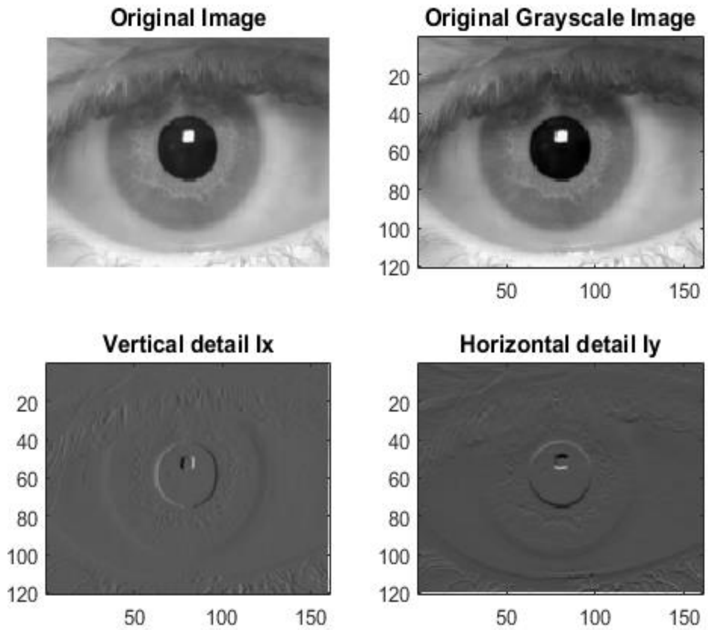


Figure2. Original image, original grayscale image vertical and horizontal detail components.

Figure 2 shows the original image, original grayscale image, the vertical component and the horizontal detail component of the image. The vertical detail component (I_x) and horizontal detail component (I_y) are the membership functions defined and they act as inputs to fuzzy model. Based on these fuzzy inputs a crisp output is obtained (figure 3) to determine the effective location of the edges based on the following defined rules :

- If I_x is zero and I_y is zero then I_{out} is white
- If I_x is not zero or I_y is not zero then I_{out} is black

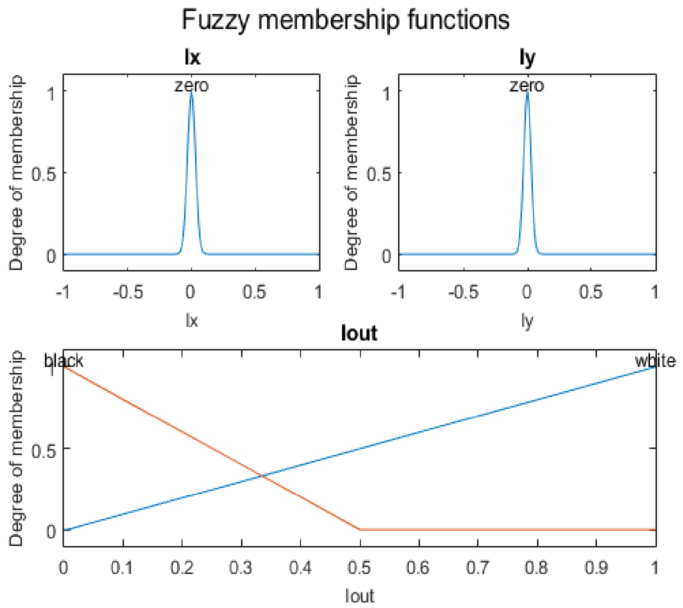
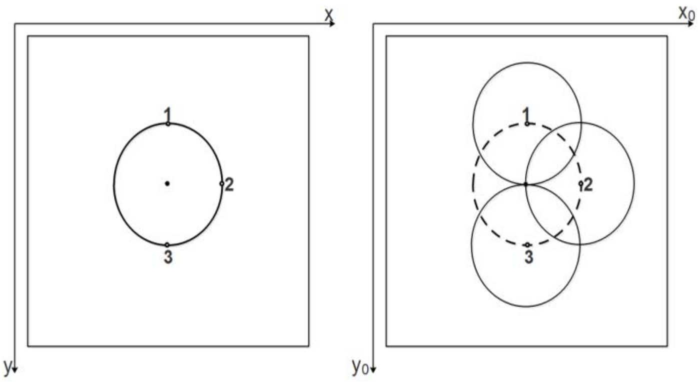


Figure3. Fuzzy membership functions.

III. Fuzzy Classifier based Edge Estimation

One of the features of circle detection retrieval is being done through CHT.[24] CHT is a specialization of the Hough transform for detecting circles. The goal of this strategy is to detect circles in areas of incomplete and distorted input images. The candidate pixels of a circle which is away from the circle’s center, cast the votes in accumulator space to trace the locus of actual circle.[25,26] The circle's center is obtained by extracting the accumulator space peak.



(a) Image of the circle (b) Accumulator space

Figure4. Implementation of CHT.

Implementation of CHT can be explained using equation of circle

$$(x - x_0)^2 + (y - y_0)^2 = r^2 \qquad (2)$$

The equation (3) can be expressed in parametric form as

$$\left.\begin{aligned} x &= x_0 + rcos(\theta) \\ y &= y_0 + rsin(\theta) \end{aligned}\right\} \qquad (3)$$

The equation (4) helps in obtaining the parameters and hence CHT mapping is determined as

$$\left.\begin{aligned} x_0 &= x - rcos(\theta) \\ y_0 &= y - rsin(\theta) \end{aligned}\right\} \qquad (4)$$

The equation (3) determines the points in the accumulator space (figure 4) based on radius r.

As both iris and pupil are circular in shape, CHT is being used for localization and subsequent pupil extraction. The original 24-bit image is initially converted into 8 bit grayscale of size 160x120 pixels. The vertical and horizontal detail components of the image are considered as the input parameters for the fuzzy model and later the fuzzy model is being used for effective edge detection.The circular Hough transform is applied on edge detected images using the imfindcircles function in MATLAB with specified small radius range for pupil detection and large radius range for iris detection part, specifying the lower value of edge threshold. This function returns the appropriate location of circle’s centre and their respective radius in the image within the defined radius range.[27] The flow chart for the proposed approach is as shown in figure5.

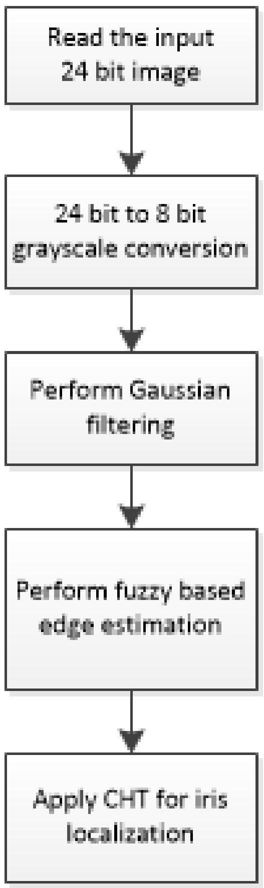


Figure5. Proposed approach flow diagram for iris localization

IV. Experimental Results

The proposed approach is applied on MMU1 database 450 eye images of size 320x240 pixels in bitmap format created by a research group at Multimedia University, Malaysia and on UTIRIS database of 792 Near Infra-Red (NIR) grayscale eye images of size 1000x776 pixels in bitmap format created by University of Tehran. For reducing computational load, the iris biometric images were resized to 160x120 pixels bitmap format. The MATLAB function imfindcircles which is based on CHT is being used for iris localization. The gradient-based edge detected image is being obtained for iris detection, for increasing the accuracy and the fuzzy-based edge detected image is being used for detecting the pupil of the eye with high accuracy rate (figure 6).

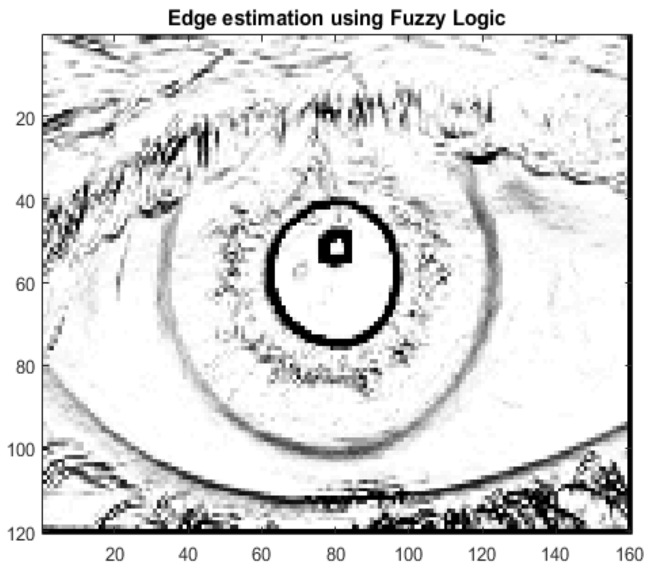


Figure6. Edge estimation using proposed fuzzy logic approach

Figure 7(a) represents the experimental result of fuzzy logic based edge estimation applied on one of the images from the database resulting into good edge estimation.

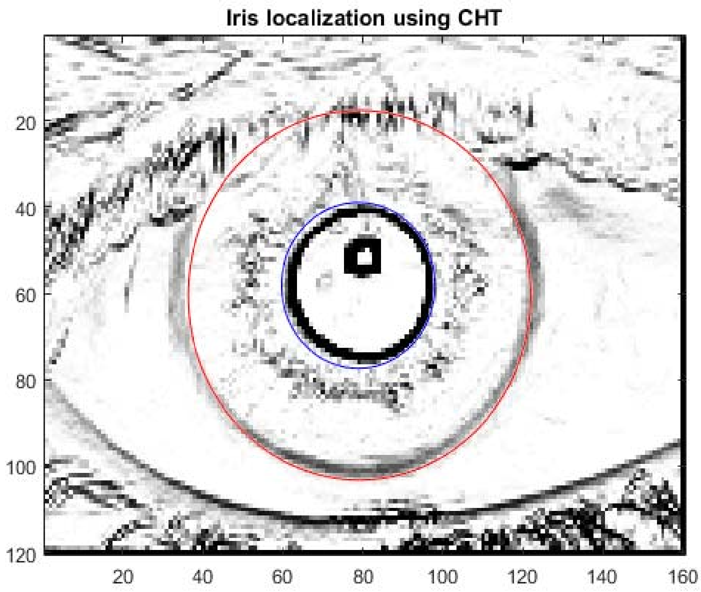


Figure7(a). Iris localization using CHT

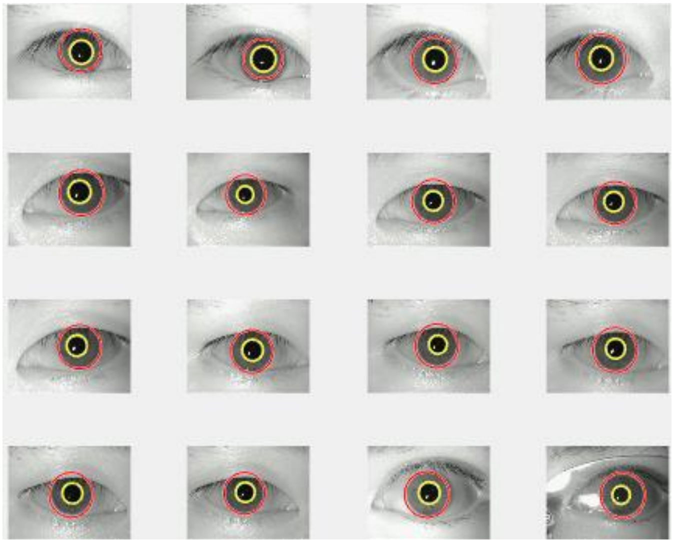


Figure7(b). Iris localization using CHT on MMU1 database

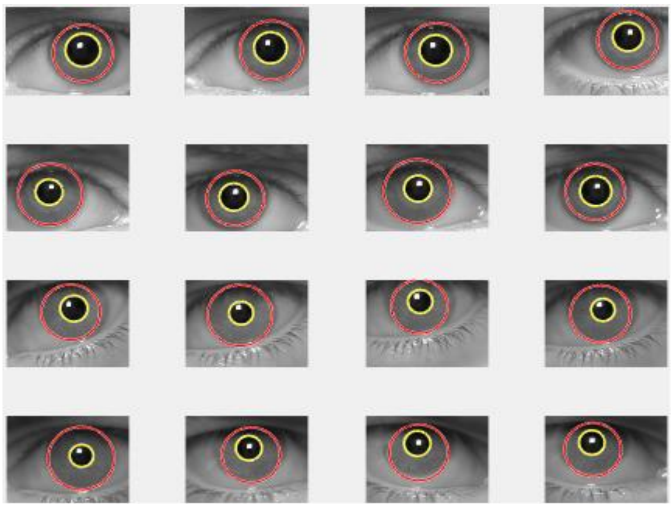


Figure7(c). Iris localization using CHT on UTIRIS database

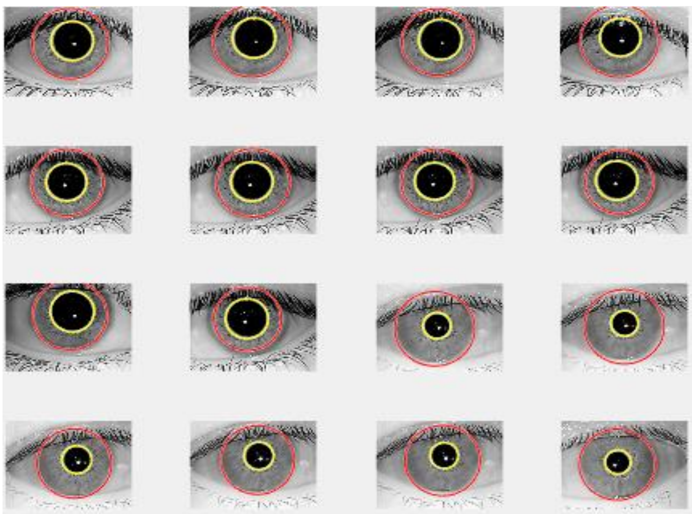


Figure7(d). Iris localization using CHT on IITD database

The mentioned results in figures 7b, 7c and 7d represent the effective iris localization on MMU1, UTIRIS and IIT-Delhi database using proposed approach. The proposed approach has correctly localized iris of 434 of 450 images of MMU1 database with an accuracy of 96.44%, 762 of 792 images of UTIRIS database with an accuracy of 96.21% and 2176 of 2240 images of IITD database with an accuracy of 97.14%

The proposed approach has also resulted into some incorrect and partial iris localization, shown in figure8, largely due to partially clear our inappropriately taken images.

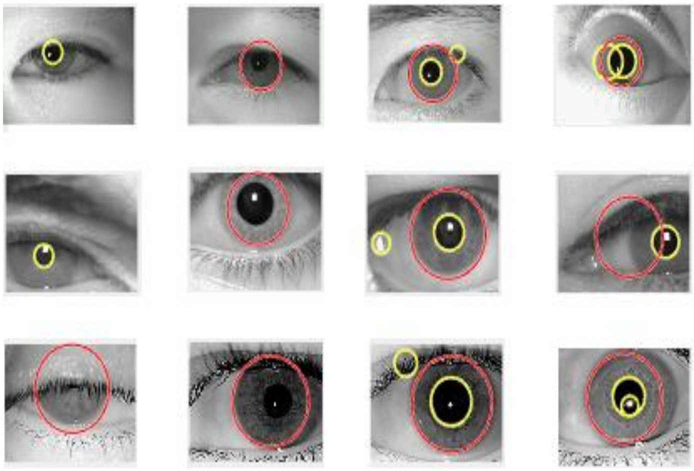


Figure8. Incorrect or partial iris localization

V. Conclusion and Future scope

The proposed approach has introduced an effective and distinct methodology for iris localization and pupil extraction using CHT in combination with fuzzy logic to increase the detection efficiency. The fuzzy edge estimation has resulted into good edge estimation technique in conjugation with CHT for appropriate iris localization and pupil detection. This method has improved the performance of CHT, which would otherwise alone detected many circles inside Iris and proper detection of Iris and pupil was not accomplished. Sometimes presence of similar pixel values in Iris region makes the pupil detection hard.

Further, this approach can be considered for implementation of effective biometric applications as an authentication unit for security purposes.

References

[1]Cost of vision problems. Available online: http://www.costofvision.preventblindness.org/home/introduction/ (accessed on 20 April 2016).

[2]Visual impairment and blindness. Available online: http://www.who.int/mediacentre/factsheets/fs282/en/ (accessed on 20 April 2016).

[3]Gary, B.; Taylor, H. Cataract Blindness–Challenges for 21st century. Bull. World Health Organ. 2001. Available online: http://www.who.int/bulletin/archives/79(3)249.pdf (accessed on 30 April 2016).

[4]Comas, O; Cotin, S.; Duriez, C. A shell model for real time simulation of intra-ocular implant deployment. Proceedings of the International Symposium on Biomedical Simulation, Phoenix, AZ, USA, 23–24 January 2010; pp. 160–170.

[5]Supriyanti, R.; Habe, H.; Kidode, M.; Nagata, S. A simple and robust method to screen cataract using specular reflection appearance. In Proceedings of the Medical Imaging International Conference of International Society for Optics and Photonics (SPIE), San Diego, CA, USA, 17 March 2008. doi:10.1117/12.770069.

[6]Supriyanti, R.; Habe, H.; Kidode, M.; Nagata, S. Cataract Screening by Specular Reflection and Texture Analysis. In Proceedings of the Systemics and Informatics World Network (SIWN 2009), Leipzig, Germany, 23–25 March 2009. ISSN 1757-4439.

[7]Supriyanti, R.; Habe, H.; Kidode, M.; Nagata, S. Compact cataract screening system: Design and practical data acquisition. In Proceedings of International Conference on Instrumentation, Communication, Information Technology and Biomedical Engineering (ICICI-BME), Bandung, Indonesia, 23–25 November 2009. doi:10.1109/ICICI-BME.2009.5417287.

[8]Shashwat Pathak, Basant Kumar, “A Robust Automated Cataract Detection Algorithm Using Diagnostic Opinion Based Parameter Thresholding for Telemedicine Application”, Journal of Electronics, MDPI, published online , 15 September 2016, DOI: 10.3390/electronics5030057,

[9] C.H Morimoto, D Koons, A Amir, M Flickner,,”Pupil detection and tracking using multiple light sources”,Image and Vision Computing,Volume 18, Issue 4,2000

[10] Xianmei Wang, Xiujie Zhao, Liying Jia, Ping Yang,“Pupil Localization for Multi-View Eyeballs by ASM and Eye Gray Distribution”,Procedia Engineering,Volume 15,2011,Pages 2993-2998,ISSN 1877-7058

[11] S. Dey and D. Samanta, "An Efficient Approach for Pupil Detection in Iris Images," 15th International Conference on Advanced Computing and Communications (ADCOM 2007), Guwahati, Assam, 2007, pp. 382-389.

[12] T. Charoenpong, P. Pattrapisetwong, T. Chanwimalueang and V. Mahasithiwat, "Accurate pupil extraction algorithm by using integrated method," 2013 5th International Conference on Knowledge and Smart Technology (KST), Chonburi, Thailand, 2013, pp. 32-37.

[13] Singh, Naveen Kumar et al. “Iris Recognition System Using a Canny Edge Detection and a Circular Hough Transform.” (2011).

[14] El-Zaart, A., & Mathkour, H. (2010, April). A new approach for pupil detection in iris recognition system. In Computer Engineering and Technology (ICCET), 2010 2nd International Conference on (Vol. 4, pp. V4-415). IEEE.

[15][06892577] V. K. Yadav, S. Batham, A. K. Acharya and R. Paul, "Approach to accurate circle detection: Circular Hough Transform and Local Maxima concept," IEEE International Conference on Electronics and Communication Systems (ICECS), Coimbatore, 2014, pp. 1-5.

[16][07248041 R. G. Bozomitu, A. Păsărică, V. Cehan, C. Rotariu and C. Barabaşa, "Pupil centre coordinates detection using the circular Hough transform technique," IEEE 38th International Spring Seminar on Electronics Technology (ISSE), Eger, 2015, pp. 462-465.

[17] Noureddine Cherabit, Fatma Zohra Chelali, Amar Djeradi, “Circular Hough Transform for Iris localization”, Science and Technology 2012, 2(5), pp. 114-121.

[18][05945571] N. Cherabit, F. Z. Chelali and A. Djeradi, "A robust iris localization method of facial faces," IEEE International Conference on Multimedia Computing and Systems, Ouarzazate, 2011, pp. 1-5.

[19][06754895] H. R. Shashidhara and A. R. Aswath, "A Novel Approach to Circular Edge Detection for Iris Image Segmentation," IEEE Fifth International Conference on Signal and Image Processing, Jeju Island, 2014, pp. 316-320.

[20][07401472] H. Ye, G. Shang, L. Wang and M. Zheng, "A new method based on Hough transform for quick line and circle detection," IEEE 8th International Conference on Biomedical Engineering and Informatics (BMEI), Shenyang, 2015, pp. 52-56.

[21][07916648] P. Khelbude and S. Shelke, "Real-time iris controlled robot," IEEE Online International Conference on Green Engineering and Technologies (IC-GET), Coimbatore, 2016, pp.1-4.

[22][07746181] P. Khelbude and S. Shelke, "Real-time iris based robot," IEEE Conference on Advances in Signal Processing (CASP), Pune, 2016, pp. 286-289.

[23][07448399] O. P. Verma and A. S. Parihar, "An Optimal Fuzzy System for Edge Detection in Color Images Using Bacterial Foraging Algorithm," in IEEE Transactions on Fuzzy Systems, vol. 25, no. 1, pp. 114-127, Feb. 2017.

[24][04666215] Q. C. Tian, "A New Iris Region Segmentation Method," IEEE Fifth International Conference on Fuzzy Systems and Knowledge Discovery, Shandong, 2008, pp. 63-67.

[25][07566017] Y. Liu and Y. Long, "Image edge extraction based on fuzzy theory and Sobel operator," IEEE 20th International Conference on Computer Supported Cooperative Work in Design (CSCWD), Nanchang, 2016, pp. 373-378.

[26][07433874] N. Mathur, P. Dadheech and M. K. Gupta, "The K-means Clustering Based Fuzzy Edge Detection Technique on MRI Images," IEEE Fifth International Conference on Advances in Computing and Communications (ICACC), Kochi, 2015, pp. 330-333.

[27][07437004] D. H. Widyantoro and K. I. Saputra, "Traffic lights detection and recognition based on colour segmentation and circle Hough transform," IEEE International Conference on Data and Software Engineering (ICoDSE), Yogyakarta, 2015, pp. 237-240.