EYE DETECTION BY COMPUTER VISION APPLYING ZERNIKE MOMENTS

VUNA VENKATA VIDYASAGAR[1]
ASSISTANT PROFESSOR
RAGHU ENGINEERING COLLEGE, VIZIANAGARAM, INDIA
E-Mail: vidyasagar.vuna@raghuenggcollege.in

ANURADHA TUTIKA[2]
ASSISTANT PROFESSOR
RAGHU ENGINEERING COLLEGE, VIZIANAGARAM, INDIA
E-Mail: anuradha.tutika@raghuenggcollege.in

Abstract

Visual impairment is noticed as a conventional problem in many from childbirth. According to the World Health Organization statistics, about one billion people globally have visual impairment. Therefore, Eye tracking technology is considered the most prominent in computer vision and Pattern recognition. Human eye applications have become essential information for streams. The recognition of the Eye patterns is carried out by rotating the pattern at different angles primarily using Gabor Filter and later trained by SVM. The extracted patterns at Labare transformed and applied with Morphological operations. Every candidate's Eye pair is detected and classified by using SVM classifier for either eye or non-eye. The Lab and HSV color space use face extraction to find eye pair candidates. Separable Gabor filters decrease computation time and rotation-invariance. The characteristics of the Gabor Filter make the above method robust against rotation. Pupillary changes help in detecting the human eye. Many studies are carried out on pupillary changes to see pupil diameter using samples. Pupil diameter supports the doctor's decision for early detection of major diseases. A reference algorithm is used for measuring pupil diameter. The proposed approach is tested on rotated images of the GTAV database and capture the videos to obtain maximum result. Zernike moments are used to find refraction errors in Opticians study. They are regularly noticed in adaptive optics to minimize atmospheric pre-compensations.

Keywords—Gabor Filter, SVM, Zernike Method, pupil measurement method.

INTRODUCTION:

The pupil is the extension of a human eye and views particular task or activity to respond constrict with the human emotions. The review stresses pupil diameter measurement superiority over other psychological measuring tools. Manual measurement is the most common method of measuring pupil diameter. A ruler or penlight is used to measure the size of the pupil. In adults, the pupil size varies from 2-4 mm in diameter in daylight and 4 – 8 mm. dark. The stress in Eye pattern drew combing empirical findings and resulted an expert knowledge showing signs using psychological measurements like Blood Volume Pulse (BVP), Galvanic Skin Response (GSR), Skin Temperature (ST) and Pupil Diameter (PD).The Pupil Diameterhas a high potential for distinguishing between different emotion conditions by dilation analysis and further human condition detections. The cognitive processobtainsthe views videos and images of pattern.Several mathematical applications wentin the medical field to find pupil diameter serving the early detection of diabetes using the Pupil Light Reflex (PLR) method.Abnormalities in pupil diameter are detected in diabeticpatients.

Several measuresare referred for detecting the pupil diameter of Eye. The Haar Classifier algorithm is accurate among them.The Haar Wavelet, Bayesian Classificationalgorithm, the Genetic algorithm and the Color Characteristics method are satisfiable to get the accurate values. Pupil detection is performed by binarizing images using a threshold, eliminating noise and segmentation. Some of the inspired algorithms are the adaptive Canny algorithm, the combination of the Fuzzy Logic and Particle Swarm Optimization algorithms, Morphology, and RGB decomposition to Lab Color Space. All these detections measure the pupil diameter brought the new IOG technology in hand. Pupil midpoint and pupil diameter are estimated using the geometric feature-fitting algorithm, Least-Square calculation using the ellipse equation followed by the Hough transform method. Pupil diameter is calculated by measuring pupil area and dividing it by phi; the square root of the result is the pupil's diameter. A low-tech, subjective technique helps to measure pupil size by Rosenbaum (or equivalent) Card with a handheld light. The Card has a series of black circles in 1mm increments, ranging from 2 to 9mm. The end of the Card with rings is held alongside the eye to be measured.

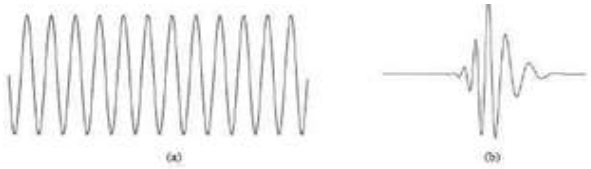


Fig1: Discrimination of Wave and Wavelet.

Investigations are carried for the accurate measurement of the pupil diameter. The algorithms of pupil diameter measurement are processed through simple algorithms that were conducted with OpenCV (Open Computer Vision) software, The Haar classifier algorithm suites for eye detection, Binary Threshold algorithm for pupil detection and Least-Square algorithm for pupil diameter measurement. The discussion of the pupil diameter measurement method is further divided into several parts.

1. Pupil measurement is processed with Image Processing algorithm.

2.Automatic pupil diameter measurement experiment using OpenCV (Open Computer Vision) software.

3. Presents future work for pupil diameter measurement and implementation.

PUPIL DIAMETER MEASUREMENT:

The measurement of the Pupil diameter measurement is moved by eye detection,pupil detection, and pupil diameter measurement. Several algorithms are studied for eye detection, pupil detection, and pupil diameter measurement.

-The operation is carried out with two emotional changes. Circumstances under drowsiness and the other under normal conditions. The lighting at the workplace through pupil movements,usingCAF-ESA(Context-awareFramework based Emotional Sensibility) is considered.

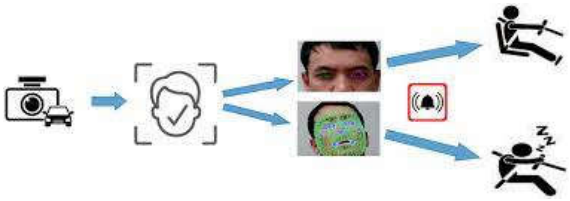


Fig2:Based on Drowsiness Detection on Eye

Many studies reportedon eye detection to facial images usingBayesianclassificationalgorithmbasedonHaarwavelet Genetic algorithm, the threshold method based on color characteristics and Haar Classifier algorithm.

The Haar Wavelet Filtering algorithm counts the number of matrices per row or per column. This algorithm is a group of basic functions which captures the relationship between average intensity in the neighboring regions of different scaleand orientation. Theadvantageof theHaar wavelet is a schematic difference in intensity which is appropriate forcapturingthecharacteristicofeyestructure,i.e.,darkcolor pupilsurroundedbysclerathatisrelativelywhite.The Genetic Algorithm (GA) for eye detection achieves high accuracy of approximately 96.5 %.The eye detection was performedby observing Color Characteristics. The Color Characteristics is easy to obtain both eye images. The flexiblethresholdwillaffecttheresultsoftheeye detection since each image has a different threshold. TheHaarClassifieralgorithmwasdeveloped from Haar wavelet algorithm.

AdaBoost Algorithm:

1. Assigning weights to the given training data of an instance space.
2. The assigned data points areinitially taken to be equal in proportion.
3. Classify the samples and create a decision stump. Create a Gini index and the lowest Gini Index is taken to be as the first stump.
4. Calculate the influence. Performance of the first stump= $\frac{1}{2}\log\frac{1-Total\ Error}{Total\ Error}$
5. Total error will be always between 0 and 1.0 indicates the perfect stump and 1 indicates the horrible stump.
6. Calculate Total Error and Performance,

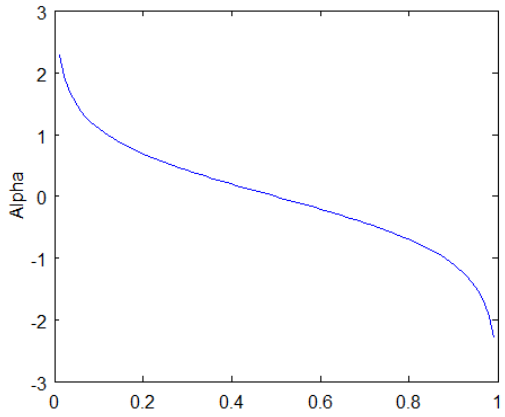
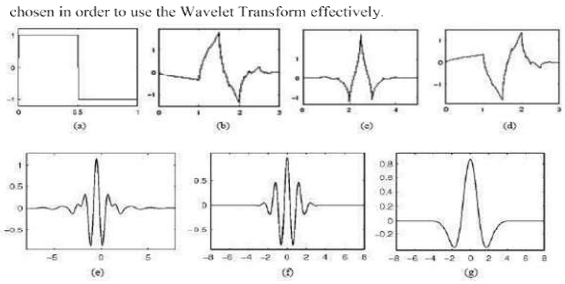


Fig: The TE and Performance in Detecting the PD.



EYEDETECTIONALGORITHMS

The Haar Classifierinstantlydetectsobjectsonahumanface, withAdaBoostCascadesClassifierbasedonHaar-likefeatures. Intel has developed a computer vision software, namely OpenCV(OpenComputerVisionLibrary),whichalsocontains Haar classifier function.

Oneyedetectionalgorithm,threealgorithmscome with high accuracy of more than 95%, namely Genetic algorithms, Color Characteristic and Haar Classifier. Genetic algorithmrequireslongcalculationprocess,ColorCharacteristic method uses flexible threshold, while Haar Classifier does not need long calculation process and can be run on OpenCV.

Wavelet Families:

There are several basis functions that can be used as the mother wavelet for wavelet Transformation. Since the mother wavelet produces all wavelet functions used in the transformation through translation and scaling. It determines the characteristics of the resulting Wavelet Transform. Therefore, the detail of the applicationisconsidered and the appropriate mother wavelet is chosen in order to use wavelet transform effectively.

Fig3: Wavelet Transformation

PupilDetection

The idea of the algorithm arises based on the hunting behavior of the birds. The detection of eye stagesto pupil diametermeasurement.Pupildetection conducts Canny algorithm, Morphology,andLabellingmethod. Thepupildetectionimplements the combination of Interval Type- 2 Fuzzy Sets(IT2FS)andParticleSwamOptimization(PSO). The BinaryThresholdcombineswithSobelalgorithm andColorSpace to smoothen Binary Threshold. The particles of light act together to form the image.

Algorithm of the PSO:

Step 1: Initialize population and parameters w, c1, c2, r1, r2, T_{max}. w is the coefficient of inertia, c1, c2 are the acceleration coefficient ranging of (1.5 – 2.5); r1, r2 are the random numbers with values in the range of [0,1].

Step 2: For each particle calculate the fitness function value. If the fitness function value is better than the best fitness function value $P_{best}$is recorded in history. Set the current fitness function value as the best new value $G_{best.}$

Choose the particle with the best fitness value of all the particles as the $G_{best.}$

Step3: Calculate particle velocity and update particle position accordingly.

Step4: If the number of loops>T_{max} or minimum error criteria is attained then stop.

Cannyalgorithmiswidelyused todetectedges.Canny algorithm is very effective in improvingtheaccuracy ofirispositiondetection. However,the algorithm cannot be applied to color image. Canny algorithmsisalsoweakinbalancingbetweeneliminatingnoise and maintaining edge. Besides that, Canny algorithm also has limitation in determining adaptive threshold.

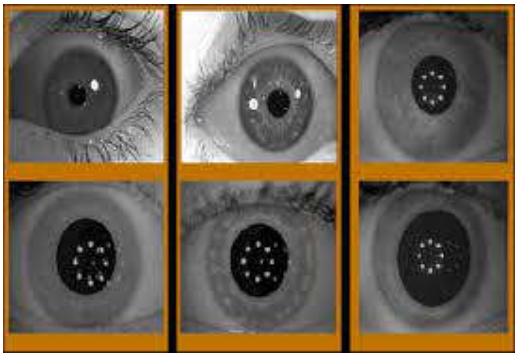


Fig4: Canny Edge Detection of Human Eye

T2FS is developed from T1FS (fuzzy functions commonly used). T2FS provides more design on the degrees of freedom. Thus, it can be used for edge detection. Optimizing fuzzy membership requires another algorithm such as Neural Network algorithm,Geneticalgorithm.The intervals usetheInterval Type2FuzzySet(IT2FS)incombinationwiththePSO(Particle Swam Optimization) to adjust the variation of membership functions.Castilloreportedthatindifferentfield,almostall research using IT2FS-PSO combination proved successful, either for intelligence control, time series prediction or pattern recognition. IT2FS in those studies was used to solve uncertainties in estimation, control, and pattern recognition.

Sobel algorithm is an edge detection algorithm that is nonsensitivetonoise.Thisalgorithmhassmallmaskandcandetect edgebycalculatingpartialderivatives3x3,andthereforeisnot optimal for complex images. Instead, the threshold helps to createbinaryimageandbyfiltering thealgorithmdetectsedges, to obtain normalized pupil at maximum value.

Morphology is a method to improve image, using multiple operators.Itdetectstheformofanimage. Morphology with closing operations cover the hole in pupil imagewhileusedmorphologyeliminatelight reflection on pupil and combine the original image with the morphology image.

Pupil images are improved using erosion morphologyoperator. The useof binaryimagemorphologyacceleratesimagerepairprocessand result in good performance. For maximum results, an appropriate morphology operator must be selected.

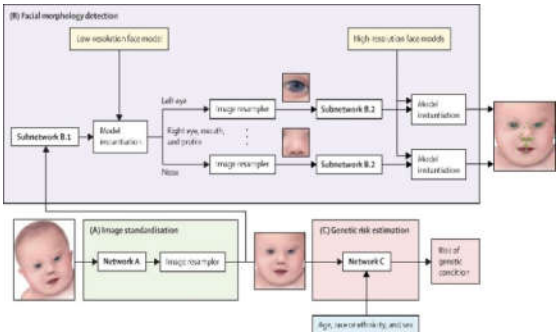


Fig5: Detection of Eye using Morphology

In image processing, by Gabor filteris by adding a reference direction. The Gabor filter is a linear filter used for texture analysis, which analyzes the specific frequency content in the image in specific directions in a localized region around the point or region of analysis. Frequency and orientation representations of filters are claimed by many contemporary vision scientists to be like those of the human visual system. They have been found to be particularly appropriate for texture representation and discrimination. In the spatial domain, a 2D Gabor filter is a Gaussian kernel function modulated by a sinusoidal plane wave.

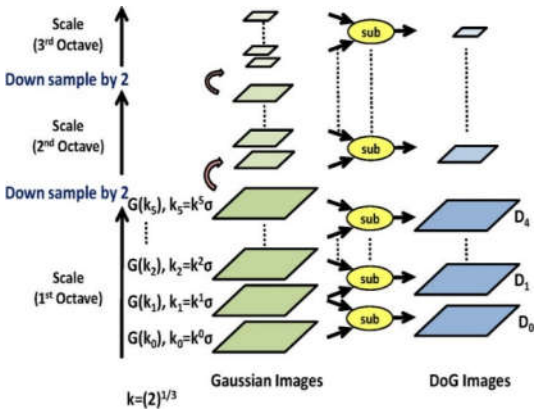


Fig6: Multistage Representation of Gaussian Pyramid and Differences of Gaussian Pyramids (DOG)

The Color Space for pupil detection converted an original image to Lab Color Space and then separatedtheRGBcolorcomponentsintoR,G,BandLab components separated into L, a, b.L symbolizes luminance (lighting),aandbsymbolizecolorchannels.Afterwards,they wererecombinedwithcompositions(R,a,b),(G,a,b)and(B, a, b). The process was repeated until a clear pupil image wererecombinedwithcomposition(R,a,b),(G,a,b)and(B, a,b). The process was repeated until a clear pupil image was obtain.Thenextstepisapplyinggrayscalethreshold,followed by pupil positioning.

BinaryThresholdisanotherpupildetectionmethod.In this method each color composition value in each pixel of image is compared to threshold.If greater than the threshold value, color pixel is scored 1 or white. If smaller than the threshold value, the color pixel is scored 0 or black. The process continues to edge detection or other processes that can be applied to detect the pupil. The Binary Threshold uses the threshold values, namelyμandσ.TheThresholdcreatedabinary image and Sobel filter algorithmto detect edge. The threshold usesbinaryimage and morphologyprocess toeliminatethereflectionoflightonpupilandcombineoriginal image with morphology image that performed Binary Threshold and continued with labelling.TheBinaryThresholdalgorithmobtainedgoodresultswith thethresholdbyproperlyselected.The edgedetection needed used to local and global threshold eliminating the noise and make the thicker lines.

On pupil detection algorithm, three algorithms have high accuracy of more than 90%, namely Canny algorithms, Morphology and Color Space algorithms.Binary Threshold is easy to apply and can run on OpenCV.

A. PupilDiameterMeasurement

After the pupil image is visible, the next process is to measurethepupildiameter.Therearevariouswaystomeasure pupildiametersuchasusinggeometryfeature-fittingalgorithm withreasonablecost.Pupildiametermeasurementuses ellipse equation, Hough Transform algorithm and circular formula where S is the circle area in the form of black pixels in the pupil area of the equation.

Ellipse fitting algorithm can be used to measure ellipse diameter with error criteria using linear Least-Squares.Thisalgorithmissimpleandaccurateif sufficient data are available. This

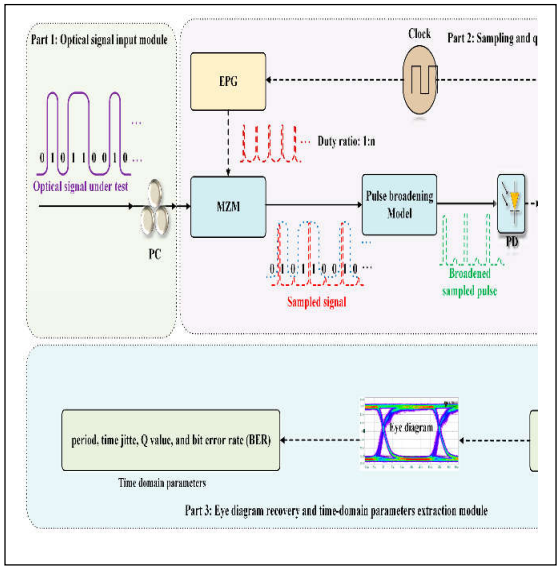


Fig7: Pulse Code Modulator (PCM) algorithm is used to calculate the pupil diameter using formula (1) todetect major and minor axis; (x_0, y_0) is the center point of the ellipse, A, B, C are coefficients. The length found is regarded as the pupil diameter.

$$a = \frac{\sqrt{(Ax^2+Bx_0y_0+Cy^2)-F}}{(A+C)^2-\sqrt{B^2(A-C)^2}}$$

EXPERIMENTOFAUTOMATICPUPILDIAMETER

MEASUREMENT USING SIMPLE METHOD

Afterreviewingliteraturesonpupildiametermeasurement, this paper also discusses about automatic pupil diameter. measurementusingOpenCVsoftwarewithsimplemethod from the literatures.

ThefirststepiseyedetectionusingHaarclassifiermethod. Fig7describestheresultofEyeDetection.

```
*IplImag*image=cvLoadImage("womans.jpg",CV_LOAD_IMAGE_COLOR);

storage = cvCreateMemStorage(0);

cascade=(CvHaarClassifierCascade*)

cvLoad("haarcascade_eye_tree_eyeglasses.xml");

CvSeq*eyes=cvHaarDetectObjects(image,cascade,storage,1.1,1,

0,cvSize( 8, 8 ) );

cvCvtColor(image, image_gray,
CV_BGR2GRAY);cvThreshold(image_gray,image_thres,20,255,CV_THRESH_BINA
RY_INV);
```

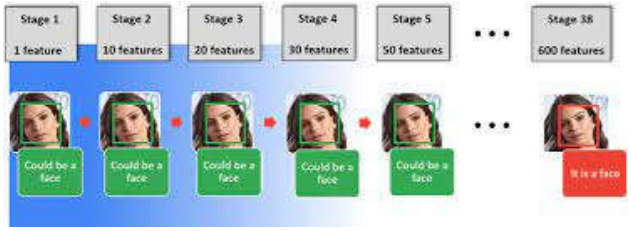


Fig8.EyeDetectionusingHaarClassifier

Steptwo,pupildetectionusingtheBinaryThreshold.Theresult of pupil detection is described by fig8.

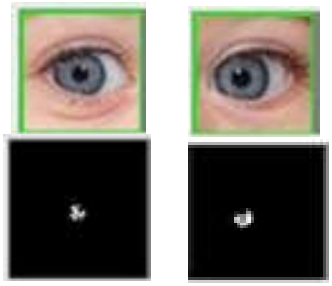


Fig9.PupilDetectionUsingBinaryThreshold

Pupildiametermeasurementisdonebyfindingthecenterpoint of the pupil using mass center point detection methods. In detectingthecenterofmass,whitepixelissearched,whilethe point information is stored in array. Further, from the information, length and height values are searched by calculating thedifference betweenthe pointstored in the array and the center point. The step continues with the Least-Square method to find the circle radius using algebraic equations (4),whereaandbarepupilcenterpoint.Themaximumvalue oftheradiusisthepupilradius.Later,HoughTransformisused tocreatepupilcircle.Fig9describestheresultofpupildiameter measurement. The algorithm for pupil diameter measurement:

1) Findcircle'scenterpointusingmasscenterpoint detection method.

2) Inprocessno1,the storedetectedwhitepixelinarraypoint.

3) Findthe differencebetweenthearraypointandcenter points.

4) Resultofno3willbetheheightandlengthvalue.

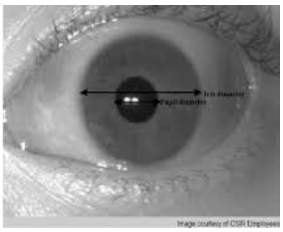
5) Findtheradiusofpupilusecircleequation(4)

$$R = \sqrt{(x - a)^2 + (y - b)^2} \quad (4)$$

Fig10.Pupilsize prediction technique

Afterward, the experiment was conducted using images from GVTA database. The experiment resulted in the detection of eyes and pupils from ten facial images, which means that there are twenty eyes whose pupil diameters were successfully measured. Fig 3 describes several results of pupil diameter measurement on images from GVTA database. The circle of pupil depends on the result of pupil detection; decent image will result in excellent image of pupil circle. For the optimalresultofpupildetection,BinaryThresholdmethodcanbe combined with other methods such as Morphology, Model- to-Image Registration or Labelling to improve the accuracy of pupil diameter measurement.

Size in detecting whether a customer likes a product. T60 eye tracker determines the relationship between pupil responses and learning activities.TobiiX120eyetracker detectstheemotional state of user when viewing pleasant and unpleasant videos. Tobii TX300 eye trackercomparespupildiameterduringpositiveandnegative emotions using eye tracking data; the eye tracking data mapped to PANAS X model to analyze the data. ASL504eyetrackermonitorspupildiameterwhenusers viewimagestodetecttheeffectsofhedonic,emotionalarousal. All these studies observed the customer behaviorsand detected the shopping sites. These helped the public service site, company website by using eye tracker.



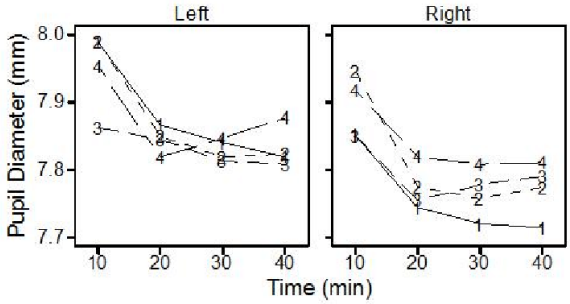


Fig11.PupilDiameterMeasurement

II. DEVELOPMENTOFPUPILSIZESTUDIES

Automatic pupil diameter measurement system can be developed to measure pupil size to detect human emotions, cognition,orconditioninseeinguserbehaviorwhileutilizing e-commerce. The experiment carried out using larger data. Previous studies in pupil size detection conducted experimenttodetectiriswhenthepositionofthefaceisrapidly changing and carried out research and analysis of the relationship between changes in human pupil diameter and emotional responses. Pupil size detection can be used in clinical studies to support additional features such as real-time pupil light reflex evaluation on both eyes simultaneously. Further research on human characters and emotions dealing with problems are based on pupil size and color.

Zernike Moments in classification of Eye:

Zernike moments are a set of orthogonal moments originated from the orthogonal moment theory put forth by Teague. There are various ways to recognize an eye, like Cornea, pupil, lens, retina and optic nerve etc. Recently, computer vision and pattern recognition techniques have been applied towards automated processes of eye recognition. Zernike Moments play an important role in the classification and recognition of Eye. Its key issue lies in whether the chosen features have good capability to discriminate the eye. Computer aided design recognition is still challenging due to many models and difficulty in representation approaches on eye. The works using Zernike Moments and Histogram of Oriented Gradients 407 A has made a lot of focus on the shape description of the eye. In the past decade, research on contour-based shape recognition was more active than that on region-based. They introduced a multiscale shape-based approach for image retrieval. The eye represented by local descriptors associated with margin sample points. Within this local description, studied four multiscale representations: the well-known spherical area representation (SAR), the Spherical side lengths representation (SSL) and two other representations, Spherical Oriented Angles (SOA) and Spherical Side Lengths and angle representation (SSLA). In this research they used 1-NN as classifier. They proposed a contour-based shape descriptor, named Multiscale Distance Matrix (MDM), to capture shape geometry while being invariant to translation, rotation, scaling, and bilateral symmetry. To classify the eye, they used 1-NN as classifier. The color information was incorporated in the identification of eye parts. The EOG circuit system will gain 1000 times from eye movement signal nature. And the frequency range of EOG monitoring system is 0.05 Hz – 30 Hz. We get that the system of EOG signal can be classified when eye movement looking at front, left and right. in and RBFNN was used as classifier.

However most researchers use yellow light as yellow light is said to be effective in protecting the retinas of patients with overexposure to blue light because it produces the best contrast. Sunglasses with yellow lenses are quite effective not only at filtering ultraviolet rays but also blue light. color, mainly due to its dependency on the illumination. They used PNN to classify 32 species of plants. All the plants they used in their research had green leaves. Also, in Zulkifli used General Regression Neural Networks (GRNN) and invariant moment to classify 10 kinds of plants. They did not include color features to the classifier. Furthermore, they used K-SVM to classify 32

species of plants and they also did not use any color features. This paper differs from the previous approaches because we propose a method for recognizing leafs using as shape descriptor the Zernike Moments (ZM) and as a descriptor for the interior of the leaf the Histogram of Oriented Gradients (HOG). Support Vector Machine (SVM) has been used as a classifier, which is among the best methods for discriminative models.

Table1: The result of Zernike Moments on ORL Database

Zernike Orders	Total Features	Image Size 32×32	Image Size 64×64	Image Size 128×128
1	2	24.5	25.5	27
2	4	56	57.5	59
3	6	66	65.5	66
4	9	72.5	73	72.5
5	12	75	74.5	75.5
6	**16**	**79**	**79**	**78**
7	20	78	78.5	77
8	25	75	74.5	75
9	30	78.5	78.5	75
10	36	76	76	76
11	42	77.5	75.5	76
12	49	72.5	72.5	73
13	56	73	72.5	73.5
14	64	69	69.5	69.5

Experimental results on dataset indicates that the proposed method yields an accuracy rate of 97.18%, on Pupil of Eye dataset with 98.13%. When we combine all the observations the obtained accuracy is 97.65%. To our knowledge these results are similar or better than the state of the art, and it is the first time someone has combined with all the popular databases. An overview of the method is given in Fig.12. More specifically we perform a preprocessing step, then we extract a feature vector per image and finally we do the classification of the image. In the next section we describe the preprocessing steps. The process outlines the features by extraction method and the classification method. The experimental result of our method concludes that by using Zernike Moments and Histogram of Oriented Gradients for classification of eye computes the shape features of aeye using Zernike Moments and the texture features using Histogram of Oriented Gradients and then the Support Vector Machine classifier is used for the image classification and recognition. Experimental results show that using both Zernike Moments and Histogram of Oriented Gradientsclassify and recognize the images yields accuracy that is comparable or better than the state of the art. The method has been validated on all spheres. The combined dataset of Zernike moment is a kind of orthogonal complex. All the moments and the kernel are a set of Zernike complete. orthogonal polynomials defined over the interior of the unit disc in the polar coordinates space.

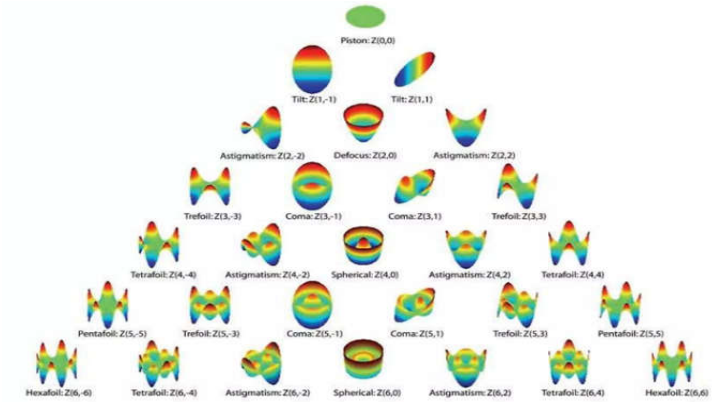
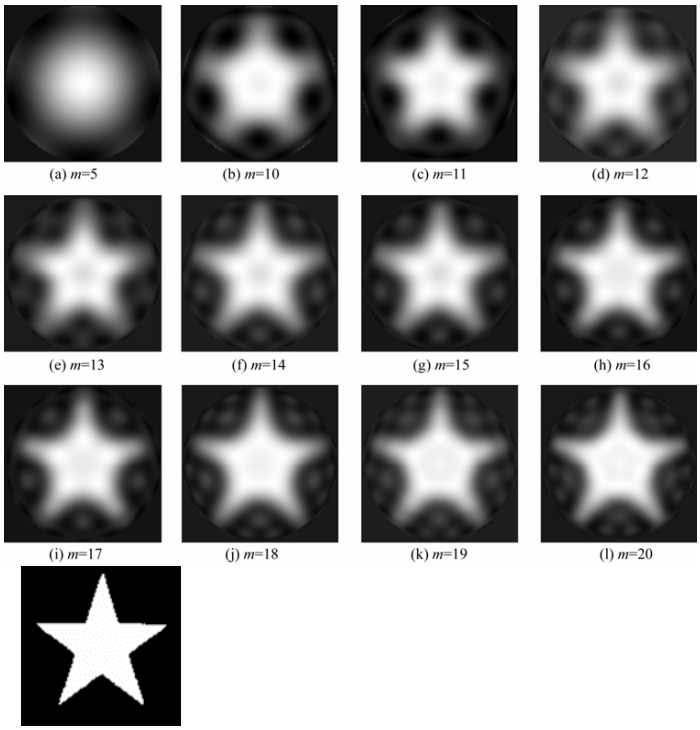


Fig12: Zernike Moments in classification of Eye

The image of Fig.13 is the testing image of the original trademark image which is reconstructedthrough the intensive images based on the Zernike moments shape feature set the original image. The magnitude of complex Zernike moments value for convenient calculation of the Trademark, without affecting the experiment results.



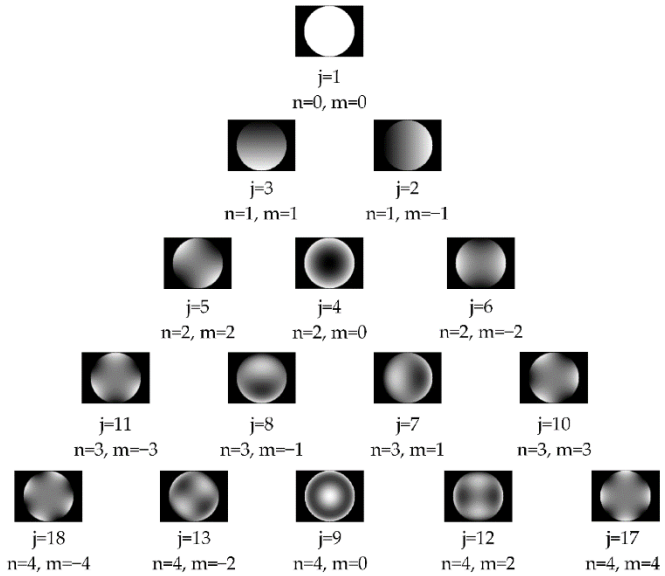


Fig13: Zernike moments based on image construction.

REFERENCE

[1] M.G.Masi,L.Peretto,R.Tinarelli,andL.Rovati,"Measurementofthe pupil diameter under different light stimula," *2009 IEEEIntrumentation Meas. Technol. Conf. I2MTC 2009*, no. May, pp.1652–1656,2009.

[2] A. Babiker, I. Faye, and A. Malik, "Differentiation of pupillarysignals using statistical and functional analysis," *2014 5th Int. Conf.Intell. Adv. Syst.*, pp. 1–6, Jun. 2014.

[3] M.Alshehri,"Anexploratorystudyofdetectingemotionstatesusingeye-tracking technology," pp. 428–433, 2013.

[4] M. M. Bradley, L. Miccoli, M. a Escrig, and P. J. Lang, "The pupilas a measure of emotional arousal and autonomic activation.,"*Psychophysiology*, vol. 45, no. 4. pp. 602–7, Jul-2008.

[5] Y. Adachi, K. Konishi, M. Ozaki, and Y. Iwahori, "Development ofan automatic measurement system of diameter of pupil - As anindicator of comprehension among web-based learners," *ProcediaComput. Sci.*, vol. 22, pp. 772–779, 2013.

[6] A.Giacomitti,G.L.Ferrari,F.K.Schneider,J.L.B.Marques,and H.R. Gamba,"Preliminaryevaluationof aSmartCam-basedsystemfor real-time pupil light reflex analysis," *IFMBE Proc.*, vol. 18, pp.365–369,2008.

[7] T.ShinodaandM.Kato,"Apupildiametermeasurementsystemforaccident prevention," in *Conference Proceedings - IEEEInternational Conference on Systems, Man and Cybernetics*, 2007,vol. 2, pp. 1699–1703.

[8] P.K.Rhee,M.Y.Nam,andL.Wang,"Pupillocationandmovementmeasurementforefficientemotionalsensibilityanalysis,"*2010IEEEInt.Symp.SignalProcess.Inf.Technol.ISSPIT2010*,pp.1–6,2011.

[9] S.Kawai,H.Takano,andK.Nakamura,"Pupildiametervariationinpositive and negative emotions with visual stimulus," *Proc. - 2013IEEEInt.Conf.Syst.Man,Cybern.SMC2013*,pp.4179–4183,2013.

[10] C.-H.HoandY.-N.Lu,"Canpupilsizebemeasuredtoassessdesignproducts?," *Int. J. Ind. Ergon.*, vol. 44, no. 3, pp. 436–441, 2014.

[11] F. Mokhayeri and S. Toosizadeh, "A Novel Approach for PupilDiameter Measurement Based on Soft Computing Techniques," pp.3–7,2011.

[12] A. Barreto, J. Zhai, N. Rishe, and Y. Gao, "Significance of pupildiameter measurements for the assessment of affective state incomputerusers,"*Adv.Innov.Syst.Comput.Sci.Softw.Eng.*,pp.59–64,2007.

[13] Hyoung-Joon Kim, Whoi-Yul Kim, "Eye Detection in Facial Images Using Zernike Moments with SVM", Etri Journal 30(2):pp:335-337, April 2008

[14] D. Arch, W. L. Wilkie, and A. Abor, "Pupil Dilation Measures in ConsumerResearch."AdvancesinCustomerResearch,pp.166–168, 1979

[15] S. Chen and C. Liu, "Discriminant Analysis of Haar Features for Accurate Eye Detection."

.[16]J.A.N.J,S.Khanchi,H.R.P.J,andC.Engineering,"EyeDetectionAlgorithm on Facial Color Images," pp. 344–349, 2008.

[17] P. I. Wilson and J. Fernandez, "Facial feature detection using Haarclassifiers," *J. Comput. Sci. Coll.*, vol. 21, pp. 127–133, 2006.

[18] J. Chinni and H. V. Reddy, "Iris Recognition based on Pupil usingCannyedgedetectionandK-MeansAlgorithm,"vol.2,no.1,pp.1–5,2013.

[19] G. Xin, C. Ke, and H. Xiaoguang, "An improved Canny edgedetection algorithm for color image," pp. 113–117, 2012.

[20] O. Castillo and P. Melin, "Optimization of type-2 fuzzy systemsbasedonbio-inspiredmethods:Aconcisereview,"*Inf.Sci.(Ny).*,vol. 205, pp. 1–19, 2012.

[21] Q.Ying-Dong,C.Cheng-Song,C.San-Ben,andL.Jin-Quan,"Afastsubpixel edge detection method using Sobel–Zernike moments operator," *Image Vis. Comput.*, vol. 23, pp. 11–17, 2005.

[22] A. Poursaberi and B. N. Araabi, "A Novel Iris Recognition SystemUsing Morphological Edge Detector and Wavelet Phase Features," *Int. J. Graph. Vis. Image Process.*, vol. 5, pp. 9–15, 2005.

[23] Q.Bai,"AnalysisofParticleSwarmOptimizationAlgorithm,"*Comput.Inf.Sci.*,vol.3,no.1,pp.180–184, 2010.

[24] Optimization of interval type-2 fuzzy system using the PSO technique for predictive problems -Dinh Sinh MaiORCIDIcon,Trong Hop Dang &Long Thanh NgoORCID IconPages 197-213 | Received 27 Apr 2020, Accepted 03 Oct 2020, Published online: 30 Oct 2020.

[25] Real Time Eye Detector with Cascaded Convolutional Neural NetworksBin Li1,2,3and Hong Fu 3 Academic Editor: Erich Peter KlementReceived 12 Jan 2018 Revised 12 Mar 2018 Accepted 14 Mar 2018 Published 22 Apr 2018