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Descriptive Analysis of Human Emotions Based on Eye Pupils

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ABSTRACT-Facial emotional expressions are viewed as the most descriptive way to understand the human's state of temperament during confronting communication. In this work, numerous statistical approaches have been applied to human eye pupils with static images of the Chicago face dataset (CFD) to analyze and classify the considered categories for emotions which are Happy, Fear, Anger, and Neutral. This study aims to develop the specific architecture for the image processing domain after applying different enhancement techniques to the human eye pupil for analysis & recognition of the facial expressions. This work is divided into three phases initially in the first phase data preprocessing is performed to prepare according to the requirement of work and also the color images are converted into negative by applying the pixel intensity controlled mechanism. The second phase defines the boundary to compute the feature by using the Circular Hough Transform algorithm. Lastly, statistical approaches are applied to extracted features to corporate the central point of the pupil. This corporation of the central point presents the effects of emotions. While comparing people of different Age groups it is concluded that pupils constricted on Anger at different levels in different age groups. If further it is discussed about cross-cultural and gender-wise comparison then Happy Emotion affects most and resulted towards dilated pupil same like that Anger emotion affects most on constricting the pupil size.

Keywords: Emotions Analysis, Pupil size, Cross-cultural Differences, Gender-based Analysis, Age-based Analysis

1. INTRODUCTION

Human emotion is one of the important aspects of daily life and also essential for significant social interaction. It is necessary that the different systems of emotion recognition provide good recognition performance, case in point to avoid misunderstanding the mental state of any person. Human eyes communicate many more than we realize in fact human eyes play an important role in non-verbal communication. It may be consciously or may not that the way we look at someone or move our eyes or make eye contact with someone can say a lot about what we are feeling and thinking. The Human Eye structure is shown in Figure 1. This work discovers the improvement in learning standards for the recognition of human emotions from images of facial expressions. Recognizing human emotions includes examining hand gestures, speech signals,

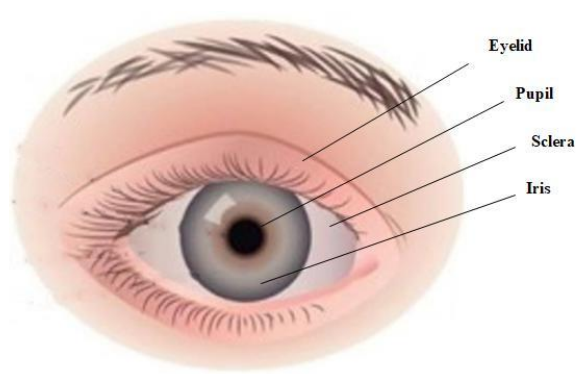


Figure 1: Human Eye structure

facial expressions, and body language, or an amalgamation of all these modalities. To be capable of recognizing human emotions is the foundation for human sympathy; while interacting with other people, human being depends on their abilities to interpret and perceive emotions in further people and also adjust automatically the responses according to perceived emotional states. Furthermore, existing literature validates that recognition from facial expressions can yield higher recognition levels. In [1] described the methods which are based on waves parameters and non-electrical parameters for measurements of emotions. There are numerous endeavors at tending to computerized emotion recognition as of the outward appearance of expressions by using Deep Learning and further new ML methods. Therefore, many advanced recognition standards have been fixed on datasets containing static face expression images gathered in controlled environs.

The aim of this work is to develop the specific architecture for image processing after applying different enhancement techniques to facial images for analysis of the facial expressions in an unimpeded environment. The considered categories for emotion analysis are Happy, Fear, Anger, and Neutral states. Latterly these emotions are considered widespread emotions across all cultures. The uniqueness of this research is the detection of pupils, especially for the objective of emotion analysis. As the problem statement defines "Is it possible to analyze the human emotions after applying various mathematical approaches to the human eye pupil with static emotional images?" The rest of the article is structured as follows: Section 2 presents the work's Literature, Section 3 presents the methodology, Section 4 presents the results and discussions, and Section 5 analyses the work's conclusion.

2. RELATED WORKS

There is a major role behind emotional understanding in the development of Human-Computer Interaction systems. Identification of human emotions supports computer systems for the formulation of proper responses. Emotional expressions have a long-lasting history. It is a deep-rooted area of research for over a century. Recognition of emotions is one of the most dynamic research topics currently and is also an increasingly great challenge and strong interest [2]. It initiated with more acceptable that reactions of emotions can be nominated as a dominant feature in sensible human behavior. Results of experiments based on subjects from a renowned dataset "Chicago Face Dataset (CFD)" [3] determine that the proposed techniques can efficiently be used to assess the analysis of facial emotions. Furthermore, with a view to proving the strength of the proposed system, images of Black people are also used from CFD to check the stability of the algorithm. Finally, the results are impressive especially when tested after the conversion of the image into negative. Some of the sample images from CFD are shown in Figure 2.

Figure 2: Sample image galleries from CFD [3]

Communities of IEEE & U.S. National Foundation of science [4-5] have pay for many workshops and conferences related to this research area. These days there is a trend to substitute traditional techniques of image representation with well-organized algorithms for semi-supervised or unsupervised feature learning & hierarchy-based feature extraction. On the other hand, Deep Learning (DL) comprises many known architectures & for outcomes, it is significant the determination the nature of problems related to Machine- Learning before it's functional. Tomkins [6] suggested nine primary emotions (interest, anger, disgust, distress, contempt, joy, fear, surprise, and shame) whereas eight basic emotions (anger, acceptance, disgust, anticipation, joy, fear, surprise, and sadness) belong to plutchik's emotion wheel [7-8-30].

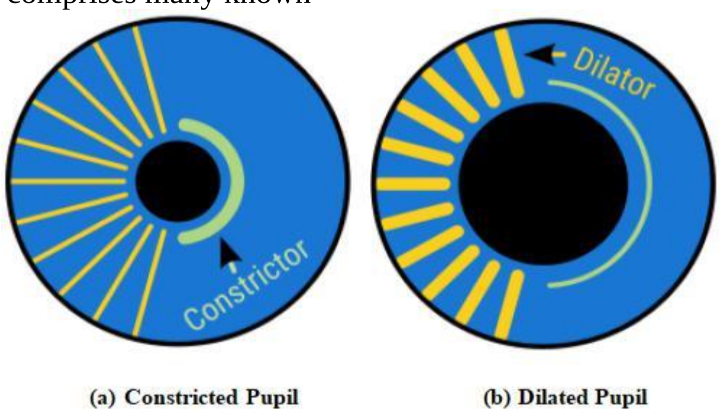


Figure 3: (a) Constriction (b) Dilation structure of eye pupil [9].

Figure 3 shows the pupil constriction and dilation which takes place while iris sphincter muscle contracts then it squeezes iris's inner side and when the iris dilator muscles contract then it pulls inner side of the iris outer, thus it causes dilated pupils [9]. For effective algorithm development of facial expression recognition, many well-known databases of enough size are requisite. The selection of datasets in this type of study is referred to as one of the most important aspects. Most of the databases are created after the requesting participants display several emotional expressions. So, the characteristic which differentiates different databases is expressions performed spontaneously or intentionally**.** For example, CK+ [10], and ADFES [11] both databases were shaped on the basis of deliberate expressions whereas DISFA [12-31] is created by using unprompted expressions. Accordingly, well-built datasets are prominent due to their ability to include as many aspects as possible. Another important characteristic is image resolution.

Depending upon utilized techniques, especially with respect to feature extractions, the image can stand effective in high resolution; this thusly could be advantageous for the computational rate of the system. High-resolution images are required in this work for preprocessing and to find better results so that Chicago face dataset [3] is selected. It consists of 158 high-resolution images and uniform images of White and Black females and males between the ages of 18 to 40 years. The Chicago Face dataset is preferred in this work on other datasets because others have fewer resolution images and also lack information about a target. Table 1 is describing the maximum number of available data sets from which the emotion analysis can be possible. Eye-Tracking is said to be the method of identification of gaze point or the spot where users are watching for a specific visual stimulus. Different devices are used by different scholars for Eye-tracking like Virtual Reality [16, 17, 28], Mobile Eye-tracking [14-15], and Desktop Eye-tracking [13-32].

Table 1: Publicly available databases of face expressions

Databases	Imaging	Camera view	Images Resolution	No of Subjects	Type
Chicago Face Database as (CFD) [3]	Static	Frontal	2444 * 1718	158	Spontaneous
Belfast Naturalistic [24]	Video Frames	Frontal	Mixed	125	Spontaneous
Cohn-Kanade CK+ [10]	Video Frames	Frontal	640 * 490	123	Posed & Spontaneous
MMI [25]	Static	Frontal and 90°	720 * 576	101	Posed & Spontaneous
DISFA [12]	Video Frames	Frontal	1024*768	27	Spontaneous
ADFES [11]	Static	Frontal	720 * 576	22	Posed
JAFFE [26]	Static	Frontal	256 * 256	10	Posed

3. METHODOLOGY

Methodology incorporates the portrayal of the phases which are followed in systematic way to create Emotion Analysis System which analyzes by Eye Pupil. For analysis of facial expression through static images, an algorithm is required which is specially designed for pupil detection and radius measurement of eye pupil at different emotional stages. The approaches used for the Eye features detection are purely based on up-to-date reports in literature. Consequently, in this research implemented technique for Pupil detection is Circular Hough transform used by [27-29] in which code for radius measurement is implemented. This influential descriptor is applied to the human eye pupil in order to get suitable information like pupil radius for each image of basic emotions like Fear, Anger, Neutral and Happy. So, the feature data is fed into a simple Excel sheet in a specific format after extraction of the data. Further analysis is done through different techniques of statistical tests or other graphical representations for comparing all emotions with each other so that the difference between each emotion can be visible. Figure 4 shows the complete framework of this work.

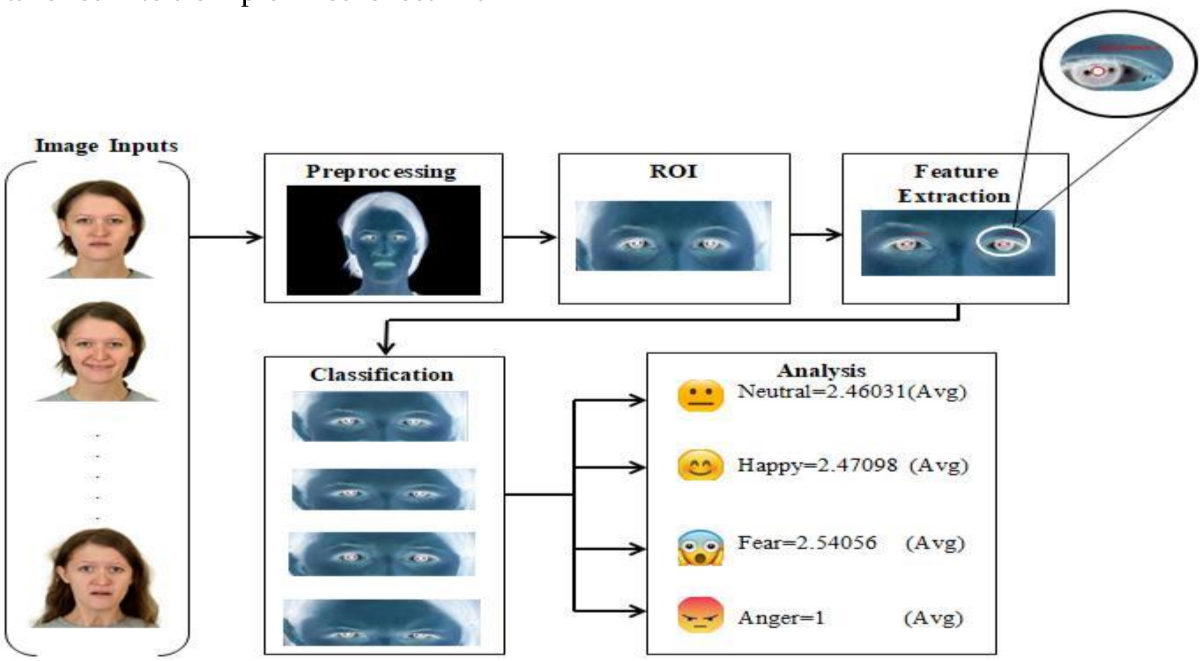


Figure 4: Representation of proposed framework

3.1 Data Acquisition and Preparation

Acquisition of data is the way towards testing sampling signals that measures genuine physical conditions & conversion of subsequent samples into alphanumeric values that can easily be influenced by computer. Analog data is acquired from images for its further. Gathered data can be used for the improvement of efficiency and to ensure reliability of Emotion recognition through different ways. Chicago Face Dataset CFD consists of 158 highly resolution and standardized images of White and Black females and males which are all in between the age of 18 to 40 years expressing emotions (Happy, Neutral, Anger and Fearful). All the data is prepared conferring upon the needs and different modifications are done on the original data set. Figure 5 expressing refined data set.

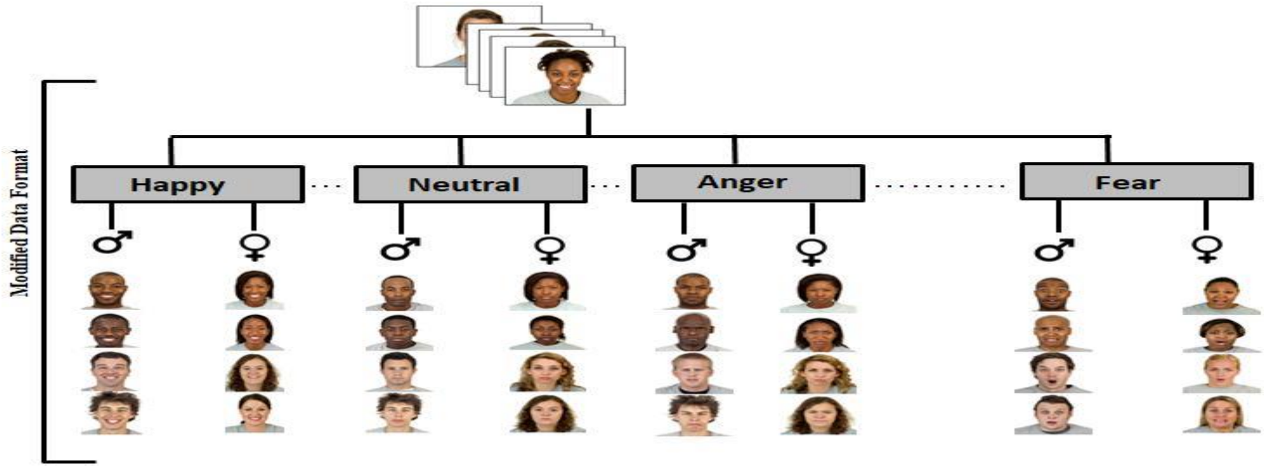


Figure 5: Refined dataset

3.2 Data Preprocessing

Data preprocessing means the transformation of raw data into meaningful or understandable information. For the meaningful results images of modified dataset is converted from RGB to Negative. So, the detection of both eye pupils can be made easy. For the conversion purpose a code in python is used which converts the image individually in to negative shown in Figure 6. Library of Python named "PIL" is used for that purpose in python. Image is loaded through the following PIL command "**im = Image.open (r' Path of image')**". Secondly point function is applied for pixels manipulation through the following command in Python of PIL library "**result = im.point (lambda p: 255 -p)**" for getting negative image and for black peoples 80 is given as pixel value instead of 255 just because of the image clarity. Whereas, lambda is an expression or function that can take any number of arguments but can only have 1 expression.

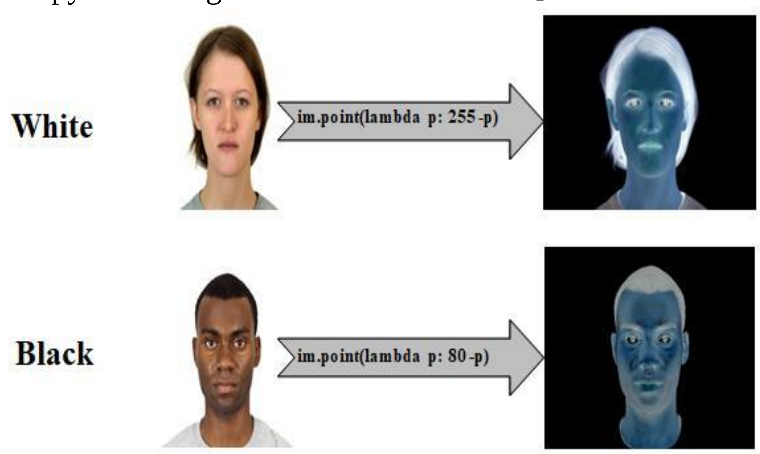


Figure 6: Images preprocessing.

3.3 Region of Interest

Region of interest (ROI) is a part of any image that you need to operate or filter in some way. All of the images are cropped so that the interested regions can be more visible and the further work can be easier. To crop the acquire image applying the function [18] which is used to compute rectangle area. Such as, rectangular values are 800 from Left, 800 from Right, 250 from Top and 650 pixels from bottom. Figure 7 shows the criteria of crop handles which remains same for all images.

Following Eqs 1 representing a simple image:

$$F(x,y) \equiv \begin{matrix} f(0,0) & f(0,1) & f(0,2) & ! & f(0,N-1) \\ f(1,0) & f(1,1) & f(1,2) & ! & f(1,N-1) \\ f(2,0) & f(2,1) & f(2,2) & ! & f(2,N-1) \\ " & " & " & " & " \\ f(M-1,0) & f(M-1,1) & f(M-1,2) & ! & f(M-1,N-1) \end{matrix} \quad (1)$$

$= (\, ,) ; =$

Then ROI as per the Matlab built-in function is extracted according to Eqs (2) & (3). (2)

$(\, , [\; h \quad h]) ;$ (3)

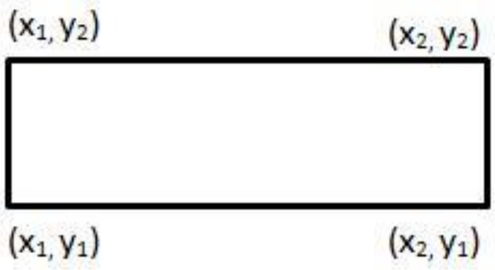


Figure 7: Representing ROI of eye region

Where

$= (\, ,)$
$= (\, ,)$
$h = (\; -)$
$h = (\; -)$

3.4 Feature Extraction

Figure 8 representing the extracted features which have been used to detect radius area of pupils so that the analysis can be done. For that purpose, function in [19] is used. It has two steps where the first step is accepting the preprocessed images for eye pupil detection and the second step is to design pupil circle and define the center area of the pupil which is used for measurement of radius.

Let $(h, \;)$ be the centers of the circles with radii r

Where

$r^2 = (\; - h)^2 + (\; - \;)^2$ (4)

Eq.4 and Figure 8 represent the Hough circle whereas value "h" is the center point x coordinate and value "k" is the center point y coordinate.

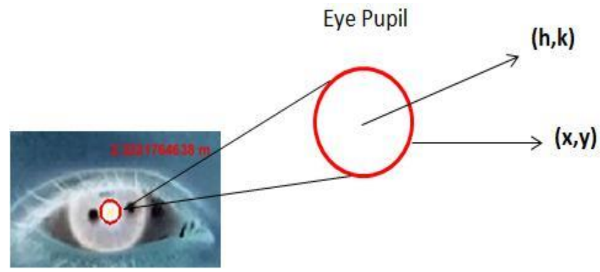


Figure 8: Representation the center point and boundary of pupil

Algorithm: Feature Extraction

1.**Input:** A raw images dataset

2.**Output:** A dataset with synchronized features

3.**Algorithm:**
4.**Declared variables** image, negative_img, roi, centers, radii, metric
5.**Take** an Image from a dataset
6.**Convert** the corresponding image into negative_img (**Fig. 6**)
7.**Crop** ROI (Region of Interest) from the entire negative_img (**Fig. 7**)
8.**Set** the range of circle Min-Max(6-15) and **Get** centers, radii, metric
9.**Focus** on both pupils and mention the size of an image
10. **for** k =1 to size(radii) **do**
11. **Size-of-pupil** = sprintf('%2.10f m', radii(k)*0.264583333);
12. **Compute** pupil radius (**Eqs. 4)**

13. text (centers (k ,1), centers(k,2)-50, size-of-pupil,'Color','r','FontWeight','bold');
14. **End**

4. RESULTS AND DISCUSSIONS

Figure 9 illustrates the process of Average through which the results are extracted whereas P_L stands for Left Pupil and P_R stands for Right Pupil. These acquired results after average are the representative of left and right pupils. Although some images of anger emotion in the dataset have closed eyes it is impossible to measure the pupil size because of the closure of Eyelids so the average default value for that type of image is taken as 1 for smooth results.

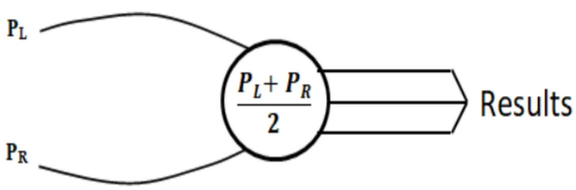


Figure 9: Extracting Average results

Average values are extracted from obtained results after applying Eqs.5.

!"# = !¦! !¦ (5)

4.1 Descriptive Statistics of Pupil Sizes between Genders

All the data of males and female is separated to examine the variations among two sexes. According to Figure 10, it is represented that the females in graph (b) show bigger pupils in all emotions despite anger emotion. In this case, a female has an average pupil size of 1.81369 mm whereas a male has 2.09650 mm. Only in anger emotion pupil size of a female is less dilated as compare to male. Results are represented in the following fig 10 (a) and (b).

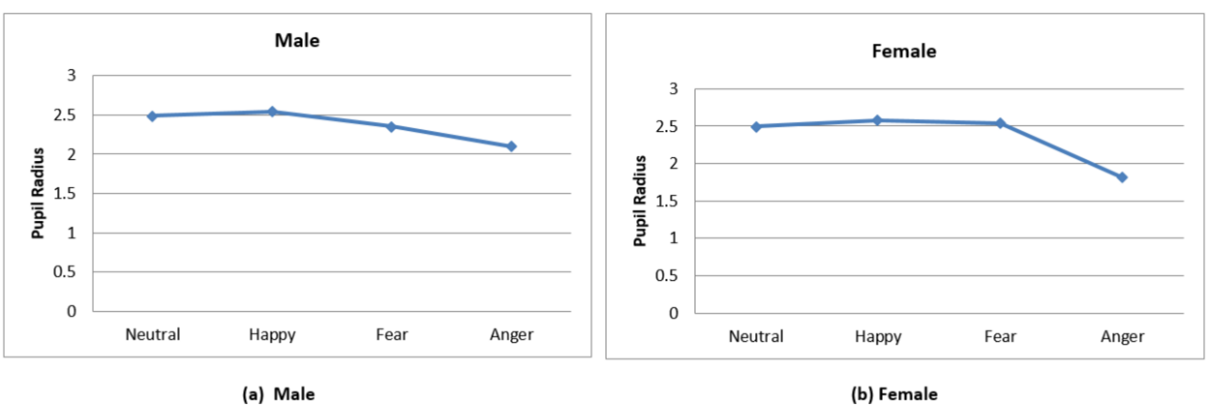


Figure 10: Pupil Size differences among two sexes (a) Male (b) Female

Descriptive analysis is performed on the dataset of 28 females and 19 males having different age slaps. Females show comparatively stronger emotional fluency, whereas males have sturdier emotional involvements with angry & positive stimuli [21]. So that the gender-based results prove the Gross & Levinson [21] work also. [20] proves the statement that minor but substantial gender variances in emotional expressions have been reported for grownups, with females showing larger emotional fluency, mainly for positive emotions & assuming negative emotions like fear & sadness. An Autonomous pairwise assessment has shown that females delivered a score of fixation duration which was meaningfully larger than the score provided by male unpleasant emotions like Anger or Fear images [22]. High Standard deviation values of females indicate that the variation among female Eye pupils is a little higher than the male Eye pupils. A detailed comparison is shown below in Tables 2 to 5.

Table 2: Neutral Emotion		
	Male	Female
Mean	2.489129	2.499918
Standard Deviation	0.262009	0.290367
Sample Variance	0.068648	0.084313
Minimum	1.84275	1.924295
Maximum	2.94249	3.300355
Count	19	28

Table 4: Fear Emotion		
	Male	Female
Mean	2.353158	2.533291
Standard Deviation	0.274112	0.29771
Sample Variance	0.075138	0.088631
Minimum	2.00798	1.97463
Maximum	2.99411	3.0975
Count	19	28

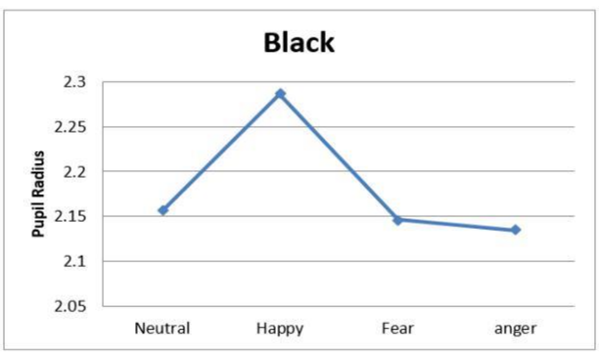
4.2 Descriptive Statistics of Pupil Sizes among Cross-cultural differences

If we talk about the people of different regions like black and white people then we can say that the black peoples have overall less pupil dilation than white. An analysis is done on 5 black and 42 white people's images. Figure 11 graphs (a) & (b) represent the detailed analysis in which neutral point

Table 3: Happy Emotion		
	Male	Female
Mean	2.541837	2.577336
Standard Deviation	0.223419	0.250817
Sample Variance	0.049916	0.062909
Minimum	2.14656	2.02378
Maximum	2.875235	3.1736
Count	19	28

Table 5: Anger Emotion		
	Male	Female
Mean	2.096506	1.813691
Standard Deviation	0.787249	0.815583
Sample Variance	0.619761	0.665176
Minimum	1	1
Maximum	2.989105	2.9938
Count	19	28

black shows smaller pupil size as compared to white people and black shows huge dilation while changing its emotion from neutral to Happy as compared to others emotions. White people didn't claim much difference from all other emotions. The main thing is that both are claiming low pupil dilation in anger situations which is unique in both.



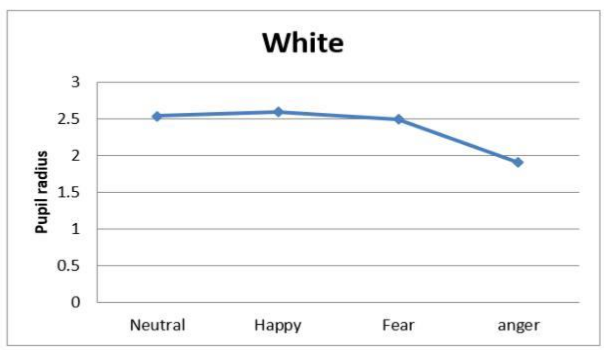


Figure 11: Pupil size differences among cross-cultural peoples (a) Black (b) White

Descriptive analysis of all of the four emotions is shown below in four Tables 6 to 9 separately through which we can do the detailed analysis and get important details about the differences between cross-cultural peoples e.g. (Black & White). The neutral emotion STD value is 0.25812 which is greater than the Neutral black value of 0.18523. Same like that Happy white = 0.223288 > Happy Black = 0.186488, Fear white = 0.286951 > Fear Black = 0.214916 and Anger white = 0.846877 > Anger Black

Table 6: Neutral Emotion

	white	**Black**
Mean	2.535961	2.156159
Standard Deviation	0.25812	0.185237
Sample Variance	0.066626	0.034313
Minimum	1.84275	1.924295
Maximum	3.300355	2.376345
Count	42	5

Table 8: Fear Emotion

	White	**Black**
Mean	2.497865	2.146358
Standard Deviation	0.286951	0.214916
Sample Variance	0.082341	0.046189
Minimum	2.00798	1.97463
Maximum	3.0975	2.43382
Count	42	5

= 0.306873. These differences in standard deviation show that the pupil variation rate among white people is much higher than black people.

Table 7: Happy Emotion

	White	**Black**
Mean	2.595912	2.286402
Standard Deviation	0.223288	0.186488
Sample Variance	0.049858	0.034778
Minimum	2.14656	2.02378
Maximum	3.1736	2.51762
Count	42	5

Table 9: Anger Emotion

	White	**Black**
Mean	1.903422	2.134651
Standard Deviation	0.846877	0.306873
Sample Variance	0.717201	0.094171
Minimum	1	1.8436
Maximum	2.9938	2.54537
Count	42	5

4.3 Age Group-wise comparison of emotions

The main effects of emotions were perceived by (Persons including males & females = 47, Mean Age = 26.50) and data is divided into four age groups with a difference of 5 years relatively to measure variations accurately without facing any issues. Line graphs are shown below in Figure 12 according to groups of 17-21, 22-26, 37-31, and 32-37. Size of Pupils and emotional perceptions are entangled with each other but their association is developed over age [23].

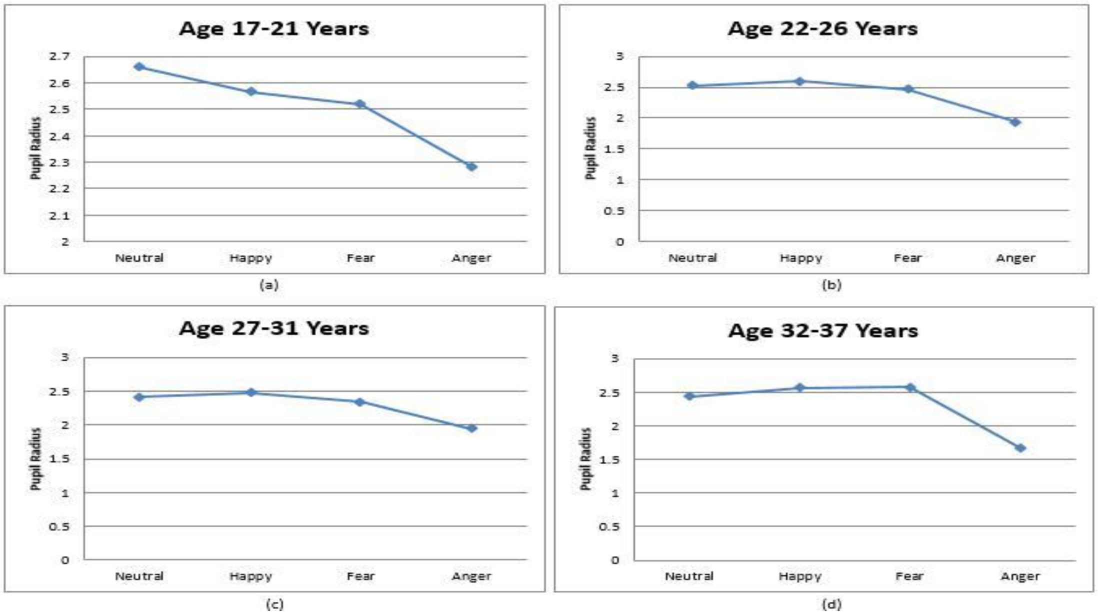


Figure 12: Representation of pupil size changes due to emotions according to Age (a) Age 17-21 (b) Age 22-26 (c) Age 27-31 (d) Age 32-37

Diminishing pupil size improves the assessment rate of valence and emotional intensity for Anger, but not happy, fear, or neutral expressions of the face. Connotation between small or large pupils and negative and positive impressions develops in overage and is absent in youngsters. A person lying under the age of 17-21 has a larger pupil size at neutral and it decreases while it changes in Happy as well as Fear and Anger. Persons lying under age 22-26 have a larger pupil at happy emotion because they claim 2.594782 mm pupil radius which is larger than all other emotions average between same age emotions. If we talk about the persons lying under 27-30, they also show larger pupil size on happy emotions and claim a 2.47633 mm pupil radius. Persons aged 31-37 claimed most dilated pupils on Fear emotion which is 2.571194 mm and greater than other emotions average values. Average pupil size with respect to age is represented in Table 10 below.

Table 10: Average pupil size according to age

	17-21	22-26	27-31	32-37
Neutral	2.66050	2.52057	2.40750	2.43415
Happy	2.56535	2.59478	2.47633	2.56732
Fear	2.51943	2.46890	2.33745	2.57119
Anger	2.28200	1.9360	1.94713	1.66869

5. CONCLUSIONS

This study aimed to develop the specific architecture for the image processing domain after applying different enhancement techniques to human eye pupils for analysis of the facial expressions. Three different algorithms were combined for emotion analysis purposes and achieved good analysis results on the Chicago face database. Furthermore, an algorithm that describes the eye's Image luminance at different values according to the clarity of an image for white and black people is presented. The RGB image is converted into a negative image as a texture analysis approach. Initially, descriptive analysis is performed on two different sexes which shows that in both sexes' happy emotion affects more than others, and pupil dilation takes place more than other emotions. Female pupils dilated more than males in Fear emotion. In cross-cultural differences, the experiment concludes that the black people's pupil dilation is more than white on happy emotions whereas their variation rate is low as compared to white people. According to the Age differences, it is concluded that the peoples who comprise between the age of 17- 21 at a neutral point claim high pupil size as compared to other age groups, and the persons lie between 32-37 claims high pupil size in fear emotion. In general, on the basis of results, we can say that happiness affects more on pupil size & tends towards more dilated pupils and in the anger emotion, the pupil size is constrained as compared to other emotions.

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