Textured Contact Lenses Detection in Iris Recognition Using Weber Local Descriptor (WLD)

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ABSTRACT

Out of many available biometric identification methods, iris recognition seems to be promising and most accurate method. The reason is iris structure remains unchanged throughout one's lifetime. One of the live applications of this is: over 1000 ATMs of financial institutions in Chicago and Montreal are now using iris recognition in lieu of debit cards. Imagine the situation if iris recognition systems/scans used in ATMs are fooled or spoofed. Financial system will break with a huge damage. To avoid this, there must exist technique(s) to determine if iris recognition methods are being bypassed.
This paper presents an in-depth analysis of the effect of contact lens on iris recognition performance. We also present the IIIT-D Contact Lens Iris database with over 6500 images pertaining to 101 subjects. For each subject, images are captured without lens, transparent (prescription) lens, and color cosmetic lens (textured) using two different iris sensors. Weber Local Descriptor (WLD) is proposed in this paper for feature extraction in contact lenses detection. Also, the results are compared with Binarized Statistical Image Feature (BSIF) analysis which shows that WLD gives favorable results. We organize WLD features to compute a histogram by encoding both differential excitations and orientations at certain locations. This method focuses on different properties of a pixel of iris image and thus, it provides more accurate results than other techniques.

Keywords- Iris Recognition, Retina, SVM, Biometric, Segmentation, Contact lenses.

1. INTRODUCTION

Biometric is the process of identifying people based on their unique biological characteristics which involves biological input, or the scanning or analysis of some part of the body. Iris, fingerprint, DNA are some of the biometric identifiers. Iris is more popular among these identifiers since it is more accurate and unique. It is a thin circular physiological structure in the eye which is generally responsible for controlling the diameter and size of the pupil. Human iris is formed by early months of age. It remains unchanged throughout one's lifetime and thus, it is unique. Iris pattern is different for everyone, even for identical twins also. Of all the biometric technologies used for human authentication today, it is accepted that iris recognition is the most accurate.

A circular black disk known as pupil lies in the center of the eyeball which is controlled by the automatic nervous system. The pupil is responsible for adjusting to the amount of light, so the size of the pupil varies with respect to the amount of light it is exposed to. The annular ring that is located between the sclera and pupil boundary is called the iris and contains large number of minute details [fig.1]. The iris also has an extremely data rich physical structure and contains the flowery pattern that is unique to an individual. This pattern remains unchanged with age.

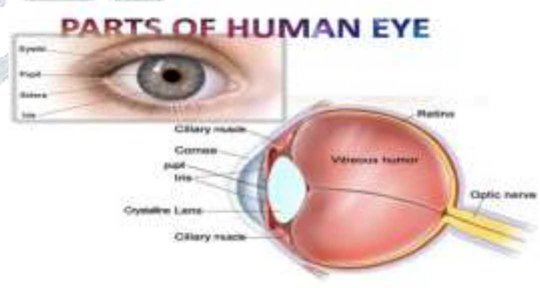


Fig.1 Structure of Human Eye

2. LITERATURE SURVEY

He et al. [2] presented statistical texture analysis-based method for detecting fake iris. Four distinctive features based on gray level co-occurrence matrices (GLCM) (mean and standard deviation of pixel values, contrast and the angular momentum) are used as a feature vector. A support vector machine (SVM) is used for classification. They reported the main drawback of the GLCM approach that it needs large storage space. An example of 8-bit image can be considered where the co-occurrence matrix has 65536 elements [2].

Zhaofeng He et al. [3] implemented texture-based method for iris spoof detection for contact lens. Firstly, the normalized iris image is divided into sub-regions according to the properties of iris textures. Local binary patterns (LBP) are then adopted for texture representation of each sub-region. Finally, Adaboost learning is performed to select the most discriminative LBP features for spoof detection. A kernel density estimation method is proposed. It is found that LBP is efficient in texture representation and Adaboost algorithm is efficient in learning the most discriminative features for spoof detection. The division of iris into sub regions represents iris texture effectively [3]

Daksha Yadav [4] has shown in experimental results that wearing of contact lenses, both soft contact lense and textured cosmetic contact lense degrades the accuracy of iris recognition. The effect is relatively small increase in the false non-match rate with the clear soft contact lense, but it is major increase in the flase non-matchrate with the textured contact lenses. The problem of lens detection in an iris image is approached as a three class classifiaction problem: no lense, soft lense and textured lense. Three types of experiments were performed such as Intra-sensor validation, inter-sensor validation and multi-sensor validation to evaluate the correct classification rate of the consructed models.

D. Gragnaniello [5] had proposed a new machine-learning technique for detecting the presence and type of contact lenses in iris images. They had extracted the regions of interest for classification, then computed a feature vector based on local descriptors, and feed it to a properly trained SVM classifier by following the usual paradigm. Major improvements are in the current state of the art concern the design of a more reliable segmentation procedure and the use of a recently proposed dense scale-invariant image descriptor. They had experimented results on publicly available datasets. It shows that the proposed method outperforms significantly all other reference techniques.

Hanna Ali [7] presented a complete iris recognition system in which the iris features are obtained using Speeded Up Robust Features (SURF) after enhancing the image using Contrast Limited Adaptive Histogram Equalization (CLAHE). They proposed a novel matching algorithm based on applying fusion rules at different levels which has the advantage of reduced data storage and fast matching. The algorithm is implemented and tested using CASIA(V4) database. They obtained recognition accuracies as 99% using left images and 99.5% using right images

Pedro Silva [8] presented an approach to iris contact lens detection. They focused on a three-class detection problem such as images with textured contact lenses, soft contact lenses and no lenses. In this approach they used a convolutional network to build a deep image representation and an additional fully connected single layer with soft max regression for classification. They conducted experiments in comparison with a state-of-the-art (SOTA) approach on two iris image databases for contact lens detection.

Lovish et al. [9] created a contact lens dataset containing 12823 images acquired from 50 people. For every subject images images are collected without lens, with soft lens and with cosmetic lens class. The authors proposed cosmetic lens detection approach based on Local Phase Quantization (LPQ) and Binary Gabor Pattern (BGP). The results proved that due to blur tolerance of LPQ and robustness of BGP, cosmetic lens detection can be done accurately [9].

3. SYSTEM DEVELOPMENT

3.1 System Architecture

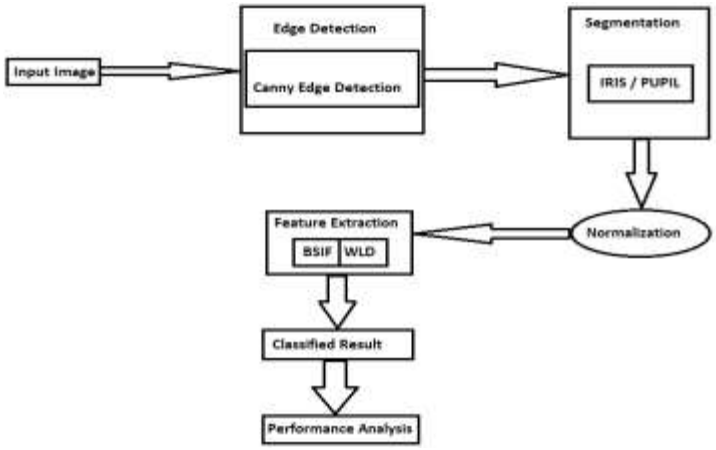


Fig. 3.1 System Architecture

3.2 Dataset

The IIIT-D CLI database is prepared with three objectives:

(1) capture images pertaining to at least 100 subjects

(2) for each individual, capture images without lens, With transparent (prescription) lens and with color cosmetic lens

(3) capture images with variations in iris sensors and lenses (colors and manufacturers).

3.3 Segmentation

Iris localization or segmentation segments the iris from the rest of the acquired image. The main steps in Localization are determining the boundary of iris and pupil, removal of eyelids and eyelashes. The segmentation divides each iris image into two regions: Iris and Pupil

3.3.1 Edge Detection

Edges occur on the boundaries of two regions. The first step involves in an image recognition system is the Edge detection which is a basic and important tool in the main areas of image processing such as feature detection and feature extraction.

Canny Edge Detection Algorithm:

The Canny algorithm basically finds edges where the grayscale intensity of the image changes the most. It is used to reduce the amount of data in an image and preserve only the important one for further processing. This algorithm works in 5 different steps as described below:

(1) Noise Reduction: Smooth the image with a Gaussian filter to reduce noise, unwanted data and textures.

(2) Finding gradients: The edges are marked where the gradient of the image has large magnitudes.

(3) Non-maximum suppression: Only local maxima would be marked as edges.

(4) Double thresholding: Potential edges are determined by checking the thresholding values.

(5) Edge tracking by hysteresis: Final edges are determined by suppressing all edges that are not connected to a very certain (strong) edge.

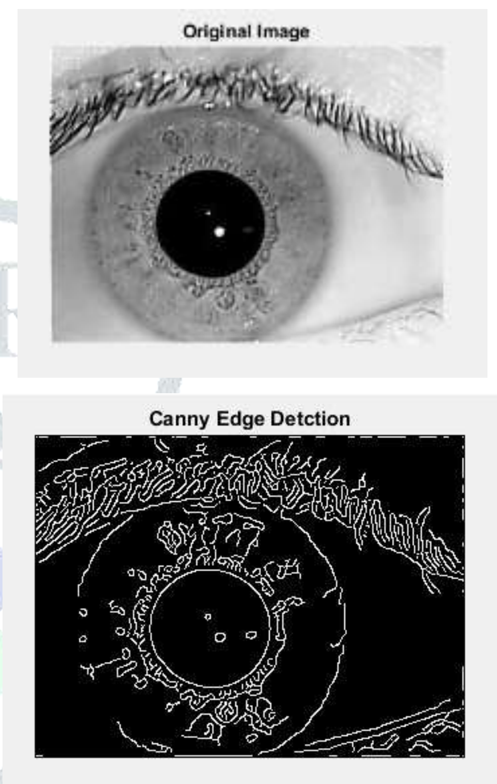


Fig. 3.3 Original Image and Image After Applying Canny Edge Detection Algorithm

3.3.2 Pupil and Iris Detection

The acquired iris image is preprocessed to detect the iris, which is an annular portion between the pupil (inner boundary) and the sclera (outer boundary). The first step in localization is to detect pupil which is the black circular part surrounded by iris tissues. The center of pupil is used to detect the outer radius of iris patterns. The inner pupil boundary is detected after eliminating specular reflections using a combination of thresholding and morphological operations. Then, the outer iris boundary is detected using the modified Circular Hough transform. The important steps involved are:

- ✓ Pupil detection (Inner Circle)
- ✓ Iris Detection (Outer Circle)

Circular Hough Transformation for pupil detection is used. This technique finds the curves that can be parameterized like straight lines, polynomials, circles, etc., in a suitable parameter space.

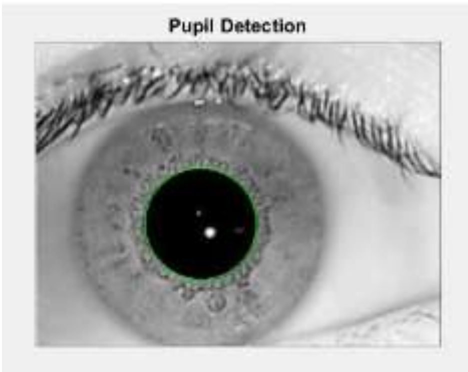


Fig. 3.4 Detection of Inner Pupil Boundary

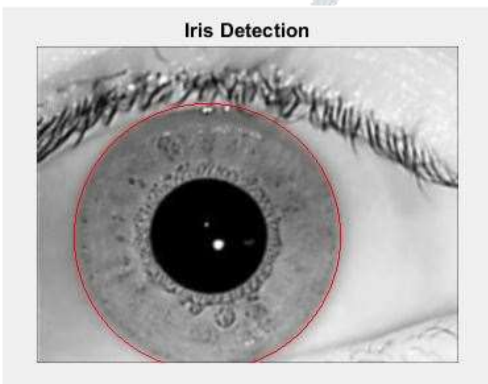


Fig. 3.5 Detection of Outer Pupil Boundary

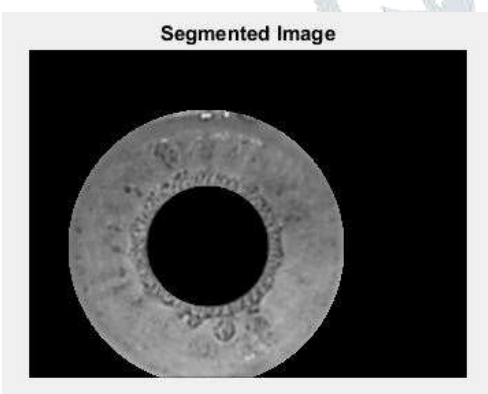


Fig. 3.6 Segmented Image after Subtraction of Inner Boundary from Outer Boundary

3.4 Normalization

Once the iris region is successfully segmented from an eye image, the next stage is to transform the iris region so that it has fixed dimensions in order to allow comparisons. Normalization is a process of transforming the segmented iris region into fixed dimension. The normalization process will produce iris regions, which have the same constant dimensions, so that two photographs of the same iris under different conditions will have characteristic features at the same spatial location.

Taking the computed circle of the iris, we transformed the image such that the circle becomes a square, and we transformed the image from a polar coordinate system to a Cartesian coordinate system, localizing the iris from the rest of the image. Sorting the pixel intensities within the iris images and removing the extreme pixel intensities also allows for the filtering of additional noise caused by skin and eyelashes. This gives us a clean rectangular image of the iris to work with for the purpose of feature extraction and comparison. The polar coordinates are defined in terms of r and $\emptyset$, where r is the distance of the point from the origin and $\emptyset$ is the angle made with the positive x-axis.

$$x = rcos\emptyset \qquad (1)$$

$$y = rsin\emptyset \qquad (2)$$

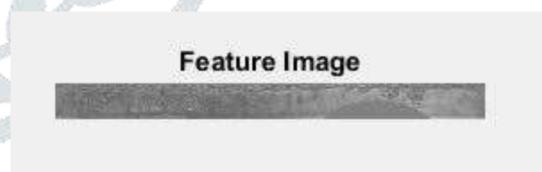


Fig. 3.7 Feature Image After Normalization

3.5 Feature Extraction

In Image processing a very important part is feature which is a piece of information relevant for solving computational task. Feature is described as specific structures in the image such as points, edged or objects. They correspond to local regions in the image. Feature Extraction is used when we need to reduce the number of resources needed for processing without losing important or relevant information. It also reduce the redundant data.

3.5.1 Binarized Statistical Image Feature (BSIF)

This method computes a binary code string for the pixels of a given image. The code value of a pixel is considered as a local descriptor of the image intensity pattern in the pixel's surroundings. Further, histograms of pixels' code values allow to characterize texture properties within image subregions. Thus, descriptor can be used in texture recognition tasks in a similar manner as local binary patterns or quantized local phase values. The value of each element in this binary code string is computed by binarizing the response of a linear filter with a threshold at zero. Each bit is associated with a different filter and the desired length of the bit string determines the number of filters used. The set of filters is learnt from a training set of natural image patches by maximizing the statistical independence of the filter responses.

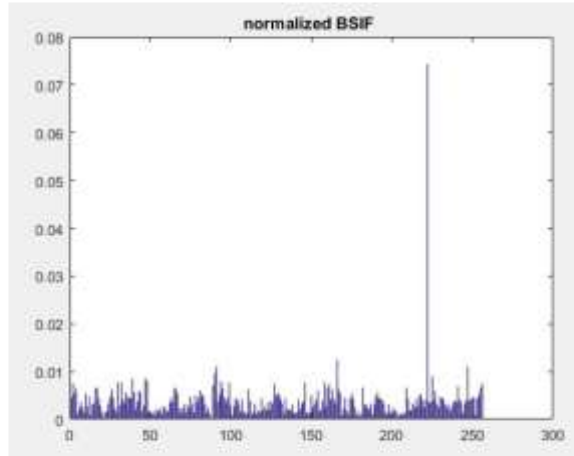
The details of learning the linear filters follow and they are briefly described below. Details. Given an image patch X and a linear filter W_i, the filter response si is obtained by

$$si = \sum_{u,v} W_i(u,v)X(u,v) = w_i^T x \qquad (1)$$

where vector notation is introduced in the latter stage, i.e., vectors w and x contain the pixels of W_i and X. The binarized feature bi is obtained by setting $bi = 1$ if $s > 0$ and $bi = 0$ otherwise.

Algorithm:

(1) Input image
(2) Initialize textured filter(by the size 3*3,6*6,9*9)
(3) Generate a sliding window
(4) Pad the input image
(5) Scale the image and apply textured filter to each image
(6) Combine each scale output so that we will get BSIFDescription
(7) Apply histogram to BSIFDescription
(8) Normalize histogram



Graph 3.1 BSIF Histogram

3.5.2 Weber Local Descriptor(WLD)
Weber's Law

The law states that the change of a stimulus that will be just noticeable is a constant ratio of the original stimulus this means that the ratio of the increment threshold to the background intensity is constant. It can be expressed as

$$\frac{\Delta I}{I} = K$$

where ΔI represent the increment threshold, I represents the initial stimulus intensity and k signifies that the proportion. Based on this idea, WLD is proposed for texture characterization which is composed of two components: Different excitation and orientation. Based on two terms, a joint histogram can be constructed, followed by converting it into one dimensional histogram which is WLD.

Differential Excitation

Differential Excitation is the function of the ratio between two terms one is relative intensity differences and other is intensity of the current pixel. In WLD, differential excitation $\xi(x_c)$ of a current pixel x_c is calculated. The differences between the center point and its neighbors is calculated by using

$$v_s^{00} = \sum_{i=0}^{p-1}(\Delta x) = \sum_{i=0}^{p-1}(x_i - x_c) \qquad (1)$$

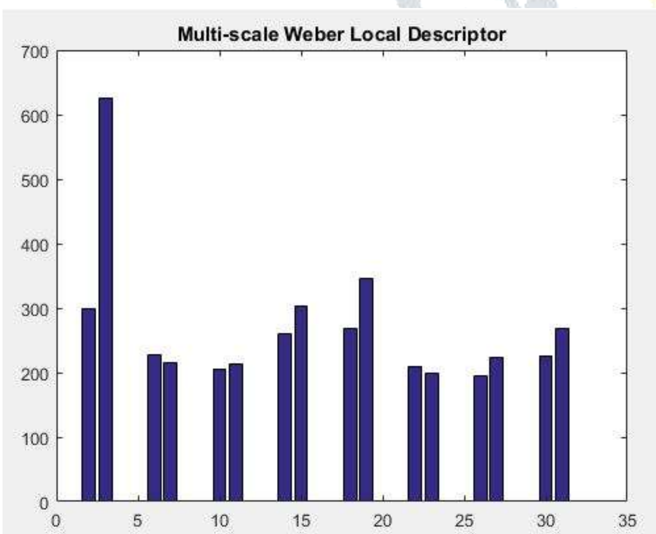
where $x_i (i = 0, 1 \ldots p\text{-}1)$ denotes the ith neighbour of x_c and p is the number of neighbours. Following the hints in Weber's law, by combining the two filters f_{00} and f_{01}, the ratio of the differences to the intensity can be computed.

Histogram of Gradient

By computing the gradient of an image, we can observe that the image is changing rapidly. Gradient of an image has two kind of information, one is magnitude and other is direction of the gradient. Magnitude gives the information of how rapidly the image is changing and direction of the gradient tells us direction image is changing more rapidly. The gradient of the image $f(x,y)$ at location $(x,y)$is defined as

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \tag{2}$$

Algorithm:
1. Compute the differential excitation and gradient of each pixel in cell.
2. Quantize the gradient information into 8 dominant orientations. Map the differential excitation into 256 bins.
3. Compute the histogram of each gradient orientation by accumulating the differential excitation showing the same gradient orientation.
4. Cut the histograms of each gradient orientation into M=6 segmentation obtained from step 3.
5. Assign the Weight to each segmented area as in [6].
6. Concatenate eight segmentations from eight dominant orientations into one histogram. We can get 6 histograms.
7. Concatenate these M=6 histograms into one histogram, which is the final histogram.



Graph 3.2 WLD Histogram

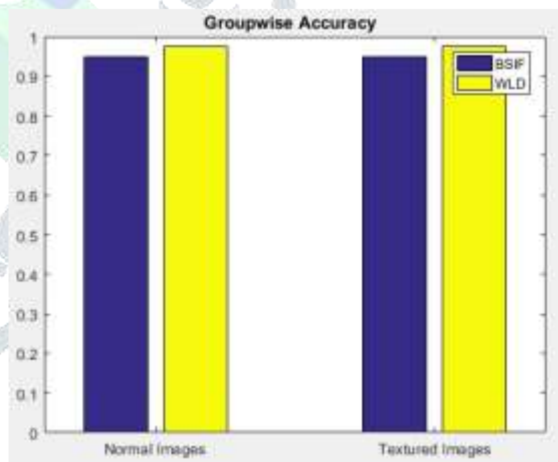
3.6 Model Training
In this system Linear SVM classifier is used to train model on the feature sets. Linear SVM is the fast machine learning algorithm used to solve multiclass classification problems from large datasets. Linear SVM also work with high dimensional data(thousands of features, attributes) in both sparse and dense format.

4. PERFORMANCE ANALYSIS

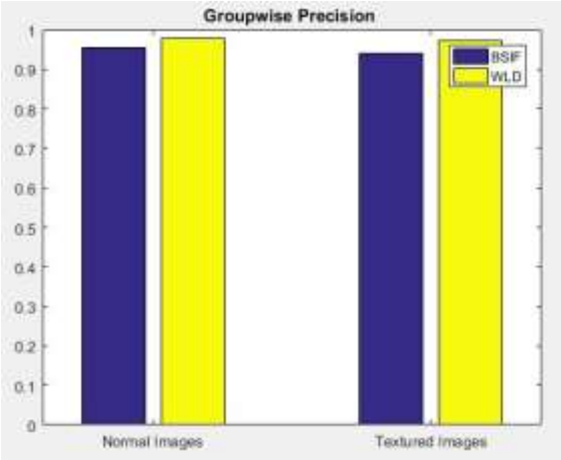
Feature extraction & classification scheme simulations has been carried out in MATLAB environment. For validation images are taken from IIT DELHI Contact Lenses IRIS dataset. IITD IRIS dataset contains 6500 images which are classified as the normal & textured. The proposed Weber Local Descriptor (WLD) provide better accuracy than the BSIF. BSIF algorithm gives 0.94 accuracy & WLD gives better accuracy of 0.97 in IITD IRIS dataset.

Analysis of BSIF and WLD technique results based on different parameters

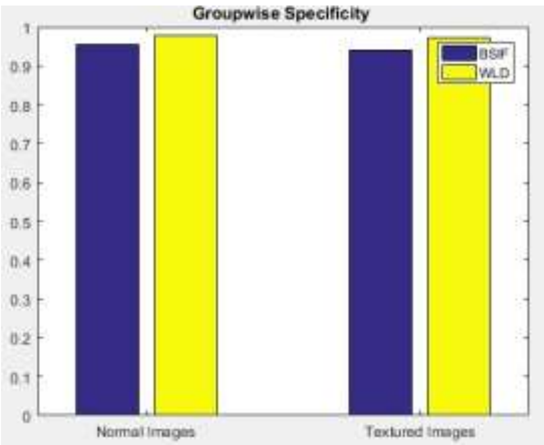
Method	Recall	Precision	Accuracy	Specificity	Fscore
BSIF	0.9482	0.9482	0.9482	0.9482	0.9482
WLD	0.9757	0.9757	0.9757	0.9757	0.9757



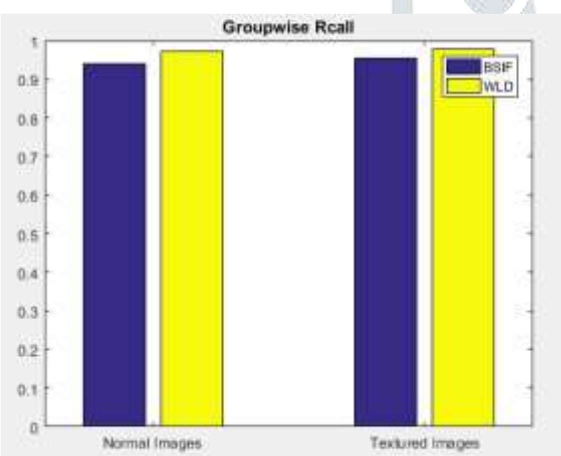
Graph 4.1 Groupwise Accuracy



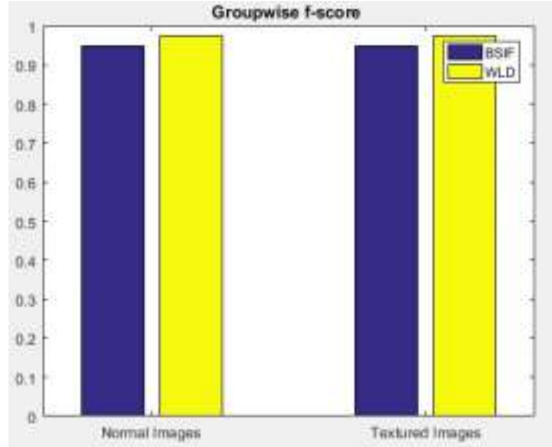
Graph 4.2 Groupwise Precision



Graph 4.3 Groupwise Specificity



Graph 4.4 Groupwise Rcall



Graph 4.5 Groupwise F-score

5. CONCLUSION

The presence of a cosmetic contact lens is an important issue in iris recognition as it disturbs the natural iris patterns. Differentiating between without lens and transparent lens iris images is a challenging problem. There is a need for a better lens classification approach that can delineate different lens classes correctly. This paper analyzes the different techniques of contact lens detection in iris recognition. Increased accuracy of lens detection algorithms can improve the verification accuracy of iris recognition systems. Proposed a novel discriminative descriptor called WLD. It is inspired by Weber's Law, which is a law developed according to the perception of human beings. We organize WLD features to compute a histogram by encoding both differential excitations and orientations at certain locations. This method focuses on different properties of a pixel of iris image and thus, it provides more accurate results than other techniques. Experimental results show that WLD illustrates a favorable performance on dataset compared with the BSIF.

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