Face Recognition with Illumination Invariant Methods

Govindraju, Madhusudan
Elecrical and Computer Engineering
University of Florida

***Abstract*—Face recognition suffers from various challenges which include, head pose, illumination conditions, expressions, facial accessories and aging effects. In this paper we will try to solve the problems posed by difficult illumination conditions. This paper provides a way to normalize the effects due to bad illumination. Object Detection with feature based methods suffers greatly due to bad illumination.In the preprocessing stage, the image/video can be normalized by using retinex algorithm to seperate the illumination and reflectance of the image. The reflectance obtained is free from any illumination defects or it is reduced to minimum. Thus highlighting the features. Thus helping in object detection and recognition. This paper focuses in particular on the face detection & recognition and uses single scale retinex algorithm to normalize the illumination defects.**

***Index Terms*—SSR - Single Scale Retinex, Retnex, HOG-Histogram of Oriented Gradients, SVM - Support Vector Machine.**

I. Introduction

There have been numerous approaches to face recognition in the past decade. All of them have a good accuracy and work excellent for some special condition. There has been numerous attempts to provide solutions to the major challenges of face recognition. The major challenges to face recognition are

1) Head pose. The in frame & out of optical axil head rotation will reduce the amount of information we can recover from the captured image.
2) Illumination. The features can be extracted from the image only when the features are visible for that the image should be captured under proper lighting conditions. Butu that is not possible in all applications. Thus causing a serious drop in accuracy.
3) Facial Expressions. The face is a non rigid object . The face's structure and essential features change when the expression changes. Such as the distance between the two tips of the mouth and the chin location change when the person is laughing.
4) Aging process seriously deform the face features. The cheeks become sagged and the peri-occular region becomes much more darker with age. These might cause problems for those face recognition systems that use that feature for face recignition.

In this paper we will discuss about a method to overcome the illumination problem. Face detection and recognition is one part of the object recognition problem. For a face to be recognized first it has to be detected. The algorithms for the face detector and the classifier depend on features to detect and identify the face. One drawback in this approach is illumination. Bad illumination, tends to hide the major features and hence decrease the chances of detecting the face or recognizing the face. Thus methods to normalize the image with a bad illumination is needed. Some of the most famous existing face recognition methods are not robust to illumination variance. Their performance curve will fall suddenly with bad illumination conditions. Most face detection methods on features based suffer greatly under bad illumination.

In the preprocessing stage we can normalize the image for illumination effects. There are various methods for normalization and they are explained in the survey paper [6] one among them is [2], where the author states that the image is composed of reflectance and illumination components, hence can be separated from each other. Thus this paper will provide proofs to state that illumination will not pose a problem for face recognition.

There are various approaches for object detection, one among them is [3]. It uses cascaded classifiers to detect objects in the image. The faces detected, will then be sent to the feature extractor, the histogram of oriented gradients are the feature descriptors. These features are then sent to the classifiers for recognition. The classifier used is support vector machines. Fro testing and training purposes Yale B face database will be used. They include various illumination conditions and also account for various face poses.

II. Related Work

There are various methods for face recognition. They can be classified as Feature based if they use local features only for face classification some common examples are geometry correlation technique. If they use the entire face information we classify that method as Holistic method. Holistic methods are very famous, some examples are PCA and LDA methods. There are a other methods that use both the local and holistic features they are called the hybrid methods. An example of that kind is the Elastic Bunch Graph Matching based face recognition. None of the current face recognition systems use pure geometry or pure local information methods. They use some version hybrid method to increase the accuracy.

These surveys [7][8][9] gives us a full summary of the evolution of the face recognition systems available since the early 20th century. Some of the most famous methods approached are the eigen faces method proposed by Turk M A & Pentland A P . Followed by the template matching method proposed by the Brunelli and Poggio. A few more methods with fisher faces , elastic graph matching and Bayesian probablity estimates for face recognition have been developed after significant contributions to the recognition tehnology with statistical methods. The different methods for face recognition can be classifed superficially based on feature extraction as recognition baed on geometric features, recognition with template matching. Recognition based on Hidden Markov Models [10][11], And then there are methods based on Neural Network used with PCA . 3-D Model based face recognition is another approach where we build a 3D model for the captured image and then perform recognition techniques. The survey [9] classified face recognition into three major methods, the eigen faces approach, fisher approach and local binary pattern approach. [9] also compared the algorithms and said that "Compared to Eigenfaces and Fisherfaces methods, we found that LBPH is significantly more robust under illumination and pose variations. "

During the years there has been various approaches to correct illumination in face recognition . Different methods to correct illumination variance using wavelet methods have been described in [12] where they use various wavelet transforms such ash Discrete Wavelet Transform to provide a normalization technique to remove the effects due to illumination. In [14] the author talks about various methods that use local skin texture to recognize the faces. In [13] the author compares techniques such as Local Binary Pattern and Singular Value decomposition techniques with Single Quotient Image and Histogram based techniques. In [6] the author gives various retinex algotithms based on retinex theory to remove the effects of illumination. We will be using the single scale retinex algotithm mentioned in this theory to remove the secularities in the image due to illumination.

III. Data Set

For testing and training purpose, the yale-B face recognition data set will be used. This data set includes challenging data with various illumination effects, which would be perfect for testing and training our system. A subset of fifty images have been removed from each class and has been separated into 38 training images and 12 testing images. They include the various illumination defects. An example of images taken for testing and training has been shown in the images 9 & 10 . So here we use a training to testing ratio of 3:1 for every class. While choosing the subset of images from the dataset, we choose the images with the same pose and illumination condition. This will enable us to compare the recognition and detection rate between the classes.

IV. Proposed Method

Various steps involved in the proposed technique has been described in detail in this section. The flow chart in fig 1 clearly explains the flow diagram of the proposed method.

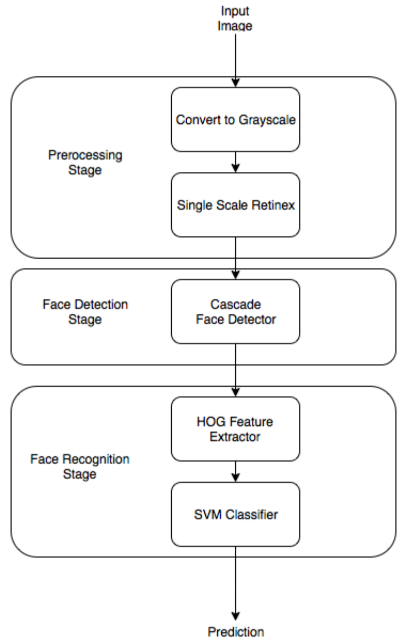


Fig. 1: Flow Chart of the proposed system

A. Preprocessing

First the image is preprocessed to remove the illumination defects using algorithms based on the retinex theory [1]. The author of [1] explained that the human eye can correctly detect the color of the image even in difficult illumination conditions by perceiving the reflectance of the image and thus neglecting the illumination effects, and gave a mathematical model for the image,

$$I(x, y) = R(x, y)L(x, y)$$

where, $I(x, y)$ is the image $R(x, y)$ is the reflectance and $L(x, y)$ is the illumination at each position (x, y).[1]

One of the algorithms developed on this retinex theory in the single scale retinex algorithm[2]. This algorithm explains that the reflectance and the illumination parts of the image can be isolated by taking a log function of the image. By using a gaussian soothing kernel we will be able to successfully separate the reflectance and illumination from the input image. We can then use the reflectance part of the output and omit the illumination part for further processing. The normalized image after applying this algorithm can be seen in figure 2. We use Illumination Invariant Toolbox from [5] for this approach.

B. Face Detection

The pre processed images are then given to cascaded object detector to detect faces in the image. The cascaded object detector uses a lot of simpler classifiers in cascade where each classifier is trained to give a good detection rate. Thus using it in cascade will enable us to achieve high detection rates. In [3] the author explains that the detector will be able to process 15 frames per second and also has a 90% plus detection rate. In this method we will implement this cascade detector using computer vision and object detection tool box in MATLAB.

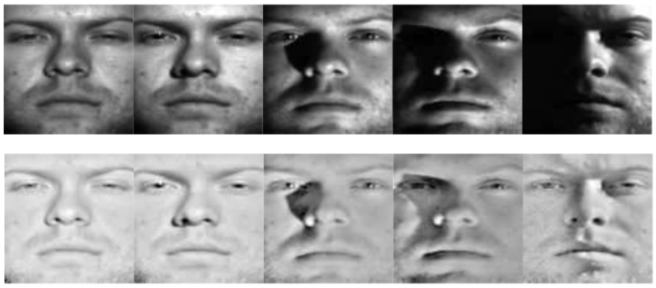


Fig. 2: Illumination Normalization after applying SSR ; source:[2]

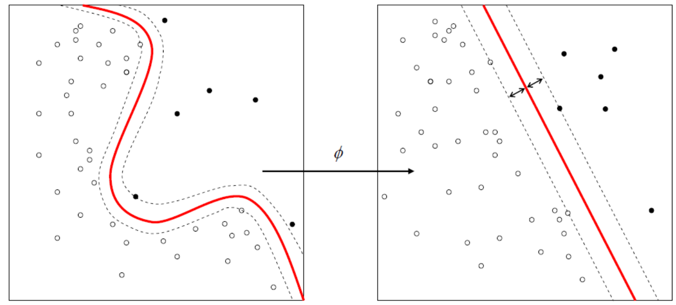


Fig. 3: Basic Linear SVM ; source:wikipedia

C. Face Recognition

Since the image is already pre processed and normalized , this face recognition step wouldn't require any more preprocessing stage before the feature extractor.

1) Feature Extraction: The detected faces are then sent to the feature extractor to extract the required features. The feature descriptors used here are the histogram of oriented gradients. The input image is gamma corrected or converted to grayscale. As this step is already finished in the pre processing stage we don't need this step. Second step is to calculate the gradient magnitude along the x and y directions and gradient orientations. Third step, calculate the histogram for the orientations for a small subset of the image called the cell. We are using a cell size of 8x8 pixels. Every pixel orientation in the cell will cast a weighted vote for a bin in the histogram. In this implementation we are using a bin size of 20. And the values range from $0°$ to $180°$. So a total of 9 bins. Every orientation value will caste a vote to its respective bin and a partial vote to the nearest neighbor bin. The weight that is given to the vote here is the Gradient magnitude. So every cell will have 9 bins. And there will be 128 cells in an image of size 124x68 pixels. Fourth step, Normalize the bins. For this step we use overlapping bin normalization technique. We use a set of 2x2 cells and perform bin normalization. The overlapping bin help in keeping smoothing the normalization over the entire image leaving no artifacts but also retains the local illumination and contrast differences. The normalized histograms are arranged in a one dimensional vector and concatenated with the normalized histogram obtained from the other blocks in order. This final vector is the feature vector containing the histogram of oriented gradients.

This feature vector extracted with the above mentioned method is passed on to the classifier for recognition purposes.

D. Classifier

The feature descriptors are given to the Support Vector Machine(SVM). A binary linear support vector machine will define a space with a hyperplane separating the two categories and the hyper plane will be defined by the support vectors. This hyper plane marks the maximum distance between the support vectors such than every test point will lie on either side of the hyper plane with very small or no overlap. Thus giving a accurate classification. This SVM needs to be trained with normalized data. The more the training data the better will be the classification results. Our implementation has more than one class so a normal SVM cannot be used since it is a discrete classifier. The binary linear SVM will just predict if the test data in the class or not in the class, thus we have to train multiple classifiers for this purpose. We can use N number of SVM machines for N number of classes and must run N comparisons to predict the class. This is called a one against all classification. The second method is to use a pairwise classification method where we compare every class with every other class to get N-1 comparisons to get the result but the drawback being we have to train N(N-1)/2 classifiers. Thus we will restrict ourself to the on against all classification. This is implemented by using the fitcecoc method in MATLAB.

V. Evaluation

A sample of the data set taken for training and testing is available in the figure 10 & 9. We chose training images with different poses and no occlusion due to illumination. The testing set has images with almost 50-60% occlusion due to bad illumination. The following evaluation methods were tested and their performances are available in graphs.

A. Confusion Matrix

The figure 4 shows the confusion matrix. There were a total of 12 images in every class and there are a total of 15 classes in the dataset. The confusion matrix was created by checking every image from one class with every other class. As we can see in the confusion matrix for the system with the retinex Class 3 had the best detection rate and class 13 had the worst detection rate and class 15,11 and 5 have very bad recognition rates of only 4 images out of 12. Thus we are able to identify the detection rates as well as the recognition rates for each class. The confusion matrix for the system without the retinex algorithm shows that the system's detection rate and accuracy has improved after applying the retinex algorithm.

B. Genuine and Imposter Distribution

The genuine vs imposter distribution can be observed in the fig 5 . Comparing the graphs of the system before applying retinex and the system after applying retinex the area overlapped by the the imposter distribution and genuine distribution is more for the system without the retinex algorithm.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	7	0	1	0	0	1	0	0	0	0	0	0	0	0	0
2	0	7	0	0	0	0	0	1	0	0	0	0	0	0	0
3	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	1	5	0	1	0	0	0	0	0	0	0	0	0
5	1	0	1	0	4	0	1	0	0	0	0	0	0	0	1
6	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0
7	0	0	1	0	0	1	6	0	0	0	0	0	0	0	0
8	0	0	1	0	0	0	0	9	0	0	0	0	0	0	0
9	0	0	1	0	0	0	0	1	6	0	0	0	0	0	0
10	0	0	1	0	0	1	0	0	0	4	0	1	0	0	1
11	0	0	1	0	0	0	0	0	0	0	1	1	0	1	0
12	0	0	1	0	0	0	1	0	0	0	0	8	0	0	0
13	0	0	1	0	0	0	1	0	0	0	0	0	5	0	0
14	0	0	1	0	0	0	0	1	0	0	0	1	0	6	0
15	0	0	1	0	0	0	0	1	0	0	0	0	0	0	6

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	10	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	7	0	0	0	0	0	1	0	0	0	0	0	0	0
3	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	4	1	0	0	0	1	0	0	0	1	1
6	0	0	0	1	0	7	1	0	0	0	0	0	0	0	0
7	0	0	0	0	0	2	7	0	0	0	0	0	0	0	0
8	0	0	1	0	0	1	0	9	0	0	0	0	0	0	1
9	0	0	0	0	0	0	0	0	9	0	0	0	0	1	0
10	0	0	0	1	0	0	0	0	0	7	0	0	0	1	0
11	0	0	1	1	0	0	0	0	0	0	4	0	0	1	0
12	0	0	0	0	0	0	1	1	0	0	0	7	0	1	0
13	0	0	0	1	0	0	0	1	0	0	0	0	5	1	0
14	0	0	1	0	0	0	0	0	0	0	0	0	0	8	0
15	0	0	1	0	0	0	1	2	0	0	0	0	0	1	4

Fig. 4: Confusion Matrix
The first matrix is for the system without the retinex algorithm and the second matrix is for the system with the retinex algorithm.

Which means that the system with the retinex algorithm works better compared to the system without the retinex algorithm.

C. FMR vs FNMR Graph

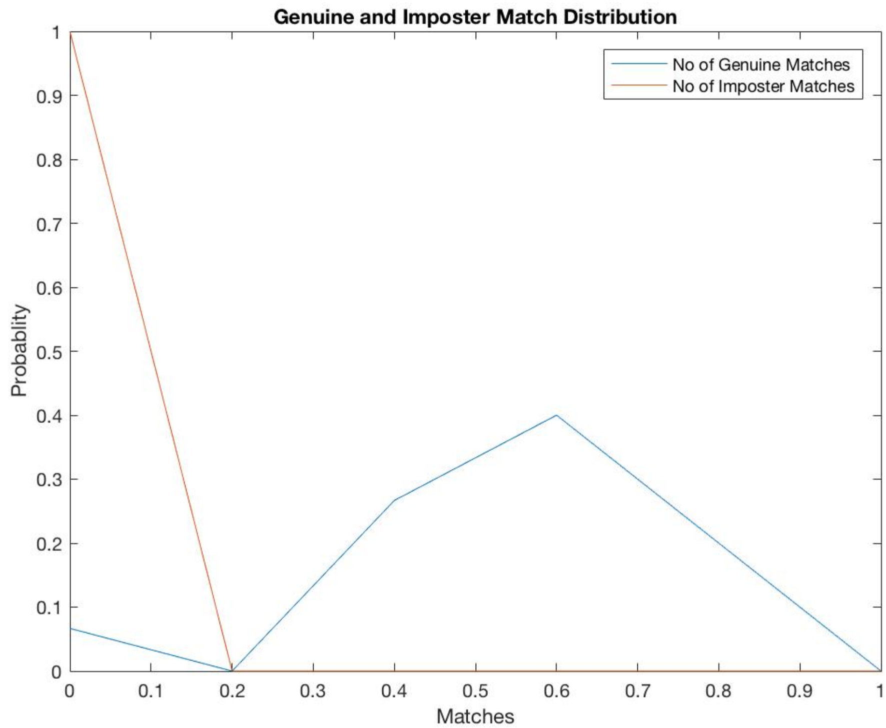
From the FMR vs FNMR graph in image 6 we can clearly see that for increase in threshold the false match rate does not change much, but the False Non Match rate decreases with increase in threshold. From this graph the point of intersection of the two plot gives us the Equal Error Rate Value of approximately 0.1. And the best threshold to run the system is at 4.4. This means the minimum cost to run the system is obtained at a threshold of 4.4(similarity score measure - the larger the better). Comparing it with the system without the retinex algorithm the FMR remains the same but the the threshold drop by a marginal value. With the threshold being a similarity measure the system with the larger threshold better is the performance.

D. ROC Curve

Counting the number of imposter scores lesser than the threshold and dividing that by the number of imposter comparisons will give the False Match Rate(FMR). Counting the number of Genuine matches lesser than the threshold divided by the number of genuine comparisons will give the Genuine match rate(GMR). Plotting the FMR against the GMR will give the Receiver Operator Characteristics(ROC) curve. From this curve we can see that the system is not the best system available. Its area under the curve is directly proportional to the accuracy of the system. From this curve we can see that the area under the curve is only around 60-70% hence we can deduce that the accuracy is low. The accuracy is even more lower when comparing it to the ROC curve of the system without the retinex algoithm. Retinex algorithm definitely makes the system better but not the best.

E. Cumulative Match Characterisitics Curve

The Cumulative Characteristics curve is obtained by calculating how many comparisons result in a score lesser than the genuine score. This plot is available in the figure 8 We take a probability distribution for this count and plot it against the ranks to get the CMC curve. The CMC curve gives us how much percent of time the system gets a rank 1 recognition rate and rank2 recognition rate and so on. From this curve we can see that the system has a Rank 1 identification rate at approximately 60%. From the CMC curve for the system without the retinex algorithm , we can deduce that rank 1 identification rate is much lower at 50%. Thus again proving that applying retinex algorithm to the system helps in increasing the performance.



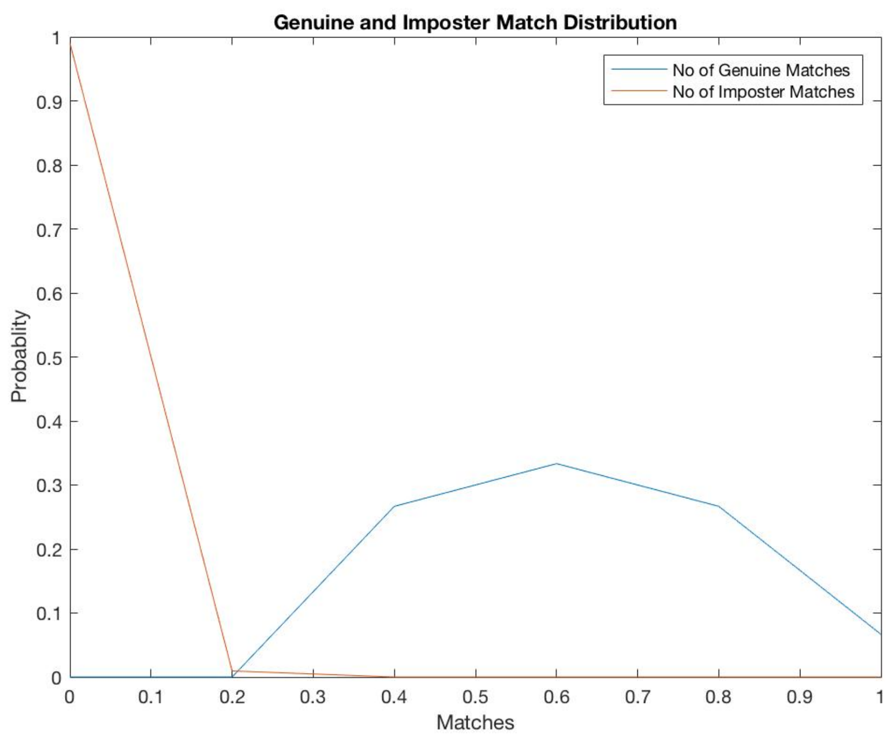


Fig. 5: Genuine Vs Imposter Match Score for the system
The first Graph is for the system without the retinex and the second one is for the system with the retinex

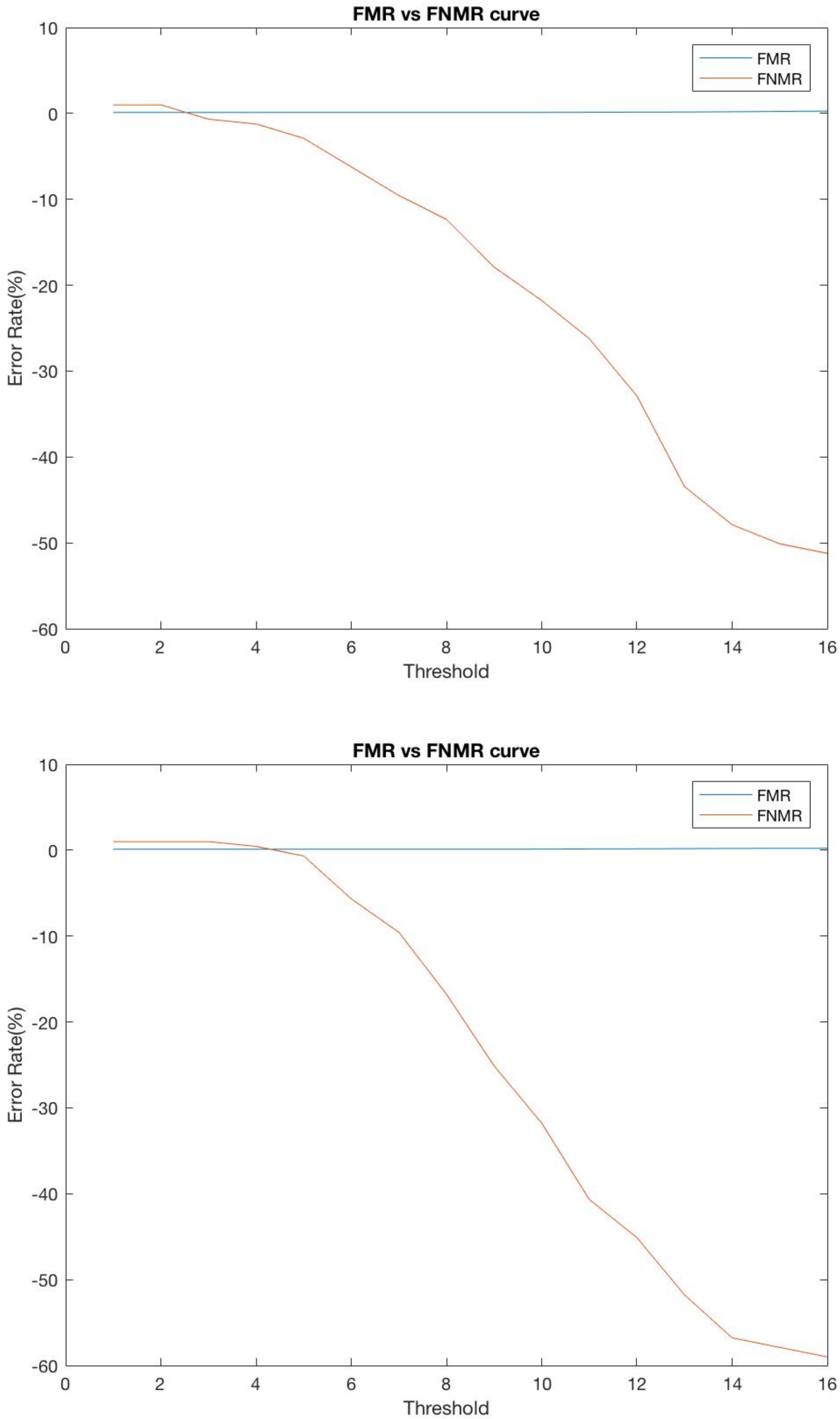


Fig. 6: False Match Rate vs False Non Match Rate
The first Graph is for the system without the retinex and the second one is for the system with the retinex

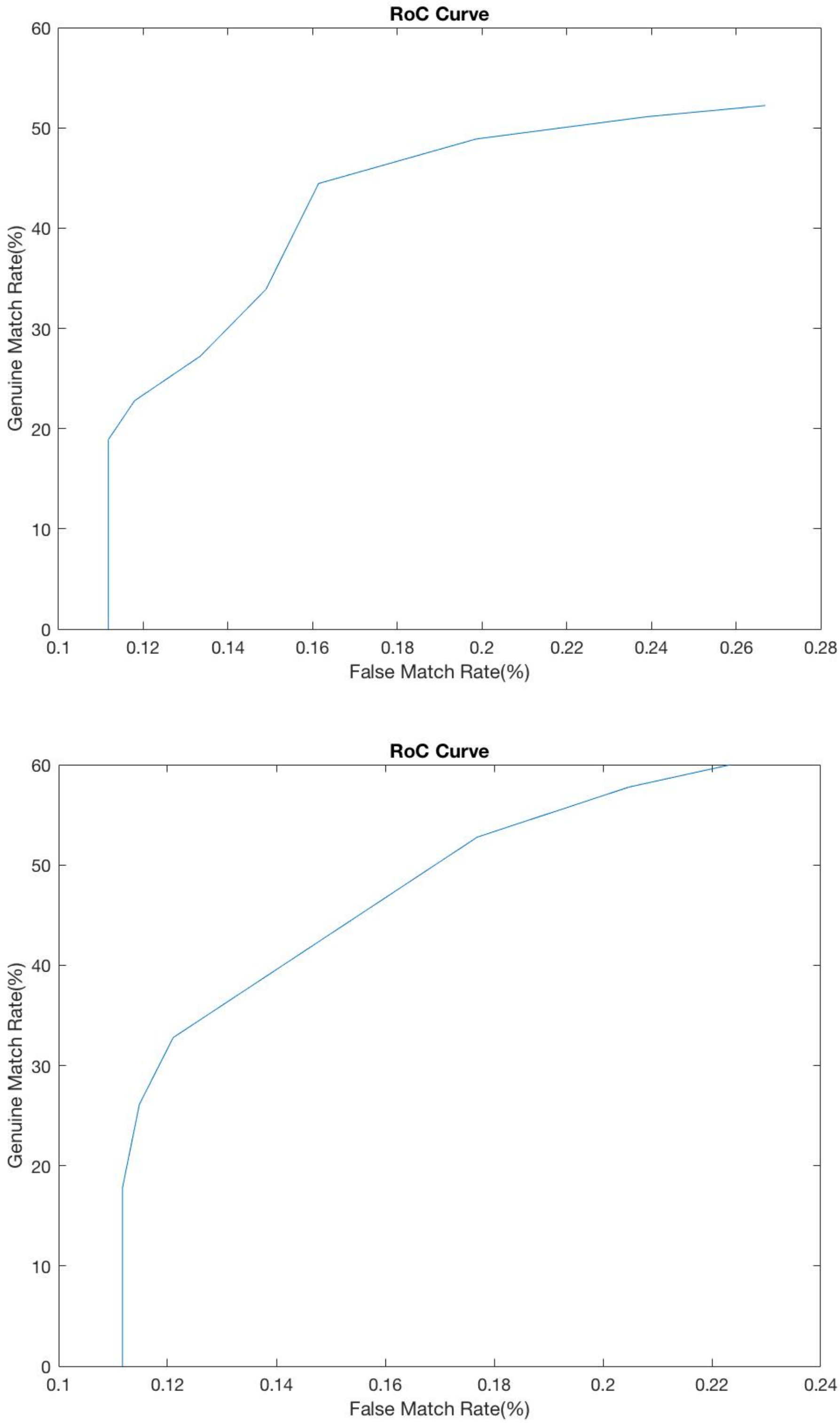
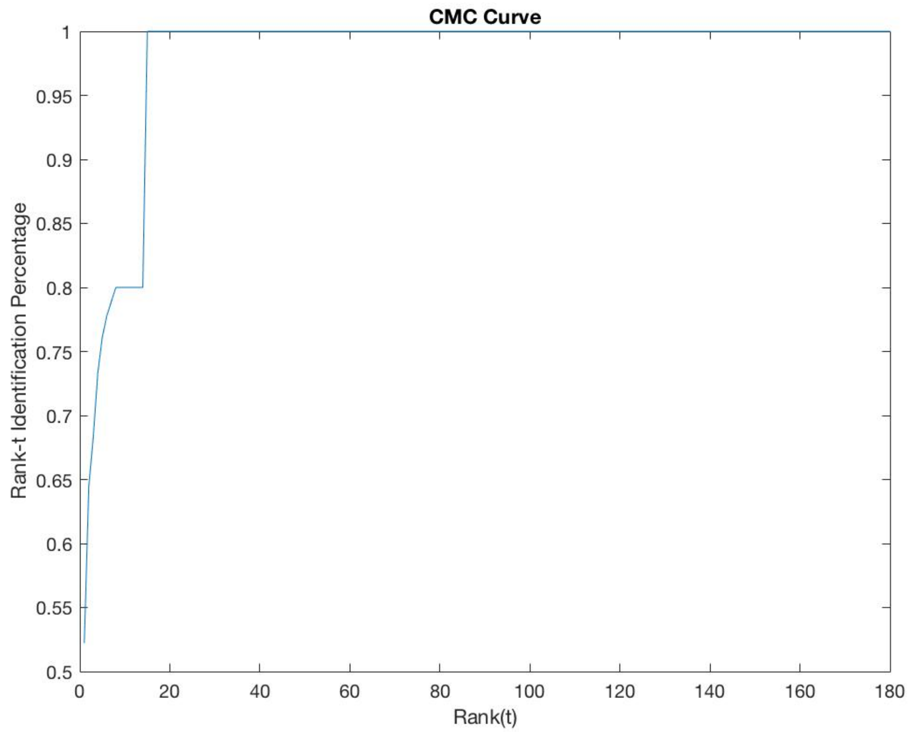


Fig. 7: Receiver Operator Characteristic Curve
The first Graph is for the system without the retinex and the second one is for the system with the retinex



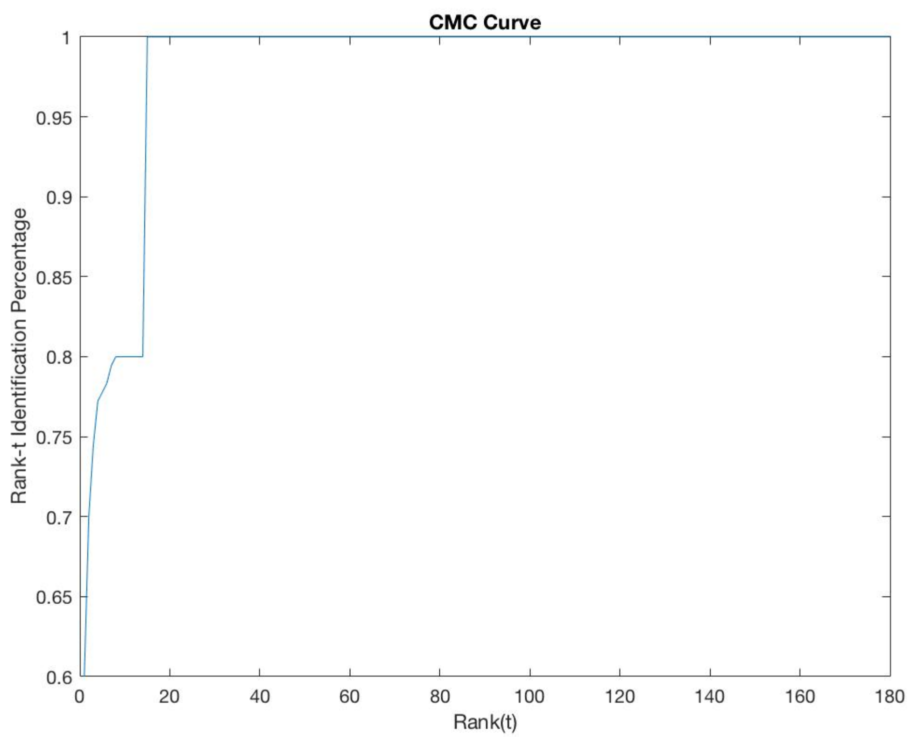


Fig. 8: Cumulative Match Characteristics Curve
The first Graph is for the system without the retinex and the second one is for the system with the retinex

F. D Prime Value

The dprime value of the system measures the difference between the means of two distributions genuine and imposter in standard deviation units. The greater the value the better it is. The dprime value for the system is 3.1696. For the system without the Single Scale Retinex the dprime value is 2.7727. This clearly proves that the system with the retinex algorithm performs better, but not good as expected.

VI. Conclusion

The implementation of the system with the retinex algorithm increases the overall performance of the system but our implementation suffers greatly due to the feature vector used. Instead of using Histogram of Oriented Gradients if we had used other features such as Local Binary Pattern we would have achieved much better accuracy. (Using Local Binary Pattern for feature increases recognition rate, this can be seen in the extra credit implementation). Some systems work with excellent accuracy in some application but fail to provide even marginal accuracy in other application. From the FMR vs FNMR graph we see that the implementations's equal error rate is less, but the Genuine vs Imposter distribution and the confusion matrix easily proves that the accuracy of the system is also very low which is not good. The CMC also proves that the rank1 recognition rate is just 60% this is not good for a recognition system to have a rank1 recognition rate so low but definitely performs than the system without the retinex algorithm. Thus it is important to construct the system based on the application it is required for. Hence domain knowledge is an important factor during the development of the system. Finally we can conclude by saying that the system with the retinex algorithm performs better than the system without it, but the cons of this implementation is the feature vector.

References

[1] Edwin H. Land and John J. McCann, "Lightness and Retinex Theory," J. Opt. Soc. Am. 61, 1-11 (1971)

[2] V. Struc and N Pavesic, "Photometric normalization techniques for illumination invariance?, In: Y.J. Zhang (Ed.), Advances in Face Image Analysis: Techniques and Technologies. IGI Global, 2011, pp. 279 to 300.

[3] Viola, Paul, and Michael Jones. "Fast and robust classification using asymmetric adaboost and a detector cascade." Proc. of NIPS01 (2001).

[4] N. Dalal and B. Triggs, *Histograms of oriented gradients for human detection*, Computer Vision and Pattern Recognition, 2005. CVPR 2005. IEEE Computer Society Conference on, San Diego, CA, USA, 2005, pp. 886-893 vol. 1.

[5] http://www.mathworks.com/matlabcentral/fileexchange/26523-the-inface-toolbox-v2-0-for-illumination-invariant-face-recognition

[6] X. Zou, J. Kittler and K. Messer, "Illumination Invariant Face Recognition: A Survey," Biometrics: Theory, Applications, and Systems, 2007. BTAS 2007. First IEEE International Conference on, Crystal City, VA, 2007, pp. 1-8

[7] R. Chellappa, C. L. Wilson and S. Sirohey, "Human and machine recognition of faces: a survey," in Proceedings of the IEEE, vol. 83, no. 5, pp. 705-741, May 1995. doi: 10.1109/5.381842

[8] X. Zhang, D. Ren, L. Yan, Z. Jing and J. Zhang, "A survey of approaches to feature extraction in face recognition," Computer Science and Network Technology (ICCSNT), 2012 2nd International Conference on, Changchun, 2012, pp. 1534-1539.

[9] A. zdil and M. M. zbilen, "A survey on comparison of face recognition algorithms," Application of Information and Communication Technologies (AICT), 2014 IEEE 8th International Conference on, Astana, 2014, pp. 1-3.

[10] Samaria F, Young S. HMM-Based Ar chitecture for Face Identification. Image and Vision Computing, 1994, 12(8): 573-543.

[11] Nefian A, Hayes M. Hidden Markov models for face recognition [A]. IEEE International Conference on Acoustics, Speech and Signals Processing [C]. Seattle, Washington, 1998, 5:2721-2724

[12] M. P. Beham, S. M. M. Roomi and J. Alageshan, "Wavelet based illuminant invariant face recognition ? A review," Computational Intelligence and Computing Research (ICCIC), 2013 IEEE International Conference on, Enathi, 2013, pp. 1-6.

[13] A. G. Pai et al., "Recognizing human faces under varying degree of Illumination: A comprehensive survey," Electronics and Communication Systems (ICECS), 2015 2nd International Conference on, Coimbatore, 2015, pp. 577-582.

[14] J. Rajeshwari, K. Karibasappa and M. T. GopalKrishna, "Survey on skin based face detection on different illumination, poses and occlusion," Contemporary Computing and Informatics (IC3I), 2014 International Conference on, Mysore, 2014, pp. 728-733.

Fig. 9: All the testing Images of one class

Fig. 10: All the training Images of one class