# OPTIMIZED GABOR FEATURES FOR FACIAL RECOGNITION SYSTEM

Taye Oladele ARO[1], Oluwakemi Christiana ABIKOYE[2] and Amos Orenyi BAJEH[3]

[1,2,3]University of Ilorin, Department of Computer Science, Ilorin, Nigeria

[1]taiwo774@gmail.com, [2]kemi_adeoye@yahoo.com, [3]bajeh_amos@yahoo.com

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*Abstract: Feature extraction is a significant process in any pattern recognition, computer vision and image processing. Among several feature extraction techniques like Fisher Linear Discriminant Analysis (FLDA), Principal Component Analysis (PCA), Elastic Bunch Graph Matching (EBGM) and Local Binary Pattern (LBP), Gabor-filters possess the ability of obtaining multi-orientation features from a facial image at several scales with the derived information being of local nature. Its optimal functionality in facial recognition is linked to its biological importance (similarity to the receptive fields of simple cells in primary visual cortex) and computational properties (optimal for calculating local spatial frequencies). Despite all the outstanding properties of Gabor-filters, this technique suffers high feature dimensionality. This paper addresses the problem of high feature dimensionality by application of Ant Colony Optimization meta-heuristic algorithm for feature selection of relevant and optimal features. Two face image databases; Olivetti Research Laboratory (ORL) Database and Locally Acquired Face Image Database (LAFI) are used to evaluate the performance of the proposed facial recognition model. The final experimental results showed better performance.*

## 1. INTRODUCTION

In facial recognition system, one of the major problems is how to describe and extract accurately features for face image representation [1]. An effective face recognition system is determined by a quality of feature representation method, which also involves the extraction of discriminant information from a face image [2]. The most essential and unique features are extracted from localized image during feature extraction phase [3]. The feature extraction represents the most important phase of face recognition due to the dependency of face recognition accuracy on the level of features extracted from face image region [4].

Gabor-filter represents a band-pass linear filter used for edge detection in image processing and computer vision [5] [6]. The Gabor- filters are directly similar to Gabor-wavelets since each component may be produced for a number of dilations and rotations [7]. Gabor filter captures salient visual properties such as orientation selectivity, spatial localization and spatial frequency [8]. These filters have been applied successfully and broadly in several areas such as face detection, handwritten numeral recognition, texture segmentation, edge and fingerprint recognition [9] [10].

Although several algorithms like Principal Component Analysis (PCA), Independent Component Analysis (ICA) and Fisher's Linear Discriminant Analysis (LDA) have been extensively identified to be successful and commonly used techniques for feature extraction in face recognition [6].

Among the Feature extraction techniques, Gabor-filter has been identified to be a robust technique at local and discriminate feature extraction of maximum information from image regions due to their level of similarity in characteristics to those of visual system of a human [11].

Gabor-filter has gained substantial attention in computer vision, object recognition, image processing and pattern recognition [12]. These filters show better distinct characteristics, which make this extraction method invariant to changes in rotations, translations, scales and illuminations [13].

The optimal functionality ability of Gabor-filter in face recognition is traceable to its biological importance (comparable to the receptive fields of simple cells in primary visual cortex) and computational properties (optimal for calculating local spatial frequencies)[14] [15]. Gabor-filter has achieved great success and considered as one of the best technique for face representation [16]. This technique ranks high and performs optimally in removing useless and redundant feature in pattern recognition [17]. In feature extraction method, the Gabor-filter approach has been showed to be efficient for texture segmentation and discrimination in image processing [18] [19].

This paper focuses only on the reduction of high dimensionality problem which results into less memory space consumption, reduced computational time and misclassification of 2-dimensional Gabor-filters based facial recognition system. Ant Colony Optimization Algorithm was applied on Gabor feature vectors for selection of the most relevant and optimal features, which thus adequately decrease Gabor features and also obtain optimal features without losing much information in a reasonable time.

## 2. RELATED WORK

The Gabor-wavelets was originally used in face recognition by the application of Dynamic Link Architecture (DLA) framework [20]. The DLA gives a flexible template comparison between Gabor wavelet representations of different face images. [21] introduced an expansion of DLA using a Gabor wavelet-based Elastic Bunch Graph Matching (EBGM) Algorithm to label and recognize human faces. The system was evaluated using FERET database, final experimental result showed better recognition rate for frontal face images. The following studies have been carried out by researchers using Gabor-filters as feature extraction technique with different dimensionality reduction methods:

[22] developed an algorithm based on the Gabor wavelet transformation and non-negative matrix factorization (G-NMF). The process included image pre-processing, feature extraction and classification. At first phase, the face region containing emotional information was obtained and normalized. Thereafter, expressional features were extracted by Gabor wavelet transformation and the high-dimensional data was reduced by non-negative matrix factorization (NMF). Finally, two-layer classifier (TLC) was applied for expression recognition. The system was evaluated using JAFFE facial expressions database. The results showed that the method proposed has a better performance.

[6] proposed a face recognition by applying Gabor-filter for feature extraction with Anisotropic Diffusion as a pre-processing technique to enhance the face recognition performance. Gabor-filter was employed to obtain the features of face image aligned at specific angles. A binary particle swarm optimization based feature selection algorithm was used to find the feature space for optimal feature subset. The model was evaluated on four benchmark facial image datasets; ORL, Color FERET, Cropped Yale-B and FEI datasets. The experimental results outperformed existing methods in the presence of pose, illumination and expression variation.

A comparative study on Gabor wavelet features for face recognition with PCA and KPCA [23]. Principal Component Analysis (PCA) and Kernel Principal Component Analysis (KPCA) were applied after the feature extraction phase to decrease dimensionality of filtered face images and comparison between the two methods showed the performance of the recognition models. The model was evaluated using the publicly available ORL database. Experimental result reviewed that GABOR-PCA outperformed the GABOR-KPCA method for facial recognition.

[24] conducted a face recognition system using Gabor features and HIK Toolkit. Facial image features are extracted using Gabor filters. The dimensionality of those features was reduced using the linear discriminant analysis (LDA) method to keep only the most relevant

information. The system injected the resulting feature vectors to the Hidden Markov Model Toolkit (HIKT). Experimental results on YALE and ORL database showed the efficiency of the proposed system.

[19] developed a face recognition system using Gabor wavelets, Principal Component Analysis (PCA) and Support Vector Machine (SVM). The model combined magnitude and phase of Gabor filter. The eigenvectors of the face images was extracted using PCA. The recognition of face images was achieved using SVM. The performance of the system was validated by application of public and largely used datasets; FRGCV2 and ORL. Results showed that the combination of the magnitude with the phase of Gabor features can achieve better results.

[25] extracted facial features based on Gabor-filters as these filters present desirable characteristics of spatial locality and orientation selectivity. The reduction of large feature dimensions into feature subspace was achieved by Sparse Random projection (RP) technique. Back Propagation Neural Network (BPNN) was applied on the feature vectors for classification. The model was evaluated using AR database with a collection of twenty people from database. Each person represented by twenty samples, ten used for training and ten for testing. The recognition rate of the model was high with better classification when feature vectors have low dimensions.

## 3. METHODOLOLGY

This study employed two face image datasets; Olivetti Research Laboratory (ORL) database and locally acquired image database (Locally Acquired Images of Students from University of Ilorin). 300 face images were used each for the two databases. All face images were taken against a dark homogenous background with the subjects (images) in uprights and frontal positions. The preprocessing / normalization technique was performed on each facial image of the two datasets by cropping, resizing of facial image and the contrast adjustment of illumination was achieved using Adaptive Histogram Equalization. Gabor-filters with 5 scales and 8 orientations were used to obtain facial features. The Ant Colony Optimization Algorithm was applied as a feature selection technique to select optimal features from high Gabor features as shown Figure 1.

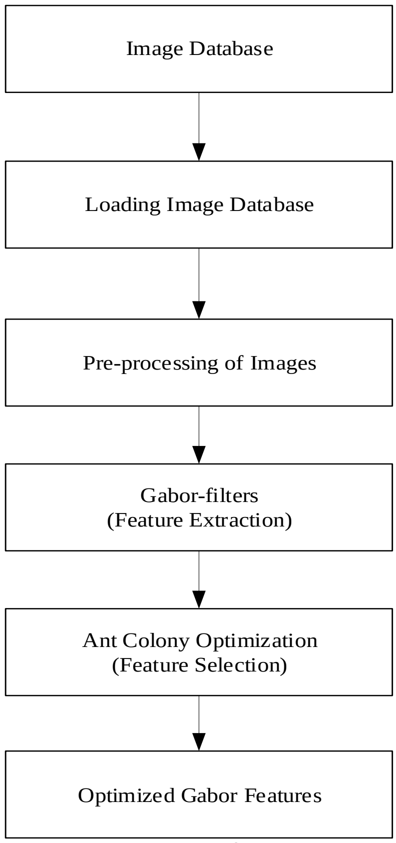



*Fig. 1: Block Diagram of Optimized Gabor Features System*

### 3.1. Acquisition of Face Images

The evaluation of optimal Gabor features for face recognition system is necessary and should be carried out with image database. In the proposed recognition system, certain provision has been made available for several standard online face datasets, general features of these commonly available datasets include face image captured in a well-controlled environment and image tailoring towards a specific requirement of an algorithm. On the other hand, the performance of face recognition system is affected when datasets used to benchmark the algorithms changes due to differences in facial features from race to race. These conditions result to the need for a new database. This study acquired face images from Olivetti Research laboratory (ORL) as shown in Figure 2 and locally acquired black faces were captured from students of the University of Ilorin, Ilorin, Nigeria as shown in Figure 3.

*Fig. 2: Sample of ORL Image Database*

*Fig. 3: Sample of LAFI Image Database*

### 3.2. Image Pre-processing Stage

The images in two face image datasets were pre-processed for image normalization. The preprocessing phase involves the improvement with deference to the quality of the image, but not to head position (tilt) or emotion. Locally acquired face images were properly pre-processed since they were not captured under a controlled condition compared to what is obtainable in ORL database. The pre-process methods involve geometrical normalization, gray-scale conversion and illumination normalization.

### 3.3. Facial Features Extraction Using Gabor-filters

The Gabor-filters was applied for extraction of features. Gabor filters parameters were set as follows: 8 orientations ( $\mu$ = 0,………7) and 5 spatial frequencies (v = 0,…….. 4). Then face image of size 75 x 75, 100 x100, 125 x 125 and 150 x 150 image pixel from the two datasets (ORL and LAFI Database) were convoluted separately by applying designed Gabor-filters on each face image.

The convolution result was further decomposed into real and imaginary part. For this two parts, magnitude of filter responses calculated and then concatenate to produce Gabor features in this study as illustrated in Figure 4.

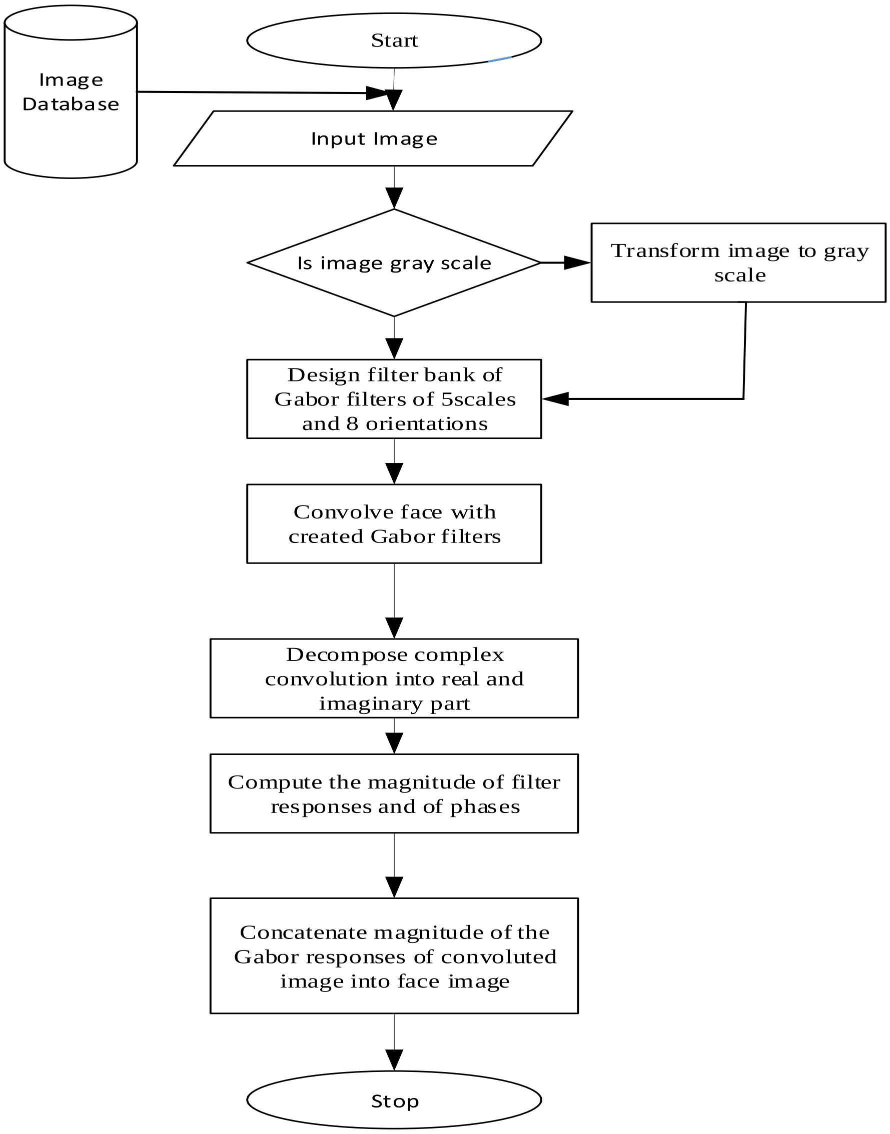



*Fig. 4: Gabor-filter Extraction Algorithm*

## 3.4. Optimization of Gabor Feature Using ACO

The image data matrix obtained from the feature extraction phase was passed to ACO meta-heuristic Algorithm. A Region of Interest from the output of Gabor features were defined from the features based on the information of ROI that do not change over period of time. The ROI was passed unto ACO for optimal feature selection. Based on feature correlation, a subset of the Gabor feature ROI was selected, then was used as the permissible range of ant movement. The ants move randomly over the Gabor features to construct pheromone matrix by initialization of ACO parameters $\alpha$, $\beta$, $\rho$, $\tau_0$ K, N, $\varphi$ $\eta$ on Gabor feature data matrix.

Where $\alpha$ = constant value (determine importance of pheromone value)
$\beta$ = constant value (determine the importance of heuristic information)
$\rho$ = evaporation rate (pheromone update factor)
$\tau_0$ = pheromone matrix value
N = number of ants
K = k ants
$\varphi$ = decay coefficient
$\eta$ = heuristic desirability

A solution was constructed based on probabilistic transition rule as shown in Equation 1.

$$P_{IJ}^{K}(t) = \frac{[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}}{\sum_{j\epsilon J^k}[\tau_{ij}]^{\alpha}[\eta_{ij}]^{\beta}} \qquad (1)$$

The size of the pheromone matrix for this study varies with different Gabor feature matrix of image of the cropped image; the heuristic desirability which is the measure of attractiveness of a feature image based on the local statistics was obtained. The heuristic desirability is obtained by computing the correlation between pairs of pixels. The construction process of solution by the ant was carried out by adopting the probabilistic transition rule as discussed in Equation (1). Global and Local Pheromone update were performed as shown in Equation 2 and Equation 3.

$$\tau^{n} = (1 - \varphi)\cdot\tau^{k} + \varphi\cdot\tau^{(n)} \quad (2)$$

$$\tau_{ij}^{k} \leftarrow (1 - \rho)\cdot\tau_{ij} + \rho\cdot\Delta\,(ij)^{k} \quad (3)$$

The resulted features of pixels represent the optimal features of Gabor feature as shown in Figure 5.

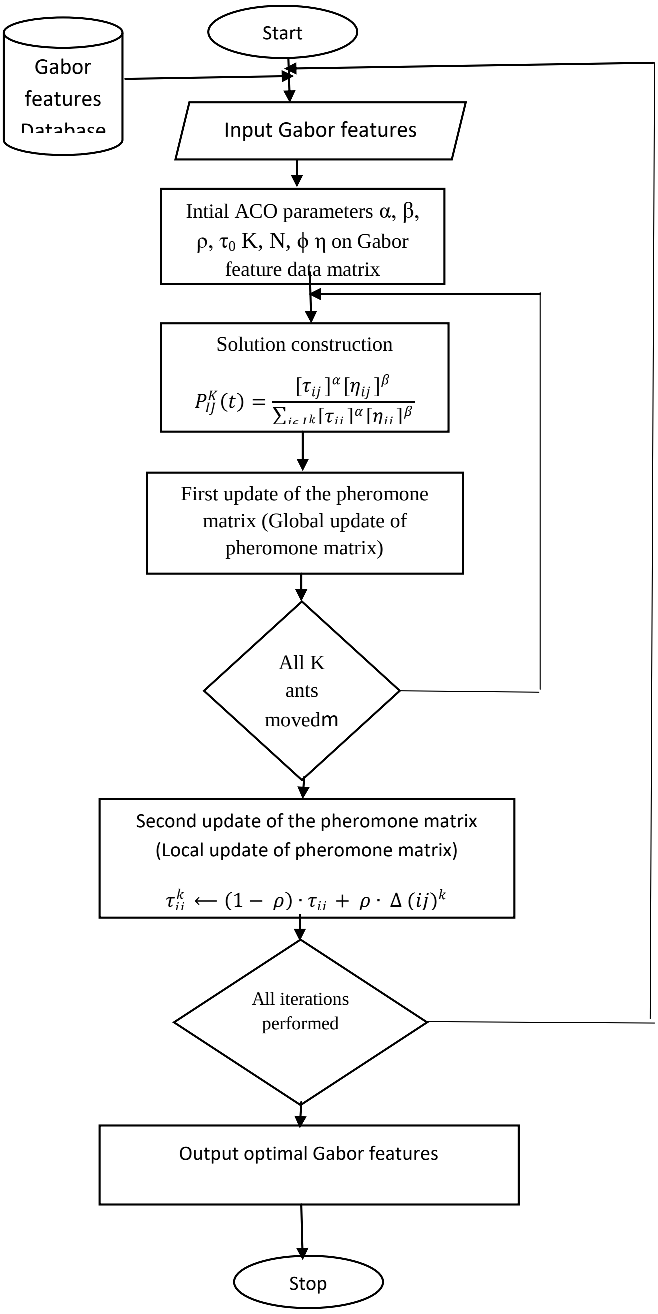



*Fig. 5: ACO Feature Selection of Gabor Features*

## 4. RESULTS AND DISCUSSION

The section presents the results of each of the phases in the proposed optimal Gabor feature face recognition system. The results are further discussed as follows:

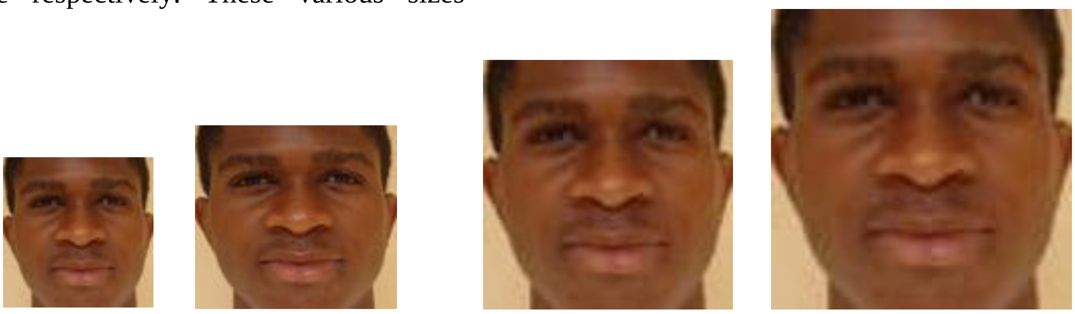
### 4.1. Gray-scale Conversion Result

The colored face images from LAFI database were passed through gray-scale process. The sample of result is shown in Figure 6.

*Fig. 6: Sample of Gray-Scale Images (LAFI Database)*

### 4.2. Geometric Normalization Results

The face images from LAFI and ORL database were normalized geometrically by cropping and resizing. The sample results of the geometric normalization are shown in Figures 7 and Figure 8 for LAFI and ORL database respectively. These various sizes show varying number of fundamental facial features and the sizes; 75x75, 100x100, 125x125 and 150x150 for the two database were chosen arbitrarily to test for the effect of the variation in image size on the proposed face recognition system.



75x75 100x100 125x125 150x150

*Fig. 7: Sample of Geometric Normalization Result (LAFI Database)*

75x75 100x100 125x125 150x150

*Fig. 8: Sample of Geometric Normalization Result (ORL Database)*

### 4.3 Results of Feature Extraction Using Gabor-filters

The extraction of features phase is shown by graphical user interface (GUI) in Figure 9 for LAFI Database, while the Figure 10 represents the GUI of extracted Gabor features for ORL. It was observed that the time taken to perform feature extraction for two datasets increase with increase in image pixel size (the higher image pixel size the higher time taken to extract features) as discussed in Table 1 and Table 2.


Fig. 9: GUI for Extracted Gabor Facial features (LAFI Database)

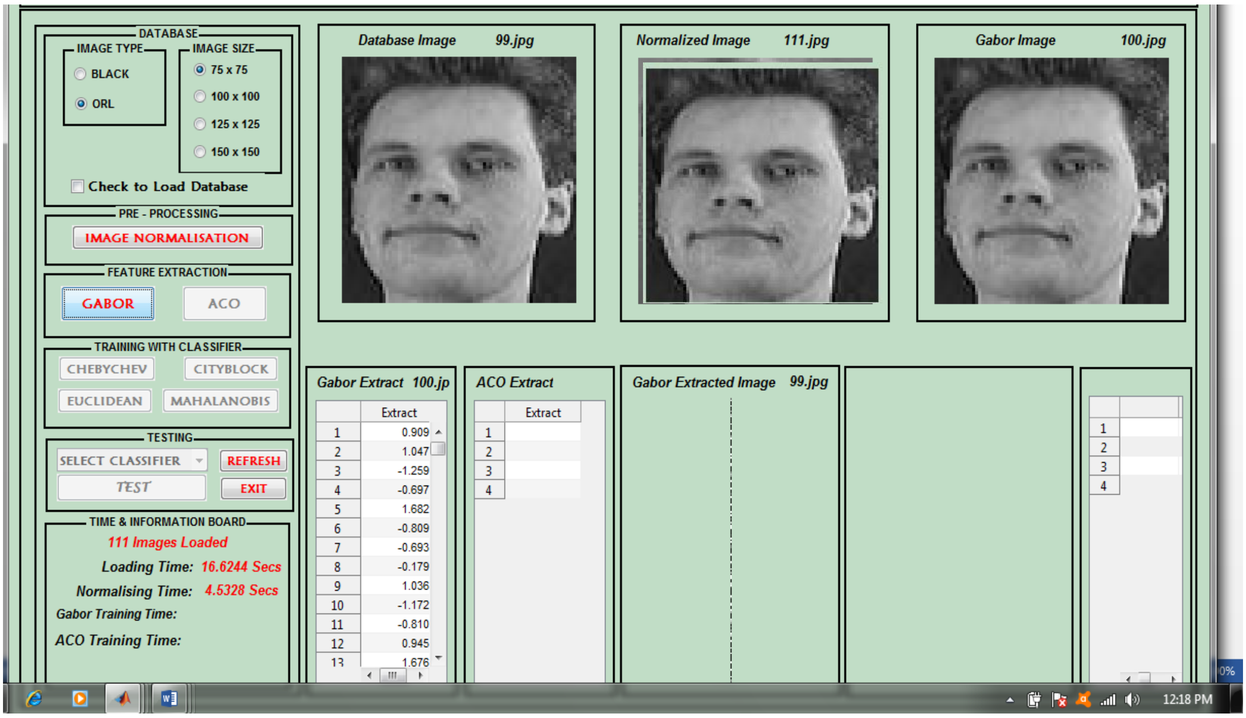



Fig. 10: GUI for Extracted Gabor Facial features (ORL Database)

**Table 1: Features Extraction Time (LAFI)**

| Image size | Time (secs) |
|---|---|
| 75x75 | 118.2510 |
| 100x100 | 121.1642 |
| 125x125 | 156.4176 |
| 150x150 | 197.1525 |

**Table 2: Features Extraction Time (ORL)**

| Image size | Time (secs) |
|---|---|
| 75x75 | 117.1351 |
| 100x100 | 120.5418 |
| 125x125 | 153.6782 |
| 150x150 | 195.3781 |

### 4.4. Results of Optimized Gabor Features Using ACO

The Gabor features obtained from the face images in the feature extraction phase serves as a platform which provides ACO a suitable representation for encoding the procedure for optimal features selection. The input to the ACO feature selection process was the product of Gabor features obtained from the feature extraction phase. Only subset from feature vectors of Gabor features was retained by the optimization algorithm as indicated in Figure 11 for LAFI Database and Figure 12 optimal Gabor features for ORL Database.

*Fig. 11: Optimal Gabor features Using ACO (LAFI Database)*

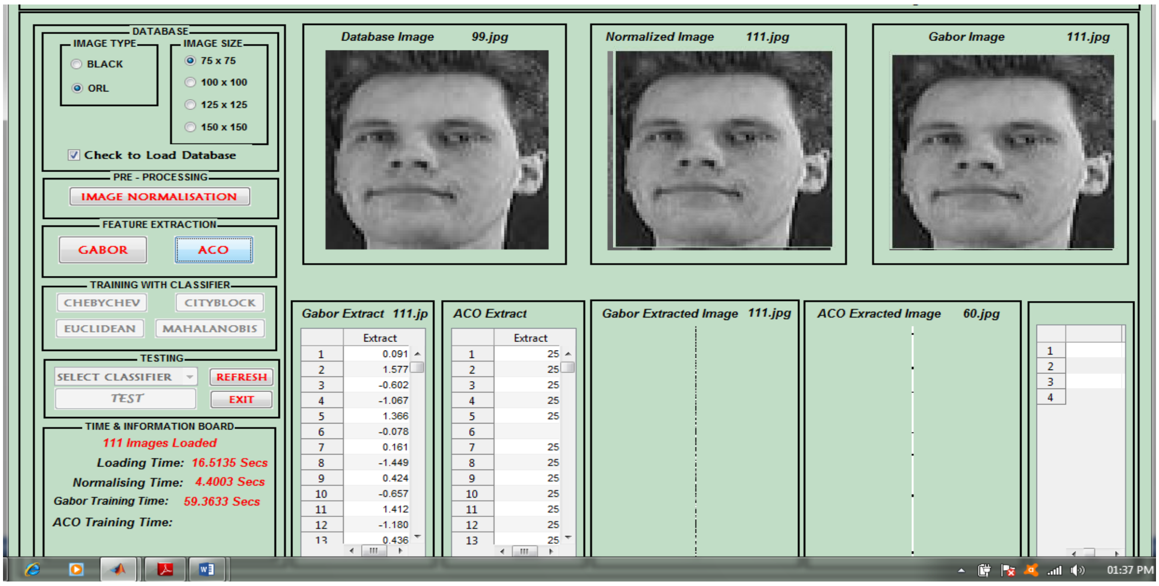


*Fig. 12: Optimal Gabor features Using ACO (ORL Database)*

## 5. CONCLUSION

Gabor-filter method proves to be effective feature extraction technique in facial recognition system due to some unique characteristics, but the high dimensionality of features remains a challenge. This problem has resulted into large computational complexity, large memory space usage and mis-classification of any Gabor features-based face recognition algorithm.

Application of an efficient feature dimensionality reduction method which involves the introduction a nature inspired meta-heuristic optimization algorithms, Ant Colony Optimization approach was used to select randomly the most relevant and discriminant features from the high Gabor features.

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