# Astudy on feature extraction for face recognition using Self Organizing Maps

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**Abstract:*****This paper deals with the study related to the face recognition algorithms and process of developing a Self-Organizing Map (SOM) in order to carry out the process of face recognition in case of humans. Initially the paper deals with the various general steps involved in the structure and statistics based face recognition algorithms. However in the later part the key step used in the unsupervised algorithm as well as the combination of SOM and Hierarchical Self Organizing Map (HSOM) along with the aid of Gabor filters were discussed in order to carry out an efficient process of facial recognition. The feature selection criteria are also discussed in detail in order to achieve a high end result.***

**Keywords:**SOM, HSOM, Gabor filters, unsupervised learning, feature extraction.

## 1. Introduction

It has been more than a decade that face recognition has been identified as an active research area. This domain found greater importance after the September 11 attacks on the United States, after which there rose an emergent demand in utilizing biometric features such as iris patterns, finger prints, including face and voice for security purpose. Out of these, the area concerning face recognition systems stands out with an increased interest among the researchers. This particular field has been found to be contributing most in preserving the identity of any person. This is because, it follows the same procedure in recognizing a person as a human does. To be able to build a robust face recognition system, one must be able to extract the personal facial features. Supporting this fact, a lot of algorithms have been proposed till date.

Theoretically it has been found that based on the use of Karhunen-Loeve transform [19], Principle Component Analysis (PCA) method allows to extract the most significant Eigen faces of a particular sample and the mean square error to it has also been found to be minimum. However, computationally the PCA method has been found to be a power hungry process making it less feasible to implement them on real-time face recognition applications.

Feature-based techniques make use of the relationship between facial features, such as the locations of eye, mouth and nose. Although feature-based techniques can be implemented in a very fast manner, its recognition rate is very much dependent on the location accuracy of the facial features. Thus it cannot give a satisfied recognition percentage.

Some of the other noteworthy algorithms that have been used to build face recognition systems include Local Feature Analysis (LFA) neural network [20], Local Autocorrelations and multi-scale integration technique etc. have been proposed. Among these, the Kohonen Self-Organizing Maps, (SOM) a neural unsupervised learning algorithm, has been widely utilized in pattern recognition area. In this paper, we will try to put forward an insight into SOM-based face recognition applications. The learning mechanism of SOM has many advantages. It can be considered as a promising approach to be used in the feature extraction process of face recognition. This is because it doesn't demands pre-classified images to work on and also the learning is unsupervised. SOM guarantees when high compressed representations of facial images or their parts are produced, the final classification to be fairly simple, which would take only a moderate number of labelled samples.This paper is designed in the following steps: in the beginning a review is presented about the previous work done in the field given, followed a background study on concerned topics of approach. This is then followed by the methodology describing some of the technique about the implementation. Finally a conclusion related to the survey and the future scope of the research is discussed which might me possible.

## 2. Literature Survey

### 2.1 Review of Face Recognition

The algorithms that have been proposed for face recognition can be broadly classified into two categories/approaches. They are namely, structure-based and statistics-based. Structure based approaches are dependent on the relationship between the facial features of a human such as eye, mouth, nose, profile silhouettes and face boundary. On the other hand, statistics-based approaches make an attempt to capture and define the entire face. It treats the face as a two-dimensional pattern of intensity variation. This approach adopts the underlying statistical regularities to match a particular face.

TABLE I. ***Structure-based Face Recognition Algorithms***

A very interesting algorithm has been described by Wiskott et al.[23], in their paper, which describes an elastic graph-matching algorithm in combination with a neural network for recognizing facial inputs. Here faces are stored as flexible graphs or grids with some characteristic visual features known as Gabor features and are attached to the nodes of a labelled graph. The so called Gabor features are based on the wavelet transform, and have proven to give a robust information coding for object recognition. These features are said to be invariant against intensity and contrast change. Adding to it, Gabor-features are less dependent upon the pose, size and facial expression than the traditional raw grey level features. In order to match an image against a stored graph, the location of the graph in the image is optimized.

The EBGM, or Elastic Bunch Graph Matching has been found to successfully recognize faces from facial line drawings. The line drawings of the facial inputs have dominant orientations of bars and edges. Gabor wavelengths too have a similar characteristic. This comes as an efficient quality of the Gabor wavelengths in recognizing line drawings. Experiments of gender classifications based on line drawings resulted in a correct decision rate of more than 90%.

A similar concept to EBGM was proposed by Perronnin & Dugelay. A very novel and probabilistic model which gave a deformable approach towards face mapping. Their model was based on bi-dimensional extension of the 1D-HMM. The probabilistic model tries to maximize the likelihood of P(FT|FQ,M), given a face template, FT, a query face FQ and a deformable model sample M. EBGM and the above model however has the following differences. Firstly, taking into account the elastic properties of different parts of a face, the HMM-based model is extended to 2D case to estimate the probability, thereby automatically training the parameters of M. The model M in the HMM-based process, is shared among all the faces, thus making the method more robust even if little enrolment data is available.

An analytic and holistic method was proposed by Ref. (Lam & Yan, 1998), which successfully identified faces at different perspective variations. The database used for all these experiments was ORL. Under different perspective variations, the overall recognition rates are over 84% and 96%.

In another work, a classification method was proposed called as the Nearest Feature Line(NFL). The nearest feature line method achieved an error rate of 3.125%, and the authors claim that it is the lowest reported rate for the ORL database

TABLE II. ***Statistics-based Face Recognition Algorithms***

Talking of statistics based approaches [14]; we see the method described by Turk and Pentland as the most popular approaches towards face recognition. An unknown face is classified if its distance to the clusters is below a certain threshold, using an appropriate classifier. Turk and Pentland reported a correct recognition rate of 95% in the case of the FERRET database, containing about 3000 different faces. The tested face images however seem to be taken with little variation in viewpoint and lighting, although with significant variation in facial expression. The major drawback of the Eigenface approach is that the scatter being maximised is due not only to the between-class scatter' that is useful for classification, but also to the within-class scatter' that, for classification purposes, is unwanted information. The Eigen face approach was implemented by many researchers. The Fisherface method proposed by Belhumeur et al. projected face images into a three dimensional linear subspace. This projection was based on Linear Discriminant in order to maximize the 'between-class scatter' while minimizing the within-class scatter. Experimentally, this approach was proved to be more efficient than the Eigen face approach, especially in the case of variable illumination. The ORL database was used for implementation. From which 150 faces from 15 subjects were selected. The Eigen face method was found to be more robust, especially when dealing with glasses and facial expressions, but at the same time sensitive to scale, pose and illumination. The correct recognition rate achieved is 95% for only 150 images, selected from the 400 images of the ORL database.

## 3. Background

### *a.* Face recognition system structure

The term face recognition includes several sub-problems. Among the different classification methodologies, we will try to explain some of them, finally proposing a general and unified classification strategy will be proposed.

### *b.* A generic face recognition system

A face recognition system always takes input as an image or video stream. The corresponding output is an identification or verification of the subject or subjects that appear in the image or video. However, some face recognition systems define it as a three step process as shown in the following Figure [1]. Thus, we can take the Face Detection and Feature ExtrssFrom this point of view, the Face Detection and Feature Extraction phases could run simultaneously.


**Figure 1:** Ageneric face recognition system Source: Ref[2] Face Recognition Algorithms Proyecto Fin de Carrera,June 16, 2010,Ion Marqu´es

The work of the face detection is defined as the process of extracting faces from scenes if any. As such the system definitely identifies a certain region in the scene as a face if so present. The face detection step has many parts/processes under it such as face tracking, pose estimation or compression etc.

The step following face detection is feature extraction wherein the relevant facial features are extracted from the face so identified. The features so obtained can be certain face regions, variations, angles or measures which can be taken as human relevant (e.g. eyes spacing) or not. The probable applications of this process can be like facial feature tracking or emotion recognition. Finally, the system does recognize the face. In the identification task, the system would eventually report an identity from a database. A comparison method is adopted with the help of a classification algorithm and an accuracy measure. This comparison and classification strategy so adopted is similar to other classification based tasks in some popular domains such as datamining, sound engineering.

### *c.* Face detection

In the present days, some of the applications related to face recognition don't require the face detection process. The databases with the face images stored in it are already in normalized form. The facial samples stored pertain to be of a particular standard. So the detection step can be eliminated. The criminal database can be thought of a probable example.

There are many challenges that the face detection process has to encounter. These are seen usually to be present in images captured in uncontrolled environments, such as surveillance video systems. These challenges can be attributed to some factors:

1. **Pose variation**: The most ideal scenario for face detection would be one in which only frontal images were involved. Unfortunately it is not possible to obtain such images in uncontrolled conditions. Large pose variations also leads to a massive drop down in the accuracy of face detection algorithms. The two major factors responsible for pose variations can be stated as subject's movement and movement of the camera's angle. The presence of elements like beards, glasses or hats introduces high variability. Faces can also be partially covered by objects or other faces.
2. **Facial expression**: Facial features also vary greatly because of different facial gestures.
3. **Imaging conditions**. Different cameras and ambient conditions can affect the quality of an image, affecting the appearance of a face.

### *d.* Feature Extraction

The humans are gifted the capability of recognizing faces from the age of 4-5 years. Being a much debated issue, our recognition seems to be an automated and dedicated process in our brains. This is because, we can recognize people we know, even when they are wearing glasses or hats. We can also recognize men who have grown a beard. It's not very difficult for us to see our grandma's wedding photo and recognize her, although she was 23 years old. All these processes seem trivial, but they represent a challenge to the computers.

There are different steps in the feature extraction process. Commonly they include dimensionality reduction, feature extraction and feature selection. These steps may overlap, and dimensionality reduction could be seen as a consequence of the feature extraction and selection algorithms. In any pattern recognition system, dimensionality reduction is the most essential task. However the performance of a classifier highly depends upon the amount of sample images, number of features extracted and the complexity of the classifier. There is a notion that as the number of features increases the false positive ratio of a classifier does not increase. This can happen only when the number of training samples is relatively small to the number of features. This problem is called "curse of dimensionality" or "peaking phenomenon". A probable solution to this problem is to increase the number of training samples as compared to the number of features. This requirement should be satisfied when building a classifier. Hence it is to be noted that the complex the classifier is, the larger should be the mentioned ratio [48]. Keeping the curse as one of the reason, it is important to keep the number of features as small as possible. The other main reason is the speed. Considering lesser number of features will make it faster and will less memory. Moreover, a large set of features can result in a false positive when these features are redundant. Thus one's choice in the number of features has a large effect on the performance of the pattern/face recognition system. Too less or redundant features can lead to a loss of accuracy of the recognition system.

Although the terms, feature extraction and feature selection seems similar, but they can be used interchangeably. We can make a distinction between them. A feature extraction algorithm extracts features from the data. It creates those new features based on transformations or combinations of the original data. In other words, it transforms or combines the data in order to select a proper subspace in the original feature space. On the other hand, a feature selection algorithm selects the best subset of the input feature set. It discards non-relevant features. Feature selection is often performed after feature extraction. So, features are extracted from the face images, and then an optimum subset of these features is selected. The dimensionality reduction process can be embedded in some of these steps, or performed before them.

### *e.* Feature selection methods

Aiming the smallest classification error, the feature selection algorithm's work is to select a subset of the extracted features. The significance of this error whether high or low is what makes the feature selection strategies dependent on the type of classification method so adopted. Examining every possible subset and choosing the one which fulfils the criterion function can be thought of as the most straight ward approach to this problem. The most straightforward approach to this problem would be to examine every possible subset and choose the one that fulfills the criterion function. However, there are equal chances of this approach of becoming a compute intensive task. The branch and bound algorithms etc. can be taken as some of the effective approaches towards this problem.

## 4. Methodology

A general process implementing Self Organizing Map (SOM) for face recognition algorithm is depicted in Figure 2. Generally SOM plays the role of reducing the dimension and extraction of features for face space representations. Lawrence et al.[21] deployed a self-organizing feature map classifier and a convolutional neural network which can be utilized for invariant facial recognition which was tested on the database of the ORL and it recorded a result with an accuracy of 96.2% on a test set which comprised of a training set involving five faces per person. Concurrent Self Organizing Map (CSOM), a unique and new classification model for neural networks discussed by Neagoe et. al[22] and it represents a winner-takes-all strategy for miniature SOM networks. Here each class is a result of an individual SOM wherein a recognition score of 91% with CSOM (40 linear SOMs) was obtained after experimenting on the ORL database. An algorithm based on SOM in order to solve a face recognition problem based on a single training sample was proposed by Tan et. al. which could extract facial features that were based on local regions which resulted in a lesser fault ratio as compared to Principle Component Analysis (PCA) due to its unsupervised, parameter less nature. A combination of efficient techniques for reduction in dimension and feature extraction was proposed by Kumar et. al.[16] which was basically utilized for performance analysis

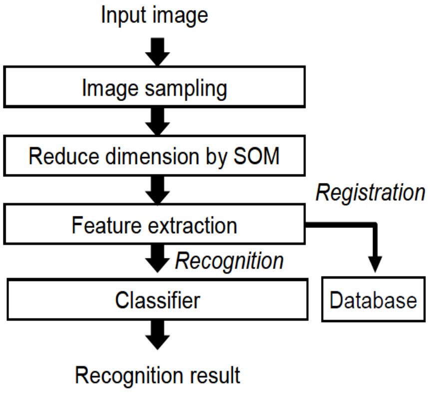


**Figure 2:**General procedure of face recognition algorithm using Self-Organizing Map (SOM) Source:Ref[2]

This experiment created a major improvement as individually both the techniques i.e. SOM and PCA are efficient mechanisms for complex domains like face recognition. However combination of both of them could also be utilized for the same purpose which improved efficiency which was a result of higher data reduction but the rate of recognition was compromised. Another significant effort was generated by Oravec et. al. where combination of MLP (Multilayer perceptron interpolation) and PCA was used for human face recognition where the final output generated by the PCA was compared with respect to direct classification of the input images by the combination of networks of MLP that was used for the role of feature extraction and RBF (Radial Basis Function) was used to play the role of a classifier. In addition to this, a 2 staged method based on feature extraction tool in the form of Kohonen SOM (KSOM) is also being used which effectively makes use of extraction of features from the data generated by the image. Basically this is related to vector quantization (VQ) of images along with the combination of KSOM for design of the codebook which made use of transmission of images for face recognition. An experiment for the evaluation of robustness with respect to illumination changes based on an appearance based method was depicted by Aly et. al. where SOM is used for the transformation of images in higher dimension to lower dimension in the topological space. While the original SOM learning algorithm makes use of Euclidian distance, this method uses Mahalanobis SOM (MSOM) which uses Mahalanobis distance to determine similarities between the given input and the related images of codebook which are very much sensitive to factors like illumination. MSOM effectiveness was proved by the experimentation on facial databases like Yale B and CMU-PIE. In another attempt Garcia et. al explained a unique method whose primary aim was to quantify the similarity that lies between a class model and an image which can be used in various problems like image classification, object recognition etc.

Figure: 3 represents a schematic drawing of feature extraction and compression. Initially a 16 Gabor filters bank is applied to each of the image windows. Basically these Gabor filters are based on masks based on frequency of spaces and orientation and is used to detect the various facial image micro features. These regions which are smaller in sizes are known as "Gabor jet" (the output generated from the utilized 16 local Gabor filters). Generally a 2 layered SOM is used for this purpose where it is used for clustering of the vectors which has predominantly been trained by other natural objects and a variety of face images.

### *4.1.* ***Feature extraction and compression in object recognition***

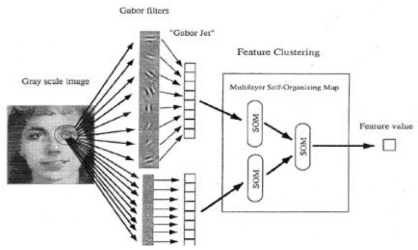


**Figure 3 :**Feature extraction and compression, Source:Ref[3]

Initially the input space is divided into convex clusters which would centre around the weight vector's map by the 1st layer and the second layer is responsible for capturing the smaller variations in the images by combining the clusters that were formed by the 1st layer into approximately 100 nonconvex clusters and these cluster numbers in return is responsible for representing the feature code for that particular region of the image segment.

### *4.2.* ***Gabor Filters***

The Gabor filters possess good relevance towards biological aspects as well as efficient properties of computation as a result of which they are extensively used in image analysis. The wavelets have their kernels are similar to the profile fields (2D in nature) of the simple cells of the cortical of the mammals. These are located in an optimal condition in space and the frequency domain and represents selectivity based n orientation and spatial locality characteristics. In this paper the following 2 D Gabor filter function is employed in a space domain that is continuous in nature.

$$\psi(x, y, \theta, \lambda, \gamma)=e\text{-}(x'\gamma 2y'2)/2\sigma 2\cos(2\pi x'/\lambda) \qquad (1)$$

$$x' = x\cos\theta + y\sin\theta,\ y' = -x\sin\theta + y\cos\theta \qquad (2)$$

Here,

θ represents the wavelets orientation which in return depicts the bars and edges for whom that particular wavelet will sow any type of response.

λ is inversely proportional to the wavelet and depicts a parameter which stands for the cosine wavelength. Low frequency or large wavelength corresponds to the gradual changes in the image intensity while higher frequency or shorter wavelength is responsible for the sudden changes or sharp edges and bars.
σ is the radius of the Gaussian and is directly proportional to the wavelength which determines what amount of the image will be affecting the convolution.

γ is responsible for the aspect ratio of the Gaussian.

In a face detection based on the Gabor jets, initially the fiducial points like corners of the eye and the mouth and then the relative positions are verified using graph for reference which would validate the detection. Figure 4. represents a general overview of the various steps in the detection based on Gabor jets.

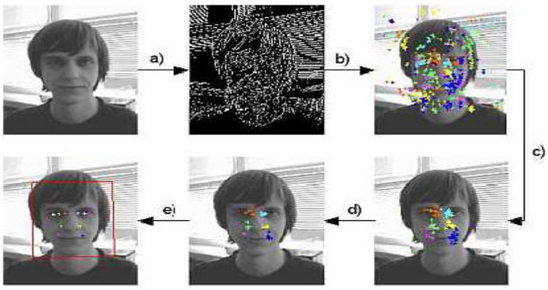


**Figure4 :**Face detection scheme: a) edge detection, b) LDA for discrete Gabor jets, c) matching facial features. d) Facial features merging (separately, once for every scale), e) computing eye centers. Source: Ref[4]

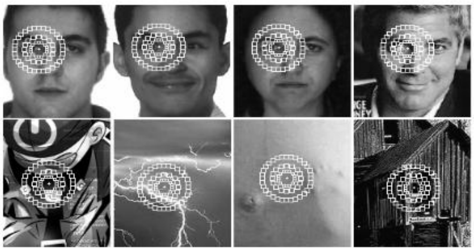

**Figure 5:** Rings of small squares as neighborhood of analysis. Source: Ref [4]

In this process initially combination of Sobel operator and canny edge detector is used for the edge detection process. The goal of this process is reduction of the pixel number that requires analysis and focus on the primary regions which are not uniform in nature of the input image. Succeeding this process feature extraction from the neighborhood is performed which involved extraction using small rectangles in a ring like fashion around the edge pixels (Figure 5.). To be precise, Fourier analysis is done on the single rings along with the combination of the adjacent rings which has some contrast in them. The feature vectors thus extracted are then fed as an input to a modified version of Linear discriminant Analysis Classifier (LDA) which is utilized to classify the edge pixels into 7 primary classes: non face fiducial point, left eye corner, right eye corner, left nose corner, right nose corner, left mouth corner and right mouth corner. These point are then used to represent a candidate face with the aid of a reference graph. The final combination of the candidates are merged so that the multiple detections of the same face are avoided.

### 4.3. *Implementation of Hierarchical Self-Organizing Map (HSOM)*

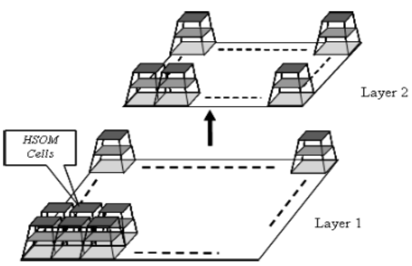


**Figure 6:** HCM Network structure Source: Ref[6]

Any 2 layer SOM network which resembles a feed forward network can be categorised as HSOM OM which means that each of the units that are there in the layer is connected to every unit in the sending layer. However having an indigenous characteristics and using the simple learning algorithm of Kohonen in both the layers it leads to a much efficient and simpler form of implementation. The winner neuron index of the first layer is fed into the second layer as an input. In addition to it both the layers possess the same training algorithm. The only difference in both the layers is in the number of neurons which means that the number of layers in the second layer is smaller in size as compared to the first layer which enables HSOM to combine the various features that were extracted in the first layer which depicts a feature space that is rich in dimension. However this technique demands duplication of the described process or structure in each of the region in the input space. This structure is termed as Hyper column model.

## 5. Conclusion

This technique (SOM) provides an efficient mechanism for mapping higher dimensional input space into a much lower Dimensional space. It provides mechanism for reduction of dimension and extraction of features in case of a face recognition algorithm. This can also be combined with advanced image processing processes like translation, rotation, scaling, deformation etc. along with similar neural network methods which can be experimented in order to improve the mechanism to an extent which will result in better noise removal and image processing activities. It could prove to be an effective blessing for the development of various software which can be utilized to create a revolution in the digital image processing domain and make life simpler for the mankind.

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