Chapter 4

Graph Representation for Partial Face Recognition

4.1 Preamble

The face image differences caused by rotations are often superior to the inter-person differences used in distinctive identities. Initially we have taken full face as training set, part of the images are make it as rotational, flip horizontal, flip vertical, scaled up, scaled down facial images which are considered as testing set (for both we use AR database) then convert the colored images in to gray level images. Secondly normalize the histogram of an image it represents the relative frequency of occurrence of the various gray levels in the image. Subsequently, testing cases are divided in to four ratio cases like as 70:30, 60:40, 50:50, 80:20 using this bifurcation cases of images we will get different recognition results. Simultaneously we have computed histogram of the normalized images and we got features in the form of matrix or vector representation and then compare the values of different testing cases. Finally, matching the features using template matching the proposed algorithm has been tested with AR dataset and results obtained are satisfactory.

In this work, we have proposed two different methods to carry out partial face recognition. Initially we proposed a partial face recognition system based on template matching and then technique based on graph matching which is stand on local feature descriptors and which is process to efficient than template matching method. Experimentations were performed and results were presented to show their proposed system, it is capable of effectively detecting and recognizing the human faces in partially occluded conditions and worked better in different illuminations of face
orientations. The results generated by proposed methodology are sufficient and concrete to support the idea; however, critical discussion should be added to show the impact and improvements introduced by the proposed research and also advised to add future research directions to strengthen this study. More references relevant to research added to show work of other researchers and support comparative analysis.

Today Face recognition is very challenging and well developed research area [Ahonen et al., 2004 ]. Especially, Recognition of a particular object or person under partial visible condition is very challenging ongoing research domain with great expectation in all over the world. In this thesis, we describe full face as training and part of that image is considered as testing. In both stage, Images are in RGB formats so, we need to standardize and preprocess these images by converting RGB into gray scale images. Then extracted SIFT features form and texture based then by using these specific features we need to draw graph for it and searching for dominant feature points using K-NN clustering technique. Then we used to find the adjacency matrix that is the distance between four dominant features in an adjacency graphs for both training and testing. Finally, searching for a sub-graph in a main-graph, if it is present then recognition is true otherwise false. This methodology has given good recognition results compare to other existing face recognition algorithms.

4.2 Challenges

Reliable authentication of people has long been an interesting goal and is becoming more important as the need of security grows. Security is an aspect that is given top priority by organizations, educational institutions, political and government in personal identity and forgery issues. Technologies called biometrics can automate the identification of people by one or more of their distinct physical or behavioral characteristics. They are pattern recognition system which makes personal identification by determining the faithfulness of the specific trait haunt by the user.

Biometrics Terminology: Certain terminology has very specific meaning in the context of biometrics. Biometrics [Jain, Anil K et al, 2012] is the use of physical or behavioral traits to verify personal identity. A specific trait, such as fingerprint, is referred to as the biometric mode. The process of obtaining a biometric sample is acquisition these samples are captured and turned into digital signatures using a
sensor. The database of collected samples and identity information is referred to as the gallery. A sample acquired for purposes of querying the gallery is called a probe. Enrolling is the process of acquiring a biometric sample, along with other information, to be used as part of the gallery, a step which must occur before the system can make positive identification of the person involved. The process of comparing a probe sample and gallery sample is called matching, which returns a match score. Samples are compared using one of many algorithms [Phillips, P. Jonathon, et al. 2008]. A biometrics system usually has a threshold value, which determines whether the match score indicates a match (meaning that the samples are likely of the same person) or a non-match (meaning the samples are probably of two different people). Multi-modal biometrics is the process of using multiple biometric modes simultaneously to increase the accuracy of the identification system.

Humans often use faces to recognize individuals and advancements in computing capability over the past few decades now enable similar recognitions automatically. Early face recognition algorithms used simple geometric models, but the recognition process has now matured into a science of sophisticated mathematical representations and matching processes. Major advancements and initiatives in the past ten to fifteen years have propelled face recognition technology into the spotlight. Face recognition can be used for both verification and identification. Motivation for partial face recognition there is a lot of literature, but only a few studies have attempted to investigate if and how partial visible face biometrics actually have a negative effect on accuracy and error levels. Therefore drawbacks of full visibility face biometrics are: Under Partial Visibility condition performance of the Biometrics reduces and many real time captured face images are much closer to Partial Visibility.

Now a days, Face recognition is very needful research progressive area in many applications, including, surveillance, access control and personal authentication, recognition, identification, forensic and law enforcement applications [Pereira, Shelby, and Thierry Pun, 2000]. Face recognition has been an active research area over the last more than twenty years. Modern face recognition systems are based on application of mathematical and statistical concepts for taking actions on raw data. Both full Face
and partial face recognition algorithms try to solve the problem of verification, authentication and identification. When verification is on demand, the face authentication system is given a face image and with a claimed identity. The system is expected to either reject or accept the claim based on the face image as well as full and partial facial features images. On the other hand, in the recognition problem, the system is trained by some images of known individuals and given a test image; it decides which individual the test image belongs to. The problem of face recognition can be stated as follows: Given still images, identifying particular person in a crowd, Recognition of faces due to some partial face expressions and lighting conditions of occluded images etc. There are several strategies used to overcome problems arising in such situations. One of them is to discard those parts of the face which more intra-class variance.

Detection of a person face is more challenging in partial face recognition. Face detection is not straightforward, as it is very challenging task to detect the face because when we are going to implement face detection in real time data application then we have to face very challenging problems like pose variation, occlusion, and expression variation, illumination conditions. There are many different algorithms [Nageswara Rao, S. V. D et. Al, 2000] that have been implemented for face detection, including the use of color information, edge detection, and neural networks. And Cluster analysis is a vital building block to investigative data analysis. Generally, the categorization of dissimilar things is a natural process for human beings. There subsist abundant normal examples about diverse classifications for livelihood in the humankind or world. For example, various monster and plant species are the consequences of unsupervised classification. And the more important components for cluster analysis are Data presentation. Choice of variables, objects, what to cluster, variables normalization, similarity and dissimilarity measures, criterion for clustering, strategy for missing data, convergence, results for interpretation and clusters numbers.

In this research work, we have a database of a full and partial face images for training and querying. Then, given a known face image, we need to answer the doubtful question that is “which person in our database does this part of the image or partial image belong to?” Many algorithms and techniques have been proposed for solving such a problem.
4.3 Template Matching and its Limitations

Template matching [Lalonde et al., 2001] is a technique in digital image processing for probing small parts of an image which match a template image. It is a procedure used to classify objects. A template is a small image (sub-image) the goal is to find occurrence of this template in a larger image that is, you want to find matches of this template in the image. Sample image may be used to recognize similar objects in source image. Template matching method to compare portions of images against one another and it is a classical approach to the problems of locating and recognizing of an object in an image.

Template Matching techniques are flexible and relatively straightforward to use, which makes them one of the most popular methods of object localization. Their applicability is limited mostly by the available computational power, as identification of big and complex templates can be time-consuming. Therefore drawbacks of full visibility face biometrics are: Under Partial Visibility condition performance of the Biometrics reduces and many real time captured face images are much closer to Partial Visibility.

We have faced certain problems in present facial recognition system so, to robust the face recognition scheme we have experimented using Color, Texture, Shape and experimented on individual features or characteristics does not have capability in recognizing face due to similarity in nature exist across similar color faces, similar shapes and similar textures. Keeping these issues in view, we can go through fusing all 3 global parameters for recognition.

4.4 Proposed Model: Template Matching

The face detection and recognition problem here is actually an occluded facial image problem in which the image position of the single face has to be determined. The goal of our proposed model is to make partial face features detection and recognition to detect the presence of features, such as partial eyes, nose, eyebrows, mouth, lips, ears, etc., the assumption there is only one in an image. The system should also be occluded against human emotional expressions like happiness, sadness, disgust etc. and partial part, occluded images. The difficulties associated with face detection
systems due to the variations in image appearance such as pose, scale, image rotation and orientation, facial expressions, partial parts of an image and occluded facial images make face recognition a difficult pattern recognition problem. Hence, for face detection the following types of problem need to be taken into account.

Template matching technique, in particular in two dimensional cases, has many applications in object tracking, image compression, stereo correspondence and other computer vision applications. Still now, it is a fundamental technique to solve them. Among several matching methods, Normalized Cross Correlation (NCC) and square root of Sum of Square Differences (SSD) [Twisk, Jos WR, et al., 2013] have been used as the measure for similarity. Moreover, many other template matching methods, such as Sum of Absolute Differences (SAD) [Bockris, John O’M et al., 2013] and Sequential Similarity Detection Algorithm (SSDA) [Ma, Liyong, et al., 2009] have been adopted in many applications for pattern recognition, video compression and so on. In addition, Template matching has been extensively used in various applications, for example, extraction of container identity codes, image detection segmentation and so on.

Figure 4.1 Architecture of the proposed template based model
Here, Full face images and partial face images are taken as training and querying. We convert color (RGB) scale image into Gray level image, after that we compute histogram values which is obtained from histogram normalization. Usually the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values and vector or matrix representation. It means an image is stored as a 2D matrix (of size mxn) where each element of the matrix represents the intensity of light/color of that particular pixel. Hence, for a binary image, the value of each element of the matrix is either 0 or 1 and for a grayscale image each value lies between 0 and 255. A color image is stored as an mnxn3 matrix where each element is the RGB value of that particular pixel (hence it’s a 3D matrix). We can consider it as three 2D matrices for red, green and blue intensities. After getting these types normalized intensity values of a face image matching the training and querying face images using template matching. Finally, we got satisfactory recognition results comparing to existing systems.

4.5 Proposed Methodology: Graph based representation

In this proposed work, the term 'partial' refers to a part or combination of parts of frontal face image such as eye, nose and mouth. Graph Matching is going to be used for face recognition under partial visibility to reduce image information; images should be converted to gray scale RGB level. Each color image from the three given channels show red, green and blue components in RGB color scheme. Here, we first transform the RGB full face scale image to gray scale image then an image is defined by a gray scale level, which means pixels in images are stored in 8 bit integer to represent color from black to white. In preprocessing stage, equalized the histograms of gray level images, is a statistical method of image processing in which method we used. Histogram equalization [Celik, et al., 2012] is a method of contrast adjustment using histogram. This method usually increases the contrast of the input image. In the next step the gray scale image must be converted to edge image by using some of the edge detection methods like canny, sobel etc. Some morphological techniques are applied to reduce noise, fill holes and reconstruct the shape of skin like regions. Then
we find connected components which are present in the edge image and fix a threshold 'T' value for a number of connected components by eliminating the connected components which are lesser than the threshold 'T', in order to get clear region of intersect for edge mask. Next step is to apply segmentation for the original image after this we apply the Scale-Invariant Feature Transform (SIFT) [Ke, Yan, and Rahul Sukthankar, 2004] feature detector to detect local feature key points and Key points detected by SIFT key point detector are marked out as dots on full face and partial face images as we shown in figure 4.3 to 4.4 respectively. By using Partitioned clustering techniques, we can cluster the major components such as eye, nose, and ear regions, by considering those cluster centroids as points (vertex of a Graph) generate a adjacency matrix for all the vertices of a image. After getting adjacency matrix values of a face image match the training and querying face image using graph Matching. Finally we got desirable recognition results when compared to existing systems and to evaluate the performance of partial face recognition methods more effectively.

4.5.1 Preprocessing

In preprocessing stage, equalized the histograms of gray level images, is a statistical method of image processing in which method we used. Histogram equalization is a method of contrast adjustment using histogram. This method usually increases the contrast of the input image. In the next step the gray scale image must be converted to edge image by using some of the edge detection methods like canny, sobel etc. Hence, all the parameters need to be taken into account for efficient face recognition.

4.5.2 Feature Extraction

We propose to use local features by applying the Scale-Invariant Feature Transform (SIFT) [ ]feature detectors to detect local feature key points. Before matching, key points selection is performed to filter out obvious outliers. Since there exists rotation, translation, scaling and even occlusions between querying image and training images of same identity, it is very difficult to normalize them to eye positions. Without proper face alignment, holistic features would fail to work. So we proposed to use local features and detect key points with SIFT feature detector. Normally for a typical 128×128 face image, SIFT feature detector could output hundreds of feature points.
Figure 4.2 Block diagram of the proposed graph based model
The geometric feature of each key point, denoted as \( C \), records its relative position in the image frame.

![Figure 4.3 Images of training dataset, (a) Full Face Image (b) Shift Features points (c) clustered centroids (d) Complete graph for cluster centroids](image)

**Figure 4.3** Images of training dataset, (a) Full Face Image (b) Shift Features points (c) clustered centroids (d) Complete graph for cluster centroids

The number of key points of facial image could be up to hundreds. Matching point sets at this scale is computationally intensive. Moreover, irrelevant key points might hamper point set matching process, such as misleading the matching process to a local minimum, especially when genuine matching pairs are few among all matching features. Hence, it is beneficial to filter out obvious outliers before point matching.

Our proposed system explains how graph method is used for the identification of occluded components. Individual components can be detected by statistical approaches. Occluded components cannot detect by statistical approaches because these approach requires constant features. In our proposed method we denote graph by \( G (V, E) \), where \( V \) represents vertices of graph and \( E \) represents edges of graph, both are finite set and non-empty set. Components presents in the face are represented by nodes \( v \) and \( V \) and \( G_v \) is component type. Euclidian distance \( \delta e = \delta ij \), is defined by edge \( e \in E \), between components \( i \) and \( j \) centers. Edges and nodes levels should be same in case of exact graph matching and level difference allowed for inexact graph case.

Graph \( GR = (VR, ER) \) is used to represent the face. 550 example graphs and geometric mean of node sizes and edge distances are used to design face graph. Size
and position of components are used to design each example graph. This gives the formation of graph for face.

Graph $G_D$ constructed from detected components used for designing of graph. A node $v \in V_D$ is face components and an edge $e \in E_D$ is used to connect nodes. Deviation is represented by the two measures of each node pairs.

Many connected components of face are consisted by graph $G_D$. The graph $G_D$ extracted in many graphs $G_{f} = (V_{f}, E_{f})$ and each graph represent single face. There is different size and location of components consisted by each graph $G_{c}$. Matching process is done and matched sub graph find out in this step. Low similarity combinations should be removed. A component $v \in V_{w}$, without size and distance information is introduced for completion of face. All sub graphs $G_{f} = (V_{f}, E_{f})$ with minimum two different detected components are selected from the resulting graph.

The majority distinguishing characteristic of a graph is its geometry, which is described by the way the vertices of the graph are prearranged spatially. Graph geometry plays an significant responsibility in discriminating the graphs of different face images for full and partial face images. In our proposed methodology, the graph geometry is defined by constructing a graph with constraints obligatory on the length of the edges between a vertex and its neighbors. And in our method construct taking into account that we extract around $n$ feature points from each full face and partial face images using SIFT feature descriptors, at least $n!$ Graphs can be generated for each image. Evaluating this number of graphs for each testing image would be very computationally costly. Therefore, a graph generating method that generates a exceptional graph with the given set of vertices is projected. At each iteration, vertices and edges are added to the graph in a Breadth-first search manner and considering a spatial neighborhood distance for each vertex. This generates a unique graph for a set of feature points.

The theme in the rear representing full and partial face images using graphs is mainly due to the spatial characteristics of the graph, as a graph can represent the inherent shape changes of a full and partial face and also gives a easy and simple, but dominant corresponding matching designing methods to compare graphs. Finally,
searching for a sub-graph in a main-graph, if it is present then recognition is true otherwise false.

### 4.5.3 Partitioning-based clustering algorithm

The Aim of clustering is to diminish the amount of data or facts or information by categorizing or grouping reminiscent of data items together. Such grouping is insidious in the way human’s process information, and one of the motivations for using clustering algorithms is to make available automated tools to help in constructing categories or taxonomies and the methods may also be used to decrease the effects of person factors in the process. So our proposed work is based on Partitioning Clustering algorithms.

Partitioning-based clustering algorithms [Sanville, Edward, et al. 2007] conceivably the most accepted group of clustering algorithms is the combinatorial optimization algorithms and iterative rearrangement algorithms. These algorithms reduce a prearranged clustering principle by iteratively relocating data points between clusters until a optimal partition is attained. In a basic iterative algorithm, such as K-means, convergence is local and the globally optimal solution cannot be assured. Because the number of statistics points in any data set is always fixed or restricted and, thereby, also the number of separate partitions is limited, the problem of neighboring minima could be controlled by using exhaustive search methods. On the other hand, this is truth only in theory, since finding the internationally optimal partition is known to be NP-hard problem and exhaustive methods are not useful in practice.

The number of different partitions for \( m \) observations into \( L \) groups which is given by

\[
\mathcal{S}_n^{(L)} = \frac{1}{k!} \sum_{i=0}^{i=k} (-1)^L - i \binom{L}{i}^m
\]

This shows that inventory of all probable partitions is not possible for flush relatively small problems. The problem is even more challenging when additionally the number of clusters is unfamiliar. Subsequently, the number of different combinations is the sum of the Stirling facts of the second kind:
Where $L_{\text{max}}$ is the maximum number of cluster and it is understandable that $L_{\text{max}} \leq m$. The fact is that exhaustive search methods are outlying too time overwhelming or consuming still with present computing systems. Furthermore, it seems be an inestimable race between computer power and quantity of facts, which together have superior than constantly for the duration of the years to years. Consequently, additional realistic approach within off than comprehensive search is the iterative optimization.

### 4.5.4 Scale Invariant Feature Transforms

For Every object there are many characteristics or features, interesting points on the object that can be extracted to gives a feature explanation of the object. This depiction can then be used when attempting to establish the object in an image containing many other objects. There are many considerations when extracting these features and how to record them. SIFT image features provide a set of features of an object that are not affected by many of the complications experienced in other methods, such as object scaling and rotation.

### 4.6 Experimental Analysis

The experimental results are obtained in terms of correctly searched faces over the number of faces in the available datasets. A total of 500 face images were tested by creating the dataset contains 50 subjects, including 40 male and 10 female, respectively. Each person has 4 testing ratio different partial occlusion cases. Out of 500 partial face images ratios are 70:30, 60:40, 50:50 and 20:80 for testing process. And these training and testing images correspond to the different occluded and illuminations images. All of the images in the training set were frontal, with neutral expression and with occlusions.

For every face, ‘K’ probable partial segment are identified. For each partial segment obtain a histogram normalization and equalization. Images ratios are 70:30, 60:40, 50:50 and 20:80 for testing process and it will provide good results such as 78.50, 79.00, 69.25 and 88.50 respectively. In this analysis, 20:80 training and testing ratio
cases will give satisfactory results compared to another three cases. Because, image ratio cases can be used to enhance data as a prelude to visual interpretation. Digital processing and analysis may also be carried out to automatically identify targets and extract information completely without manual intervention by a human interpreter.

Here, Precision means percentage of selected faces that are correct. Recall is measured by percentage of corrected faces that are selected. And a combined measure that assesses the Precision/Recall tradeoff is F-measure. Using these precision, recall and F-measure we have to calculate the recognition results for different cases of partial face ratio cases. Table 4.1 shows the results obtained for the proposed graph based model.

Table 4.1 Recognition Rate of different partial conditions based on template matching.

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Partial Face Ratio Cases (Training and Testing)</th>
<th>Recognition Rate in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>70:30</td>
<td>78.50</td>
</tr>
<tr>
<td>2</td>
<td>60:40</td>
<td>79.00</td>
</tr>
<tr>
<td>3</td>
<td>50:50</td>
<td>69.25</td>
</tr>
<tr>
<td>4</td>
<td>20:80</td>
<td>88.50</td>
</tr>
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</table>
To evaluate the ability of the proposed technique to detect Partial faces, we acquired a dataset of 600 face images for training. The experimental results are obtained by correctly identified partial faces over a number of all faces in the available datasets. Each person has 4 testing ratio different partial occlusion cases Images ratios are 70:30, 60:40, 50:50 and 20:80 for testing process. In this evaluation image ratios provide better classification accuracy such as 65.23, 72.55, 82.36, 79.12 and the analysis of 70:30 training and testing ratio gives better result compared to other three cases.

Following table 4.2 shows the comparative results of the proposed model for various training and testing ratios with other different partial face recognition models.

<table>
<thead>
<tr>
<th>Partial Face Ratio Cases</th>
<th>Classification Accuracy in %</th>
<th>Method proposed in Naveen et al., 2015</th>
<th>Method proposed in Naveen et al., 2016</th>
<th>Proposed Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>30:70</td>
<td>68.25</td>
<td>74.50</td>
<td>65.23</td>
<td></td>
</tr>
<tr>
<td>50:50</td>
<td>67.50</td>
<td>69.25</td>
<td>72.55</td>
<td></td>
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<tr>
<td>60:40</td>
<td>70.50</td>
<td>79.00</td>
<td>79.12</td>
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<tr>
<td>70:30</td>
<td>69.25</td>
<td>78.50</td>
<td>82.36</td>
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</table>
In can be observed that in Table 4.2, the proposed model of 70:30 partial face case will provide better percentage of recognition results compare to other models.

In this Experimentation, a methodology for recognizing the face, when only its occluded and partial images such as eyes, nose, Cheeks and mouth etc are available is proposed. These images are very noteworthy for face recognition, because, it is potential to identify, authenticate and recognize the persons without having to see the full face.

In this work, performance evaluation of partial face recognition approaches has been studied. In this method, K-means is used as classifier for both full and partial facial components such as eyes, nose, Cheeks and mouth etc and training and testing purpose and accuracy evaluation has been done on ORL databases.

4.7 Conclusion

Experimental results show that the method mentioned in this report can achieve the high recognition accuracy specifically for 20:80 and 60:40 partially ratio cases for both Training and testing in a single face image. The system effectively detected and recognized the human faces in partially occluded conditions and worked better in different illuminations of face orientations.

In this research study, we proposed a novel method to carry out Partial face recognition technique based on graph matching, which provides better results are compared with other existing systems. The proposed method detects and recovers from SIFT features and then we have applied graph matching methodology based on centroid points and it will be worked as searching for a sub-graph in a main-graph, if it is present then recognition is true otherwise false. Experimental results show that the method mentioned in this work can achieve the high recognition rate. And in this approach we have introduced very new ratio cases because to get better performance and accuracy level using varying full and partial face features and then compare with previous works. The most vital challenging ratio cases are, 30:70, 50:50, 70:30 and 60:40. Among these cases better Accuracy specifically for 70:30 partially ratio case for both Training and testing in a single face image as well as image groups. In the first topology, clustering techniques are developed based on the graph method to
generate a complete vertex of a graph representation for face image then generate an adjacency matrix for all vertices of a single sample images. The results are obtained by testing the methods on the training face database (AR). This work shows a remarkable increase in the performance of the system with respect to the previous work based on the linear regression and template matching methods. The obtained results show the capability of the system to effectively detect and recognized the human faces in partially occluded conditions and worked better in different illuminations of face orientations.