

Face detection and its applications

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Abstract

In the past two decades, face detection has been proven as the most interesting research field from the domain of image processing. In this paper, we are going to describe some important aspects of face detection, which are very much useful in many applications like face recognition, facial expression recognition, face tracking, facial feature extraction, gender classification, identification system, document control and access control, clustering, biometric science, human computer interaction (HCI) system, digital cosmetics and many more [1]. Before that, I would like to focus on some well-known face detection techniques [2] and then some feature detection methods because until and unless we extract the important features (eyes, nose, mouth) from a face we won't be able to uniquely identify the person properly.

Keywords: Face detection, segmentation, facial features, contour, feature restoration, fiducial point.

1. Introduction

'Face detection' as the keyword itself reveals it's meaning that it concerns about where a face is located in an image. Now it may seem very easy but in reality we have to consider many constraints like single face or multiple faces, image rotation, pose etc. So there may arise some false detected regions of an image, which do not contain any face. In spite of all these problems there are lots of techniques available. Here we start our journey from the introduction of face detection and the areas where it is used.

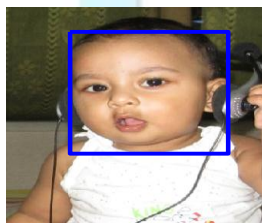


Figure 1: Result of a face detection algorithm

Face detection is a procedure by which we can able to extract face region from a human body. Now, the concept can be implemented in various ways but mainly we use four steps for this implementation. In the first step, we localize the face region that means we are anticipating those parts of an image where a face may present. In the second step we normalize the detected region, so that the alignments of various facial features are in the proper location. In the third step we extract various facial features like eyes, nose, mouth, etc. And in the forth step, we actually verify whether the anticipated parts are actually carrying out a face or not. We are doing this using some rules, template or image databases. The concept of extraction can be implemented by various techniques. There are a huge number of papers regarding the literature survey of face detection [3]. Most of the earlier work was on the frontal upright face, but recent work is mainly focus on non-frontal face with variation in their alignment. Also instead of still image, they are considering video stream images.

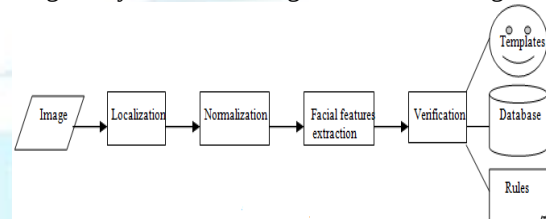


Figure 2: Steps of face detection

1.1 Localization

In this step we locate the region of an image where the face is located [4]. A face region only contains some facial features, now the number of features is application dependent. In the localization process we may go through some problems like false detection due to the presence of some obstacles on the face, poor quality of picture, orientation of head position, expression, etc. Hence we have to consider all these limitations to make the face detection process more powerful.

1.2 Normalization

After properly locating the region that contains a face, we must normalize the face region [5]. Using normalization process, we align the face region in such a way that all the facial features are in their proper location. Not only this, we may have to scale, rotate the image or some other transformation to correlate it with the entry in that database.

1.3 Facial feature extraction

In this step of face detection, we extract various facial features like eyes, nose, mouth, etc from the detected face region [4]. There are three types of feature extraction methods: Generic methods based on edges, lines, and curves; Feature template based methods that are used to detect various facial features like eyes, nose, and mouth; Color segmentation based methods that use face color instead of the intensity values; Appearance based methods that are able to manage changes in illumination conditions, shape, pose and reflectance and even to handle translation and partial occlusions.

1.4 Verification

In the verification process, we verify the relationships between various features with some database entry containing a huge number of faces. Now verification can not be done using only database entry, but also we can use some rule based techniques that uses the correlations of various facial features as its parameter, or by using so template based methods where we use a specific template model and try to find out a face region that fits into this model.

2. Face detection techniques

A huge number of representation techniques are available for face detection, including Knowledge-based, Feature invariant based, Template matching method, Appearance-based methods, Part-based methods, etc.

2.1 Knowledge-based methods

These rule-based methods encode human knowledge [6] of what constitutes a typical face. Usually, the rules capture the relationships between facial features. These methods are designed mainly for face localization, which aims to determine the image position of a single face.

2.2 Feature invariant approaches

These algorithms aim to find structural features that exist even when the pose, viewpoint, or lighting conditions vary, and then use these to locate faces. To distinguish from the knowledge-based methods, the feature invariant approaches start at feature extraction process and face candidates finding, and later verify each candidate by spatial relations among these features, while the knowledge-based methods usually exploit information of the whole image and are sensitive to complicated backgrounds and other factors. Readers could find more works in [4][7][8]. Face detection based on color information, random labeled graph matching fall in this category.

2.3 Template matching methods

In this category, several standard patterns of a face are stored to describe the face as a whole or the facial feature separately. The correlations between an input image and the stored pattern are computed for detection. These methods have been used for both face localization and detection. Deformable template matching [9] falls in this category, where the template of faces is deformable according to some defined rules and constraints.

2.4 Appearance-based methods

In contrast to template matching, the models (or templates) are learned from a set of training images, which should capture the representative variability of facial appearance. These learned models are then used for detection. More significant techniques are included in [1][2]. Examples of such type of methods are view-based face detection, Haar features and the Adaboost algorithm.

2.5 Part-based methods

With the development of the graphical model framework and the point of interest detection such as the difference of Gaussian detector [10] (used in the SIFT detector) and the Hessian affine detector, the part-based method recently attracts more attention. Some well-known approaches like face detection based on the generative model framework, component-based face detection based on the SVM classifier falls into this category.

3. Face recognition

Face detection is the first step towards many applications; one of them is face recognition. To recognize a face, we first detect the face and then we compare it with a set of known individuals present in a database to verify the identity of the person. The concept of face recognition can be further extended to various biometric approaches including fingerprint, iris/retina and voice recognition.

Face recognition techniques can be classified as two main approaches: Geometric approach or Feature-based approach where we analyze various features by means of their relationships [11] and holistic approach [12] such as Eigenfaces, neural networks [13].

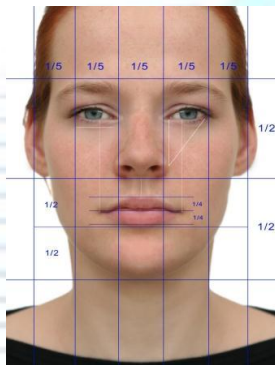


Figure 3: Face recognition using geometric approach

3.1 Geometric approaches or Feature-based approach to recognize a face

In Feature-based approaches [17] we first preprocess the input image to remove the noise, and then we extract distinctive facial features such as the eyes, mouth, nose, etc., and then compute the geometric relationships among those facial points, thus reducing the input facial image to a vector of geometric features. Standard statistical pattern recognition techniques are then employed to match faces using these measurements. Most of the previous works was based on this technique.

3.1.1 General approaches

The general approaches to feature based face recognition are concerned with using a priori information of the face to find local face features. Alternatively, another general approach is to find local significant geometries of the face that correspond to the local features of faces. We will now discuss the general approaches that have been applied to face recognition. Craw et al. (1992) [14]

were motivated to locate features within faces. Their approach utilized a priori information to accurately find local features. Their implementation consisted of two parts: first part was designed to identify individual features, such as the eyes (general location of the eyes), cheek, hair, jaw-line, mouth, mouth bits (edges and outline of the lips), head outline and the nose; the second part refined the features found from the first part by using a priori information to locate all pre-defined face features.

3.1.2 Elastic Bunch Graph Matching

A very well known feature-based approach is the Elastic Bunch Graph Matching method proposed by Wiskott et al. [15]. This technique is based on Dynamic Link Structures [16]. In these methods a face is considered as a graph having several inter connected nodes, which are called fiducial point. Each node corresponds to a specific feature point. For example, a node may corresponds to an eye, another node may corresponds to nose etc. There is also an arch between two fiducial points labeled with the distance between the correspondent nodes. Therefore the nodes for the input face graph are interconnected to form a graph like data structure, which is fitted to the shape of the face.

Here we recognize faces by matching the probe set represented as the input face graphs, to the gallery set that is represented as the model face graph. Hence, this model face graph can be conceptually thought of as a number of input face graphs stacked on top of each other and concatenated to form one model face graph, with the exception that this is applied to the gallery set instead of the probe set. Therefore, this would allow the grouping of the same types of face features from different individuals. For example, the eyes of different individuals could be grouped together to form the eye feature point for the model face graph and the noses of different individuals can be grouped together to form the nose feature point for the model face graph.

3.2 Holistic based face recognition

Unlike Feature based method, holistic based approaches use the global information rather than local feature information of the face. Here we represent the entire image with some small key values, which are directly derived from the pixel information of face images. This small key information is sufficient to uniquely differentiate individual faces. Here we describe two holistic approaches to face recognition called statistical and

AI approaches. An overview of some of the methods in these categories follows.

3.2.1 Statistical approach

In this simplest approach we represent the image as a 2D array containing the intensity values and recognition is performed by direct correlation comparisons between the input face and all the other faces in the database. Though it seems very simple to implement but they often face some common problems like variation in illumination, scale, pose, etc. More precisely, it is computationally very expensive and suffers from the usual shortcomings of straightforward correlation-based approaches, such as sensitivity to face orientation, size, variable lighting conditions, background clutter, and noise. The major encumbrance to these statistical approaches [18] is that, they attempt to perform classification in a very high dimensional space. To defeat this type of high dimensionality, some other schemes have been proposed. These types of schemes have been proven to reduce the dimension but obtain and retain the most meaningful feature dimensions before performing recognition.

3.2.2 Principal Component Analysis

A very popular method based on the concept of reduced dimensionality is Principal Component Analysis (PCA) [19]. PCA is a technique based on the concept of eigenfaces and was first introduced by Kirby and Sirovich in 1988. PCA is also known as Karhunen Loeve projection. It is one of the more successful techniques of face recognition and easy to understand and described using mathematics. This method uses Eigen faces. Eigen faces have been used to track human faces. They use a principal component analysis approach to store a set of known patterns in a compact subspace representation of the image space, where the Eigen vectors of the training image set span the subspace. In this method, the input image and images of the eigenface gallery should be the same size and we have to normalize the input image so that the eyes, nose and mouth are properly lined up i.e. we only consider the face region and that should be a frontal face. In case of a non-frontal face it may result poor performance. The primary advantage of this approach is that, it reduces the dimension of the data by some compression technique.

3.2.3 Linear Discriminant Analysis

Fisher's Linear Discriminant known as Linear Discriminant Analysis finds a small number of features that differentiates individual faces but

recognizes faces of the same individual. A small number of features are found by maximizing the Fisher Discriminant Criterion (Fisher 1936) [20], which is achieved by maximizing the grouping of individual faces whilst minimizing the grouping of different individual faces. Therefore by grouping faces of the same individual these features can be used to determine the identity of individuals.

As highly structured two-dimensional patterns, human face images can be analyzed in the spatial and the frequency domains. These patterns are composed of components that are easily recognized at high levels but are loosely defined at low levels of our visual system. Each of the facial components (features) has a different discrimination power for identifying a person or the person's gender, race, and age. There have been many studies of the significance of such features that used subjective psychovisual experiments. Using objective measures, in this section we propose a computational scheme for evaluating the significance of different facial attributes in terms of their discrimination potential. The results of this analysis can be supported by subjective psychovisual findings. To analyze any representation V , where V can be the original image, its spatial segments, or transformed images, we provide the following framework. First, we need a training set composed of a relatively large group of subjects with diverse facial characteristics. The appropriate selection of the training set directly determines the validity of the final results. The database should contain several examples of face images for each subject in the training set and at least one example in the test set. These examples should represent different frontal views of subjects with minor variations in view angle. They should also include different facial expressions, different lighting and background conditions, and examples with and without glasses. It is assumed that all images are already normalized to $m \times n$ arrays and that they contain only the face regions and not much of the subjects' bodies.

Second, for each image and subimage, starting with the two-dimensional $m \times n$ array of intensity values $I(x, y)$, we construct the lexicographic vector expansion $\phi \in R^{m \times n}$. This vector corresponds to the initial representation of the face. Thus the set of all faces in the feature space is treated as a high-dimensional vector space. Third, by defining all instances of the same person's face as being in one class and the faces of different subjects as being in different classes for all subjects in the training set, we establish a framework for performing a cluster separation analysis in the feature space. Also, having labeled all instances in the training set and

having defined all the classes, we compute the within- and between-class scatter matrices as follows:

$$S_w^{(V)} = \sum_{i=1}^L \Pr(C_i) \Sigma_i,$$

$$S_b^{(V)} = \sum_{i=1}^L \Pr(C_i) (\mu - \mu_i)(\mu - \mu_i)^T. \quad \dots(1)$$

Here S_w is the within-class scatter matrix showing the average scatter Σ_i of the sample vectors (V) of different classes C_i around their respective mean, vectors μ_i :

$$\Sigma_i = E[(V - \mu_i) \times (V - \mu_i)^T | C = C_i]. \quad \dots(2)$$

Similarly, S_b is the between-class scatter matrix, representing the scatter of the conditional mean, vectors (μ_i) around the overall mean vector μ . $\Pr(C_i)$ is the probability of the i th class. The discriminatory power of a representation can be quantified by using various measures. In this paper we use the separation matrix, which shows the combination of within- and between-class scatters of the feature points in the representation space. The class separation matrix and a measure of separability can be computed as

$$S^{(V)} = S_w^{-1} S_b$$

$$J_V = \text{sep}(V) = \text{trace}(S^{(V)}) \quad \dots(3)$$

J_V is our measure of the discrimination power (DP) of a given representation V . As mentioned above, the representation may correspond to the data in its original form (e.g., a gray-scale image), or it can be based on a set of abstract features computed for a specific task.

4. Facial features extraction

Facial features, such as eyes, nose, and mouth as well as their spatial relationships are very important in various applications like face recognition, facial expression detection, face tracking, lip reading etc. Hence, after detecting the face region from a cluttered image we should extract various features from the face, and then we verify them for our recognition purpose [21]. Extraction property of different features can be coded either by manually or by using some automatic learning procedure from a set of data. In case of automatic learning procedure if we want to increase the performance,

the system needs to be trained with several iterations. There are five types of feature extraction methods: Generic methods based on edges, lines, and curves; Gabor wavelets transform based face feature extraction; Feature template based methods that are used to detect various facial features like eyes, nose, and mouth; Color segmentation based methods that use face color instead of the intensity values; Appearance based methods that are able to manage changes in illumination conditions, shape, pose and reflectance and even to handle translation and partial occlusions. Now apart from these classification, there are some limitations also, those which are very difficult to implement. It is very difficult to design a robust facial feature detection algorithm with so many challenges like variable illumination, face orientation and facial expression. For example, when we are extracting eyes, it often happens that they are closed or open but covered with glasses that's why they are called rigid features. Extraction of mouth also faces some problem due to its rigidity, because when we want to extract the lips for uniquely identify a person we won't be able due to the unclear picture of the groove caused by the open mouth features. On the other hand nose is a non-rigid feature.

Recently, more reliable approaches have been developed to defeat the limitations stated above. For example structural matching methods such as Active Shape Model, compared to earlier methods these recent methods are much more robust in terms of handling variations in image intensity and feature shape. An even more challenging situation is feature restoration, which tries to recover features that are invisible due to some noise.

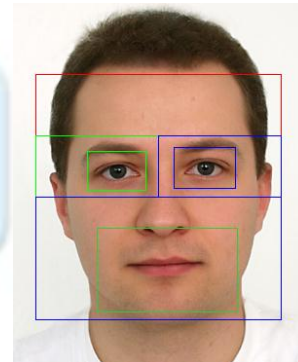


Figure 4: Facial feature extraction

4.1 Generic methods

The features are extracted by using relative positions and sizes of the important components of face. These group methods concentrate in two directions. First, detecting edges, directions of important components or region images contain

important components, then building feature vectors from these edges and directions. Using filters such as Canny filter to detect eyes or mouth region of face image, or the gradient analysis method, which is usually applied in this direction. Second, methods are based on the grayscale difference of important components and unimportant components, by using feature blocks, set of Haar-like feature [23] block in Adaboost method[22] to change the grayscale distribution into the feature. In LBP [24] method, it divides up the face image to regions (blocks) and each region corresponds with each central pixel. Then it examines its pixel neighbors, based on the grayscale value of central pixel to change its neighbor to 0 or 1. Therefore, every pixel will be represented in a binary string. Since then, we build histograms for every region. Then these histograms are combined to a feature vector for the face image.

4.2 Gabor Wavelets Transform Face Feature Extraction

Here, given the predicted feature positions, the multi-scale and multi-orientation Gabor wavelet matching method [25] is used to detect each facial feature in the vicinity of the predicted locations. In addition, the robust matching in the Gabor space also provides an accurate and fast solution for tracking multiple facial features simultaneously.

During tracking, in order to adaptively compensate for the facial feature appearance changes, the Gabor wavelet coefficients are updated dynamically at each frame to serve as the tracking template for the subsequent image frame. This updating approach works very well when no significant appearance change happens for each facial feature. However, under the large face orientations in which an arbitrary profile is assigned to the occluded feature during self-occlusions, as well as the significant facial expressions in which the facial feature appearance varies significantly, the tracker often fails.

Therefore, a shape-constrained correction mechanism is developed to tackle the above problems and to refine the tracking results. As a result, via our proposed technique, a set of twenty-eight facial features can be detected and tracked robustly in real-time under significant appearance changes in various facial expressions and face orientations.

4.3 Feature template based methods

This method group will extract feature [26] of face such as eyes, mouth, etc. based on template function [27] and appropriate energy function. An image region is the best appropriateness with template for eye, mouth or nose, which will minimize the energy. The methods have been proposed such as deformable template and genetic algorithms. In the deformable template method [28], the feature of interest, an eye, for example, is described by a parameterized template. An energy function is defined to links edges, peaks, and valleys in the image intensity with corresponding properties of the template. Then the template matching is done with the image, by altering its parameter values to minimize the energy function, thereby deforming itself to find the best fit. The final parameter values can be used as descriptors for the features.

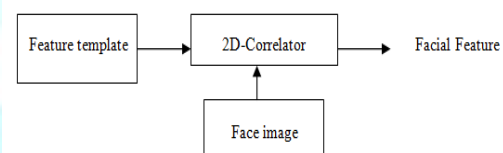


Figure 5: Template based feature detection

4.4 Color Segmentation Based Techniques

This approach makes use of skin color to isolate the face. Any non-skin color region within the face is viewed as a candidate for eyes or mouth [29]. Color based feature extraction use color models such as RGB, YCbCr or HSV with certain range of color pixels, skin region is detected [30]. After getting the skin region, facial features viz. Eyes and Mouth are extracted. The image obtained after applying skin color statistics is subjected to binarization. It is transformed to gray-scale image and then to a binary image by applying suitable threshold. This is done to eliminate the hue and saturation values and consider only the luminance part. This luminance part is then transformed to binary image with some threshold because the features for face are darker than the background colors. After thresholding, opening and closing operations are performed to remove noise. These are the morphological operations, which are used to remove holes. Then eyes, ears, nose can be extracted from the binary image by considering the threshold for areas which are darker in the mouth than a given threshold. So triangle can be drawn with the two eyes and a mouth as the three points in case of a frontal face. And it is easy to get an isosceles triangle (i j k) in which the Euclidean distance between two eyes is about 90-110% of the Euclidean distance between the center of the right/left eye and the mouth. After getting the

triangle, it is easy to get the coordinates of the four corner points that form the potential facial region. Since the real facial region should cover the eyebrows, two eyes, mouth and some area below the mouth, this coordinates can be calculated. The performance of such techniques on facial image databases is rather limited, due to the diversity of ethnical backgrounds.

4.5 Appearance Based Techniques

This type of methods is using linear transformation and statistical methods to find the basic vectors to represent the face. Methods have been proposed in the literature for this aim such as PCA and ICA [31]. In detail, goal of PCA method is to reduce the number of dimensions of feature space, but still to keep principle features to minimize loss of information. PCA method uses second-order statistic in the data. However, PCA method has still disadvantages. High order dependencies still exist in PCA analysis, for example, in tasks as face recognition, much of the important information may be contained in the high order relationships among the image pixels, not only second-order. While other method ICA uses technique independent component analysis, it is an analysis technique not only use second-order statistic but also use high order statistic. PCA can be derived as a special case of ICA, which uses Gaussian source models. PCA is not the good method in cases non Gaussian source models. It has been observed that many natural signals, including speech, natural images, are better described as linear combinations of sources with super Gaussian distributions. In that case, ICA method better than PCA method because: I) ICA provides a better probabilistic model of the data. II) It uniquely identifies the mixing matrix. III) It finds an unnecessary orthogonal basic, which may reconstruct the data better than PCA in the presence of noise such as variations lighting and expressions of face. IV) It is sensitive to high-order statistics in the data, not just the covariance matrix but it require that the image matrices must be first transformed into vectors, which are usually of very high dimensionality. This causes expensive computational cost and sometimes the singularity problem. The appearance based method group has been found the best performer in facial feature extraction because it keeps the important information of face image, rejects redundant information and reflects face global structure.

5. Facial Expression Recognition

Human facial expression recognition by a machine can be described as an interpretation of human facial characteristics via mathematical algorithms [32]-[36]. Gestures of the body are read by an input sensing device such as a web-cam. It reads the movements of the human body and communicates with computer that uses these gestures as an input. These gestures are then interpreted using algorithm either based on statistical analysis or artificial intelligence techniques. The primary goal of gesture recognition research is to create a system which can identify specific human gestures and use them to convey information. By observing face, one can decide whether a man is serious, happy, thinking, sad, feeling pain and so on. Recognizing the expression of a man can help in many of the areas like in the field of medical science where a doctor can be alerted when a patient is in severe pain. It helps in taking prompt action at that time. In this paper the main focus is to define a simple architecture that recognizes the human facial expression.



Figure 6: Facial expression detection

5.1 Neural Network based facial expression recognition

Here we describe a neural network based facial expression detection technique. This system is divided into five modules as shown in the following figure.

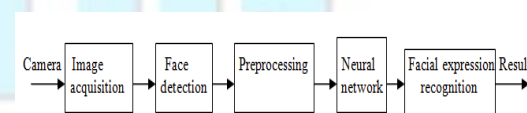


Figure 7: Simple architecture of facial expression recognition

Each box shown in the above figure is treated as one module. The first module captures the image using the web cam. Second module is for face detection, which can detect the human face from the captured image. A set of modules bounded by a boundary line represent pre-processing block. It consists of histogram equalization, edge detection, thinning, and token generation modules. The next

module is the training module to store the token information that comes from the image pre-processing module. This training has been done using back propagation neural network [37]. And the last module is the token matching and decision making called recognition module, which produces the final result. The following flow chart represents how all the modules work.

Face detection is a process that aims to locate a human face in an image. The process is applied on stored image or images from a camera. Human face varies from one person to another. This variation in faces could be due to race, gender, age, and other physical characteristics of an individual. Therefore face detection becomes a challenging task in computer vision. It becomes more challenging task due to the additional variations in scale, orientation, pose, facial expressions, and lighting conditions. Many methods have been proposed to detect faces such as neural networks [38], skin locus, and color analysis. Since these detected faces become an input to the recognition of the gestures, it is important to get rid of non-facial information in the image. In this paper, the technique proposed by Viola and Jones is used to detect the face. The main reason for using this technique is that its implementation is feature based and relatively fast compared to other available techniques. The following figure represents the detected faces with their corresponding input images.

5.2 Template Matching

For expression recognition, we first adopt template matching for its simplicity. In training, the LBP histograms of face images in a given class are averaged to generate a histogram template for this class. In recognition, a nearest-neighbour classifier is adopted: the LBP histogram of the input image is matched with the closest template. We select Chi square statistic (X^2) as the dissimilarity measure for histogram. It is observed that facial features contributing to facial expressions mainly lie in some regions, such as eye area and mouth area; these regions contain more useful information for facial classification. Therefore, a weight can be set for each face region based on the importance of the information it contains. Our weighted (X^2) statistic is

$$\chi_w^2(S, M) = \sum_{i,j} w_j \frac{(S_{i,j} - M_{i,j})^2}{S_{i,j} + M_{i,j}} \dots (4)$$

where S and M are two LBP histograms, w_j is the weight for region j.

5.3 Support Vector Machine (SVM)

Support Vector Machine [39] is a popular technique for classification [40]. SVM performs an implicit mapping of data into a higher dimensional feature space, where linear algebra and geometry can be used to separate data that is only separable with nonlinear rules in the input space.

Given a training set of labeled examples $T = \{(x_i, y_i), i = 1, \dots, l\}$ where $x_i \in R^n$ and $y_i \in \{1, -1\}$, the new test data x is classified by the following function:

$$f(x) = \text{sgn}\left(\sum_{i=1}^l \alpha_i y_i K(x_i, x) + b\right) \dots (5)$$

where α_i are Lagrange multipliers of a dual optimization problem, and $K(x_i, x)$ is a kernel function. Given a nonlinear mapping ϕ that embeds input data into feature space, kernels have the form of

$K(x_i, x_j) = \langle \phi(x_i), \phi(x_j) \rangle$. SVM finds a linear separating hyperplane with the maximal margin to separate the training data in feature space. b is the parameter of the optimal hyperplane.

6. Conclusions

In this paper, we have covered a detail discussion on the various stages of any face detection technique. Also, some popular well-known face detection techniques are described very briefly. Recently, face detection techniques have been employed in different applications such as face recognition, facial feature extraction, detection of facial expression, which are also the subjects to be focused of this paper. Hence, before developing any kind of method of your choice, if you go through this paper, you will definitely get an overview various ways and applications used in face detection process.

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