

FACE DETECTION USING CURVELET TRANSFORM AND PCA

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Abstract

Objectives: This Paper aims at the Detection and Recognition of the face which are the significant concepts in the Image processing field. Though many systems are available, they are constraint to the factors such as Pose, Illumination, Occlusion and etc. So, a powerful algorithm is needed to accurately detect and recognize the face. **Methods:** This proposed method avails mainly two concepts. They are the Curvelet Transform and Principal Component Analysis. The Curvelet transform is effective in representing the image in a sparse manner. The PCA is used for the Dimension reduction operation. **Findings:** The existing methods can only represent the face as edge points or lines. But, the Curvelet transform can represent

the image with Curve discontinuities which in turn increases the operational efficiency and improves the time complexity. **Applications:** This technique can be useful in the Security and the Law enforcement systems.

Keywords: Curvelet Transform, Canny operator, Curve discontinuities, Principal Components, Dimension reduction

1. Introduction

The process of locating faces in an image is termed as face detection. Face recognition is identifying the person from that image. Features extracted from the image plays vital role in the process of face recognition and this can be done only when the face is detected¹. So the preliminary step in face recognition is face detection. Normal objects are rigid bodies with

the same structure always. But in face detection, the object face is not perfectly rigid and rigidity changes with changes in expressions, appearance of the face. This makes the face detection a challenging task and also when conditions such as illumination, gesture and expression are not ideal, recognition accuracy suffers dramatically. Existing systems such as Wavelet transform, DCT approach fail etc. express the edges, direction of the images and curve discontinuities. Hence Curvelet transform is proposed which overcomes these problems and also sparsely represents the image².

2. Existing Techniques

There were various existing systems in the history. Each of which has certain advantages and disadvantages³.

PAPER	REMARKS
Rapid Object Detection using a Cascade of Boosted Simple Features	Works with gray scale images. Trained to detect only front facing images. Fastest in this category. Cannot detect profile and in-plane rotated faces.
Fast multi-view face detection	Trained to detect profile and rotated faces. Detection rate was less and the time requirement was more compared to Viola-Jones method

Haar-like Features for Rapid Object Detection	Trained to detect profile faces. Uses gray-scale image. Detection rate was less compared to Viola-Jones method.
Analysis of Training parameters for classifiers based on Haar-like features to detect human faces	Classifiers were trained to detect rotated and illumination varied faces. Detection rate is reduced compared as only few features were used.
A short Introduction to boosting	A generic algorithm to improve the performance of an existing learning algorithm.
Face Detection using Discrete Gabor Jets	Face detection based on edge related information. Computational time requirement is more. Extracted information for face detection can also be used for face recognition.
Discrete Fourier Transform	Suffers from curve discontinuities, cannot detect edges.

Table1. Existing Systems for Face Detection

3. Proposed Technique

The performance of all the transforms explained above is very low in terms of their time complexity and accuracy. So, the mechanism which can take care of all the performance metrics is needed⁶. The Curvelet transform can be the effective method to resolve the problems such as low accuracy, efficiency and speed. This transform uses the concept of representing an image in a sparse manner. The whole process of recognizing a face consists of Curvelet transform and the Principal Component Analysis (PCA)⁷.

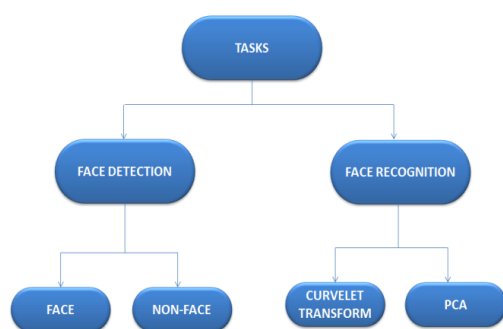


Figure1. Proposed system

3.1. Representation of an image in Curvelet Domain

The Curvelet concept gives an alternative solution to represent and process the image in the manipulation. It differs from the other transforms by representing the image as curve like discontinuities.

The older methods are effective in representing the image only as point or line discontinuities. This needs large number of computations to process the image. So, the Curvelet transform method can be the best to achieve the desired results. In this method, the image given is transformed into the frequency domain by taking the FFT⁷. Generally, the curves like features are easily extracted from the frequency domain rather than the spatial domain. After taking the curve features, IFFT of the image is computed.

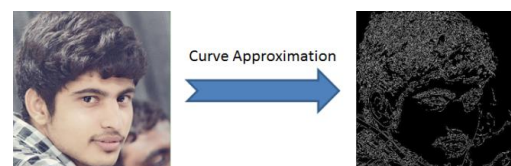


Figure2. Curvelet Domain Representation of the Image

3.2. Sparse Feature representation of Face

Already, the sparse representation provided by the Curvelet transform reduces the computation time as considerable. This computational time can again be reduced by the process called Principal Component Analysis (PCA). This PCA is mainly utilized for the purpose of Dimension reduction of the given image to be processed.

3.2.1. Principal Component Analysis (PCA)

PCA is a significant method for reducing the dimension of the data. The dimension reduction is achieved by removing the redundant data present of the image. The identification of the redundant data is very important to make the PCA more accurate. The major components are given importance to eliminate the unnecessary data and form the curve⁷. The major components are found on the fact that they lie in the direction along which the maximum data spread occurs.

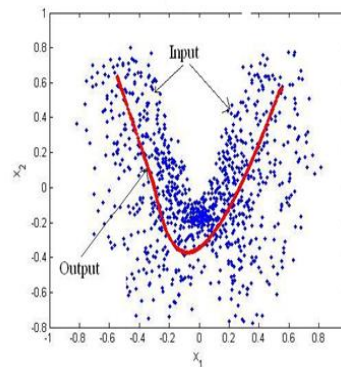


Figure3. PCA performed on the Image

The eigen vectors are found using the Covariance matrix of the input image. These eigen vectors will be separated by the distance called eigen value. If the eigen values are small, It indicates the redundant data. On the other hand, If the eigen value is large, It represents the major components present on the image. Thus, the redundant eigen vectors are neglected as they have very less contribution for representing the image's curve details¹¹. To achieve the dimension reduction, the higher dimensional image is projected into the PCA space which detects the major components.

$$\text{input data} = \sum_{i=1}^k w_i E_i$$

Where,

‘i’ indicates the position of the eigen vector.

‘k’ indicates the number of eigen vectors.

Calculations for the PCA

1. The given image is converted into the matrix format of vectors according to the presence of edges.
2. The mean vector is then calculated by taking the mean along the rows of the above matrix.

The men vector Ψ is given as

$$\Psi = \begin{pmatrix} \mu_1 \\ \mu_2 \\ \mu_3 \\ \vdots \\ \mu_{MN} \end{pmatrix}_{MN \times 1}$$

3. Calculate the mean subtracted data and form a matrix A.

$$A = [\Phi_1 \Phi_2 \dots \Phi_L]$$

Where,

$$\Phi_i = \Gamma_i - \Psi.$$

The above equation shows that the mean subtracted data is obtained by taking the difference between the eigen vectors and mean vectors.

4. Obtain the Covariance matrix from matrix A.

$$C = AA^T$$

This matrix consists of the eigen vectors that is used as the major components of the curve in the

image. These eigen vectors are also called as eigen faces and it is different for each input image thus reducing the error in the face recognition.

3.3. Operational Stages in the System

The face recognition is done by using these two phases,

- (i). Training Phase
- (ii). Testing Phase

The whole operation can be understood by considering the following Flowchart. These Operations includes from the image acquisition to the Graphical user interface through the significant Steps called training phase and the testing phase



Figure4. Operational Stages

3.3.1. Training the System

In this Phase, the Training data is used to train the system or hardware. This training is needed to determine whether the given image is a face or non-face.

The training phase has the following steps,

- i. Selecting the training data
- ii. Representing the image in Curvelet Domain
- iii. Training the system with algorithm
- iv. Classifying the image

3.3.1.1. Selecting the training data

This is the important stage as the entire operation starts with the training data.

PARAMETERS	VARIATIONS PRESENT IN THE IMAGE
TYPE OF IMAGE	Gray scale or Color Image
ORIENTATION OF FACE	Front facing, Rotated Profile, etc.
EXPRESSIONS	Neutral, Smiling, Sad
BACKGROUND	Color and Brightness of the Background

Table2. Selecting the parameters

3.3.1.2. Representing the image in Curvelet Domain

The Curvelet transform is done on the image. This produces the output image made of curves i.e. curve like discontinuities¹¹. The diagram shown below explains how the curve is made from the pixels of an image.

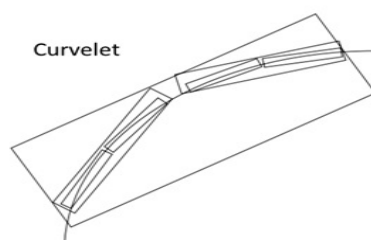


Figure5. Formation of curves from the pixels

3.3.1.3. Training the system with algorithm

The training algorithm can be explained with the help of this Flowchart.

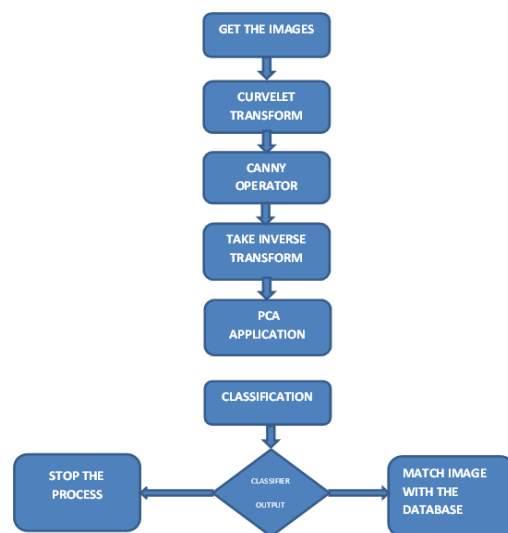


Figure6. Flowchart for the algorithm

1. The input image is given to the system for the face Recognition.
2. The Curvelet transform is taken then for the image given.
3. These image is stored as the features for the comparison purpose.
4. The PCA is done on the feature vectored image for the dimension reduction.
5. Finally, the image is classified into the face or non-face.

3.3.2. Testing Phase

In the Testing Phase, The input image is compared with the training database to display the matched output. The performance of this system availing Curvelet and PCA concepts is much better than the old techniques.

4. Performance Comparison

The existing systems that use pixels (i.e.,) image intensity values to recognize faces are compared with the proposed face detection system. This performance comparison uses standard AT&T ORL database for face detection and recognition. Standard AT&T ORL face database has 400 gray scale images (112×92) of 40 individuals with 10 different poses and expressions each.

RECOGNITION METHOD	RECOGNITION RATE	RECOGNITION TIME
STANDARD EIGEN FACE[1]	91.80%	0.042 sec
PCA+DCT [8]	94.00%	0.051 sec
PCA + SVM [3]	94.00%	0.048 sec
PCA + RBF NEURAL NETWORKS [13]	94.10%	0.049 sec
WAVELET FACE[10]	92.30%	0.045 sec
WAVELET+PCA[10]	93.50%	0.048 sec
WAVELET+2DPCA[10]	95.30%	0.047 sec
CURVELET FACE[11]	92.90%	0.038 sec
PROPOSED METHOD	99.40%	0.041 sec

Table 3. The comparison of existing and proposed method on ORL face database

To test the performance of the system, we compared the proposed system with well-established techniques such as standard eigen face, Discrete Cosine transform, Neural networks, wavelets and normal Curvelet methods. The experiment is carried out based on an average of ten random face images from the database. The recognition rates and recognition times are tabulated in Table 3.

The table shows that the speed and efficiency of the proposed algorithm are better than that of the other algorithms. The performance comparison indicates that the proposed method has better accuracy and less time complexity under different illumination, different expressions, different poses and also occlusion conditions.

5. Results

The MATLAB GUI implementation of the face detection system that uses curvelet transform and PCA is shown in figures. In the first figure, both

the images have distinct poses and the second figure shows the ability of the system to detect different illumination levels.

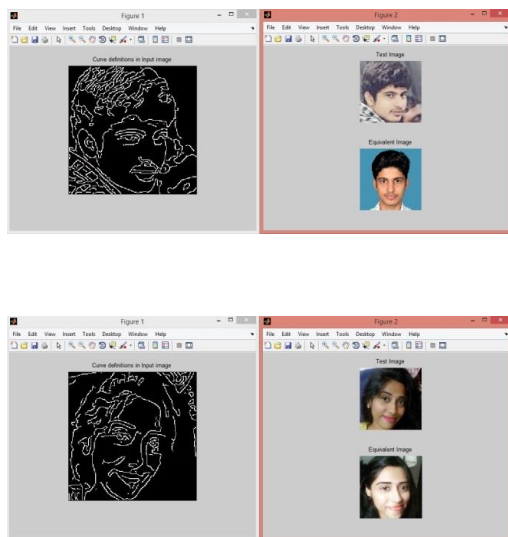


Figure7. MATLAB GUI implementation of proposed face detection system with different pose and illumination levels

6. Applications

Unlike biometrics, voice recognition, fingerprint scanning, eye detection and iris scan, the person

need not to be in close contact with the system. This is one of the major advantages in Face detection and recognition system. If the technology reaches the required performance level, it can be widely used for many applications.

AREA	APPLICATIONS
SECURITY	Access Control, User verification
PERSONAL SECURITY	Login information, Expression Interpretation
BIOMETRICS	Person Identification, Automated identity verification
LAW ENFORCEMENT	Video surveillance, Suspect tracking
ARTIFICIAL INTELLIGENCE	Computer Vision
COMMERCIAL	Video games

Table4. Applications of proposed face detection system

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