Image Processing by Preserving a Manifold Structure

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Abstract
Recently, a number of research efforts have shown that the face images possibly reside on a nonlinear sub manifold. Earlier systems failed to discover the underlying structure, if the face images lie on a nonlinear sub manifold hidden in the image space. This paper proposes a new approach to image analysis (representation and recognition), which explicitly considers the manifold structure. To be specific, the manifold structure is modeled by a nearest-neighbor graph which preserves the local structure of the image space. An efficient subspace learning algorithm for face recognition should be able to discover the nonlinear manifold structure of the face space. A face subspace is obtained based on Locality Preserving Projections (LPP). It is able to preserve local information giving the best representation and lower error rates. Finally, recognition is successfully performed on different images to identify a face.

Keywords: *Manifold, Locality Preserving Projections (LPP), Dimensionality Reduction, Portable Gray map (.pgm), Face Recognition*

1. Introduction

A number of major advances have occurred in face recognition, with many systems capable of achieving recognition rates greater than 90%. Face recognition systems generally fall into two categories: Verification and Identification. Face verification is a 1:1 match that compares a face image against a template face images, whose identity is being claimed. On the contrary, Face identification is a 1:N problem that compares a query face image against all image templates in a face database to determine the identity of the query face.

The system takes a facial image, measure characteristics such as the distance between the eyes, length of the nose, and angle of the jaw, which are nodal points and creates a unique file called a "template." Using templates, it then compares that image with another image and produces a score that measures how similar the images are to each other. Typical sources of images for use in facial recognition include video camera signals and pre-existing photos such as those in driver's license databases.

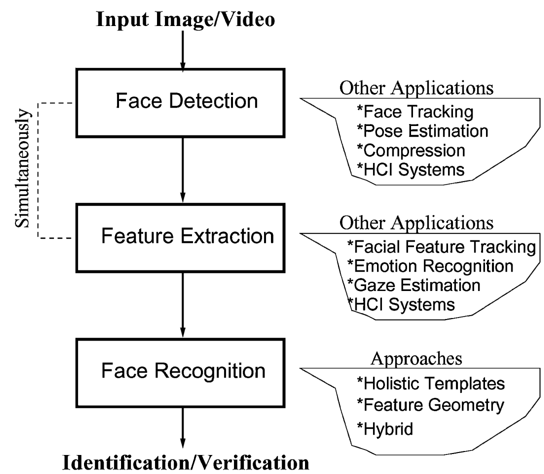

Fig. 1 Representation of an image Recognition System

However real-world scenarios remain a challenge, because face acquisition process can undergo to a wide range of variations like illumination variations, expressions and pose changes. Illumination variations occur due to skin reflectance properties and due to the internal camera control. Several 2D methods do well in recognition tasks only under moderate illumination variation, while performances noticeably drop when both illumination and pose changes occur. Pose changes affect the authentication process, because they introduce projective deformations and self-occlusion. Even if methods dealing with up to 32-head rotation exist, they do not solve the problem considering that security cameras can create viewing angles that are outside of this range when positioned. On the contrary, with exception of extreme expressions such as scream, the algorithms are relatively robust to facial expression.

This paper deals with the manifold ways of face analysis (representation and recognition) in order to detect the underlying nonlinear manifold structure in the manner of linear subspace learning. By discovering the manifold structure, the algorithm can identify the person with different expressions, poses and lighting conditions. The manifold structure is approximated by the adjacency graph computed from the data points and a transformation matrix is computed which maps the face images into a face subspace.

2. System Function and Design

The purpose of system design aims to identify the modules that should be in the system, the specifications of these modules, and to interact with each other to produce the desired results. The system consists of 3 modules and each module has an independent functionality and purpose. The 3 modules are Processing, Training & Testing modules. The processing module is designed for the processing of images. The images are read one by one and go through a filtering process. This process is important for highlighting the core gray-map values of the image for a perfect detection. The responsibility of training module is to process each image in the database and to generate the Laplacian Array matrix. The detection of the images happens in the Testing module. This module reads the input image and compares it with the images processed in the training module. The result is then compared with the threshold value and a matching image is selected if the difference value is below than the threshold.

3. Software Implementation

Java has a wide variety of package to implement the requirement and a number of classes and methods can be used for implementation purpose. Core Java contains concepts like Exception Handling, Multi-Threading and many derived classes which can be well utilized for implementation. The user interface can be done with AWT and Swings. Event handling can be performed with delegate event model. The objects are assigned to the listener that observe for event and when the event takes place, the corresponding methods to handle that event will be called by the listener which is the form of interfaces and executed.

Java Media Framework which is used for the camera capture implementation of the test images is an API for incorporating media data such as audio and video into Java applications and applets.

The database MySql is the most popular OpenSource database management system which is fast, reliable and easy to use. It works in Client-Server and embedded systems.

4. Experimental Setup

For the algorithm to work correctly, the database was constructed with a training set of 40 images of 20 individuals i.e. 2 images per individual, subjected to different expressions and lighting conditions. The testing images are captured from the camera. All these images are grayscale images of type .pgm (P5 binary). All the images are resized to 80X80 pixels with 256 gray levels per pixel for processing.

5. Implementation Based on Laplacian Faces Approach

The recognition process has the following steps:

1) The Laplacianfaces is calculated from the training set of face images.
2) Then the new face image to be identified is projected into the face subspace spanned by the Laplacianfaces.
3) Finally, the new face image is identified by a nearest neighbor classifier.

5.1 Calculation of FaceTemplate matrix

Find the average matrix for database images and save it in a variable, say FaceTemplate[][], refer Fig. 2.

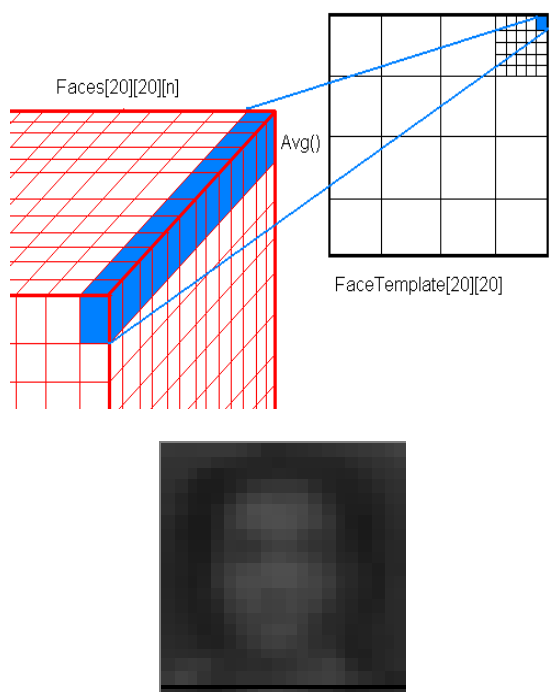

Fig. 2 Calculation of FaceTemplate

5.2 Calculation of LaplacianFaces matrix

Then subtract FaceTemplate[][] from Faces[][][] and save the output value in another variable, say LaplacianFaces[][][].

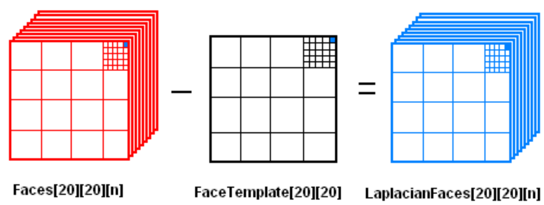

Fig. 3 Calculation of LaplacianFaces

5.3 Calculation of TestFace matrix

Read the input image and find the matrix for input image and save it in a variable, say, TestFace[][].

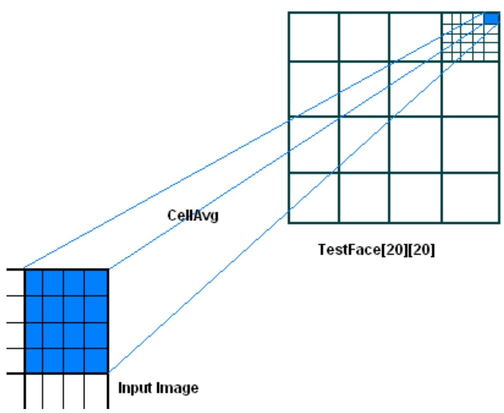

Fig. 4 Calculation of TestFace

5.4 Calculation of TestLaplacianFace matrix

To find the Laplacian difference of all database images, first subtract TestFace[][] with FaceTemplate[][] and save the output value in a variable, say, TestLaplacianFace[][].

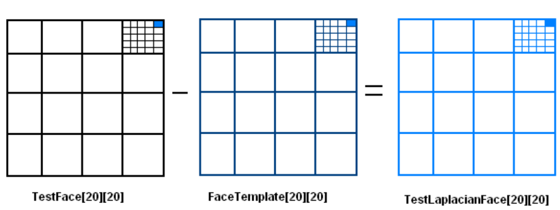

Fig. 5 Calculation of TestLaplacianFace

5.5 Calculation of TotalLaplacianDiff

Subtract the LaplacianFaces[][][] from TestLaplacianFace[][] and store value in a variable, say, TotalLaplacianDiff.

5.6 Identification of the Face image

The new face image is then identified as follows:

i. Find the database image having minimum difference.
ii. Check the minimum difference with threshold value. If minimum difference is less than the threshold value, the image is matched, otherwise not matched.

6. Applications

Table 1: Applications of Face Recognition

Areas	***Specific Applications***
Entertainment	Video game, virtual reality, training programs
	Human-robot-interaction, human-computer-interaction
Smart cards	Drivers' licenses, entitlement programs
	Immigration, national ID, passports, voter registration
	Welfare fraud
Information Security	TV Parental control, personal device logon, desktop logon
	Application security, database security, file encryption
	Intranet security, internet access, medical records
	Secure trading terminals
Law enforcement and surveillance	Advanced video surveillance, CCTV control
	Portal control, post-event analysis
	Shoplifting, suspect tracking and investigation

7. Conclusion

Recognition is successfully performed on different database images to identify the person based on the Laplacian face recognition algorithm which gave an accuracy of 99.5%.If the input image matches with the database image set, the matched image is displayed on the output console.

The manifold ways of face analysis (representation and recognition) are discussed in this paper in order to detect the underlying nonlinear manifold structure in the manner of linear subspace learning. This is the first devoted work on face representation and recognition which explicitly considers the manifold structure. The manifold structure is approximated by the adjacency graph computed from the data points. Using the notion of the Laplacian of the graph, a transformation matrix is computed which maps the face images into a face subspace.

8. Future Work

The results of this image processing and recognition system are really promising but it is clear that many improvements are possible. The main improvements can be listed as follows:

- This system performs well when all of the images are frontal. But, when non-frontal surveillance photos are compared to a database of frontal enrollment pictures, matching drops dramatically to levels that are untenable. This can be left for future work.
- Another challenge is that if the database grows exponentially, it has the potential to slow down comparisons dramatically. This might be dealt through the distributed network computing technology which can search a million picture databases in under a second.

References

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