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Face Identification

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ABSTRACT

A smart environment is one that is able to identify people, interpret their actions, and react appropriately. Face recognition devices are ideal for such systems, since they have recently become faster, cheaper. When combined with voice-recognition, they are very robust against changes in the environment. Moreover, since humans primarily recognize each other by their faces and voices, they feel comfortable interacting with an environment that does the same.

Facial recognition systems are built on computer programs that analyze images of human faces for the purpose of identifying them. The programs take a facial image, measure characteristics such as the distance between the eyes, the length of the nose, and the angle of the jaw, and create a unique file called a "template." Using templates, the software 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.

These systems depend on a recognition algorithm, such as the hidden Markov model. The first step for a facial recognition system is to recognize a human face and extract it for the rest of the scene. Next, the system measures nodal points on the face, such as the distance between the eyes, the shape of the cheekbones and other distinguishable features.

In this project, we describe Locality Preserving Projection (LPP), a new algorithm for learning a locality preserving subspace. The complete derivation and theoretical justifications of LPP can be traced back to. LPP is a general method for manifold learning. It is obtained by finding the optimal linear approximations to the Eigen functions of the Laplace Beltrami operator on the manifold. These nodal points are then compared to the nodal points computed from a database of pictures in order to find a match. Obviously, such a system is limited based on the angle of the face captured and the lighting conditions present.
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Introduction to Face Identification Technology

Face Identification technology is a computer application that can identify or verify a person from a video frame or a digital image. The other ways to determine a face is by using the facial features from an image or a facial database.

Figure 1.1

Facial Identification technology is mainly used to verify the identification of a person and can be used in security systems, biometrics, and mobile devices and mostly used by the FBI to check if the person is marked as a criminal in their facial database.

It has shown advancements in computing capabilities in the past few decades by enabling similar recognitions automatically. In early 1900’s when facial recognition technology was introduced, it had the basic and simple geometric models that were used to detect the facial images.

History

Face Identification technology was first introduced in 1960. The first semi-automated system for face identification required the administrator to locate the physical features like nose, mouth and eyes on the picture before calculating the differences and ratios to a common reference point, which were then referred to the reference data.

In the year 1970, Goldstein, Harmon and Lesk used 21 specific markers like hair color, lip thickness to automate the recognition. The problem with both theories introduced in 1960’s and 1970’s was that the measurements were to be manually computed.

In the year 1988, Kirby and Sirovich applied a standard linear algebra technique to the face identification problem. This was considered as a milestone in this technology as it showed that less than 100 values were required to accurately code an aligned and normalized image.

In the year 1991, Turk and Pentland discovered that the enduring errors could be used to detect faces in an image. This discovery enabled reliable real-time automated face recognition system. Although the approach was held back due to the environmental factors, it notwithstanding created momentous interest in furthering the facial identification technologies.

Today the science behind the software is much more mathematical and automatic. The earlier models required a greater human input and were semi-automatic. Facial identification is determined by calculating the distance between the eyes, width of the nose, depth of the eye sockets, the shape of the cheekbones, the length of the jaw line.
Face Identification is one of the few biometric methods that beholds the position of both high accuracy and low intrusiveness. Face identification has drawn the attention of researchers in fields from security, psychology to image processing. Till date, numerous algorithms have been introduced towards the face identification technology.

When compared to other biometric systems, face identification has distinct advantages because of its non-contact process. Face images can be captured from a long distance unlike finger prints. Moreover, the face images that have been recorded and archived can be later be used to identify a person.

Though face identification is an old discovery, it is still evolving throughout globe. The technology behind the face identification is just getting started.

Apple is looking at ways for iOS users to automatically share photos with tagged friends. Meanwhile researchers in Germany are working on a new technology that can also work in dark.

3 Steps Involved in Face Identification

Capture → Extraction → Comparison → Matching

Capture: A physical sample is captured by the system during enrollment.

Extraction: Unique data is extracted from the sample and a template is created.
Comparison: The template is then compared to a new sample.

Matching: The system then decides if the template is matching to the new sample or not.

As time passed by, new algorithms were introduced towards the facial identification technology to make it more accurate and helpful for the community.

The figure below shows a framework for the face identification system.

4 Techniques Used in Face Identification

The traditional face identification algorithms identify facial features by extracting landmarks, features from an image. An algorithm may analyze the relative position, size, shape of the eyes, nose, jaw, cheekbones. These features are then matched with images that has same features. While other algorithms normalize a gallery of images.

Three Dimensional Recognition: A new trend claims this technology to be more accurate as it uses 3D sensors to capture information of a face. One of the advantages of this technology is that it is not effected by the lighting changes unlike other algorithms. The sensors work by using structured light on the face. Up to a dozen or more of these censors can be placed on the same CMOS chip to capture different parts of the spectrum.

Skin Texture Analysis: This trend uses the visual details of the skin, as captured in the standard digital or scanned images. This technique turns unique lines, spots and patterns into mathematical space.

Thermal Camera: This procedure will only detect the shape of the face and will ignore all the other accessories like glasses, chains, hats and or make up. Though it is one of the best procedures used towards the facial identification, it also has a drawback that the database is limited.

5 Notable Software in Market

5.1 digiKam (KDE)

digiKam is a free and open-source image organizer and tag editor written in C++ utilizing the KDE platform.

5.2 iPhoto (Apple)
iPhoto is a digital photograph manipulation software application developed by Apple Inc. It was included with every Macintosh personal computer from 2002 to 2015, when it was replaced with Apple's Photos application.

5.3 Lightroom (Adobe)
Adobe Photoshop Lightroom is a photo processor and image organizer developed by Adobe Systems for Windows and OS X.
5.4 **Picture Motion Browser (Sony)**

*Picture Motion Browser* (PMB) is a software application from Sony for organizing and editing digital photos. In 2012, PMB was succeeded by Sony's PlayMemories Home.

5.5 **FotoBounce (Applied Recognition Inc)**

*FotoBounce* is a photo organizer using world-class face recognition to tag, organize, and privately share your photos, indexed by the people in them.

5.6 **DeepFace (Facebook)**

*DeepFace* is a deep learning facial recognition system created by a research group at Facebook. It identifies human faces in digital images.

Currently, a considerable measure of facial distinguished advancement is concentrated around smartphone requisitions. Smartphone interaction facial distinguished capacities incorporate picture tagging. What's more different interpersonal integrative purposes and also customize promoting. An exploration less group in Carnegie Mellon need formed a verification about idea iPhone app that cam wood detract a picture for a distinct inside seconds. What's more profit those individual's name, date about conception furthermore, the individual’s Social Security Number.

Facebook utilization facial distinguished product to help mechanize client tagging done photographs. Here’s how facial distinguished meets expectations done Facebook: every occasion when a distinct may be labeled in a photograph, the product provision saves data sufficient information need been gathered around an utilization that majority of the data on distinguish the consequently recommend tagging the individuals portraits for that person’s sake.

Windows 10 introduces a number about new applications and features, yet a standout amongst the more exceptional additions will be Windows hello. A under a Windows 10 pc examining will be those an extraordinary Intel existing Pc's with empower inherent RealSense cameras.

6 **Introduction to Algorithms**

6.0 **LPP (Locality Preserving Projections):** Locality preserving projections (LPP) is a linear transform that optimally preserves the local structure of the data set, and explicitly considers the manifold structure modeled by an adjacency graph. LPP has been applied in many domains successfully.

Locality Preserving Projections (LPP) are linear projective maps that arise by solving a variational problem that optimally preserves the neighborhood structure of the data set. LPP should be seen as an alternative to Principal Component Analysis (PCA) -- a classical linear technique that projects the data along the directions of maximal variance. When the high dimensional data lies on a low dimensional manifold embedded in the ambient space, the Locality Preserving Projections are obtained by finding the optimal linear approximations to the eigenfunctions of the Laplace Beltrami operator on the manifold. As a result, LPP shares many of the data representation properties of nonlinear techniques such as Laplacian Eigenmaps or Locally Linear Embedding. Yet LPP is linear and more crucially is defined everywhere in ambient space rather than just on the training data points. LPP may be conducted in the original space or in the reproducing kernel Hilbert space into which data points are mapped. This gives rise to kernel LPP.
Locality Preserving Projection (LPP) is a linear approximation of the nonlinear Laplacian Eigenmap. The algorithmic procedure is formally stated below:

- **Constructing the adjacency graph:** Let G denote a graph with m nodes. We put an edge between nodes i and j if xi and xj are "close". There are two variations:
  1. ∈-neighborhoods. [parameter ∈ R] Nodes i and j are connected by an edge if \( kx_i - x_j 2 < \) where the norm is the usual Euclidean norm in \( \mathbb{R}^n \).
  2. k nearest neighbors. [parameter k ∈ N] Nodes i and j are connected by an edge if i is among k nearest neighbors of j or j is among k nearest neighbors of i.

Note: The method of constructing an adjacency graph outlined above is correct if the data actually lie on a low dimensional manifold. In general, however, one might take a more utilitarian perspective and construct an adjacency graph based on any principle (for example, perceptual similarity for natural signals, hyperlink structures for web documents, etc.). Once such an adjacency graph is obtained, LPP will try to optimally preserve it in choosing projections.

- **Choosing the weights:** Here, as well, we have two variations for weighting the edges. W is a sparse symmetric m × m matrix with \( W_{ij} \) having the weight of the edge joining vertices i and j, and 0 if there is no such edge.
  1. Heat kernel. [parameter t ∈ R]. If nodes i and j are connected, put \( W_{ij} = e^{-kx_i - x_j 2 t} \). The justification for this choice of weights can be traced back to [2].
  2. Simple-minded. [No parameter]. \( W_{ij} = 1 \) if and only if vertices i and j are connected by an edge.

- **Eigenmaps:** Compute the eigenvectors and eigenvalues for the generalized eigenvector problem:
  \[ XLXT a = \lambda XDXT a \]

where D is a diagonal matrix whose entries are column (or row, since W is symmetric) sums of W, \( D_{ii} = \sum j W_{ji} \). L = D − W is the Laplacian matrix. The i th column of matrix X is xi. Let the column vectors \( a_0, \cdots, a_{l-1} \) be the solutions of equation (1), ordered according to their eigenvalues, \( \lambda_0 < \cdots < \lambda_{l-1} \). Thus, the embedding is as follows:

\[ x_i \rightarrow y_i = A^T x_i , A = (a_0, a_1, \cdots, a_{l-1}) \]

where \( y_i \) is a l-dimensional vector, and A is a n × l matrix.


The maps are designed to minimize a different objective criterion from the classical linear techniques.

**6.1 PCA (Principal Component Analysis):** Derived from Karhunen-Loeve's transformation. Given an s-dimensional vector representation of each face in a training set of images, Principal Component Analysis (PCA) tends to find a t-dimensional subspace whose basis vectors correspond to the maximum variance direction in the original image space. This new subspace is normally lower dimensional (t<<s). If the image elements are considered as random variables, the PCA basis vectors are defined as eigenvectors of the scatter matrix.


**6.2 ICA (Independent Component Analysis):** Independent Component Analysis (ICA) minimizes both second-order and higher-order dependencies in the input data and attempts to find the basis along which the data (when projected onto them) are statistically independent. Bartlett et al. provided two architectures of ICA for face recognition task: Architecture I - statistically independent basis images, and Architecture II - factorial code representation.


**6.3 LDA (Linear Discriminant Analysis):** Linear Discriminant Analysis (LDA) finds the vectors in the underlying space that best discriminate among classes. For all samples of all classes the between-class scatter matrix \( SB \) and the within-class scatter matrix \( SW \) are defined. The goal is to maximize \( SB \) while minimizing \( SW \), in other words, maximize the ratio \( \det|SB|/\det|SW| \). This ratio is maximized when the column vectors of the projection matrix are the eigenvectors of \( (SW^{-1} \times SB) \).
EBGM (Elastic Bunch Graph Matching): Elastic Bunch Graph Matching (EBGM). All human faces share a similar topological structure. Faces are represented as graphs, with nodes positioned at fiducial points. (Exes, nose...) and edges labeled with 2-D distance vectors. Each node contains a set of 40 complex Gabor wavelet coefficients at different scales and orientations (phase, amplitude). They are called "jets". Recognition is based on labeled graphs. A labeled graph is a set of nodes connected by edges, nodes are labeled with jets, and edges are labeled with distances.

Ref: L. Wiskott, J.-M. Fellous, N. Krueuger, C. von der Malsburg, Face Recognition by Elastic Bunch Graph Matching, Chapter 11 in Intelligent Biometric Techniques in Fingerprint and Face Recognition, eds. L.C. Jain et al., CRC Press, 1999, pp. 355-396

AAM (Active Appearance Model): An Active Appearance Model (AAM) is an integrated statistical model which combines a model of shape variation with a model of the appearance variations in a shape-normalized frame. An AAM contains a statistical model if the shape and gray-level appearance of the object of interest which can generalize to almost any valid example. Matching to an image involves finding model parameters which minimize the difference between the image and a synthesized model example projected into the image.


Three-D Morphable Model: Human face is a surface lying in the 3-D space intrinsically. Therefore the 3-D model should be better for representing faces, especially to handle facial variations, such as pose, illumination etc. Blantz et al. proposed a method based on a 3-D morphable face model that encodes shape and texture in terms of model parameters, and algorithm that recovers these parameters from a single image of a face.


SVM (Support Vector Machine): Given a set of points belonging to two classes, a Support Vector Machine (SVM) finds the hyperplane that separates the largest possible fraction of points of the same class on the same side, while maximizing the distance from either class to the hyperplane. PCA is first used to extract features of face images and then discrimination functions between each pair of images are learned by SVMs.


HMM (Hidden Markov Model): Hidden Markov Models (HMM) are a set of statistical models used to characterize the statistical properties of a signal. HMM consists of two interrelated processes: (1) an underlying, unobservable Markov chain with a finite number of states, a state transition probability matrix and an initial state probability distribution and (2) a set of probability density functions associated with each state.


GMFD (Generalized Matching Face Detection Method): Provides high speed and high accuracy for facial detection and facial features extraction. The main logic for facial recognition within GMFD is a modified Generalized Learning Vector Quantization (GLVQ) algorithm, which searches and selects face area candidates after the generation of potential eye pairs. GLVQ is based on a neural network and is not easily fooled by attempts to conceal identity via the usage of caps, hats, sunglasses, etc

PSM (Perturbation Space Method): Converts two-dimensional images (e.g., photographs) into three-dimensions (such a process is called “Morphing”). The three-dimensional representations of the head are then rotated in both the left-to-right and up-and-down directions. Further processing applies differing illumination across the face, which greatly enhanced the chances of a query “faceprint” for matching against its true mate from the database.
6.11 **(ARBM) Adaptive Regional Blend Matching Method:** To reduce the impact of adverse local changes (e.g., varying facial expression caused by smiling and blinking eyes, and intentional changes caused by the wearing of caps, hats and glasses), NEC’s face recognition technology utilizes the ABRM algorithm, which reduces the impact of such local changes during the matching process. The minimization of the local changes guarantees the overall face recognition accuracy.

7 **Requirements:**

7.1 **Hardware Requirements:**

Camera integrated system

7.2 **Software Requirements:**

Windows operating system
Visual Studio
Open-CV version 2.10

8 **References:**


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