INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATION & MANAGEMENT

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FACE RECOGNITION IN COMPUTER VISION

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ABSTRACT

Computer Vision is the process by which descriptions of physical scenes are inferred from images. Computer vision has also been explained as the enterprise of automating and integrating a wide range of processes and representations for vision perception. A facial recognition system is a computer application for automatically identifying a person from a digital image or a video frame from a video source that is computer vision. The multiple images of each person, then for each person compute in eigenspace from the points computed for each image of that person. The method requires that all images in the database contain faces of about the same size, position, and orientation, so they can be compared using this global distance function in eigenspace.

KEYWORDS

face recognition, computer vision.

1. INTRODUCTION

Computer vision is the technology of automated image analysis which is used in many fields. Computer vision is a field which includes methods for acquiring, processing, analyzing, and understanding images and, in general, high-dimensional data from the real world in order to produce numerical or symbolic information, *e.g.*, in the forms of decisions.[1] The inferences in the development of this field have been to duplicate the abilities of human vision by electronically perceiving and understanding an image.[2] This image understanding can be seen as the symbolic information from image data using models constructed with the aid of geometry, physics, statistics, and learning theory.[3] Computer vision has also been explained as the enterprise of automating and integrating a wide range of processes and representations for vision perception.[4]

2. APPLICATIONS

The various application of computer vision in image processing are listed as below:

- Medical image analysis
- Aerial photo interpretation
- Vehicle exploration and mobility
- Material-handling For example, part sorting and picking
- Inspection For example, integrated circuit board and chip inspection
- Assembly
- Navigation
- Human-computer-interfaces For example, handwriting recognition, optical character recognition (OCR), face recognition, gesture recognition, gaze tracking, 3D model acquisition
- Multimedia For example, video databases, image compression, image browsing, content-based retrieval
- Telepresence/Tele-immersion/Tele-reality For example, tele-medicine, virtual classrooms, video conferencing, interactive walkthroughs

3. FACE RECOGNITION

A facial recognition system is a computer application for automatically identifying or verifying a person from a digital image or a video frame from a video source. One of the ways to do this is by comparing selected facial features from the image and a facial database.
It is typically used in security systems and can be compared to other biometrics such as fingerprint or eye iris recognition systems.[1]

3.1 FACE RECOGNITION USING AN EIGENSPACE REPRESENTATION

There is an problem such as given a training set of *M* images, each of size *N* x *N* pixels, where each image contains a single person's face, approximately registered for face position, orientation, scale, and brightness, and a test image, determine if the person in the test image is one of the people in the training set, and, if so, indicate which person it is.

- Need a similarity metric for measuring the "distance" between two face images
- Need a way of representing face features to be compared within the similarity metric

3.2. EIGENSPACE REPRESENTATION OF IMAGES

- An *N* x *N* image can be "represented" as a point in an N^2 dimensional **image space**, where each dimension is associated with one of the pixels in the image and the possible values in each dimension are the possible gray levels of each pixel. For example, a 512 x 512 image where each pixel is an integer in the range 0,..., 255 (i.e., a pixel is stored in one byte), then image space is a 262,144-dimensional space and each dimension has 256 possible values.
- If we represented our *M* training images as *M* points in image space, then one way of recognizing the person in a new test image would be to find its **nearest neighbour** training image in image space. However, this approach would be very slow since the size of image space is so large, and would not exploit the fact that since all of our images are of faces, they will likely be clustered relatively near one another in image space. So, instead, let's represent each image in a lower-dimensional feature space, called **face space** or **eigenspace**.
- We have *M'* images, $\mathbf{E}_1, \mathbf{E}_2, \ldots, \mathbf{E}_{M'}$, called **eigenfaces** or **eigenvectors**. These images define a **basis** set, so that each face image will be defined in terms of how similar it is to each of these basis images. That is, we can represent an arbitrary image **I** as a weighted (linear) combination of these eigenvectors as follows:

1. Compute the **average image**, **A**, from all of the training images $\mathbf{I}_1, \mathbf{I}_2, \ldots, \mathbf{I}_M$:

$$\mathbf{A} = \frac{1}{M} \sum_{i=1}^{M} \mathbf{I}_i$$

2. For $k = 1, \ldots, M'$ compute a real-valued weight, w_k, indicating the similarity between the input image, **I**, and the *k*th eigenvector, $\mathbf{E}_k$:

3. $w_k = \mathbf{E_k}^T * (\mathbf{I} - \mathbf{A})$

where **I** is a given image and is represented as a column vector of length N^2, $\mathbf{E_k}$ is the *k*th eigenface image and is a column vector of length N^2, **A** is a column vector of length N^2, * is the dot product operation, and - is pixel by pixel subtraction. Thus w_k is a real-valued scalar.

4. $\mathbf{W} = [w_1, w_2, ..., w_{M'}]^T$ is a column vector of weights that indicates the contribution of each eigenface image in representing image **I**. So, instead of representing image **I** in image space, we'll represent it as a point **W** in the *M'*-dimensional weight space that we'll call **face space** or **eigenspace**. Hence, each image is **projected** from a point in the high dimensional image space down to a point in the much lower dimensional eigenspace. In terms of compression, each image is represented by M' real numbers, which means that for a typical value of M'=10 and 32 bits per weight, we need only 320 bits/image to encode it in face space. (we must also store the M' eigenface images, which are each N^2 pixels, but this cost is amortized over all of the training images.)

The image **I** can be approximately reconstructed from **W** as follows:

$$\mathbf{I} \sim \mathbf{A} + \sum_{i=1}^{M'} w_i * \mathbf{E_i}$$

This reconstruction will be exact if $M' = min(M, N^2)$. Hence, representing an image in eigenspace won't be exact in that the image won't be reconstructible, but it will be a pretty good approximation that's sufficient for differentiating between faces.

4. FACE RECOGNITION ALGORITHM

The entire face recognition algorithm can now be given:

1. Given a training set of face images, compute the *M'* largest eigenvectors, $\mathbf{E_1}, \mathbf{E_2}, ..., \mathbf{E_{M'}}$. *M'* = 10 or 20 is a typical value used. Notice that this step is done once "offline."
2. For each different person in the training set, compute the point associated with that person in eigenspace. That is, use the formula given above to compute $\mathbf{W} = [w_1, ..., w_{M'}]$. Note that this step is also done once offline.
3. Given a test image, $\mathbf{I_{test}}$, project it to the *M'*-dimensional eigenspace by computing the point $\mathbf{W_{test}}$, again using the formula given above.
4. Find the closest training face to the given test face:
5. d = min $|| \mathbf{W_{test}} - \mathbf{W_k} ||$
6. k

where $\mathbf{W_k}$ is the point in eigenspace associated with the *k*th person in the training set, and $|| \mathbf{X} ||$ denotes the Euclidean norm defined as $(x_1^2 + x_2^2 + ... + x_n^2)^{1/2}$ where **X** is the vector $[x_1, x_2, ..., x_n]$.

7. Find the distance of the test image from eigenspace (that is, compute the projection distance so that we can estimate the likelihood that the image contains a face):
8. dffs = $|| \mathbf{Y} - \mathbf{Yf} ||$

where $\mathbf{Y} = \mathbf{I_{test}} - \mathbf{A}$, and **Yf** = sum_i_from_1_to_M' ($w_{test,i}$ * $\mathbf{E_i}$).

9. **If** *dffs* < *Threshold1* ;

Test image is "close enough" to the eigenspace; associated with all of the training faces to; believe that this test image is likely to be some; face (and not a house or a tree or something other than a face)

then if *d* < *Threshold2*

then classify $\mathbf{I_{test}}$ as containing the face of person *k*,

where *k* is the closest face in the eigenspace to

$\mathbf{W_{test}}$, the projection of $\mathbf{I_{test}}$ to eigenspace

else classify $\mathbf{I_{test}}$ as an unknown person

else classify $\mathbf{I_{test}}$ as not containing a face

5. CONCLUSION

The performance using a 20-dimensional eigenspace resulted in about 95% correct classification on a database of about 7,500 images of about 3,000 people. If training set contains multiple images of each person, then for each person compute the average point in eigenspace from the points computed for each image of that person. The method requires that all images in the database contain faces of about the same size, position, and orientation, so they can be compared using this global distance function in eigenspace. If there are multiple images of a 3D object (e.g., a person's head from many different positions and orientations), then the points in eigenspace corresponding to the different 3D views can be combined by fitting a hypersurface to all the points, and storing this hypersurface in eigenspace as the description of that person. Then, classify a test image as the person corresponding to the closest hypersurface.

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