

Facial Recognition Using PCA

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Abstract

Facial recognition is an important area of research of computer science with obvious implications. As one would imagine, it is not a simple task. A large number of variables come into play including facial expressions, hairstyles, camera angle, and lighting. Our paper in particular examines Principal Component Analysis (PCA). We used databases that contained faces with different lighting and with different face angles. The PCA algorithm worked exceptionally well on classifying these data sets.

Introduction

Facial recognition is a varied area of study with applications to security, biometrics, and personal use. In terms of security, one could imagine a situation where an authority has a database of images of faces and security footage of a criminal. It is rarely feasible for a human to manually comb through a database, but a sophisticated enough facial recognition system could possibly determine the identity of the criminal. In biometrics, using a camera to confirm a subject's identity is cheaper than a fingerprint reader or an iris scanner, and is more convenient than having to manually enter a password. The personal uses of facial recognition include training some images of a photo album based on user-based tags and then automatically tagging any new photos.

However, all of these applications have clear deficiencies, some of which come from variations of facial expressions, hairstyles, camera angles, and lighting. These factors can contribute to a significant amount of inaccuracy in facial recognition. For personal uses such photo tagging, a wrongly tagged photo is not a very large issue. However, if an authorized user cannot log into their own system because they recently got a haircut, or even worse, an unauthorized user was able to log in, this is a significant security deficiency.

One of the challenges of facial recognition is the extraordinarily large space of possible images. For instance, a 100×100 image will have 10 000 pixels. A naïve method would be to take an image we want classified and compare it against known images using some notion of distance. However, given the aforementioned size of the data, this will be a very computationally intensive task. Instead, Principal Component Analysis (PCA) is used to extract the features with the most amount of variance. Using PCA, one

Table 1: Results

	Yale	Yale (modified)	Yale B
Accuracy			

can reduce the space from a dimension of 10 000 to something much more manageable, such as 10 or 20 dimensions. Once these principal components are found, we can project an image to be classified onto the principal components and determine which face it most closely resembles.

Algorithm

The PCA Algorithm begins by taking a two-dimensional matrix representing the image and flattening it into a long one-dimensional vector. Each vector is then mean-centered. The algorithm then finds the set of orthonormal vectors which has the largest projection onto the mean-centered vectors. These vectors are given by the eigenvectors of the covariance matrix of WW^T , where W is the matrix of the column vectors of the mean-centered images placed next to each other. The eigenvectors corresponding to the largest eigenvalues will produce the greatest variance. To classify an image, we project the image onto a selected number of eigenvectors with the largest eigenvalues and then find the distance (Euclidean, Manhattan, or otherwise) to each face class to see which one most closely resembles the image.

Results

The unmodified Yale Database contained images with varying facial expressions as well as lighting that created shadows that significantly obscured the images. When trying to classify these images with the shadow, accuracy was low because the region of the shadow made it more similar to other images with the shadow as opposed to an image of an actual face, in particular, the correct person's face. Once we removed the the images with the shadows from the first database, our system classified the face correctly with $> .95$ accuracy.

Conclusion

As our results showed, facial recognition on a controlled data set can work exceedingly well. Possible areas for fur-

ther research include testing how well the algorithm performs on other variations of images. In the real world, images will not all be so similar, so PCA is not suitable for general-purpose use, but it still can be used in controlled environments. There are other facial recognition systems that can better handle these variations in images, yet even the best ones have some deficiencies, whether it be accuracy, time, or space. Facial recognition is a continually-evolving field facing numerous challenges, but it has continued to improve over the years. In fact, advanced facial recognition systems using mathematical texture analysis can differentiate between identical twins according to Ralph Gross, a researcher at the Carnegie Mellon Robotics Institute. This is one of the many possible directions in which this growing field may go.

Acknowledgements

We used Yale Face Database and Yale Face Database B.

References

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