Biometrics – Face Recognition

A Comparative Study of Face Recognition Algorithms and Techniques

Robert Barbulescu
MSc Intelligent Systems & Robotics
De Montfort University

Face Recognition

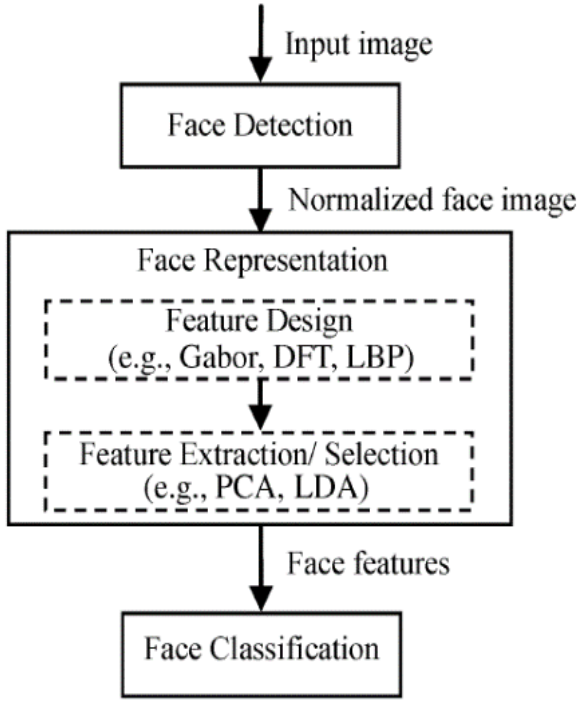
- Uses a two or three-dimensional image of the visible physical structure of an individual's face for recognition purposes [1].
- A method for identifying people based on a database with prior registration of the person.
- Becoming increasingly adopted as the main authentication methods for personal devices (smartphones, tablets, laptops), as well as being implemented as a corporate solution for increasing security.
- Used in security for identification and authentication.
- Face recognition systems should be able to automatically detect a face in an image by extracting its features and then recognize it, regardless of lighting, expression, illumination, ageing, transformations (translate, rotate and scale image) and pose [2].

[1] J. C. Price and J. S. Forrest, 'Commercial aviation airport security', in Practical Aviation Security, Elsevier, 2016, pp. 205–263.
[2] D. N. Parmar and B. B. Mehta, 'Face Recognition Methods & Applications', arXiv:1403.0485 [cs], Mar. 2014, Accessed: May 07, 2021. [Online]. Available: http://arxiv.org/abs/1403.0485.

Face Recognition System

- A face recognition system compromises the following:
- ***1. Face Detection***
- The determinations of the sizes and positions of the face, mainly human faces, from digital content such as images and videos, and is primarily a component of broader face recognition systems [4].
- Popular Algorithms: *Viola-Jones, LBP, MTCNN.*
- ***2. Feature Extraction***
- The procedure of extracting relevant information from a face image, involves several steps – dimensionality reduction, feature extraction and feature selection [5].
- Algorithms available: *PCA, ICA, LDA.*
- ***3. Face Classification***
- Allows for the classification of the features extracted from the person to recognize, the classification algorithm provides a score of similarity or distance at its output vector as well as the reference feature of the database and subsequently, the score is compared with a fixed threshold and returns a final evaluation regarding the identity [6].
- Main methods: *Eigenfaces, LBPH, SVM, CNN.*

Face Recognition System Architecture [3].



[3] S. Xie, S. Shan, X. Chen, and J. Chen, 'Fusing Local Patterns of Gabor Magnitude and Phase for Face Recognition', IEEE Transactions on Image Processing, vol. 19, no. 5, pp. 1349–1361, May 2010, doi: 10.1109/TIP.2010.2041397.
[4] T. M. Murphy, R. Broussard, R. Schultz, R. Rakvic, and H. Ngo, 'Face detection with a Viola–Jones based hybrid network', IET biom., vol. 6, no. 3, pp. 200–210, May 2017, doi: 10.1049/iet-bmt.2016.0037.
[5] A. Bouzalmat, J. Kharroubi, and A. Zarghili, 'Comparative Study of PCA, ICA, LDA using SVM Classifier', JETWI, vol. 6, no. 1, pp. 64–68, Feb. 2014, doi: 10.4304/jetwi.6.1.64-68.
[6] A. Hajraoui, M. Sabri, and M. Fakir, 'Face recognition: synthesis of classification methods', undefined, 2016. https://www.semanticscholar.org/paper/Face-recognition%3A-synthesis-of-classification-Hajraoui-Sabri/a759a2f6dd34cd776b9d8841788b1185ad24de3a (accessed May 07, 2021).

Labeled Faces in the Wild (LWF)

- A database of human face images designed as an aid in studying the problem of unconstrained face recognition [7].
- The database is a large set of unconstrained face images, meaning faces that display a high range of variation in light, pose, expression, gender, race, etc.
- Advantage: the 'arbitrary' images, a lot of datasets have images that are carefully centred and aligned in the middle, LWF simulates better the real-world situations in which the recognition systems may be subjected to various angle and conditions when performing face recognition.
- The dataset contains:

- *13,233 target face images,*
- *Some images have more than one face, the person in the centre of the image is given a unique name,*
- *The dataset is formed of 5749 different individuals from which 1680 have two or more images and the remaining 4069 have one image only,*
- *Images are structured as 250 x 250 pixels JPEG images*

[7] G. B. Huang, M. Mattar, T. Berg, and E. Learned-Miller, 'Labeled Faces in the Wild: A Database for Studying Face Recognition in Unconstrained Environments', presented at the Workshop on Faces in 'Real-Life' Images: Detection, Alignment, and Recognition, Oct. 2008, Accessed: May 07, 2021. [Online]. Available: https://hal.inria.fr/inria-00321923.

PCA, ICA, LDA using SVM Classifier

- **PCA** - *dimensionality reduction method*, discovers a set of projection vectors which retains most properties of the original data.
  - *Uses the eigenface approach where faces are converted into a subset of the main features (eigenfaces) and are used as the initial training set for learning.*
  - *Recognition is performed by having any new addition (image) projected into the eigenface subspace, after which the position in eigenface space is compared to the position of known individuals.*
- **ICA** - *generalization of PCA.*
  - *PCA decorrelates the input data with second-ordered statistics which creates compressed data with minimum mean-squared reprojection error.*
  - *In contrast ICA minimizes both second and higher order dependencies in the input data and tries to discover the basis where the data is statistically independent.*
- **LDA** - *traditional approach in pattern recognition,* technique looks for a linear combination of features or linear transformation that allows for the separation of two classes or objects.
- **SVM** - *learning machine method,* implements the basic idea of non-linear transform so that the sample space will be linearly separable after changing its characteristics.
  - *SVM does essentially a separation or discrimination between two classes.*

System Development

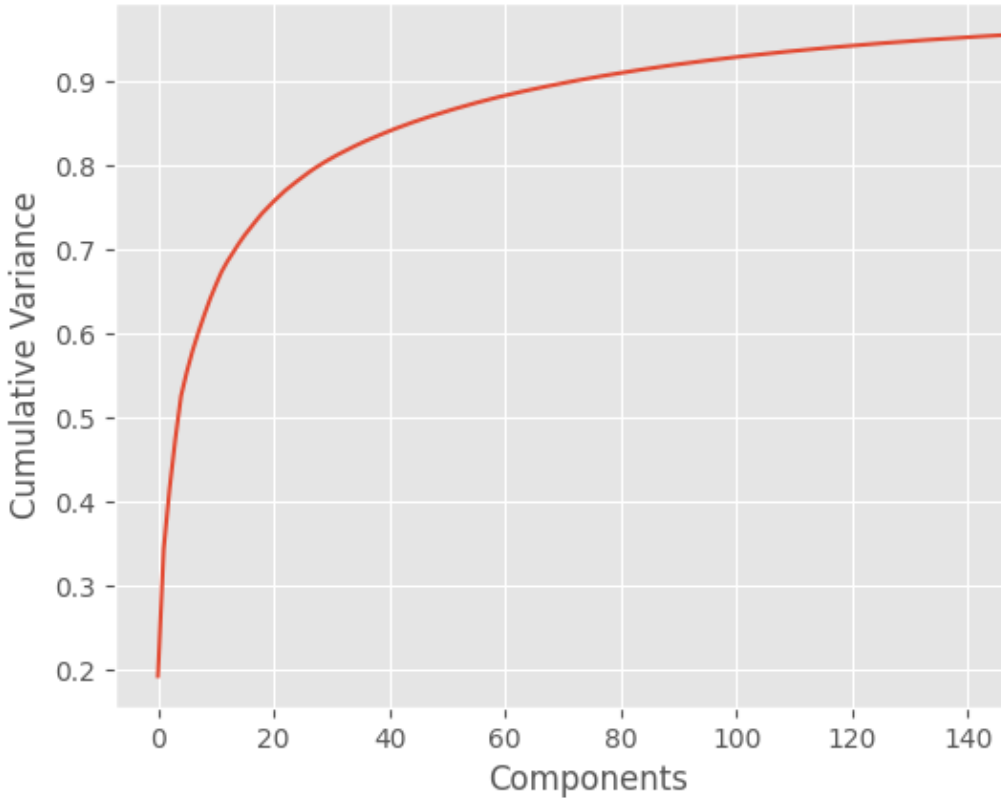
- **Data Pre-processing**

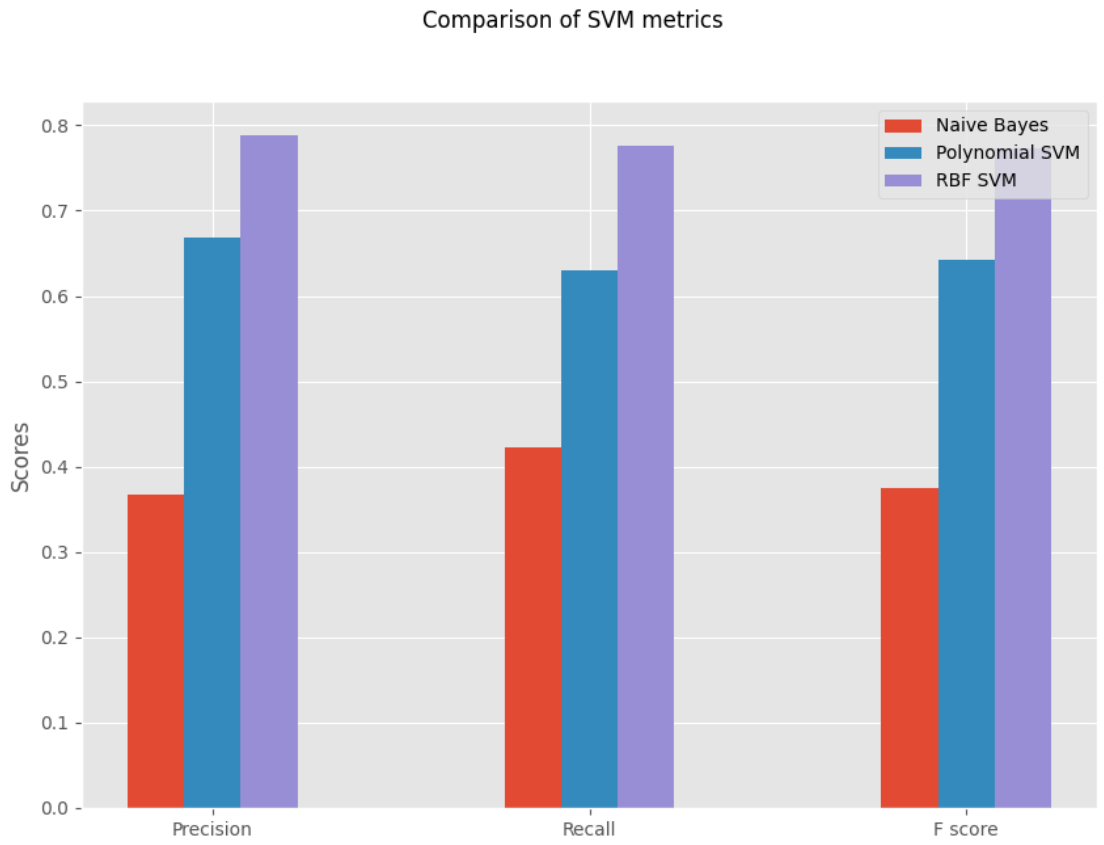
Number of Data Samples: 1288
Size of a data sample: 1850
Number of Class Labels: 7
Dimensions: 62x47

- **Dataset is then structured as a ratio of 25% testing and 75% training.**
  - **Training Set (966, 1850)**
  - **Testing Set (322, 1850)**
- Initial dimensions = 2914 pixels
- Finding ideal number of components with PCA gives us 140 and above.
  - *The component number was set to 150 for our initial design.*
- **SVM Metrics Comparison for Kernel function**
  - *Optimal kernel function is RBF.*
- Using Grid Search to find best estimator:

Best estimator found by grid search:
SVC(C=1000.0, class_weight='balanced', gamma=0.005)

PCA Cumulative Variance & SVM Kernel Functions Metrics





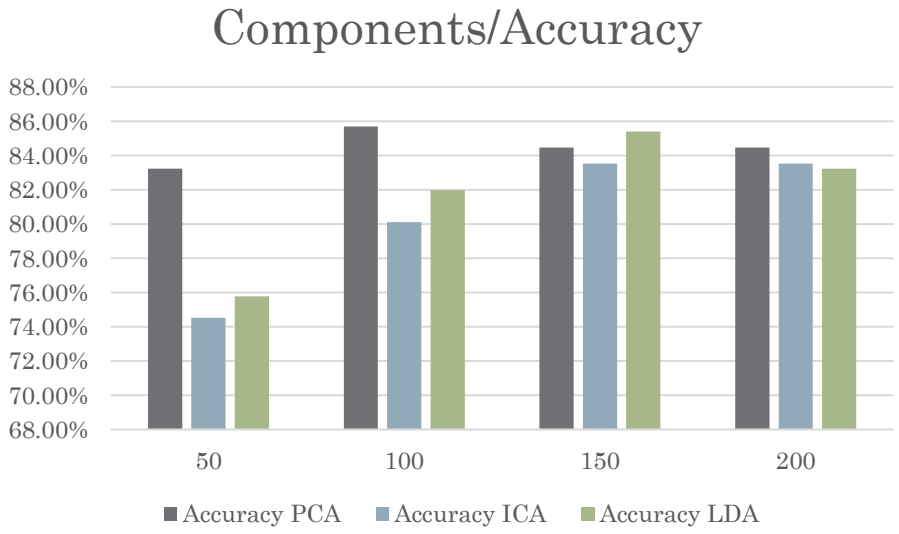
In the figure above we can see that 100 and above components can represent the entire data, this is shown by looking at the cumulative variance above, that finds the ideal number of components to be above 140, this will be tested later on our paper, but as an initial design the number the number of components is set to 150.

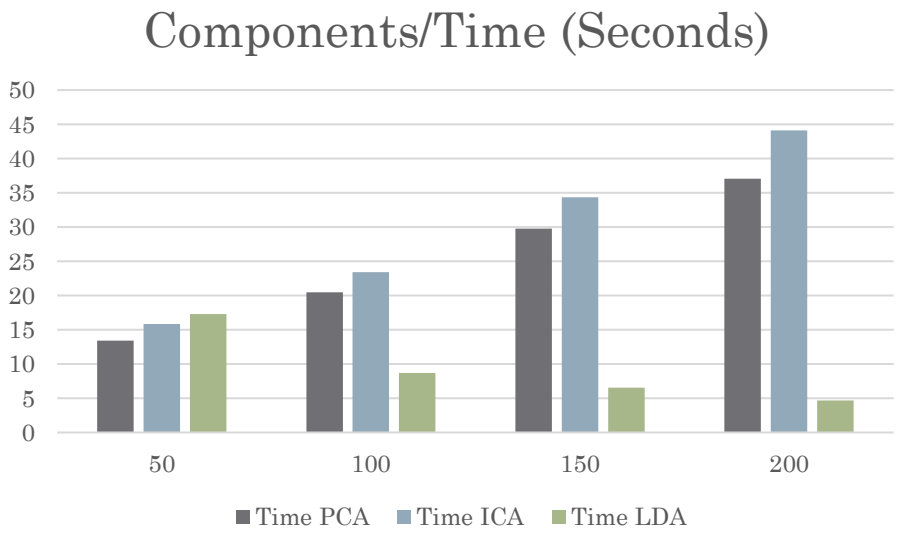
Results for PCA-SVM, ICA-SVM, LDA-SVM

Generally, we can see that most algorithms will converge with the highest accuracy for 150 components, PCA does appear to keep a consistent accuracy regardless of the component number in contrast with the other two method which increase in accuracy with the number of components.

Number of Components	Accuracy		
Eigenfaces	**PCA**	**ICA**	**LDA**
50	83.23%	74.53%	75.78%
100	85.71%	80.12%	81.99%
150	84.47%	83.54%	85.40%
200	84.47%	83.54%	83.23%

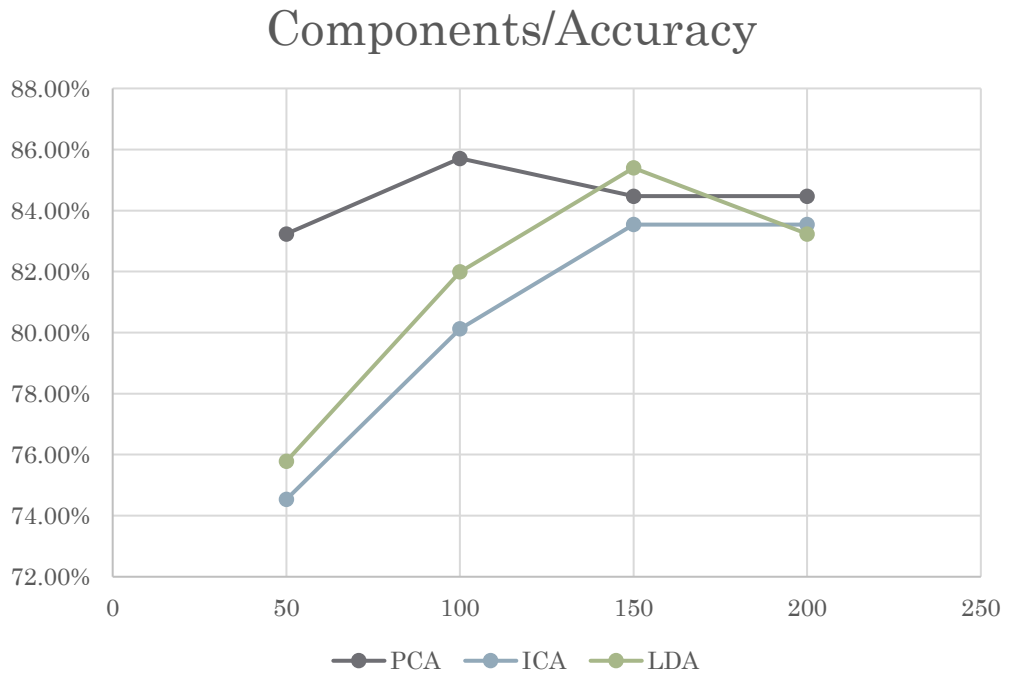
Number of Components	Time		
Eigenfaces	**PCA**	**ICA**	**LDA**
50	13.413	15.844	17.275
100	20.495	23.405	8.68
150	29.79	34.348	6.561
200	37.064	44.104	4.661

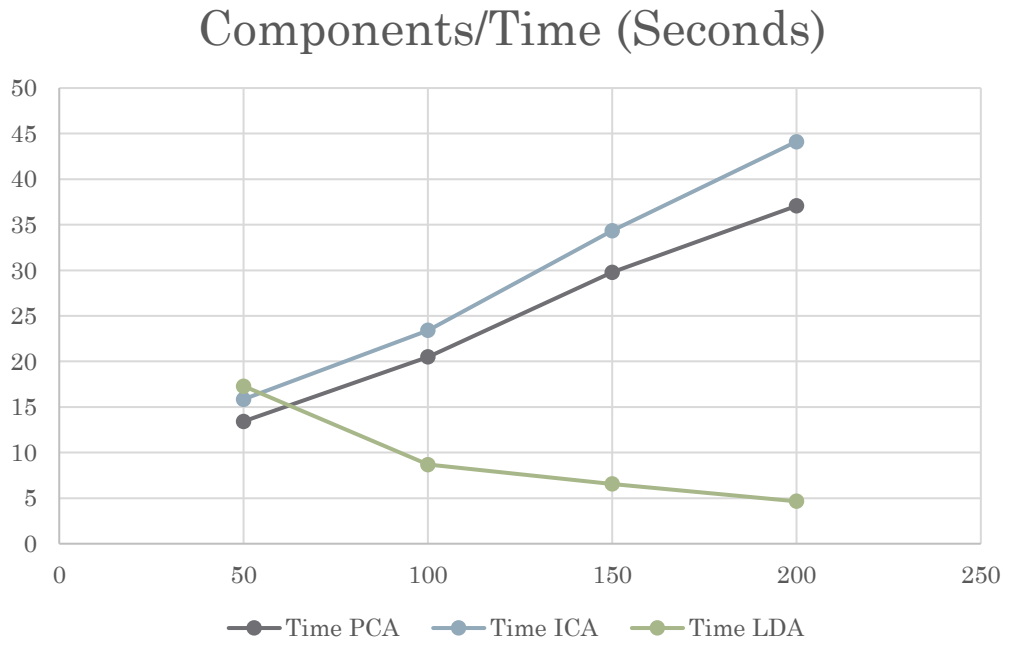




Results Continued

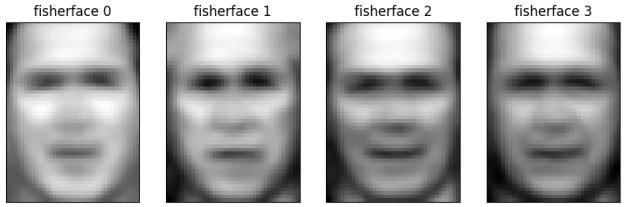
- PCA appears to reach its highest accuracy level at the 100 components mark and remains steady after that.
- Similarly, ICA-SVM shows an increase with the number of components reaching the highest accuracy at 150 components and remaining steady afterwards.
- LDA-SVM on the other hand reaches the highest accuracy also at 150 components but then registers a decrease in accuracy with the increase of components over 150.
- Note that LDA-SVM is decreasing in training time with the increase of components while PCA-SVM and ICA-SVM are seeing an increase in training time with the increase in the number of components.

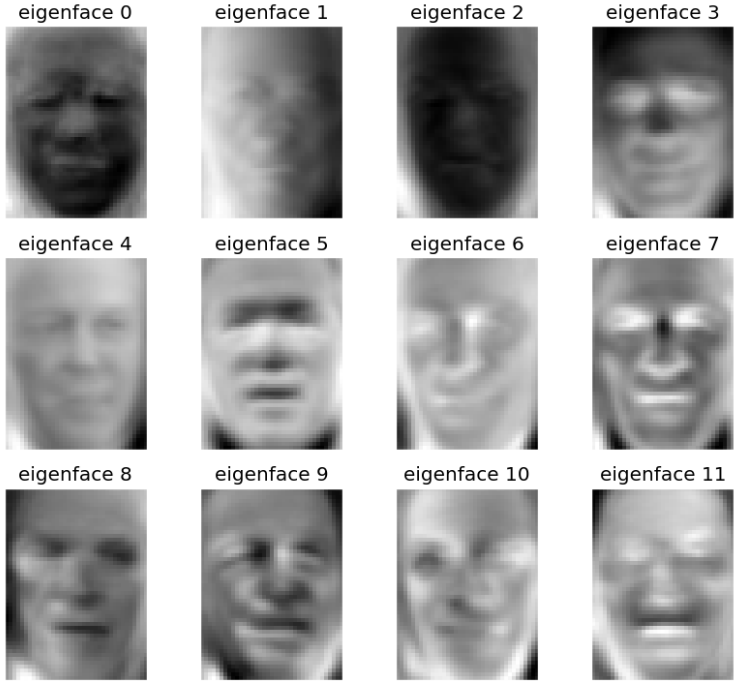


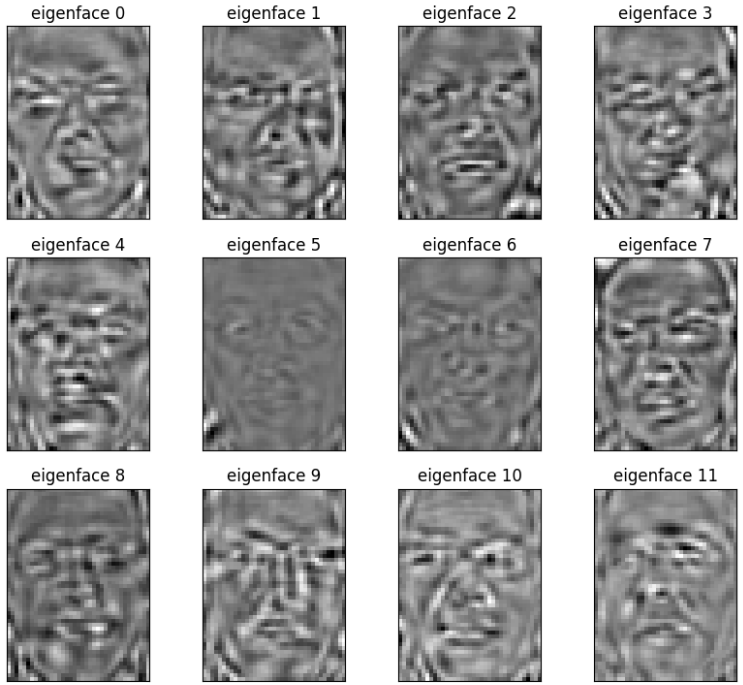


Eigenfaces/Fisherfaces

- As expected the eigenfaces generated by PCA-SVM contains features such as shadows and brightness, as well as each eigenface after the other has less information and increased noise.
- The ICA-SVM captures more facial elements such as features like the nose, eyes, lips, and shape, but it is less intuitive than the PCA eigenfaces, the overall smoothness of the face is considerably lower than in the PCA.
- The LDA-SVM' fisherface's representations appear better in contrast with PCA, ICA's eigenfaces with the overall face structure clearer and more defined, though we are losing features such as the eyes, nose and mouth.







PCA, ICA, LDA – SVM Conclusion

- No metric can replace real-world conditions.
- When using the LFW dataset with the parameters presented in the paper we can achieve a score of above 80% accuracy.
- The PCA-SVM implementation has performed best with a score of 85.71%, followed by the LDA-SVM with 85.40% and ICA-SVM with 83.54%.