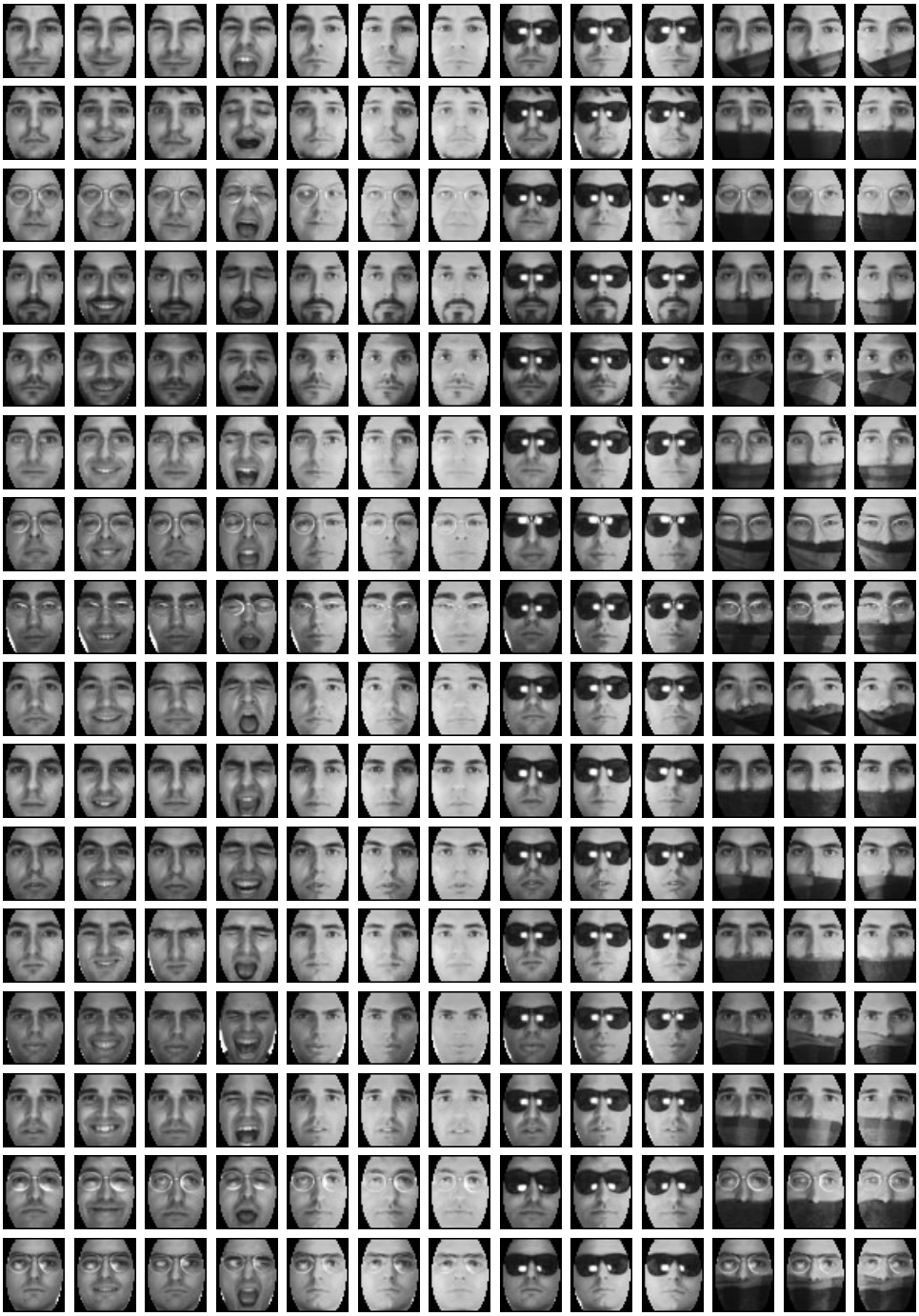

Figure C.7: AR database. Individuals from AR01 to AR16.

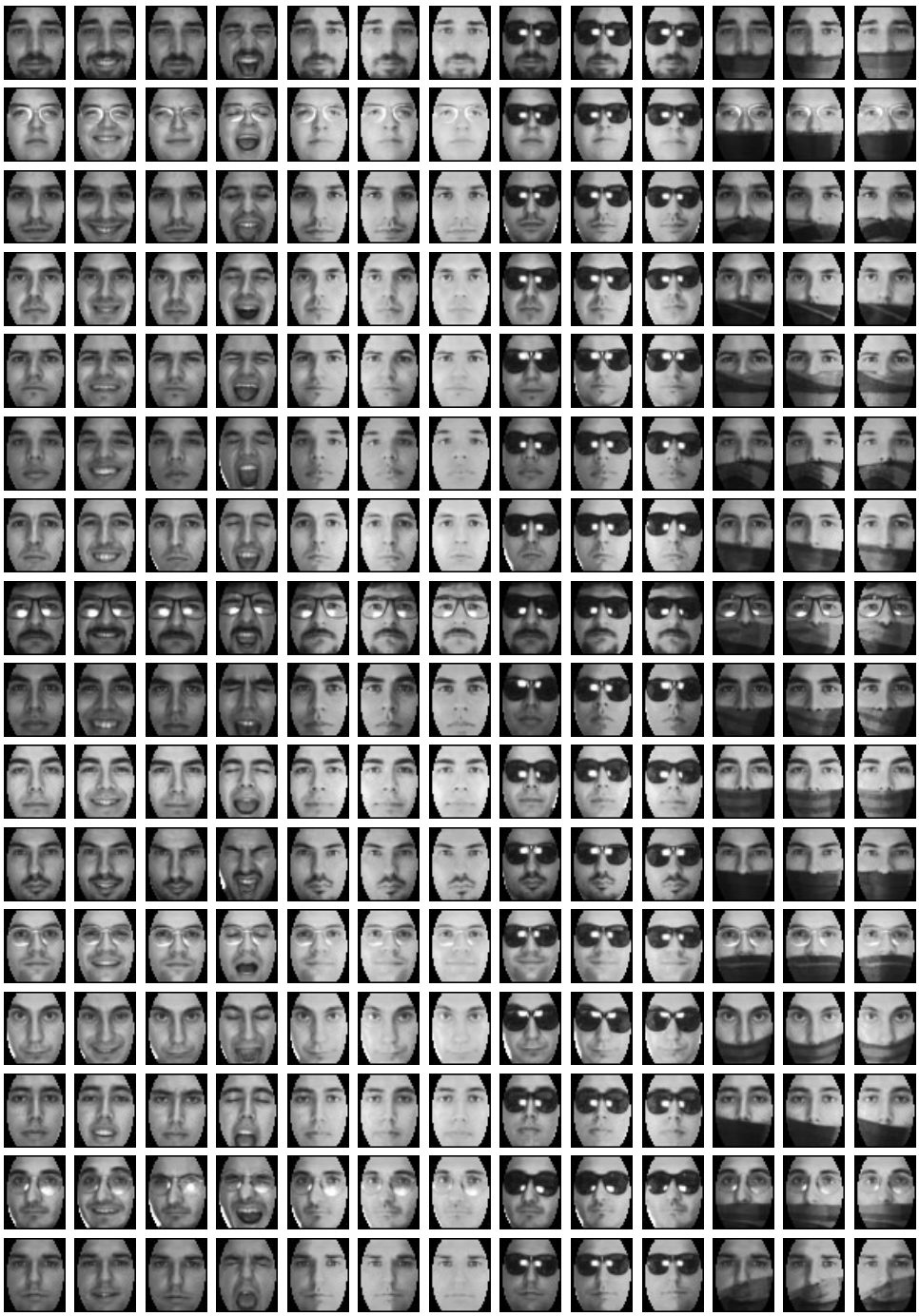

Figure C.8: AR database. Individuals from AR17 to AR32.

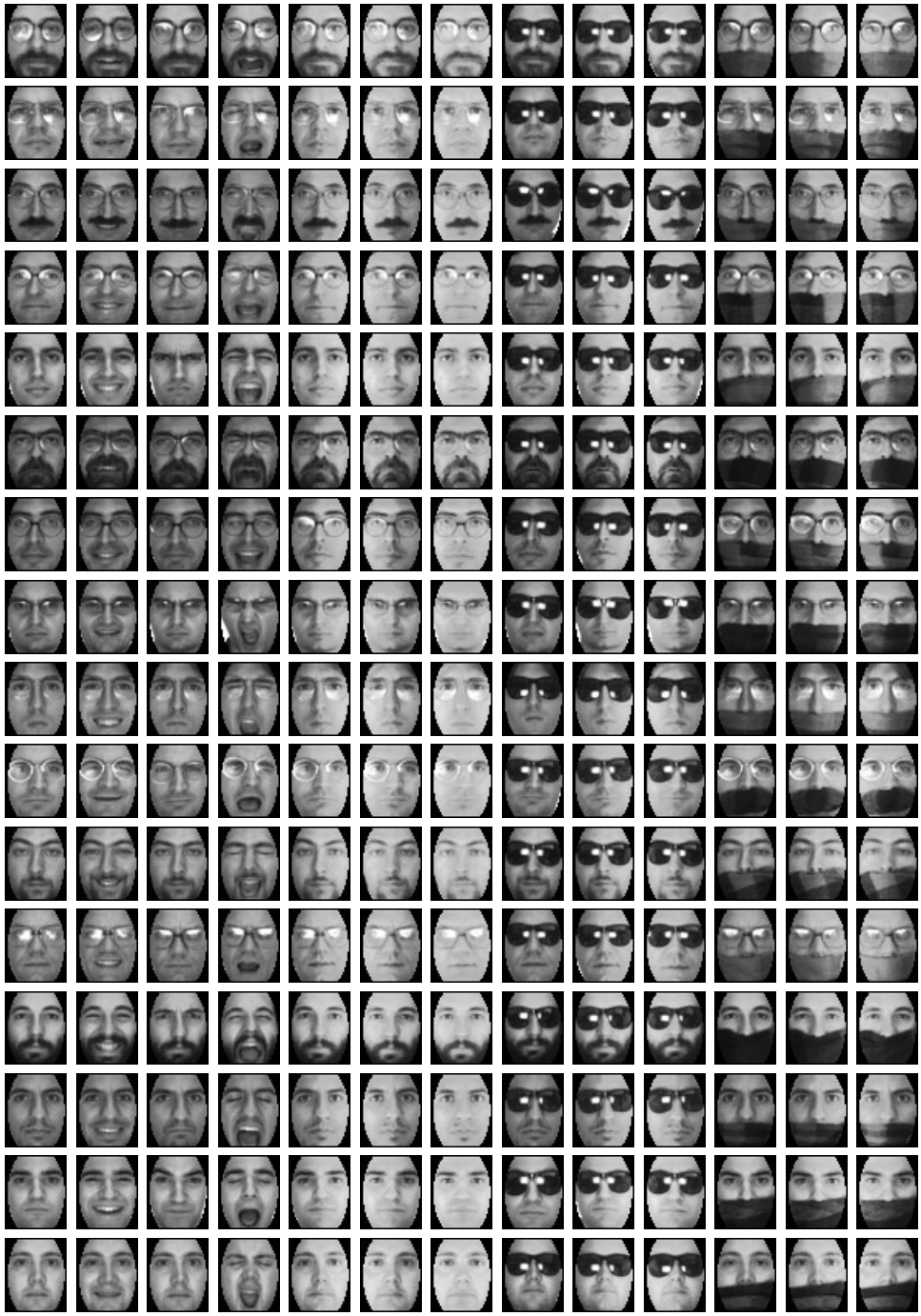

Figure C.9: AR database. Individuals from AR33 to AR48.

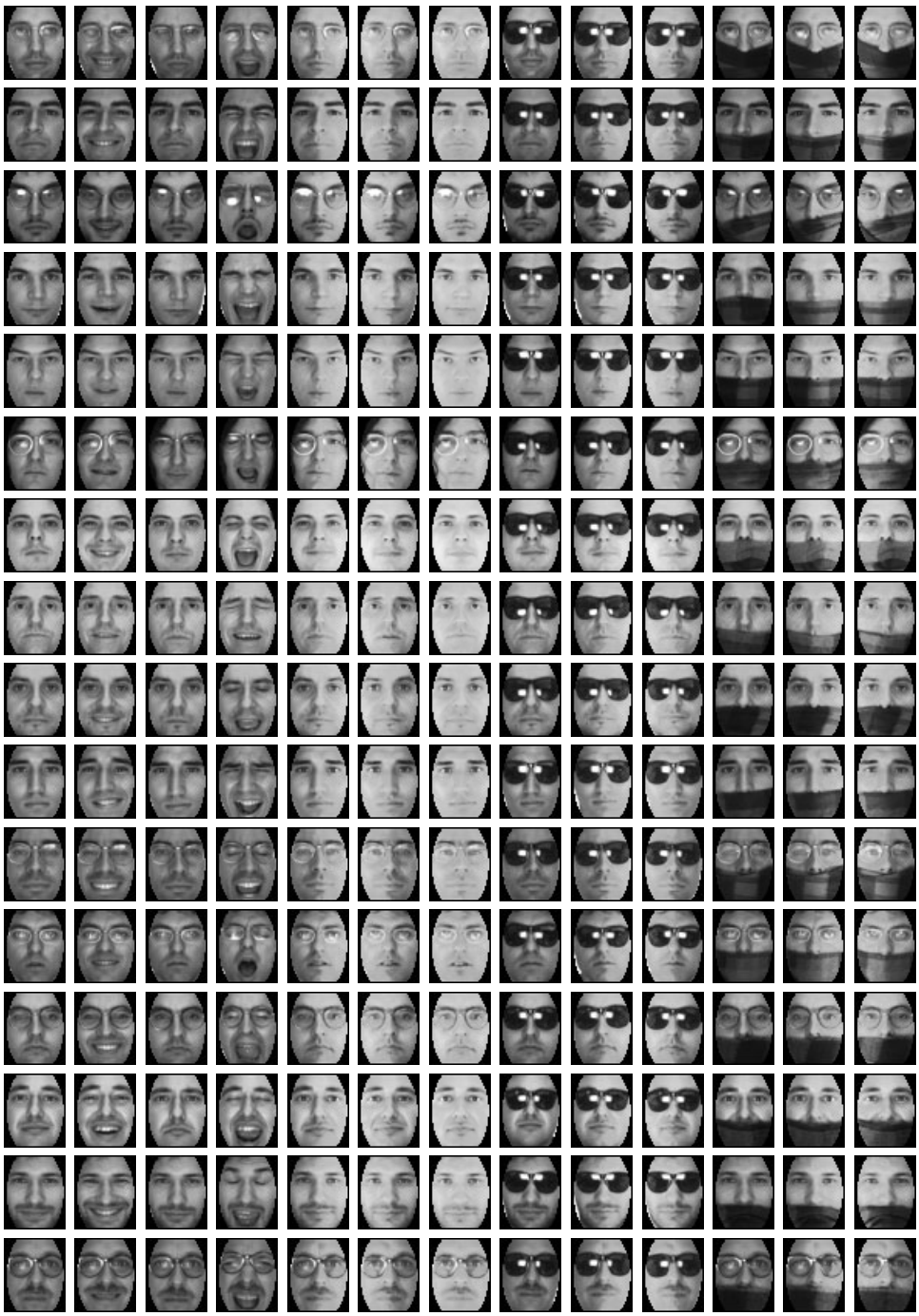

Figure C.10: AR database. Individuals from AR49 to AR64.

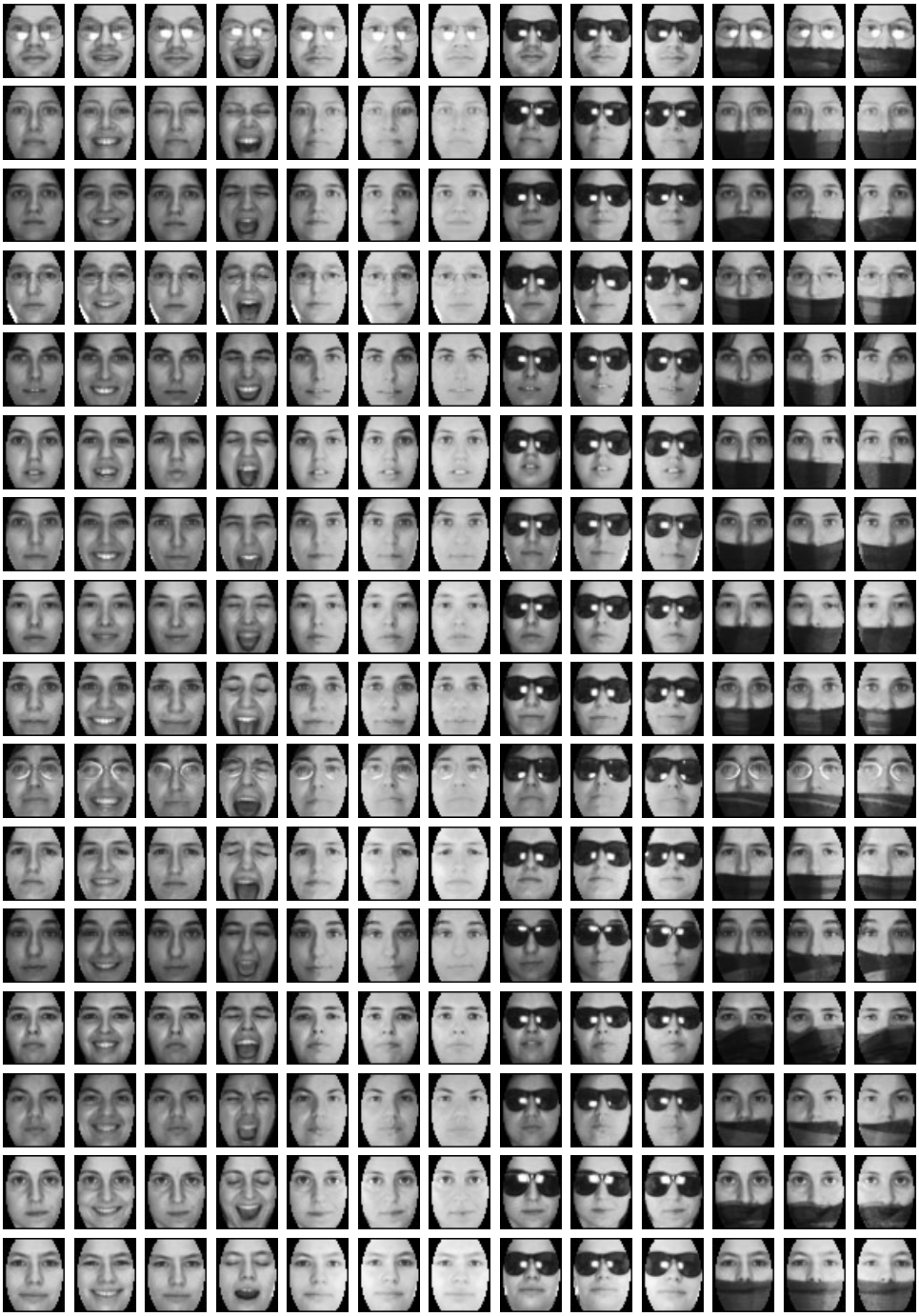

Figure C.11: AR database. Individuals from AR65 to AR80.

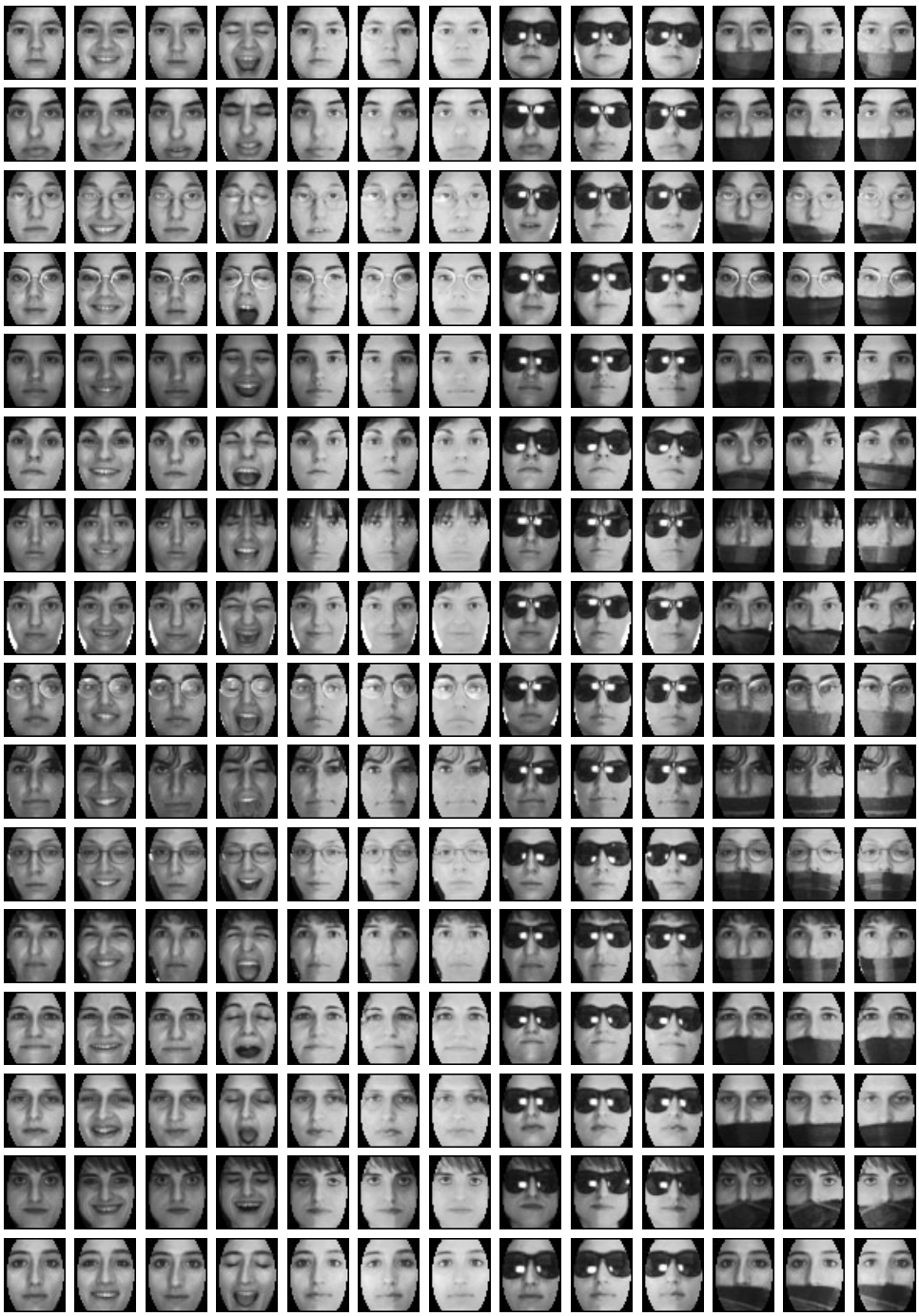

Figure C.12: AR database. Individuals from AR81 to AR96.

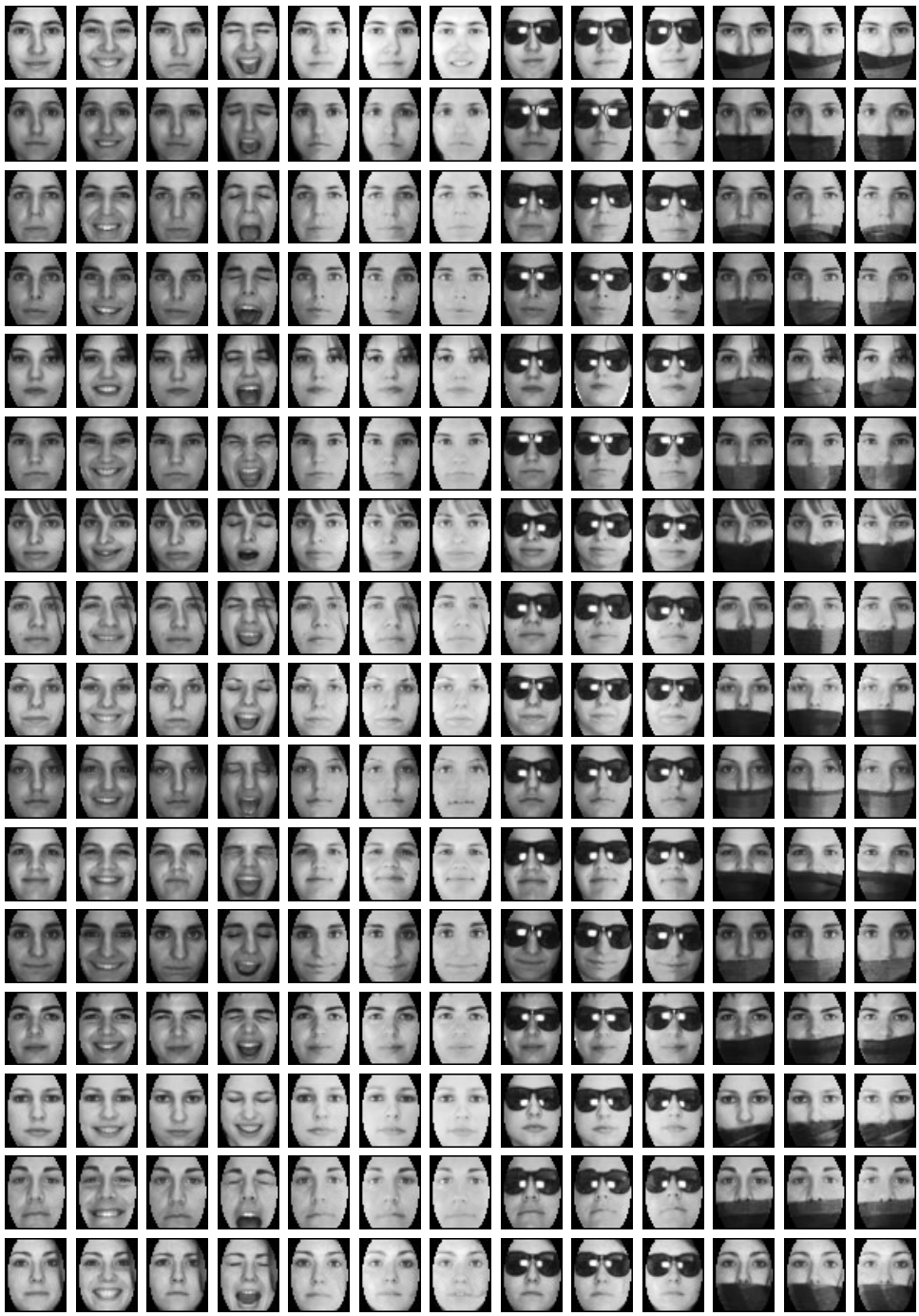

Figure C.13: AR database. Individuals from AR97 to AR112.

Figure C.14: AR database. Individuals from AR113 to AR117.

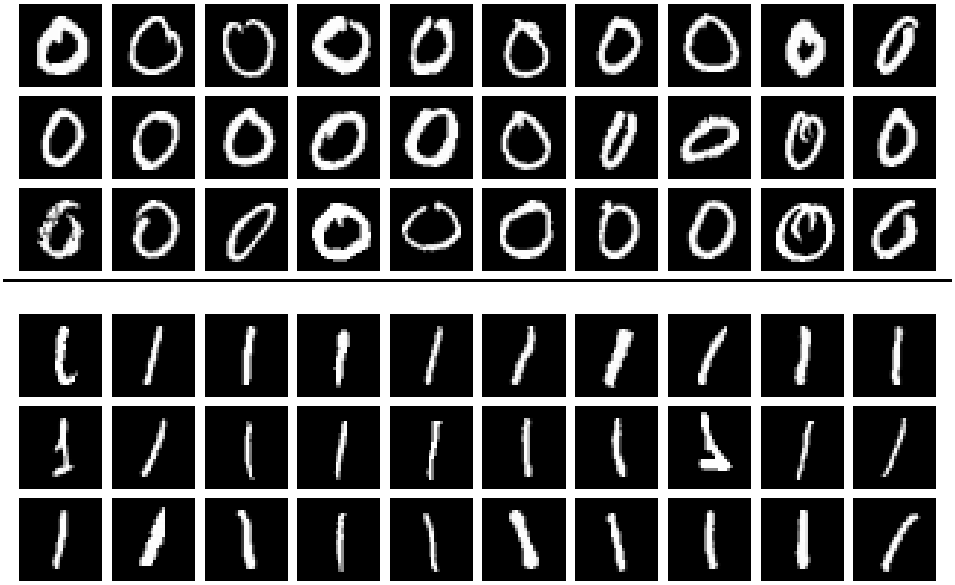

Figure C.15: MNIST digit database (digits from 0 to 1).

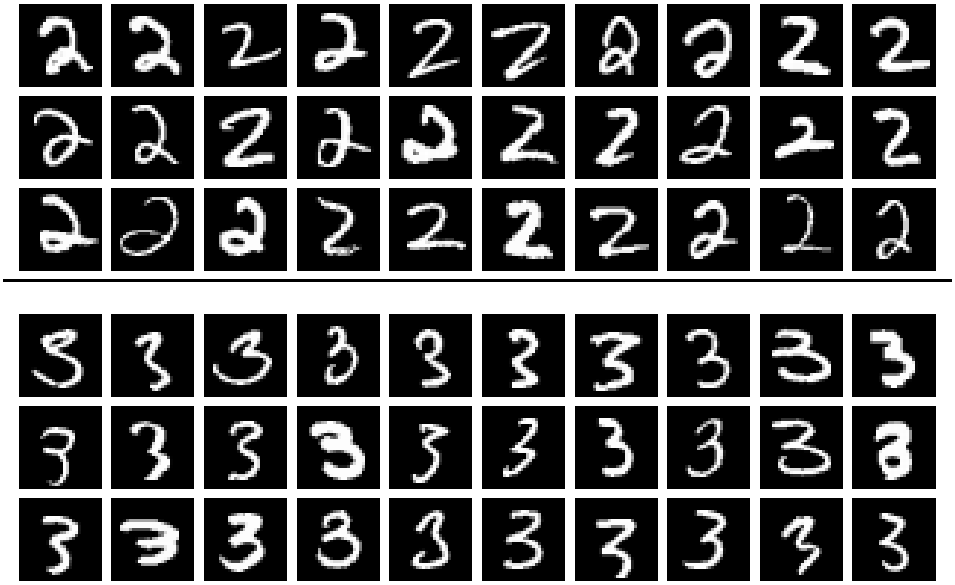

Figure C.16: MNIST digit database (digits from 2 to 3).

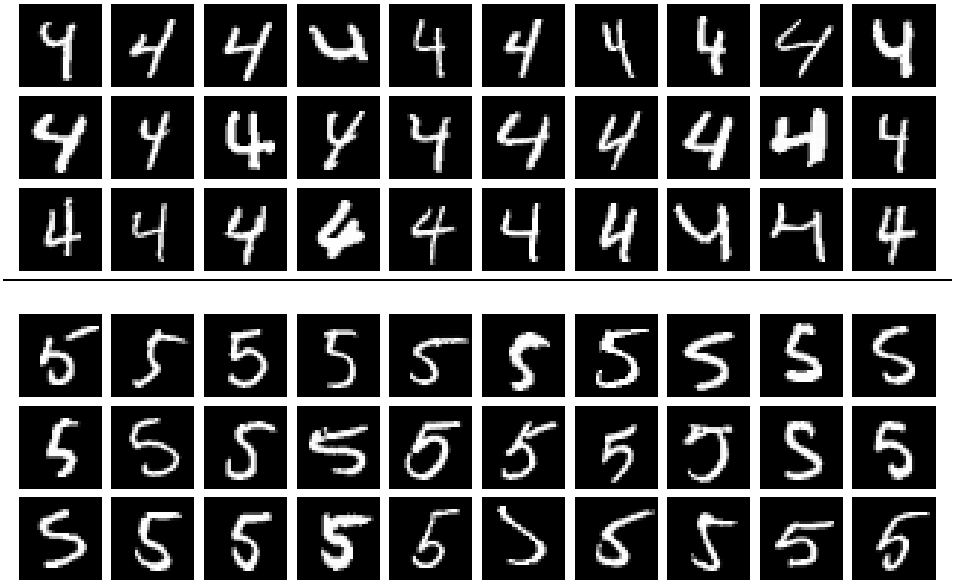

Figure C.17: MNIST digit database (digits from 4 to 5).

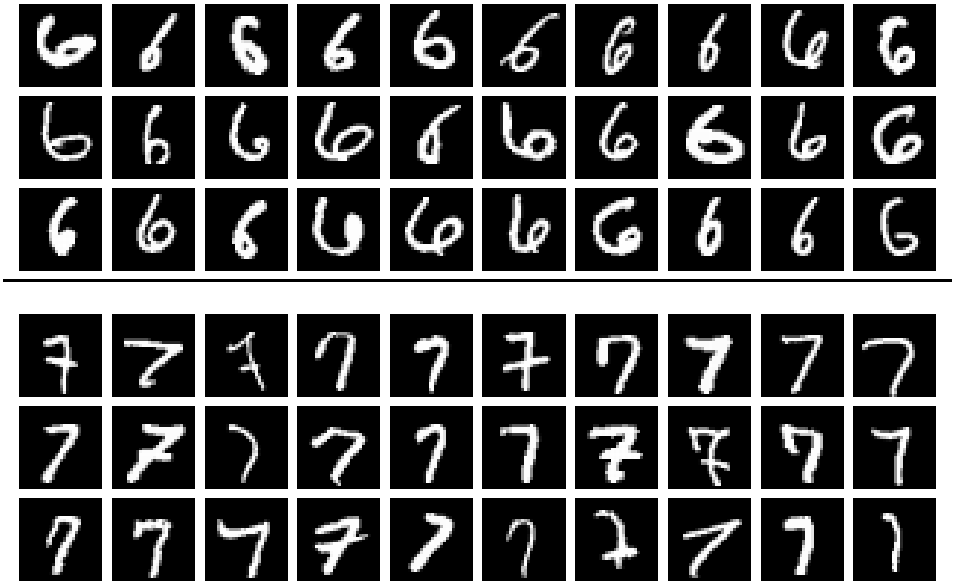

Figure C.18: MNIST digit database (digits from 6 to 7).

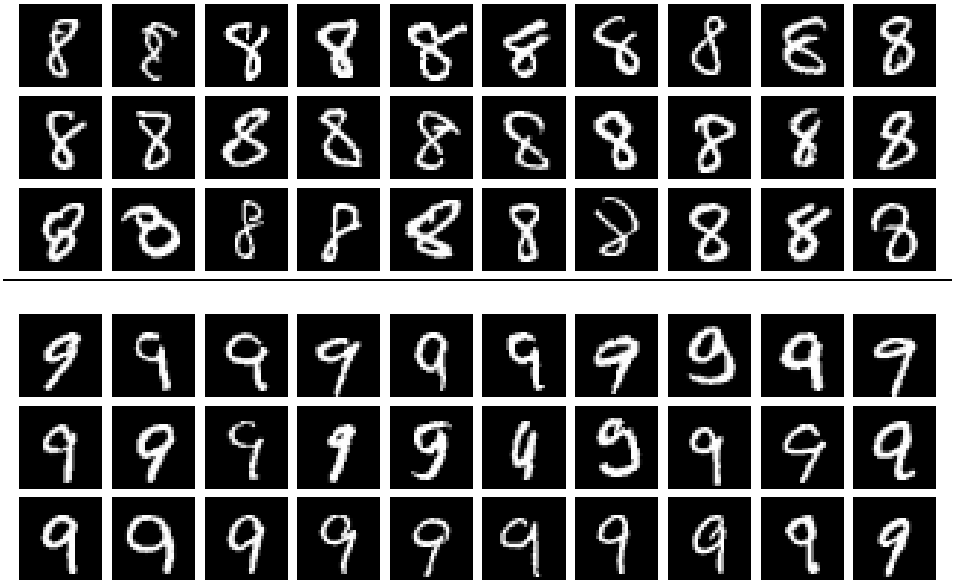

Figure C.19: MNIST digit database (digits from 8 to 9).

Appendix D

Publications

A first set of experiments using color histograms extracted from real-world scenes and objects is described in the following publications. A first experiment with color distributions appears in

- David Guillamet, Jordi Vitrià. **Using EigenSpace Analysis of Color Distributions for Object Recognition**. In Proc. of the VIII Symposium Nacional de Reconocimiento de Formas y Análisis de Imágenes, pages 219-226, Bilbao 1999.

Then, we extended this analysis to non-controlled environments,

- David Guillamet, Jordi Vitrià. **Augmenting Physical Objects Through Visual Recognition**. In Proc. of the 2 Seminari de Treball en Automàtica, Robòtica i Percepció (STAR), pages 51-58, Barcelona, 1999.

but we realized that the problem of object recognition using color features in non-controlled environments was a challenging task. We restricted ourselves with the problem of skin segmentation with

- David Guillamet, Jordi Vitrià. **Skin Segmentation Using Non Linear Principal Component Analysis**. In Proc. of the 2 Congrés Català d'Intel·ligència Artificial (CCIA), pages 224-231, Girona, 1999.

From these set of experiments and a first contact with a local based framework, I elaborated my master's thesis,

- David Guillamet. **Reconeixement d'objectes en entorns poc controlats mitjançant mètodes estadístics**. In Treball Experimental. Universitat Autònoma de Barcelona (UAB), 2001.

which produced a publication,

- David Guillamet, Jordi Vitrià. **Local Discriminant Regions Using Support Vector Machines for Object Recognition**. In Advances in Pattern Recognition, F. Ferri, J.M.Iniesta, A.Amin, P.Pudil (Eds.), Lecture Notes in Computer Science (LNCS) 1876, Springer, pages 550-559, Alicante 2000.

Then, stablishing color histograms as a good and reliable tool for object representation and recognition we realized that we need a comparative study between local and global approaches. We performed this analysis with the following publication,

- David Guillamet, Jordi Vitrià. **A Comparison of Local Versus Global Color Histograms for Object Recognition**. In Proc. of 15 International Conference on Pattern Recognition (ICPR), pages (2):422-425, Barcelona 2000.

As local based representations generated high dimensional data, we started investigating linear transforms of data in order to reduce the original dimensionality of a problem. The above mentioned publications make use of Principal Component Analysis (PCA). Then, we started investigating the Independent Component Analysis (ICA) with

- Marco Bressan, David Guillamet, Jordi Vitrià. **Using an ICA Representation of Local Color Histograms for Object Recognition**. In Proc. of Catalan Conference of Artificial Inteligence (CCIA), pages 300-307, Vilanova i la Geltrú, 2000.

Extending this research to recognition of different objects (classes), we introduced a new technique called Class-Conditional Independent Component Analysis (CC-ICA) which is explained in,

- Marco Bressan, David Guillamet, Jordi Vitrià. **Using a local ICA Representation of High Dimensional Data for Object Recognition and Classification**. In proc. of Computer Vision and Pattern Recognition (CVPR), pages (1):1004-1009, Hawaii, 2001.

making use of the feedback obtained from several international researchers from the CVPR conference where we attended thanks to the above mentioned publication, we wrote a formal exposition of the whole results that were published in

- Marco Bressan, David Guillamet, Jordi Vitrià. **Using an ICA Representation of Local Color Histograms for Object Recognition**. In Pattern Recognition (PR), 36(3): 691-701, March 2003.

Further research on nonsupervised representations leads to Non-negative Matrix Factorization (NMF). We started analyzing a possible way of representing color histograms with NMF in two publications:

- David Guillamet, Jordi Vitrià. **Unsupervised Learning of Part-Based Representations**. In Computer Analysis of Images and Patterns (CAIP), W. Skarbek (Eds.), Lecture Notes in Computer Science (LNCS) 2124, Springer, pages 700-708, Warsaw 2001.

- David Guillamet, Jordi Vitrià. **Discriminant Basis for Object Classification**. In Proc. of the 11th International Conference on Image Analysis and Processing (ICIAP), pages 256-261, Palermo 2001.

With these two initial approaches which make use of Non-negative Matrix Factorization, we realized that our initial goals to find unsupervised features that best describe

a set of objects were too ambitious. Then, we firstly focused on using NMF to classify faces,

- David Guillamet, Jordi Vitrià. **Non-negative Matrix Factorization for Face Recognition**. In Topics in Artificial Intelligence, M. Teresa Escrig, Francisco Toledo, Elisabet Golobardes (Eds.), Lecture Notes in Artificial Intelligence (LNAI) 2504, Springer, pages 336-344, Castelló de la Plana 2002.

- David Guillamet, Jordi Vitrià. **Classifying Faces with Non-Negative Matrix Factorization**. In Proc. 5th Catalan Conference for Artificial Intelligence (CCIA), pages 24-31, Castelló de la Plana, 2002.

Since we realized that NMF was a reliable technique to be used with positive representations, we continued analyzing its performance with other databases. We evaluated the subspace created by NMF in order to find a correct metric distance to be used

- David Guillamet, Jordi Vitrià. **Determining a Suitable Metric When using Non-negative Matrix Factorization**. In Proc. of the 16th International Conference on Pattern Recognition (ICPR), pages (2):128-131, Quebec 2002.

which produced an extended analysis that has been published in

- David Guillamet, Jordi Vitrià. **Evaluation of distance metrics for recognition based on non-negative matrix factorization**. In Pattern Recognition Letters (PRL), 24/(9-10): 1599-1605, March 2003.

Also, a comparative study of the neighborhood of the subspaces obtained using PCA and NMF is done in

- David Guillamet, Jordi Vitrià. **An experimental evaluation of k-nn for linear transforms of positive data**. In 1st Iberian Conference on Pattern Recognition and Image Analysis. Published in Lecture Notes in Computer Science (LNCS) 2652, F.J.Perales, A. Campilho, N. Pérez, A. Sanfeliu (Eds.), pp. 317-325, June 2003.

Thanks to Bernt Schiele who gave me the opportunity to stay in his laboratoy in the Perceptual Computing and Computer Vision, Institute of Scientific Computing, Department of Computer Science in ETH Zurich, I analyzed NMF with the Corel image database,

- David Guillamet, Bernt Schiele, Jordi Vitrià. **Color Histogram Classification using NMF**. In CVC Technical Report 057, 2001.

A short review of this technical report is presented in the following publication,

- David Guillamet, Bernt Schiele, Jordi Vitrià. **Analyzing Non-negative Matrix Factorization for Image Classification**. In Proc. of the 16th International Conference on Pattern Recognition (ICPR), pages (2):116-119, Quebec 2002.

At the same time, we were analyzing a possible drawback of NMF: its little robustness to obtain reliable representations when applied to local data representations. However, thanks to this deep analysis, we presented a weighted version of NMF, the so-called Weighted Non-negative Matrix Factorization which appears in

- David Guillamet, Marco Bressan, Jordi Vitrià. **Weighted Non-negative Matrix Factorization for Local Representations**. In Proc. of Computer Vision and Pattern Recognition (CVPR), pages (1):942-947, Hawaii 2001.

Then, we included WNMF in the previous approach and we present

- David Guillamet, Jordi Vitrià, Bernt Schiele. **Introducing a weighted non-negative matrix factorization for image classification**. In Pattern Recognition Letters (PRL), 24(14): 2447-2454, October 2003.

Then, we turned our research to another point of view: how to integrate local image features with its spatial arrangement into an unified approach. A first attempt is described in

- David Guillamet, Jordi Vitrià. **Unsupervised Learning of Structural Object Representations**. In Proc. of the IX Symposium Nacional de Reconocimiento de Formas y Análisis de Imágenes, pages (2):73-78, Castelló, 2001.

With the main goal to improve this approach to merge local information and spatial arrangement of local features, I started an internship in USA. Thanks to Baback Moghaddam who gave me the opportunity to stay in a top leading research center: MERL Mitsubishi Electric Research Laboratories, Cambridge. I started investigating the main foundations of chapter 4. Then, we wrote a first publication,

- David Guillamet, Baback Moghaddam. **Joint Distribution of Local Image Features for Appearance Modeling**. In Proceedings of IAPR Workshop on Machine Vision Applications (MVA2002), pages 346-349, Nara, Japan, 2002.

Then, the strong collaboration maintained with Baback Moghaddam generated a set of publications extending the first approach,

- David Guillamet, Baback Moghaddam, Jordi Vitrià. **Higher-Order Dependencies in Local Appearance Models**. In Proc. of the 10 International Conference on Image Processing (ICIP), pages ():-, Barcelona, September 2003.

- Baback Moghaddam, David Guillamet, Jordi Vitrià. **Local Appearance-Based Models using High-Order Statistics of Image Features**. In Proc. of Computer Vision and Pattern Recognition (CVPR), pages (1):729-735, Madison, June 2003.

- David Guillamet, Baback Moghaddam, Jordi Vitrià. **Modeling High-Order Dependencies in Local Appearance Models**. In 1st Iberian Conference on Pattern Recognition and Image Analysis. Published in Lecture Notes in Computer Science (LNCS) 2652, F.J.Perales, A. Campilho, N. Pérez, A. Sanfeliu (Eds.), pp. 308-316, June 2003.

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