ERCIM Fellow's research activity report – part one

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Contract Nr: 2004-13
Hosting Laboratory: CRCIM, Czech Republic
Scientific Advisor: Prof. Michal Haindl
Period I: April 1st – December 31th, 2005.

Summary of the research carried out by the Fellow

The research activity of the Fellow during the tenure of the first part of his ERCIM fellowship has been focused on the analysis, in particular the segmentation, of textured images in a complete unsupervised context, where no further information were available but the image itself to be segmented.

Image segmentation is a low-level processing task, aimed at the identification and separation of the different regions on the basis of their visual properties, which is of critical importance for many high-level applications in several domains, like medical imaging, remote sensing, source coding, and so on. Although the segmentation problem has been widely studied in the last decades [2, 3, 5, 6], in many situations where the spatial interactions play a relevant role, as for the textured images, it remains still open.

In particular, several solutions have been proposed to take into account the local spatial correlations. In [2] a MRF model-based unsupervised algorithm is presented, where a genetic algorithm is employed to carry out the optimization. Although the approach is quite interesting, limitations occur in the choice of the model complexity, as they need an approximation for the partition function which is reliably possible only for simple MRF models. This finally results in a limitation of the textures which can be represented. More in general, for different reasons, MRF-based approaches suffer of the same problem, so they may be limited in scope. Other approaches refer to the use of autoregressive models [6], which allow for longer range interaction description and due to their causality ensure quick processing. However, the causality may introduce artifacts depending on the given image.

The Fellow has developed a new technique for unsupervised segmentation of textured images, which has been detailed in [C3]. Such technique does not refer to a complex joint spectral-spatial modeling of the textures, but concerns on a separate modeling and processing into the two domains. So doing, the effect of model mismatching, which is a particularly critical aspect in an unsupervised setting, is reduced. Furthermore, the overall computational burden results reasonably low, and, finally, as a by-product the segmentation map is scalable, that is a region-hierarchical nested map, such that the determination of the unknown number of classes in the image might be also deferred to a subsequent application-dependent processing.

The algorithm is composed of two parts. The first step provides an over-segmentation of the image, such that basic components for each of the textures present are extracted. The second step is a region growing algorithm which reduces drastically the number of regions, and provides a region-hierarchical texture clustering.

The over-segmentation procedure is itself split in two clustering steps. The former, which provides a coarse segmentation map, is based only on the use of the spectral information and no spatial-textural properties are taken into account (which is referred to as color-based clustering, CBC). The latter, which further processes the previous segmentation (referred to as spatial-based clustering, SBC), is based on the exclusive use of the spatial information, and increases up the number of clusters providing a fine segmentation map.

In Fig.1 an example of segmentation carried out by the proposed algorithm is shown. On the left is the image to be segmented, which is a mosaic of textiles generated by the Prague Texture Segmentation Data-Generator and Benchmark [1]. The final segmentation is shown on the right side and, as can be easily recognized, the cluster validation criterion adopted correctly estimates the number of textures present in the image and the segmentation accuracy is rather good as well. In the center, a picture shoes the segmentation map during the region growing process few steps before to converge to the

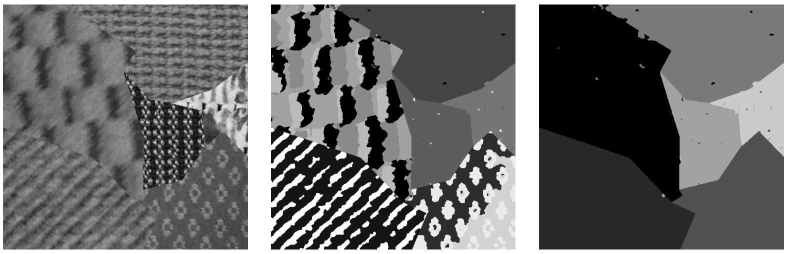

Figure 1. Example of unsupervised segmentation of a textile mosaic.

final segmentation. It can be seen how the internal hierarchical structure for each texture is revealed and could be provided as a by-product to the user. For some regions, such a structure does not appear at this intermediate state just because the corresponding components were already merged. Eventually the results are quite promising in the case of regular patterns, as for the example shown, while problems occur for less regular textures. These problems should be addressed in future work, as well as a specific application, for example in the domain of remote sensing, might be considered.

In the following, the conferences and workshops attended by the Fellow, as well as his recent publications with corresponding abstracts, are listed.

Attended conferences and workshops

During the tenure his ERCIM fellowship, the Fellow has attended the following conferences and workshops:

- *13th European Signal Processing Conference* (EUSIPCO), September 4-8, 2005, Antalya (Turkey), where he presented [C1] and [C2].
- *International Workshop on Data - Algorithms - Decision Making* (DAR), December 19-20, 2005, Prague (Czech Republic), where he has given an invited lecture about his achievements under the tenure of the ERCIM fellowship.

Publications

The Fellow has also obtained the publication of several papers stemming from his previous research activity [R1,C1,C2], but closely related to his current reserch, and submitted for publication a paper stemming from his current activity as ERCIM Fellow [C3]:

[R1] G.Poggi, G.Scarpa, J.Zerubia, “Supervised segmentation of remote-sensing images based on a tree-structured MRF model,” *IEEE Transaction on Geoscience and Remote Sensing*, vol.43, No.8, pp.1901-1911, August 2005.

[C1] R.Gaetano, G.Poggi, G.Scarpa, “Multitemporal image classification with automatic building of tree-structured MRF models,” *Proceedings of the 13th European Signal Processing Conference* (EUSIPCO), Antalya (Turkey), September 4-8, 2005.

[C2] M.Cagnazzo, L.Cicala, G.Poggi, G.Scarpa, L.Verdoliva, “An unsupervised segmentation-based coder for multispectral images,” *Proceedings of the 13th European Signal Processing Conference* (EUSIPCO), Antalya (Turkey), September 4-8, 2005.

[C3] G.Scarpa, M.Haindl, “Unsupervised Texture Segmentation by Spectral-Spatial-Independent Clustering,” submitted for *18th International Conference on Pattern Recognition* (ICPR’06), Hong Kong (China), August 20-24, 2006.

Abstract of [R1]

Most remote-sensing images exhibit a clear hierarchical structure which can be taken into account by defining a suitable model for the unknown segmentation map. To this end one can resort to the tree-structured MRF model, which describes a K-ary field by means of a sequence of binary MRFs, each one corresponding to a node in the tree.

Here we propose to use the TS-MRF model for supervised segmentation. The prior knowledge on the number of classes and their statistical features allows us to generalize the model so that the binary MRFs associated with the nodes can be *adapted freely, together with their local parameters, to better fit the data. In addition, it allows us to define a suitable likelihood term to be coupled with the TS-MRF prior so as to obtain a precise global model of the image.*

Given the complete model, a recursive supervised segmentation algorithm is easily defined. Experiments on a test SPOT image prove the superior performance of the proposed algorithm with respect to other comparable MRF-based or variational algorithms.

Abstract of [C1]

In this work we deal with the classification of remote-sensing images following a statistical approach. To take into account prior information on the class of images of interest we model the image as a tree-structured Markov random field (TS-MRF), so as to fit the intrinsic structure of the data. TS-MRF models are defined recursively and, as such, lead to the formulation and solution of the segmentation task as a recursive problem, so that the original K-ary segmentation is decomposed into a sequence of reduced-dimensionality steps, and hence to a much simpler and more manageable segmentation. Here, we propose a method to build automatically the underlying tree structure of the model, based on a metric which compares class features in order to establish the hierarchical relationships among classes, and apply the technique to the segmentation of multitemporal remote-sensing images.

Abstract of [C2]

To fully exploit the capabilities of satellite-borne multi/hyperspectral sensors, some form of image compression is required. The Gelli-Poggi coder [4], based on segmentation and class-based transform coding, has a very competitive performance, but requires some a-priori knowledge which is not available on-board. In this paper we propose a new version of the Gelli-Poggi coder which is fully unsupervised, and therefore suited for use on-board a satellite, and presents a better performance than the original. Numerical experiments on test multispectral images validate the proposed technique.

Abstract of [C3]

A novel color texture unsupervised segmentation algorithm is presented which processes independently the spectral and spatial information. The algorithm is composed of two parts. The former provides an over-segmentation of the image, such that basic components for each of the textures which are present are extracted. The latter is a region growing algorithm which reduces drastically the number of regions, and provides a region-hierarchical texture clustering. The over-segmentation is achieved by means of a color-based clustering (CBC) followed by a spatial-based clustering (SBC). The SBC, as well as the subsequent growing algorithm, make use of a characterization of the regions based on shape and context. Experimental results are very promising in case of textures which are quite regular.

References

[1] http://mosaic.utia.cas.cz (2005).

[2] P. Andrey and P. Tarroux. Unsupervised segmentation of markov random field modeled textured images using selectionist relaxation. *IEEE Trans. PAMI*, 20(3):252–262, 1998.

[3] C. D'Elia, G. Poggi, and G. Scarpa. A tree-structured markov random field model for bayesian image segmentation. *IEEE Trans. on Image Proc.*, 12(10):1259–1273, October 2003.

[4] G. Gelli and G. Poggi. Compression of multispectral images by spectral classification and transform coding. *IEEE Transaction on Image Processing*, pages 476–489, April 1999.

[5] S. Geman and D. Geman. Stochastic relaxation, gibbs distributions, and the bayesian restoration of images. *IEEE Trans. on PAMI*, 6(6):721–741, November 1984.

[6] M. Haindl and S. Mikes. Colour texture segmentation using modelling approach. In *ICAPR (2)*, pages 484–491, 2005.