ERCIM “Alain Bensoussan” Fellowship Scientific Report

Fellow: Raffaele GAETANO
Visited Location : MTA-SZTAKI, Budapest (HUNGARY) – DEVA Group
Duration of Visit: 9 months (01/01/2010 – 30/09/2010)

I - Scientific activity

Following the advances achieved in the first part of the fellowship, the research activity carried out in this second part concentrated on the further development of the TFR (*Texture Fragmentation and Reconstruction*) algorithm for the unsupervised hierarchical image segmentation based on textural content. The main aim has been the enrichment of the existing modeling approach by means of a suitable graph-based representation of the image.
The original TFR algorithm consists of three steps: a color-based classification (CBC), a clustering based on spatial context (SBC) and an iterative texture merging procedure. The first two steps constitute the fragmentation phase: first, a map of color-homogeneous areas is generated and then a clustering (the SBC step) of the connected components (fragments) within each color class provides a partition of the image into a set of elementary image patterns, homogeneous for both color and spatial context. The hierarchical texture reconstruction is performed in the last step, where these elementary patterns are merged two-by-two resorting to a hierarchy of nested segmentation maps at different scales of observation.
Recent advances concern exclusively the SBC step: it is based on a suitable description of the color context of each fragment, based on the prior color labeling provided by CBC. The classical SBC used, for this purpose, a probabilistic description of the color context by locally counting, for each fragment, the pixel-wise transitions towards the different color classes available in the 8 main spatial directions. The so obtained transition probability matrix is reduced by PCA and used for the *K-means* clustering of connected components, independently for each color class. This generally leads to a quick and reliable output. However, in more complex cases, for example when color information is limited or in presence of significant scale differences, K-means is likely to perform unsatisfactorily, mainly due to the insufficient number of samples for a statistical clustering and the absence of a spatial constraint (position of the fragments is not taken into account).
To overcome this limitations, our key idea is to consider the spatial proximity among fragments and measure context differences locally instead of relying on global statistics. This is realized by associating to each map of color-uniform fragments a graph based representation that allows for the definition of neighborhood relationships, allowing for a cluster formation by means of suitable graph cuts. Two main issues have been dealt with: the *construction of the graph structures*, to be associated to each partial map of generally non-adjacent fragments, and the *definition of the graph-cut method* and the metrics on which it relies. The first are obtained by generating adjacencies on the partial maps, using a morphological label propagation of fragment labels, and building the corresponding RAG (region adjacency graph). To perform graph cuts, a local spatial context similarity metric has been defined to annotate graph links, in order to eventually suppress the links with a “low” metric value. The actual clustering method has been object of extensive research: initially, a threshold for the context similarity metric was automatically computed as to “save” a given percentage of the links (ex. 10%), and early experimental results on TFR with the new SBC block already gave very good performances w.r.t. the old version of the algorithm. Subsequently, results have been further improved by using a regularization technique based on a sort of “network prior”, to ensure cluster

consistency. In a final testing stage, we could provide very promising results both on benchmark data for texture segmentation and the hierarchical segmentation of very high resolution remote sensing images.

II- Publication(s) during your fellowship

R.Gaetano, G.Scarpa, T.Sziranyi, "Graph-Based Analysis of Textured Images for Hierarchical Segmentation," *British Machine Vision Conference BMVC 2010, Aberystwyth (UK), August-Sept. 2010.*

Abstract: The Texture Fragmentation and Reconstruction (TFR) algorithm has been recently introduced to address the problem of image segmentation by textural properties, based on a suitable image description tool known as the Hierarchical Multiple Markov Chain (H-MMC) model. TFR provides a hierarchical set of nested segmentation maps by first identifying the elementary image patterns, and then merging them sequentially to identify complete textures at different scales of observation. In this work, we propose a major modification to the TFR by resorting to a graph based description of the image content and a graph clustering technique for the enhancement and extraction of image patterns. A procedure based on mathematical morphology will be introduced that allows for the construction of a colour-wise image representation by means of multiple graph structures, along with a simple clustering technique aimed at cutting the graphs and correspondingly segment groups of connected components with a similar spatial context. The performance assessment, realized both on synthetic compositions of real-world textures and images from the remote sensing domain, confirm the effectiveness and potential of the proposed method.

The following paper has been prepared for forthcoming conferences, but not yet submitted:

R.Gaetano, G.Scarpa, J.Zerubia, "Morphological Road Segmentation in Urban Areas from High Resolution Satellite images", to be submitted.

Abstract: High resolution satellite images provided by the last generation sensors significantly increased the potential of almost all the image information mining (IIM) applications related to earth observation. This is especially true for the extraction of road information, task of primary interest for many remote sensing applications, which scope is more and more extended to complex urban scenarios thanks to the availability of highly detailed images. This context is particularly challenging due to such factors as the variability of road visual appearance and the occlusions from entities like trees, cars and shadows. On the other hand, the peculiar geometry and morphology of man-made structures, particularly relevant in urban areas, is enhanced in high resolution images, making this kind of information especially useful for road detection. In this work, we provide a new insight on the use of morphological image analysis for road extraction in complex urban scenarios, and propose a technique for road segmentation that only relies on this domain. The key point of the technique is the use of skeletons as powerful descriptors for road objects: the proposed method is based on an ad-hoc skeletonization procedure that enhances the linear structure of road segments, and extracts road objects by first detecting their skeletons and then associating each of them with a region of the image.

Experimental results are presented on two different high resolution satellite images of urban

areas.

A **joint journal paper** and an **INRIA research report** are currently under preparation.

III -Attended Seminars, Workshops, and Conferences

The fellow attended one conference:

- **British Machine Vision Conference**, *BMVC 2010*, Aberystwyth (UK), August 31st to September 2nd. One paper presented (Poster session).

He took part, as a speaker, in two seminars:

- Presentation talk, "*Hierarchical Texture-Based Segmentation of Very High Resolution Remote Sensing Images*", February 10th 2010.
- Demo on "*Urban Area Classification from VHR Remote Sensing Images by Texture-based Segmentation*" and "*Road Extraction by Mathematical Morphology*" for the ASTRIUM delegates, May 5th 2010

IV – Research Exchange Programme (12 month scheme)

Not applicable.