Report of Jocelyn Chanussot, Professor at the Grenoble Institute of Technology on the PhD presented by Bangalore Ravi KIRAN.

Title: Energetic-Lattice based optimization / L'optimisation par treillis énergétique.

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In the field of computer vision and image analysis, Bangalore Ravi KIRAN investigates in his thesis different issues related to the concepts and design of hierarchical segmentation methods. This actually emcompasses several distinct major theoretical contributions. This is detailed in the following.

The submitted report suffers from a large number of typos. The notations are sometimes not consistent, making the reading a little bit less comfortable. I trust the actually archived version will fix all these minor issues.
On the other hand, the report is very well organized and structured, following a clear logical path.

Chapter 0 presents the **motivation and the thesis overview**. These introductory pages set the general framework of the thesis, briefly discussing hierarchical clustering from a morphological point of view, introducing convex and lattice based optimizations and eventually presenting the organization in 4 chapters of the report.

Chapter 1 introduces the notions of **braids and energetic lattices**. Some basic notions are first recalled, the central one being the notion of hierarchy, such as offered by tree based representations. The inherent fundamental issue related to these representations is the notion of pruning, which can be addressed as an optimization problem once an energy has been defined. The fascinating notion of braids of partitions is then introduced. Such hierarchical representations relax the strict nesting property usually ensured with tree structures (one node is always the union of its 2 children) and hence offer more flexibility, paving the way toward local optimization strategies, which is clearly an improvement over existing methods and a need for pratical applications. The issue of constrained optimization for the optimal pruning of hierarchies is then discussed. Energetic ordering is introduced, leading to the definition of energetic lattices. Illustrations are provided on some toy examples, involving various properties (h-increasingness, scale-increasingness).

Chapter 2 presents different contributions addressing the problem of **constrained optimization** for the segmentation of images based on hierarchies. In a first part, different constrained optimization strategies are recalled. For instance, the rate/distortion theory is briefly presented. This function leads to the definition of one optimal segmentation solution. In a second part, the formulation of the optimization problem in terms of Lagrangian Multipliers is recalled. A new contribution of the thesis is the very interesting discussion demonstrating how the segmentations obtained by Guigue's lamda-cuts correspond to lower bounds of the considered optimization problem on hierarchies of partitions. After discussing another property of energies defined for a family of partial partitions (namely inf-modularity), the chapter focuses on additional contributions: in order to solve the Lagrangian minimization, 3 different models are presented and discussed (namely minimization by energy, cut-constrained and class constrained). The respective theoretical merits of each approach are discussed (properties, locality, genericity...). At this point, however, the translation of these merits in terms of actual guidelines for the enduser is not provided.

Chapter 3 presents some **applications of energetic lattice**. It starts by presenting a number of possible energies fulfilling the *h*-increasingness property and corresponding illustrative results where saliency or texture based features are used. In a second part, a specific application is considered: if a rough ground truth is available a proximal energy can be defined and used to define the optimal cut within a hierarchy. This problem is addressed from the most general point of view: how shall one deal if multiple "ground truths" are available ? or if different hierarchies are available for one given "groud truth" ? In such cases, one has to consider a number of situations: local over- or under-segmentation, overlaps. Braids of partitions offer an appealing framework to deal with these cases. Of course, using ground truth and looking for the closest solution requires the definition of segmentation evaluation measures. A critical review of standard measures is thus presented at this point. A new local Haussdorf-based proximity measure is presented. This is another contribution of the thesis. In the remainder of the chapter, different approaches are presented and discussed. They are based on reasonable intuitive assumptions and rationale, and then featured in the general theoretical framework (super-pixel, intersection graph...). Again, despite presenting some illustrations on various real images, the potential end-user will not be provided with clear guidelines: which energy, which measure shall one use to adress one given kind of images, one given class of applications ? This is not easy to infer, even if each criterion is discussed. In addition to the very interesting discussion provided in the last section (3.5), some more conclusive conclusions would have been appreciated. However, one should stress at this point the outstanding scientific maturity of Bangalore Ravi KIRAN who demonstrates an excellent command of a wide variety of issues, problems and solutions in image segmentation and computer vision. This is clearly supporting the proposed formalized approach based on braids of partitions.

Chapter 4 deals with **hierarchies and saliency functions**. Focusing on contour-based respresentations of the images and partitions, this chapter considers hierarchies represented by a saliency function, which is related to a unified representation framework including Ultrametric contour maps, watershed of floodings etc... Starting from contours, seen as a finite set of Jordan curves, this chapter proposes the construction of a hierarchy of partitions using a lattice structure over this set of curves. This is an extension of the previously presented work, adapting the work done on partitions to deal with contours. Suited operators consequently need to be defined (typically, the *net*-opening, or a new distance function). This is another theoretical contribution of the thesis, further demonstrating the genericity, the flexibility, and hence the remarkable potential of the initially defined framework.

Chapter 5 presents the **conclusion**. The main – numerous ! – contributions of the thesis are summarized. With that respect, figures 5.1 and 5.2 clearly put the main contributions in perspective, featuring the pursued chain of ideas leading to the definition of an optimal segmentation (minimal cut in a braid). Eventually, a number of very interesting perspectives are then developped, including

potential very promising applications in remote sensing.

As a conclusion, I think that Bangalore Ravi KIRAN is an outstanding PhD candidate, with a very good scientific maturity. He has proposed clear innovative contributions to address very timely and challenging problems for the hierarchical analysis of images. His proposals are very sound and certainly make a significant contribution to the knowledge. It is fairly rare to see PhD contributions with such a groundbreaking theoretical contribution. This work will very likely open new horizons in a number of applications in computer vision and the analysis of multivariate images.

One should also underline that this work has been validated through several publications in highly recognized international journals (Pattern Recognition, Pattern Recognition Letters) and conferences (IEEE ICIP, ISMM (2), ECCV, SSVM and CIARP).

As a consequence, I fully support the application of Bangalore Ravi KIRAN in order to earn the PhD Degree from the Université Paris Est, MSTIC Doctoral School.

En conséquence, j'émets un avis très favorable pour que ce travail soit présenté en l'état et défendu devant un jury pour obtenir le grade de Docteur en Informatique de l'Université Paris Est, Ecole Doctorale MSTIC.

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