Chapter 6

A Marked Point Process Model Including Strong Prior Shape Information Applied to Multiple Object Extraction from Images

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ABSTRACT

Object extraction from images is one of the most important tasks in remote sensing image analysis. For accurate extraction from very high resolution (VHR) images, object geometry needs to be taken into account. A method for incorporating strong yet flexible prior shape information into a marked point process model for the extraction of multiple objects of complex shape is presented. To control the computational complexity, the objects considered are defined using the image data and the prior shape information. To estimate the optimal configuration of objects, the process is sampled using a Markov chain based on a stochastic birth-and-death process on the space of multiple objects. The authors present several experimental results on the extraction of tree crowns from VHR aerial images.

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INTRODUCTION

Object detection from optical satellite and aerial images is one of the most important tasks in remote sensing image analysis. The problem arises in many applications, both civilian and military, e.g. tree counting and species classification for biomass or biodiversity estimation; and bird counting for monitoring population changes. Nowadays the resolution of aerial images is approaching a few centimeters. At this level of resolution, the geometry of objects is clearly visible, and needs to be taken into account for accurate object extraction.

Stochastic point process models are known for their ability to include this type of information. A probability distribution is defined on the space of configurations composed of multiple objects which depends on the relation between the objects and data, and on the configuration of individual objects as well as their joint relations. The extracted objects are then those in the ‘optimal’ configuration, which is usually estimated using maximum a posteriori (MAP) estimation.

In previous work, Marked Point Process (MPP) models have been used for the extraction of road networks (Lacoste, Descombes, & Zerubia, 2005), buildings (Ortner, Descombes, & Zerubia, 2007), trees (Perrin, Descombes, & Zerubia, 2005) and birds (Descamps, Descombes, Béchet, & Zerubia, 2009), from images of more than 50 cm/pixel resolution. At that level the objects have a simplified geometrical shape and were thus represented using simple shape objects, e.g. discs, ellipses, or rectangles.

Recently we lifted this restriction without increasing the dimension of the space of a single object (Kulikova, Jermyn, Descombes, Zerubia, & Zhizhina, 2010). A single object was represented by its boundary, a closed curve, but the set of possible single objects (i.e. boundaries) was defined not a priori, but by the image data and a single-object version of the model. A probability distribution was then defined on the configuration space of an unknown number of objects.

This approach is well suited to scenes composed of objects that do not vary too much in shape and size within a class, and that have smooth enough boundaries. In this case, accuracy in the number of extracted objects can be achieved by favouring the smoothness term that controls, as well, the length of the curve. The model can thus to some degree separate objects that overlap, but this leads to imprecision in delineating objects.

The aim of this paper is to incorporate into the single-object model prior knowledge about the shape of the objects sought, in order to deal with overlapping objects with complex shapes without losing their geometric details and without significantly increasing the computational complexity of estimation.

Our work can also be viewed as an extension of the active contour methodology (Kass, Wiktarkin, & Terzopolous, 1998) to cases in which the number of objects is unknown a priori, and where shape prior information is incorporated as well. Much work has been already done based on the active contour approach. Some of this work, e.g. (Caselles, Kimmel, & Sapiro, 1997), includes only weak shape information, essentially smoothness, but can in principle detect multiple (although not overlapping) objects using the level set representation (Osher & Fedkiw, 2003; Sethian, 1999). Other work includes much stronger prior information about shape (Cremers, Tischauer, Weickert, & Schoerr, 2002; Cremers, Osher, & Soatto, 2006b; Joshi, & Srivastava, 2009; Leventon, Grimson, & Fougeras, 2000), but the method used to do this means that it is difficult to treat an unknown number of objects (and in practice only single objects are treated). Cremers et al. (2006a) treat the problem of image segmentation into connected components each of which corresponds to one class of a number of distinct classes of objects, but only one object can be found in each connected component.

Additionally, the results obtained by these methods may be very dependent on the initial configuration, since the algorithm typically used is