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Detecting parametric objects in large scenes by Monte Carlo sampling

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Abstract Point processes constitute a natural extension of Markov random fields (MRF), designed to handle parametric objects. They have shown efficiency and competitiveness for tackling object extraction problems in vision. Simulating these stochastic models is however a difficult task. The performances of the existing samplers are limited in terms of computation time and convergence stability, especially on large scenes. We propose a new sampling procedure based on a Monte Carlo formalism. Our algorithm exploits the Markovian property of point processes to perform the sampling in parallel. This procedure is embedded into a data-driven mechanism so that the points are distributed in the scene in function of spatial information extracted from the input data. The performances of the sampler are analyzed through a set of experiments on various object detection problems from large scenes, including comparisons to the existing algorithms. The sampler is also tested as optimization algorithm for MRF-based labeling problems.

Keywords Stochastic modeling · Monte Carlo sampling · Object detection · Large scenes · Energy minimization · Point processes · Markov random fields

1 Introduction

Markov point processes are probabilistic models introduced by Baddeley and Lieshout (1993) to extend the traditional Markov random fields (MRF) by using an object-based formalism. Indeed, Markov point processes can address object recognition problems by directly manipulating parametric entities in dynamic graphs, whereas MRFs are restricted to labeling problems in static graphs.

These mathematical tools exploit random variables whose realizations are configurations of parametric objects, each object being assigned to a point positioned in the scene. The number of objects is itself a random variable, and thus must not be estimated or specified by a user. Another strength of Markov point processes is their ability to take into account complex spatial interactions between the objects and to impose global regularization constraints in a scene. A point process is usually specified by three key elements:

- *Some parametric objects.* They can be defined in discrete and/or continuous domains. They usually correspond to geometric entities, *e.g.* segments, rectangles, circles or planes, but can more generally be any type of multi-dimensional function. The complexity of the objects directly impacts on the size of the configuration space.
- *An energy.* It is used to measure the quality of a configuration of objects. The energy is typically defined as a combination of a term assessing the consistency of objects to the data, and a term taking into account spatial interactions between objects in a Markovian context.
- *A sampler.* It allows the search for the object configuration minimizing the energy. As the configuration space is of variable dimension and the energy is usually nonconvex, Monte Carlo based samplers capable of exploring the whole configuration space are required, in most cases a Markov Chain Monte Carlo (MCMC) algorithm (Hastings 1970; Green 1995; Liu 2001).

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