Model-Based Learning for Point Pattern Data

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Abstract

This article proposes a framework for model-based point pattern learning using point process theory. Likelihood functions for point pattern data derived from point process theory enable principled yet conceptually transparent extensions of learning tasks, such as classification, novelty detection and clustering, to point pattern data. Furthermore, tractable point pattern models as well as solutions for learning and decision making from point pattern data are developed.

Keywords: point pattern, point process, random finite set, multiple instance learning, classification, novelty detection, clustering

1. Introduction

Point patterns–sets or multi-sets of unordered points–arise in numerous data analysis problems where they are commonly known as 'bags', e.g. in multiple instance learning [1, 12, 11], natural language processing and information retrieval ('bag-of-words') [40, 31, 41], image and scene categorization ('bag-of-visual-words') [14, 48, 61], and in sparse data ('bag-of-features') [13, 30]. A statistical data model, usually specified by the *likelihood* function, plays a fundamental role in model-based data analysis. However, statistical point pattern models have not received much attention in the development of machine learning algorithms for point pattern data.

To motivate the development of suitable likelihood functions for point patterns, let us consider an example in novelty detection. Suppose that apples from an apple tree land on the ground independently from each other, and that the daily point patterns of landing positions are also independent. Further, the probability density, p_f, of the landing position, learned from 'normal' training data, is shown in Fig. 1. Since the apple landing positions are independent, following common practice (see e.g., [40, 31, 41, 14, 9]) the likelihood that the apples land at positions $x_1, ..., x_m$ is given by the joint (probability) density $p(x_1, ..., x_m)$, which by the independence of the landing positions, is $\prod_{i=1}^{m} p_f(x_i)$.

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