Modelling Forest Tree Data Using Sequential Spatial Point Processes

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Spatial structure of a forest stand is naturally modeled by spatial point process models. Motivated by aerial forest inventories and forest dynamics in general, we propose a sequential spatial modeling approach to forest data. It is better justified than a static point process model for describing the long-term dependence among the spatial location of trees in forest, and the locations of detected trees in aerial forest inventories. Tree size can be used as a natural measured surrogate of the unknown tree age to determine the order in which trees have emerged, or are observed on an aerial image. The sequential spatial point processes differ from spatial point processes in the sense that the realizations are ordered sequences of spatial locations, which allows us to approximate the spatial dynamics of the phenomena. This feature shall be useful to interpret the long-term dependence and the history formed by the spatial locations of trees. For the application, we use forest data set collected from the Kiihtelysvaara forest region in Eastern Finland.

Point process models for sweat gland activation observed with noise

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The aim of this work is to construct spatial models for the activation of sweat glands for healthy subjects and subjects suffering from peripheral neuropathy by using videos of sweating recorded from the subjects. Several image analysis steps are needed to extract the point patterns from the videos and some incorrectly identified sweat gland locations may be present in the data. We regard the resulting sweat patterns as realizations of spatial point processes, and propose ways to take into account the errors. In our first model we included an error term in the point process model. In the second model we used an estimation procedure that is robust with respect to the errors.

References

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Maximum likelihood calibration of stochastic multipath radio channel models

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When transmitting data via a wireless channel, a signal undergoes a series of reflections, so that a receiver perceives a distorted version resulting from the superposition of multiple signal paths. More concisely, the received signal $y(\cdot)$ is related to the transmitted signal $x(\cdot)$ via

$$y(\tau) = \sum_{k \geq 1} \alpha_k x(\tau - \tau_k) + W(\tau),$$

where the collection $\{(\tau_k, \alpha_k)\}_{k \geq 1}$ contains both the delays $\{\tau_k\}_{k \geq 1}$ and the amplitude losses $\{\alpha_k\}_{k \geq 1}$ along the paths. The term $W(\tau)$ denotes thermal noise. Hence, the choice of a suitable model for the marked point process $\{(\tau_k, \alpha_k)\}_{k \geq 1}$ precedes any further analysis of detailed channel properties via extensive simulations. In the Turin model, the delays form a homogeneous Poisson point process and the marks are independent Rayleigh random variables with a mean decaying exponentially in τ_k. However, for indoor environments the simple Turin model is inappropriate and it has been suggested to use an inhomogeneous intensity.

In this talk, I will present Monte Carlo maximum likelihood estimation as a novel approach in the context of calibration and selection of stochastic channel models in signal processing of wireless networks. First, considering a Turin channel model with an inhomogeneous arrival rate as a prototypical example, I will explain how the general statistical methodology is adapted and refined for the specific requirements and challenges of stochastic multipath channel models. Then, I will illustrate the advantages and pitfalls of the method on the basis of simulated data and apply the calibration method to wideband signal data from indoor channels.

Finally, I will outline possible extensions to Bayesian inference and clustered arrival models.

References

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Methods for sampling designs based on the integrated Bernoulli variance of spatial presence/absence data

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There has lately been growing interest in creating better habitat maps of the sea bottom [2]. Improved understanding of for instance coral presence and absence distribution in space can provide insightful information for environmental management planning. It is very costly to explore the oceans, and the sampling designs of surveys must be planned wisely. This information gathering can be performed by survey expeditions using several types of devices. Of lately, particular focus has been on underwater vehicles of different levels of autonomy and restrictions related to the duration of the survey. In any case, the vehicle data handling must be scalable both for computational resources and for the high-resolution ocean mapping that is desired. In this setting of survey paths planning and execution, elements from statistical experimental designs can be useful.

In this work we propose methods for statistical sampling design that will aid in the mapping of corals in selected regions. The scope is in this binary case of presence / absence of coral in a spatial region to reduce the integrated Bernoulli variance (IBV) [1]. We develop sequential sampling to cover unknown regions that contain rich new information about the ocean bottom presence or absence of corals. We propose approximate closed form solutions for the IBV in the setting of a spatial generalized linear model (GLM), and study their properties in simulation studies.

We apply this method to batch sequential designs, which consider the use of floating devices that can be dropped at determined locations and will follow different paths influenced by the ocean currents. We present applications with simulated and real data.

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A natural spatio-temporal extension of Gaussian Matérn fields

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The Matérn family is the most well known family of covariance functions used for spatial modelling. Often, this family is generalised to space-time through the use of a Kronecker product, resulting in separable models, but recent literature argues against separability. We follow the arguments in the original research by Whittle (1953 and 1964) to develop a natural generalisation from space to space-time, from a physical point of view, that turns out to give non-separable models.

The resulting spatio-temporal covariance function is further generalised to a family of covariance functions, as a spatio-temporal analogue of the Matérn family. The new family has both range parameters in space and in time, smoothness parameters in space and time, and an extra separability parameter.

This contribution defines the new family, discusses marginal behaviour, interprets all parameters, and recommends default priors for Bayesian analysis. The family includes both separable and non-separable models. Further, we detail a computationally efficient representation that can be included in software for hierarchical modelling, and we provide a ready to use implementation in the R-INLA software as a random effect in latent Gaussian or generalised additive models.

The end goal of this research is to replace the most commonly used model for the spatio-temporal random effect with a new default recommendation.

References

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