# A spatio-temporal model for locations of trees in the Barro Colorado Island plot

**Abdollah Jalilian, Razi University**

Locations of alive trees in the 50-hectare permanent study plot in the tropical rain forest of Barro Colorado Island (BCI), Gatun Lake, Panama, have been recorded in 8 consecutive censuses since 1980. In each census, new trees tend to grow near existing trees in the preceding census due to seed dispersal mechanisms and favorable topography and soil conditions. On the other hand, elimination of trees from one census to the next seems to occur more frequently in dens areas where there are competition for resources and light among trees. Let $\mathbf{x}_t$ denotes the spatial point pattern of locations of trees in the $t$-th census, $t = 1, ..., T = 8$. We assume that each tree $u \in \mathbf{x}_t$ is no longer present in the subsequent census $\mathbf{x}_{t+1}$ with probability $1 - p(u; \mathbf{x}_t)$ and $u \in \mathbf{x}_t$ is potentially able to produce a cluster of new trees $Z_{t+1}^{(u)}$ in the next census $\mathbf{x}_{t+1}$. This means that $\mathbf{x}_{t+1}$ is a combination of a thinned version of $\mathbf{x}_t$ and $\cup_{u \in \mathbf{x}_t} Z_{t+1}^{(u)}$. Thus, elimination of trees between two consecutive censuses can be modeled by a random thinning mechanism and the addition of new trees can be modeled by a suitable spatial cluster point process. Following this approach, in the present talk, we introduce a spatio-temporal model for population dynamics in the BCI plot and discuss parameter estimation methods and model checking tools for the introduced model.

# Sparse models for highly multivariate log-Gaussian Cox processes

**Achmad Choiruddin, Aalborg University**

Studies regarding biodiversity in tropical rainforest ecology are conducted using large data sets containing locations of thousands of trees for each of hundreds of species. To get insight in the multivariate dependence structure for a high number of species, a model-based approach is required. Waagepetersen et. al., (2016) proposed to use multivariate log-Gaussian Cox process models but their data analysis only involved nine species. One problem using their approach for a large number of species is model complexity where the numbers of parameters increase very fast as a function of the number of species. Another related problem is computational where general off-the-shelf optimization algorithms may be slow and unstable partly due to the high dimension of the parameter space.

In this project we aim at extending the methodology in Waagepetersen et. al., (2016) by constructing more reliable optimization methods and introducing regularization of parameter estimates. In addition to providing computationally more stable results, use of Lasso regularization may also lead to biologically more interpretable models. To do so, we note that the estimation method from Waagepetersen et. al., (2016) can be approximated by a least squares method which enables us to benefit from well-known and robust Lasso and elastic net techniques.

Based on the joint-work with Rasmus Waagepetersen, Jean-Franois Coeurjolly and Francisco Cuevas-Pachecho

# Analysis of point patterns on linear networks — a review

Adrian Baddeley
CURTIN UNIVERSITY, PERTH, WESTERN AUSTRALIA

This talk is a review of research on the statistical analysis of spatial point patterns on linear networks over the last two decades. The goal is to draw lessons and identify challenges for future research.

Topics include methodological errors; kernel estimation of intensity and relative risk; parametric modelling; (non-)existence of stationary processes; (non-)constancy of spatial scale; and the challenges of real network data.

The talk includes unpublished research by the Perth (Western Australia) research group on spatial point processes and applications (SPPA).

# Spatial analysis of sweat glands

Aila Särkkä
Chalmers University of Technology and the University of Gothenburg, Gothenburg, Sweden

Dr William Kennedy's group at the University of Minnesota has developed a novel device, the sensitive sweat test, which offers the potential for non-invasive early diagnosis of peripheral neuropathy. The test measures the secretion of sweat from hundreds of individual sweat glands, and shows the location and distribution of active sweat glands. Kennedy's group performed a study, in which 200 healthy control subjects without neuropathy or known risk factors and 20 subjects with a known diagnosis of peripheral neuropathy, participated. For each subject and for four different body parts/subject, a one minute video at one frame/sec was recorded. Each video shows sweat glands appearing, growing, and sometimes disappearing.

We have performed some preliminary analysis of the data and e.g. compared the intensity of sweat glands, the wet area, and the spatial distribution of sweat glands of healthy and neuropathic subjects using simple summary statistics. We have also fitted point process and random set models to parts of the data sets. We will present some preliminary results of our analysis.

This is joint work with Mikko Kuronen and Tuomas Rajala at Natural Resources Finland and Adam Loavenbruck at the University of Minnesota.

## Pair correlation functions and limiting distributions of iterated cluster point processes

**Jesper Møller and Andreas dyreborg Christoffersen**

We consider a Markov chain of point processes such that each state is a superposition of an independent cluster process with the previous state as its centre process together with some independent noise process and a thinned version of the previous state. The model extends earlier work by Felsenstein and Shimatani describing a reproducing population. We discuss when closed term expressions of the first and second order moments are available for a given state. In a special case it is known that the pair correlation function for these type of point processes converges as the Markov chain progresses, but it has not been shown whether the Markov chain has an equilibrium distribution with this, particular, pair correlation function and how it may be constructed. Assuming the same reproducing system, we construct an equilibrium distribution by a coupling argument.

**Presentation by: Andreas Dyreborg Christoffersen**

# The Thinner Takes it All: applications of thinned Poisson processes in ecology

**Andy Seaton, University of St Andrews**
**Janine Illian, University of St Andrews**

A thinned Poisson process is also a Poisson process. This is one of the most attractive features for applied users of point processes. This talk will show how several types of "observation processes" that are common in ecological statistics can be formulated as a thinning of a Poisson (or log-Gaussian Cox) process.

Plot sampling, distance sampling (with lines and point transects) and spatial capture-recapture (SCR) methods will be discussed. SCR demonstrates the flexibility of thinning, where the thinning occurs conditional on observations at a fixed detector array and involves an implicit animal movement model. It is likely that many problems not typically viewed as a thinned point process can be reformulated as such.

To end we will discuss an application of thinning as a method of partitioning data for spatial cross-validation.

By doing this we hope to show that point process models can be used in cases where a researcher may not initially think they are applicable. Complicated observation processes can be incorporated into point process models using existing software that allows users to define thinning functions, thus providing an extra tool in an ecological statisticians toolbox.

# Maximum likelihood estimation of determinantal point processes

**Poinas Arnaud, University of Rennes 1**

The likelihood of a Determinantal point process (DPP for short) has an explicit expression. Unfortunately, this expression requires the knowledge of the spectral decomposition of the DPP kernel which is usually unknown, making maximum likelihood based inference difficult. One solution suggested in (Lavancier, Møller, Rubak, '15) is to approximate the DPP kernel by a truncated Fourier series. This approach has showed very good performances on numerical simulations. However, it is limited to rectangular observation windows and no theoretical guarantee has been established. In this talk, we present a slightly different approximation where the Fourier series are replaced by Fourier transforms. This continuous approximation has the advantages of yielding a smoother contrast function than the previous discrete approximation while working for any observation window. Moreover, we give a proof, under some technical assumptions, that our approximated MLE is asymptotically equivalent to the MLE and that it is consistent.

# GPU-Accelerated Real-Time Downscaling of Malaria Incidence in Zambia

**Benjamin M. Taylor, Lancaster University**

We propose an inferential framework for the formal downscaling of estimates of malaria incidence derived from health care facilities in Zambia. Health facilities have unknown and overlapping catchment areas, which change over time, and report on an inconsistent basis. We use the log-Gaussian Cox process as a basis for the unobserved disease process and the technique of data augmentation to complete the picture of incident cases at the sub-catchment-area level. The graphics processing unit (GPU) implementation of our model brings an order of magnitude improvement in computation time and thus, is suitable for real-time outbreak detection. We apply our method to modelling monthly malaria incidence in Zambia between 2012 and 2016. This is a large model, with 917,515 parameters each year and predicting at 65,536 locations across the country.

# Maximum likelihood fitting of stochastic channel models

**Christian Hirsch, University of Mannheim**

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. The Turin model assumes that the delays incurred in the paths form a Poisson point process on the real line.

Due to its simplicity, the case of a constant intensity has received substantial attention in literature. However, for indoor environments, this model is inappropriate and it has been suggested to use instead a power intensity function.

In this talk, we discuss how Markov chain maximum likelihood can be used for parameter estimation and model selection. A particular difficulty of the stochastic channel model is that although the model is set up in the time domain, the measurements are taken in the frequency domain.

This talk is based on joint work with Ayush Bharti, Troels Pedersen and Rasmus Waagepetersen.

# Anisotropy analysis of spatial point patterns

**Claudia Redenbach, Technische Universität Kaiserslautern**

This talk will give an overview of techniques for anisotropy analysis of spatial point patterns in $\mathbb{R}^2$ and $\mathbb{R}^3$. The common idea of all methods is to analyse the second order structure of the point pattern by estimating suitable directional summary statistics of point pair difference vectors - the Fry points - of the observed pattern. We focus on regular point patterns subject to geometric anisotropy. The performance of the methods depending on the strength of compression, the regularity of the point pattern, and in the presence of noise is evaluated in a simulation study. Based on the results, we formulate recommendations for the selection of a method and the choice of its parameters.

As an example of application, we will consider anisotropy analysis of the pore system in polar ice. In a depth below approx. 100 m, the ice contains isolated air bubbles which can be studied by using tomographic images of ice core samples. Using the methods described above, the direction and strength of compression of the ice sheet can be estimated.

Joint work with Martina Sormani, Tuomas Rajala, and Aila Särkkä.

# Hyperuniformity and Number-Rigidity for Point Processes

**David Dereudre, University of Lille**

Recently two notions of rigidity for spatial stationary point processes appear in the literature. The first one is the *Hyperuniformity property*, which claims that the variance of the number of points in any bounded domain $D$ is strictly sub-linear with respect to the volume of $D$. This notion notion has been introduced by physicists to describe the nature of crystals or pseudo-crystals. The second notion is the *Number-rigidity property*, which claims that in any bounded domain $D$, the configuration of points outside $D$ determines almost-surely the number of points inside $D$. This notion has been introduced by mathematicians to describe unusual rigidity properties for point processes. It is not difficult to see that the standard Poisson Point Process is not Hyperuniform nor Number-rigid. The Poisson Point process is not rigid enough! During the talk we will give the main results involving these rigidity properties. In particular, we will see that they are not equivalent but not so far. We will see that some determinantal point processes, Gibbs point processes or perturbed lattices are Hyperuniform or/and Number-rigid. Several conjectures will be presented as well. Let us note that nobody has investigated yet these notions using tools from spatial statistics. This point could be discussed during the workshop.

# Predicting the intensity function of point processes inside unobserved windows

**Edith Gabriel, Avignon University**

Mapping is a key issue in environmental science. A common example lies in ecology when mapping species distribution. When the location of individuals is known, we can estimate the intensity, usually by kernel smoothing. However exhaustive point patterns are usually unreachable at the survey scale so that sampling methods are used. Our aim is thus to predict the spatial distribution of species from the knowledge of presence locations and environment relationships, taking into account any interactions between individuals. Namely, we aim to estimate the intensity function of a point process in windows where it has not been observed, conditional to its realization in observed windows, as in geostatistics for continuous processes. We define a predictor as the best linear unbiased combination of the point pattern. We show that the weight function associated to the predictor is the solution of a Fredholm equation of second kind. Both the kernel and the source term of the Fredholm equation are related to the second order characteristics of the point process through the pair correlation function. In order to obtain practical solutions, we restrict the solution space to that generated by linear combinations of elementary functions of a finite element basis. Results are presented and illustrated on simulations and real data in different situations: first for a stationary process, then for nonstationary processes, using continuous covariates or the realization of an additional point process.

# Couplings of Determinantal Point Processes and Quantifying Repulsiveness

**Eliza O'Reilly, University of Texas at Austin**

Determinantal point processes (DPPs) are a useful class of random point configurations exhibiting repulsion between points. In this talk, we will describe a recent result on obtaining the reduced Palm distribution of a DPP by removing at most one point from the DPP. This result will be used to discuss the nature of repulsiveness of DPPs in terms of this removed point, and specific parametric models for DPPs will be compared. This talk is based on joint work with Jesper Møller.

# Dynamics on point processes and random graphs

**F. Baccelli, INRIA and UT Austin**

This talk is centered on covariant dynamics on unimodular random graphs and random networks (marked graphs), namely maps from the set of vertices to itself which are preserved by graph or network isomorphisms. Such dynamics are referred to as vertex-shifts here. These dynamics have point-shifts on point processes as a subclass. First we give a classification of vertex-shifts on unimodular random networks. Each such vertex-shift partitions the vertices into a collection of connected components and foils. The latter are discrete analogues the stable manifold of the dynamics. The classification is based on the cardinality of the connected components and foils. Up to an event of zero probability, there are three classes of foliations in a connected component: F/F (with finitely many finite foils), I/F (infinitely many finite foils), and I/I (infinitely many infinite foils). In the especial case of point-shifts on stationary point processes the notion of relative intensity can be defined. This notion formalizes the intuition of invariance of dimension between consecutive foils and it is the key element to prove this result for the Hausdorff unimodular dimension of foils. An infinite connected component of the graph of a vertex-shift on a random network forms an infinite tree with one selected end which is referred to as an Eternal Family Tree. Such trees can be seen as stochastic extensions of branching processes. Unimodular Eternal Family Trees can be seen as extensions of critical branching processes. The class of offspring-invariant Eternal Family Trees, allows one to analyze dynamics on networks which are not necessarily unimodular. These can be seen as extensions of not necessarily critical branching processes. Several construction techniques of Eternal Family Trees are proposed, like the joining of trees or moving the root to a far descendant.

Joint work with M.O. Haji-Mirsadeghi and A. Khezeli.

# Non-parametric inference of spatial birth-death point processes

**Frédéric Lavancier, Nantes University, France**

We assume to observe the realisation of a spatial birth-death point process in a bounded region $S$ of $\mathbb{R}^d$ and during a time $T$. This situation is motivated in bio-imaging by the temporal observation of certain molecules in a cell membrane, where as a first approximation their spatio-temporal dynamics can be viewed as a spatial birth-death mechanism. Our objective is the non-parametric estimation of the characteristics of the process, that are, for all point configurations $x$, the intensity of births $\beta(x)$ and of deaths $\delta(x)$, and given that a birth (respectively a death) occurs in $x$, the probability density of births $k_\beta(x, u)$, $u \in S$ (respectively of deaths $k_\delta(x, u)$, $u \in S$). In this study, we focus on the estimation of the intensities and provide a kernel estimator. We prove its consistency, as $T \to \infty$, under the assumption that there exists an upper bound for the number of particles in $S$ and for standard rates of convergence of the bandwidth. Our proof exploits the uniform rate of convergence to equilibrium of the birth-death process and its underlying martingale properties, that allow us to use stochastic calculus tools (like Itô's formula) and to derive a crucial concentration inequality for the "time spent" by $X_t$ at $x$. This is a joint work with Ronan Le Guével (Rennes 2 University).

# Stochastic Quasi-Likelihood for Case-Control Point Pattern Data

**Ganggang Xu, University of Miami**

We propose a novel stochastic quasi-likelihood estimation procedure for case-control point processes. Quasi-likelihood for point processes depends on a certain optimal weight function and for the new method the weight function is stochastic since it depends on the control point pattern. The new procedure also provides a computationally efficient implementation of quasi-likelihood for univariate point processes in which case a synthetic control point process is simulated by the user. Under mild conditions, the proposed approach yields consistent and asymptotically normal parameter estimators. We further show that the estimators are optimal in the sense that the associated Godambe information is maximal within a wide class of estimating functions for case-control point processes. The effectiveness of the proposed method is further illustrated using extensive simulation studies and two data examples.

# Poisson-saddlepoint approximation for gibbs point processes

**Gopalan Nair, The University of Western Australia**

The intensity of a Gibbs point process model is usually an intractable function of the model parameters. This is a severe restriction on the practical application of such models. This talk will cover recent development on computational approximation to the intensity of a Gibbs spatial point process having interactions of any order.

The new approximation is qualitatively similar to the mean field approximation, but is far more accurate. It may be regarded as a counterpart of the Percus-Yevick approximation. The approximate intensity is obtained as the solution of a self-consistency equation. Method will illustrated for the area-interaction model and the Geyer saturation model.

*This is joint work Adrian Baddeley, Curtin University of Technology.*

# Spatial Survival Analysis
# Space-time data in public health

**Henrike Häbel, Karolinska Institutet**

Traditionally in public health studies, spatial data arises over regions, where the county level usually corresponds to the highest resolution. In a survival analysis on the time to the occurrence of an event, so-called shared frailty models offer one way to include a spatial effect. A frailty refers to a latent random effect that enters multiplicatively on the baseline hazard function and accounts for within-region correlation. However, it is assumed that there is independence between the regions. But what if there is also between-group correlation and spatial dependence?

As geographic information systems software become more accessible, the analysis of location dependent data has gained increasing interest also in public health. In my talk, I will give an overview on the analysis of survival data that is spatially referenced to the location of the occurrence of the event. On the basis of examples from the literature and current research, I would like to discuss how common analysis tools from point pattern analysis may be useful for spatial survival data.

# Point processes on directed linear networks

**Jakob G. Rasmussen, Aalborg University**

Point pattern datasets are sometimes restricted to a network, rather than being defined on (an open subset of) $\mathbb{R}^d$. Examples include car accidents or street crimes on road networks, or positions of spines on a dendrite tree. To take account of the fact that the points occur on the network only, this kind of data is typically modelled as point processes on linear networks.

However, some networks have natural directions, e.g. river networks (direction of flow) or dendrite trees (direction away from root). This can be accounted for by associating a direction to each edge in the linear network to obtain a directed linear network. Once directions have been included we can adapt the concept of the conditional intensity function commonly used for defining temporal point processes to the setting of directed linear networks. This approach has the advantage that various results and concepts can be adapted from the theory of temporal point processes, e.g. a closed form expression for the likelihood function, two simulation algorithms (inversion method and Ogata's modified thinning algorithm), and model checking based on residual analysis. The theory can easily be extended to the case of marked points.

Models are specified by giving an explicit expression for the conditional intensity function. We consider classical temporal point processes adapted to the setting of directed linear networks, such as Hawkes processes or self-correcting processes.

The theory is exemplified by both simulated and real data, the latter being the positions of spines on a dendrite tree.

# Quantifying emergent spatial patterns: an application in cancer

**Janine B Illian, Centre for Research into Ecological & Environmental Modelling (CREEM), School of Mathematics and Statistics, University of St Andrews, UK**

Central to cancer patient diagnosis and prognosis is the pathological assessment of the histopathological, architectural and morphological properties within patient tissue sections. These tissue sections are typically a mix of cancerous and non-cancerous cells together with areas where there exists no tissue. Based on these tissue section properties, pathologists stage tumours to estimate both cancer progression and patient outcome. Cancer staging predicts survival at the scale of the population well, but prediction is less accurate for individual patients. This is because the tissue is heterogeneous and pathological features are difficult to quantify. Image analysis can, in principle, provide quantitative measures of pathological features. To date, the focus has been on cell shape, the invasive edge of the tumour and proximity of the lymphatic system. Little consideration has been given to the spatial arrangement of cells.

Here, we present the findings of Jones-Todd et al (2018), which employs spatial statistics to quantify cancerous and non-cancerous cell distributions within tissue samples from colorectal cancer (CRC) patients. We used spatial point processes approaches to model the distribution of cells. We investigated the capability of each estimated point process parameter to discriminate between patient mortality outcomes. For mortality we found significant differences in the density of both cancerous and non-cancerous cells between patients who lived and patients who died.

**Reference:**

Jones-Todd, C. M., Caie, P., Illian, J. B., Stevenson, B. C., Savage, A., Harrison, D. J., & Bown, J. L. (2018). Identifying prognostic structural features in tissue sections of colon cancer patients using point pattern analysis. *Statistics in Medicine*. https://doi.org/10.1002/sim.8046

# Monte-Carlo estimation of $\int_{[0,1]^\iota} f_\iota(u)\mathrm{d}u$ for any $\iota = 1, \ldots, d$ using determinanatal point processes

**Jean-François Coeurjolly, Université du Québec Montréal**

Bardenet and Hardy (2019) have recently built an ad-hoc Orthogonal Polynomial Ensemble (OPE) and used the point pattern as quadrature points to estimate $\int_{[0,1]^d} f_d(u)\mathrm{d}u$ where, for some $d \geq 1$, $f_d$ is a $d$-dimensional Lebesgue measurable function (the authors actually considered more general measures). The authors proved that their estimator satisfies a central limit theorem with explicit variance and rate of convergence $\sqrt{n^{1+1/d}}$ (to be compared with the rate $\sqrt{n}$ for standard Monte-Carlo), under the main assumption that $f_d$ is continuously differentiable and compactly supported.

OPE are particular examples of projections determinantal point processes (DPPs) which produce exactly $n$ points. Instead of orthogonal polynomials, we use a product of Dirichlet type kernels (based on the Fourier basis) and extend this work in two directions: first and most importantly, to mimic a problem encountered in computer experiments, we investigate the problem of estimating $\mathcal{I}_\iota = \int_{[0,1]^\iota} f_\iota(u)\mathrm{d}u$, for any measurable function $f_\iota : [0,1]^\iota \to \mathbb{R}$ and any $\iota = 1, \ldots, d$. Our Dirichlet model is actually well-suited to such a problem since we can prove that any projection on a lower dimensional space of this model is distributed as an $(\alpha)$-DPP (with $\alpha < 0$). We exploit this property and exhibit estimates of $\mathcal{I}_\iota$, for any $\iota$, that satsify a CLT with rate of convergence $\sqrt{n^{1+1/d}}$ for any $\iota = 1, \ldots, d$. Second, our results are obtained under weaker assumptions. We only require that $f_\iota$ is "half"-differentiable (an assumption which is for instance satified for $f_\iota(u) = \|u\|_1$) and do not impose that the integrands are compactly supported.

Joint works with Pierre-Olivier Amblard (CNRS, Université Grenoble Alpes, France) and Adrien Mazoyer (UQAM).

Bardenet, R., & Hardy, A. (2019). Monte Carlo with determinantal point processes. arXiv preprint arXiv:1605.00361, to appear in Annal of Applied Probability.

# Non-parametric testing of independence between marks and covariates in marked point process setting

**Jiří Dvořák, Charles University, Prague,**
joint work with Tomáš Mrkvička, Jorge Mateu and Jonathan Gonzáles

In a marked point process the points carry certain additional information, called mark. Both cathegorical marks, such as a tree species, and numerical marks, such as a tree height, occur frequently in practice. Sometimes a marked point pattern dataset is accompanied by a covariate describing e.g. the heterogeneity of the environment, such as altitude, acidity or soil content of a specific nutrient. The covariate is often modeled by a random field. Cathegorical covariates may also be relevant to a given problem.

One of the natural questions to ask is whether the marks are influenced by the covariate value at the given locations. Hence it is useful to test the hypothesis of independence between the marks and the covariate. We present a non-parametric approach to testing independence, conditional on the marginal structure of the marks and the covariate, using a modified version of the classical random shift method. In case of cathegorical marks or cathegorical covariates with more than two levels we take advantage of the global envelope test.

To illustrate the performance of the test we present a simulation study. We also discuss some data examples and investigate e.g. whether the length of fallen trees after a windstorm is independent of the intensity of the fallen trees occurrence.

# Multinomial logistic regression for multivariate street crime point pattern data

**Kristian Hessellund, Aalborg University**

Joint work with Rasmus Waagepetersen, Ganggang Xu and Yongtao Guan.

The aim is to propose new methods for analysis of multivariate point patterns (MPP) that is observed in a heterogeneous environment. For instance, a such MPP could be the locations of street crimes in a city, where the different types of point patterns correspond to different types of street crimes. Clearly, the street crimes must be non-stationary due to the geography of the city and the variation of crimes from one street to another, hence the intensity function of each street crime is complex. Therefore, the task to model the intensities is rather difficult. To accommodate this issue we assume that each type of street crime share a common unobserved and possibly complex factor. By using this assumption it enable us to estimate some first order parameters (demographic covariates) along with non-parametric estimation of ratios of the so-called cross-pair correlation function without specifying the complex factor. Thereby, we can analyze how the street crimes relate to some demographic covariates and we can study the pairwise dependence structure between the street crimes non-parametrically.

# Zoonotic surveillance for plague via point processes in geographic and principle components space

Lance A. Waller and Ian Buller, Emory University

*Yersinia pestis* is a gram-negative bacterium, primarily transmitted via flea bite, causing plague in numerous mammal species. While human cases are rare in the United States (US), consequences of infection are severe (often fatal) and motivate expanded methods for disease surveillance including monitoring of infection within animal hosts. The incidence and prevalence of zoonotic diseases are influenced by climate variables through the ecological niche of and interactions between hosts, vector, and pathogen. *Canis latrans* (coyotes) provide one sentinel species for plague. In order to describe geographic patterns of infection within the coyote host, we define and apply non-parametric regression and spatial point process methods to both geographic space and the space defined by the first two principle components of climate variables. More specifically, we utilize spatial ecological niche models applied to approximately 29,000 locations of coyotes tested for plague antibodies by US government agencies linked with PRISM 30-year climate averages to determine the spatial distribution of *Y. pestis* infection within the principle components space of climate variables (PC space). Monte Carlo assessments identify significantly different patterns of infected and non-infected sampled coyotes yielding "maps" of high and low risk climatic niches for infection within PC space. Areas in *PC space* with predicted with higher likelihood of plague in coyotes are then transformed to *geographic space* to provide inference regarding specific areas of surveillance interest in the western US. We illustrate the approach in the state of California and more broadly across the western US. Results to date allow public health officials to gather more information from existing data as well as to strategize future sampling and testing plans, particularly to identify geographic areas which are historically undersampled but fall within predicted higher-risk PC (climate) space. We outline the methodological approach, applications to date, and areas for further development and refinement.

# Global envelopes with intrinsic graphical interpretation in R

**Mari Myllymäki, Natural Resources Institute Finland (Luke)**

In this talk, I will introduce intrinsic graphical interpretation property for global envelopes and describe some new global envelopes that have the property. Further, I will present the R package GET that implements the global envelopes with intrinsic graphical interpretation and show how examples on point processes and beyond can easily be performed by means of the GET package. This is joint work with Tomáš Mrkvička. The development version of the GET package is available at https://github.com/myllym/GET/.

# A multi-scale area-interaction model for spatio-temporal point patterns

**Marie-Colette van Lieshout, CWI/University of Twente**

Models for fitting spatio-temporal point processes should incorporate spatio-temporal inhomogeneity and allow for different types of interaction between points (clustering or regularity). We propose an extension of the spatial multi-scale area-interaction model to a spatio-temporal framework. This model allows for interaction between points at different spatio-temporal scales and for the inclusion of covariates. We illustrate the new model using data on varicella cases registered during 2013 in Valencia, Spain.

This is joint work with Adina Iftimi and Francisco Montes.

# Statistical analysis of space-time cluster point processes

Michaela Prokešová, Charles University

In the talk we investigate a class of parametric models suitable for modeling of clustered space-time point patterns which are encountered e.g. in epidemiology. Namely we will consider the inhomogeneous shot-noise Cox processes. The model produces clustered point patterns and enables the first-order intensity function to be inhomogeneous and dependent on covariates. Since the maximum likelihood estimation is computationally prohibitive in this case alternative moment estimation methods have to be used instead.

A natural option is to use a two-step estimation procedure when first the inhomogeneity parameters are estimated from the first-order intensity function and then in the second step the inhomogeneous K-function is used to estimate the interaction parameters. However the estimate of the full inhomogeneous space-time K-function may be quite variable and this influences the quality of the minimum contrast estimate. The variability may be reduced by using the K-functions of the spatial and temporal projection processes separately. However in such case further assumptions on separability of the first-order intensity function are needed. Moreover the effect of overlapping of the clusters in the projection causes loss of information and implies suboptimal asymptotic convergence rates.

To solve the above described problems we suggest to use the so-called profile minimum contrast method for the space-time K-function – i.e. to use in the second step the minimum contrast estimation for the profile functions $K(R,\cdot)$ and $K(\cdot,T)$ with fixed spatial and temporal range, respectively. No assumptions on separability of the first-order intensity function are needed and the minimization is computed separately for two sets of interaction parameters with smaller dimension. The asymptotic convergence rates are the same like for the minimum contrast with the full space-time K-function but the numerical stability of the newly suggested procedure is better. We demonstrate the efficacy of the profile minimum contrast method through a simulation study and an application to the FMD data set.

# Coherence in randomness: On the zeros of time-frequency transforms of white noise

Rémi Bardenet, CNRS & Univ. Lille, France

Time-frequency analysis is the part of signal processing concerned with spectrograms. A spectrogram is the modulus of a particular linear transform of the signal, and its values can be interpreted as measuring how much of the signal's energy is spent on each time and frequency. Spectrograms are thus akin to musical score: a 2-dimensional representation of a signal, where one dimension is time and the other frequency. Many signal processing algorithms rely on finding the maxima of a spectrogram in the time-frequency plane. In this talk, we take the dual approach of rather looking at the zeros of spectrograms. When the signal is modeled by a random process, these zeros become a point process.

As first noted by Flandrin [2015], when the linear transform used in the spectrogram is a short-time Fourier transform with a Gaussian window, the zeros of the spectrogram of white noise spread very uniformly over the time-frequency plane, as if these zeros "repelled" each other. We initially wanted to prove that these zeros were a so-called *determinantal* point process. We will see that for the short-time Fourier transform, the zeros of the spectrogram of white noise are not determinantal. However, we will give a general recipe to tweak the linear transform in the spectrogram for these zeros to span known point processes, including determinantal ones. In passing, we will sketch a general relation between time-frequency transforms and repulsive point processes.

This talk is based on joint work with Julien Flamant, Pierre Chainais, and Adrien Hardy.

# At the crossroads of spatio-temporal point processes and stochastic trajectory models

**Lionel Roques, Olivier Bonnefon and Samuel Soubeyrand, INRA**

For modeling the movement and deposition of individuals in a $d$-dimensional space, we consider independent spatially heterogeneous Itô stochastic differential equations and exponential stopping times. Under this formal setting, one can derive partial differential equations satisfied by the intensity function of moving individuals and the intensity function of deposited individuals.

Using these equations, we propose pseudo-likelihoods (for estimating model parameters) based on either counting data or point patterns (about moving or deposited individuals) observed in non-overlapping observation windows (in some particular cases, the pseudo-likelihood is actually the likelihood).

The analysis of Fisher information in particular cases gives indications about the relative performance of pseudo-likelihood estimators based on diverse data settings (counts / points; moving / deposited individuals). A complementary simulation study allows the evaluation of estimation accuracy in practical cases and to design efficient sampling surveys.

The theoretical framework that we propose is a powerful tool to build spatio-temporal point processes with mechanistic dependencies and to infer mechanisms modeled by these processes. We will show how this framework is related to the Minkowski space-time and other major paradigms.

# Estimation for Mixed-Effects Point Process Models using Second-Order Laplace Approximation

**Stephen L. Rathbun, University of Georgia**

Suppose that we wish to estimate the impact of one or more time- and/or space-varying covariates on the intensities of one or more independent realizations of point processes $N_i$, observed within sampling windows $A_i \subset \mathbb{R}^d$; $i = 1, \cdots, n$. Conditional on the realization of a vector $\beta_i \sim N(0, \Sigma)$, and independent realizations of zero-mean Gaussian random fields $\varepsilon_i(s)$; $s \in A_i$, the events for each subject $i$ are assumed to be realized from Poisson point processes with conditional intensity $\lambda_i(s) = \exp\left\{\alpha^T x_i(s) + \beta_i^T z_i(s) + \varepsilon_i(s)\right\}$; $s \in A_i$. The covariates $x_i(s)$ and $z_i(s)$ are taken to be observed at the locations of the events in $N_i$ and independent Poisson point processes $D_i$ with known intensity functions $\pi_i(s)$; $s \in A_i$. Using the probability-generating functional of the Poisson point process, it can be demonstrated that the complete-data likelihood may be approximated by the product of probability density functions of $\beta_i$, $\varepsilon(s)$; $s \in N_i \cup D_i$, and the joint probability mass function for logistic regression of the indicator variables $Y_i(s) = I(s \in N_i)$; $s \in N_i \cup D_i$. A modified version of the EM algorithm of Steele (1996; *Biometrics* **52**, 1295-1310) for generalized mixed models may be applied to obtain approximate maximum likelihood estimates based on the marginal likelihood the model parameters. The E-step of the proposed algorithm is based on a multivariate version of the second-order Laplace approximations (Tierney et al. 1989; *JASA* **84**, 809-834) of the conditional expectation of the complete-data score function given the observed data and current estimates of model parameters. The proposed approach will be illustrating using data from an Ecological Momentary Assessment (EMA) of smoking.

# Multivariate spatiotemporal point processes, individual-based simulation models and the dynamics of species-rich plant communities

**Thorsten Wiegand, Ecological Modelling, Helmholtz Center for Environmental Research - UFZ, Leipzig, Germany**

Assessing the relative importance of processes that determine the spatial distribution of species and the assembly and dynamics of species rich plant communities is one of the major challenges in ecology. I argue that we can advance in this question by adopting a spatially explicit perspective that allows using the incredible information that is buried in fully mapped forest dynamic plots of the CTFS-ForestGEO network. This can be done by taking advantage of recent advances in three fields: individual-based simulation models, spatial point process theory, and inference for stochastic simulation models. First, the individual-based model, which can be viewed as a multivariate spatiotemporal point process, mimics the most important biological processes and produces a time series of multivariate point patterns (with tree species and possible tree size being marks) of the same type as the CTFS census data sets. Second, a variety of summary functions of the multivariate point patterns is estimated to capture the main features of the observed and simulated data. They include summary functions of uni- and bivariate patterns, but also novel summary functions that characterize spatiotemporal structures in species and functional diversity. Examples for such functions are the individual species-area relationship or the phylogenetic mark correlation function. Finally, statistical inference for stochastic simulation models is used to fit the individual-based model to the multiple summary functions. This step involves aggregation of simulated and observed data via summary statistics, likelihood approximation based on the summary statistics, and efficient sampling. I show examples of this approach from tropical forest communities. This spatially-explicit approach moves previous ecological theory towards a dynamic spatial theory of biodiversity and demonstrates the value of spatial data to identify ecological processes. This opens up new avenues to evaluate the consequences of additional process for community assembly and dynamics.

# Revisiting the random shift approach for testing in spatial statistics

Tomas Mrkvicka, University of South Bohemia

Robust nonparametric methods are important in spatial statistics since the assumptions of parametric methods are often not fulfilled or the distributions of the data changes across the space. The random shift permutation scheme is used for testing of independence between two random fields or for testing of independence between two point processes. It is known that the random shift approach with toroidal correction is liberal when the spatial autocorrelation is present in the objects of study. This liberality is caused by breaking the correlation structure by the toroidal correction in the random shift.

In this talk we will present a new version of the random shift method, random shift with variance correction, which fixes the liberality and maintains the power of the tests. The approach is applicable in both the random field case and the point process case.

This is project is done under collaboration with Jiri Dvorak, Jonathan Gonzales and Jorge Mateu.

# Modelling In-room Radio Channels Using Point Processes

**Troels Pedersen, Dept. Electronic Systems, Aalborg University**

Point processes of various kinds have been applied to model multipath propagation observed in a radio channel. Complex propagation medium, such as the indoor scenarios, give rise to multipath propagation, i.e. the transmitted signal arrives at the reciever via multiple paths. Each path is characterized by its socalled multipath parameter which in the simplest case include only a propagation delay and complex gain. The number of multipath components and their parameters are generally unknown and are thus modelled as random entities. Specifically, since the early works 1970s, various types of (marked) point processes has been applied to model the set of multipath components. Experimentally, the points themselves are not observed, but the observed signal is a shotnoise driven by the point process.

In this talk, we develop a shot noise model for the in-room radio channel. We approximate mirror source positions for the inroom scenario using a homogeneous Poisson process in $\mathbb{R}^3$. Mapping this process to the propagation delays and gains, results in an inhomogeneous marked point process in time ($\mathbb{R}_+$) of delays (points) and complex gains (marks) of multipath components. The intensity of this point process increases quadratically and thus the early delays well separated while the later points are very dense. The received signal is a shotnoise driven by this marked point process. We apply the point process model to derive moment properties of the resulting shotnoise model.

# Decorrelation of a class of Gibbs particle processes with applications to facet processes

**Viktor Beneš, Charles University**

A stationary Gibbs particle process on Euclidean space, with deterministically bounded particles, defined in terms of a non-negative potential and an activity parameter, is studied. For small activity parameters, we can prove a central limit theorem for certain $U$-statistics of $\Xi$. To this end an exponential decorrelation property, a result of independent interest, is established. Applications to facet processes are presented. It is a joint work with Ch. Hofer-Temmel, G. Last and J. Večeřa.