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Report on the habilitation thesis of Dr. Jiří Dvořák „Nonparametric tests in spatial statistics“

This thesis presents the author's recent work in the field of spatial statistics, in particular concerning the analysis and modeling of spatial point and marked point processes. The author has been interested in this area for a long time, he has achieved significant results and has published a number of papers in prominent journals. While in the past he has studied various aspects of the stochastic processes, including both parametric and non-parametric analysis and modeling, the present thesis is based on author's results achieved through several last years and on several recent publications (some of them are also attached to the thesis) devoted predominantly to the methodology of nonparametric testing of dependence structure in spatial marked point processes with covariates.

Analysis and modeling of spatial random processes is a very contemporary topic, studied by researchers all over the world. Simultaneously, testing the hypotheses is one of traditional subjects in mathematical statistics. Therefore, the combination of both these fields is of high importance, which follows also from the broad scope of potential applications.

Marked point process is given by two components, namely the intensity function of points occurrence and the distribution of marks „values“ (they may be both quantitative and qualitative). These two components can be dependent mutually, typically this dependence is modeled as a dependence of marks values distribution either directly on points location or also on points intensity (i.e. a character of point process in the surroundings). Moreover, one can consider another exogenous variables, the covariates, they may influence both the point process and the marks. And the crucial problem arises to assess the structure and character of this dependence. This is the main problem studied in a set of recent author's publications. Namely, how to reveal this structure, via statistical tests, without any assumptions on the functional forms of model components, i.e. in a purely non-parametric setting. That is why the proposed tests are based on the Monte Carlo methods and of random replication (mostly) of data. The author presents several different approaches how to accomplish such a replications in a non-parametric case.

One of traditional approaches in this sense is the method of permutations (permutation-based test). Its application to independence testing is discussed from several points of view, which also reflects the results published by the author (with co-authors) in recent years. A brief description is given of some other methods, without details, though the author has contributed also to those methods development. It concerns the method based on stochastic reconstruction and the global envelope tests. However, this thesis concentrates, besides other mentioned methods, mainly to the

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method of random shift. Relevant basic results of the author and his colleagues are collected in the paper [4] J. Dvořák, T. Mrkvička, J. Mateu, J.A. González: „Nonparametric testing of the dependence structure among points-marks-covariates in spatial point patterns“ published in the International Statistical Reviews 90 (2022). Here, a systematic treatment of possible dependence structure is provided. Still, as discussed also in the thesis, a problem arises how to separate the dependence on covariates of marks and points as they are tied closely together (as a rule) and the interpretation of test results based on admissible random shifts is not easy. Therefore, the authors recommend that a PM-C (their notation) test should be accompanied by a P-C and a P-M tests to help in the results clarification.

When reading the thesis, repeatedly I have thought whether a limitation to purely non-parametric tests is reasonable (i.e. without any assumptions about proper model structure). It has to be said again that the results contained in thesis and related papers are valuable and contributive, from both theoretical and methodological point of view. On the other hand, non-parametric methods serves often as a primary tool of exploratory analysis, on their basis the appropriate models are constructed. Then, certain assumptions on model structure (here for instance the separability of functional models for point process and marks, which, in fact, has been studied by the author as well) makes it possible to formulate a more precise tests. For instance those based on non-parametric ways of estimation and on generalized residuals (as also mentioned in the thesis).

To summarize, the proposed thesis contributes to the formulation, use, and further development of non-parametric tests revealing a dependence structure in spatial marked point processes with covariates. It simultaneously demonstrates a high level of knowledge of the author in the fields of probability theory, mathematical statistics, random processes and in mathematics generally. The research approaches are well explained, and the results are both compelling and relevant. The author’s work, represented by the present thesis, is undoubtedly a valuable contribution to the analysis and modeling of spatial stochastic processes. I therefore recommend to accept the present work as the habilitation thesis.

V Praze 27.1.2024

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Test of thesis originality was performed with the system Turnitin. The test revealed just match with papers of Dr. Dvořák and co-authors, none match with other sources was detected, hence the originality of the text was proved.