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## Software for Spatial Statistics

**Edzer Pebesma**  
University of Münster

**Roger Bivand**  
Norwegian School  
of Economics

**Paulo Justiano Ribeiro**  
UFPR Brazil

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### Abstract

We give an overview of the papers published in this special issue on spatial statistics, of the *Journal of Statistical Software*. 21 papers address issues covering visualization (micromaps, links to Google Maps or Google Earth), point pattern analysis, geostatistics, analysis of areal aggregated or lattice data, spatio-temporal statistics, Bayesian spatial statistics, and Laplace approximations. We also point to earlier publications in this journal on the same topic.

*Keywords:* spatial statistics, special issue, software, R.

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## 1. Introduction

As a reaction to the steadily growing availability of open source software for spatial statistics, the success of the *Journal of Statistical Software*, and the need for papers on scientific software in general, in February 2013 we issued a call for papers for a special issue on spatial statistics.<sup>1</sup> In total, 21 papers submitted to this call were accepted, and are bundled in this special issue.

The papers in this issue largely focus on packages for the R system for statistical computing (R Core Team 2014). This may be either because the special issue call was best circulated among R users and developers, or perhaps because most scientific software about spatial statistics is currently being developed in R.

Meaningful statistical analysis of spatial or spatio-temporal data (Stasch, Scheider, Pebesma, and Kuhn 2014) needs to discern whether observations represent records of discrete entities (objects in space, events in time) such as disease cases or tornados, or observations on continuous phenomena, or *fields*, such as air temperature or wind speed. In the spatial statistics literature, the first type of data is usually referred to as *point patterns*, the second as *geostatistical data*. A third type of data arises when either entities or field values are aggregated

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<sup>1</sup>As on, for example: <https://stat.ethz.ch/pipermail/r-sig-geo/2013-February/017419.html>.

over regular or irregular areas, such as grid cells or administrative regions, and form *lattice or areal data*.

We will briefly discuss the contributions in this special issue under their sub-area *visualization, point patterns, geostatistics*, and *lattice or areal data*, and mention with each paper whether they involve Bayesian methods and spatio-temporal processes.

## 2. Visualization

The first two papers present software to create micromaps. Payton, McManus, Weber, Olsen, and Kincaid (2015) present ways to create linked micromaps, and Pickle, Pearson Jr., and Carr (2015) present micromaps for US State data.

The two following papers both discuss how R data can be plotted on external mapping systems. Loecher and Ropkins (2015) discuss ways to do this using *Google maps*, while Hengl, Roudier, Beaudette, and Pebesma (2015) present ways to convert R data to KML, a display format the dominant viewer of which is *Google Earth*.

Older papers published in the *Journal of Statistical Software* on the topic of visualizing spatial data include Josselin (2005); Tanimura, Kuroiwa, and Mizota (2006) and Laurent, Ruiz-Gazen, and Thomas-Agnan (2012).

## 3. Point patterns

Three papers deal with the analysis of point patterns. Pélissier and Goreaud (2015) present an efficient way to compute the K-function of point patterns in irregular-shaped sampling windows. Taylor, Davies, Rowlingson, and Diggle (2015) present methods for spatial, spatiotemporal and multivariate log-Gaussian Cox processes. Brown (2015) shows how log-Gaussian Cox processes can be modeled using Laplace approximation.

Besides the highly cited Baddeley and Turner (2005), earlier papers published in the *Journal of Statistical Software* on point pattern analysis include Harte (2010); Taylor, Davies, Rowlingson, and Diggle (2013); Gabriel, Rowlingson, and Diggle (2013) and Baddeley, Turner, Mateu, and Bevan (2013).

## 4. Geostatistics

**RandomFields** is a package that has been on the Comprehensive R Archive Network (CRAN) since 2001. Schlather, Malinowski, Menck, Oesting, and Strokorb (2015) describe recent developments in **RandomFields** that concern the modeling of multivariate random fields. Padoan and Bevilacqua (2015) analyze random fields by composite likelihood methods, an approach motivated by large data sets. Paciorek, Lipshitz, Zhuo, Prabhat, Kaufman, and Thomas (2015) present and analyze parallelized Gaussian process calculations. Jing and De Oliveira (2015) present an R package for the analysis of count data. Finley, Banerjee, and E.Gelfand (2015) present Bayesian methods for univariate and multivariate data. Sigrist, Künsch, and Stahel (2015) present a modeling approach where the data are assumed to come from a stochastic advection-diffusion process. Bakar and Sahu (2015) deal with a Bayesian approach to modeling spatio-temporal data. Brown (2015) presents interfaces that simplify the use of

Bayesian methods, using MCMC or Laplace approximations, based on other packages.

Earlier papers published in the *Journal of Statistical Software* on the topic of geostatistics include Barry (1996) — the first paper published in the Journal, Finley, Banerjee, and Carlin (2007); Smith, Yan, and Cowles (2008); Davies and Bryant (2013); Peterson and Ver Hoef (2014) and Ver Hoef, Peterson, Clifford, and Shah (2014).

## 5. Lattice or areal data

Gaudart, Graffeo, Coulibaly, Barbet, Rebaudet, Dessay, Doumbo, and Giorgi (2015) present methods for spatial partitioning, i.e. to classify points into areas based on attribute similarity. Gollini, Lu, Charlton, Brunson, and Harris (2015) present software that extends geographically weighted regression to broader model descriptions, including summary statistics, principal components, regression and discriminant analysis. Bivand and Piras (2015) compare implementations of estimation methods for spatial econometrics across different systems, including R, Python (**PySAL**), Stata and MATLAB. Gerber and Furrer (2015) describe pitfalls in the implementation of Bayesian hierarchical modeling of areal count data. Lindgren and Rue (2015) describe Bayesian spatial modeling with the R package **INLA**, which is not on CRAN<sup>2</sup> but is nevertheless open source and widely used. Bivand, Gómez-Rubio, and Rue (2015) present some spatial statistical extensions to R package **INLA**. Finally, Umlauf, Adler, Kneib, Lang, and Zeileis (2015) present **R2BayesX**, an R interface to BayesX, for structured additive regression models.

Earlier papers published in the *Journal of Statistical Software* on the topic of analyzing lattice data include Brezger, Kneib, and Lang (2005); Piras (2010); Almquist (2010); Davies, Hazelton, and Marshall (2011); Millo and Piras (2012), and Lee (2013).

## 6. Discussion

This special issue demonstrates that spatial statistics is a lively area where development of new statistical methods and visualization techniques and their application to real data sets go hand in hand with the development of software needed to realize this. Publishing the software and the code underlying the papers further enables the readership to reproduce this and experiment with using the software on their own data.

The special issue process has enabled the authors to look at one another's work in cases where mutual reviews made sense, and has also triggered (and in some cases forced) authors to look at their software developments in the broader context of what others have developed previously. Although the concept of the *software paper* is still in its early days, we do feel that as in methods papers, publication of software requires authors to explain the need for, or added value of their contribution in the context of what has been done before.

Several papers published in this issue build software systems from scratch (R), whereas others build systems by combining existing packages, creating new interfaces: Hengl *et al.* (2015) and Loecher and Ropkins (2015) interface spatial data in R to popular virtual globe and web mapping systems, Bivand *et al.* (2015) build new models that extend the **INLA** package, Brown (2015) presents two packages that simplify the use of Bayesian methods for Gaussian

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<sup>2</sup>It can be found on <http://www.r-inla.org/>.

and point processes, building on other packages such as **geoR** and **INLA**.

For completeness, we mention a number of earlier papers that were published in the *Journal of Statistical Software* on topic areas that do not directly fall in the categories dealt with in Sections 3–5. They include papers in the area of ecology Calenge (2007); Goslee and Urban (2007), in the area of handling and analyzing spatiotemporal data Pebesma (2012); Leibovici (2010), spatial sampling Bowman, Gibson, Scott, and Crawford (2010), remote sensing Goslee (2011), and modeling solar radiation Perpiñán (2012).

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**Affiliation:**

Edzer Pebesma  
Institute for Geoinformatics  
University of Münster  
Heisenbergstraße 2  
48149 Münster, Germany  
E-mail: [edzer.pebesma@uni-muenster.de](mailto:edzer.pebesma@uni-muenster.de)  
URL: <http://ifgi.uni-muenster.de/>

Roger Bivand  
Department of Economics  
Norwegian School of Economics  
Helleveien 30  
N-5045 Bergen, Norway  
E-mail: [Roger.Bivand@nhh.no](mailto:Roger.Bivand@nhh.no)

Paulo Justiniano Ribeiro Jr.  
LEG (Laboratorio de Estatística e Geoinformação)  
Universidade Federal do Paraná  
Curitiba, PR, Brazil  
E-mail: [paulojus@ufpr.br](mailto:paulojus@ufpr.br)  
<http://www.leg.ufpr.br/~paulojus/>