Week 10

Distance Methods and Spatio-Temporal Processes

Overview

Welcome to Week 10 of Spatial Analysis.

This week we will cover two topics:

- Using distance methods for spatial processes

- Introduction to spatio-temporal models

This week continues our studies of spatial point process models. You will study several geometric methods to characterise distributions of random points. Two specific functions will demonstrate how to compare these geometric distributions with the one that is expected for Poisson processes.

In the second topic, we consider spatio-temporal point processes. These processes describe data with time of occurrence attached to each spatial point. You will learn how to represent such data in R and will produce several visualisations and descriptive plots that can be useful in investigating these data dynamics in space and time. You will practise these methods the R package spatstat.

Finally, you will participate in a workshop, in which you can practise conducting an analysis of real spatial data.

By the end of this week, you will learn about:

Topic 1: Distance methods

- Introduction to distance methods.
- G(r) and F(r) functions.

Topic 2: Foundations of spatio-temporal models

- Introduction to spatio-temporal point processes.
- R class ppx.
- Plotting of spatio-temporal point process data.
- Spatio-temporal Poisson process.
- Using north Cumbria data.

By completing this module, you will be working towards the following subject-intended learning outcomes:

1. Formulate purposeful questions to explore new statistical ideas and subsequently design valid statistical experiments.
2. Present clear, well-structured analysis of important statistical model results.
3. Creatively find solutions to real-world problems consistent with those commonly faced by practising statisticians.
4. Professionally defend or question the validity of existing statistical analyses and associated evidence-based conclusions that are derived via application of sound spatial statistical methodology.

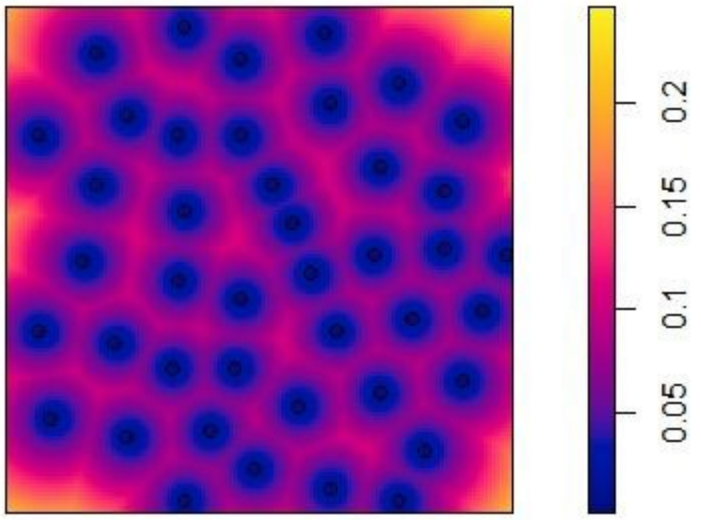
Topic 1: Modelling by using spatial Poisson processes

In this topic, we will mainly concentrate on spatial data modelled by Poisson processes. We will consider how to use different distance characteristics of spatial point patterns to compare them with the point distributions expected for spatial Poisson processes.

We will use several real datasets to illustrate applications of these approaches in R. These datasets are mainly from the forestry industry, but similar approaches can be applied to other point patterns as well.

Figure 1

Visualisation of empty space distance distribution around points



Upon completion of this topic, you will be familiar with distance characteristics of point patterns and their applications to distinguishing between 3 types of distributions. You will further develop your spatial computational skills using the spatstat package from R.

Distance methods

First, in this part, you will learn about 3 types of distances between spatial points: pairwise, nearest neighbour, and empty space distances. These distances are useful to investigate interpoint interactions.

Then, we will use these distances to introduce two functions, called F and G. They are the cumulative distribution functions of the empty space and nearest-neighbour distances respectively. You will learn how to compute the empirical versions of these functions using point pattern data. Then, these results will be used to classify the point patterns by comparing empirical functions with the known theoretical result for the Poisson spatial process. You will be familiar with the three types of patterns: regular, clustered and Poisson (complete spatial randomness).

You will apply distance methods to several real datasets with locations of trees using R.

Read

In this part of the reading Studying Poisson process, you will explore how to compute 3 types of interpoint distances for spatial point data. You will apply these distances to several datasets from the R package spatstat.

From the folder, open the document titled **Week_10_Topic_1** and read **slides 1–18**.

Revise key R commands used in the first topic.

Read

In the reading Key R commands, you will revise some of the key R commands that were used in this topic's materials.

From the folder, open the document titled **Week_10_Topic_1** and read **slide 19**.

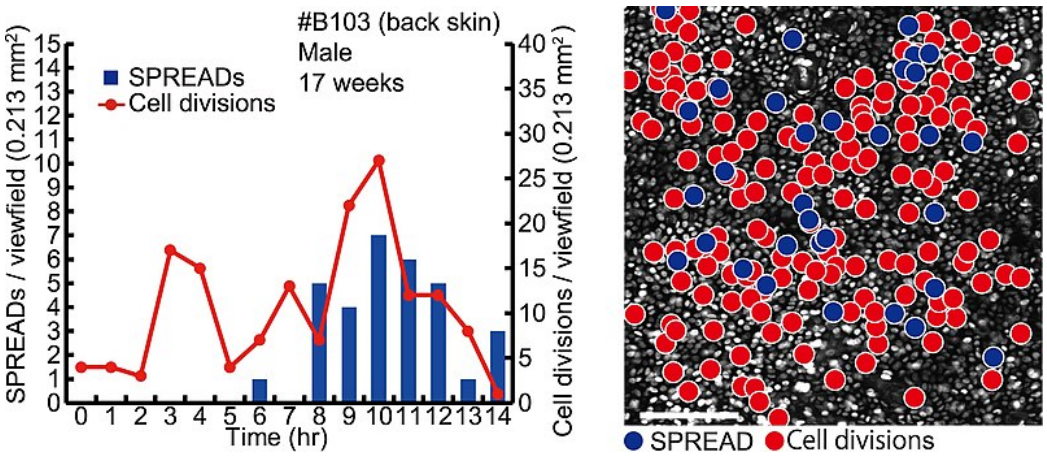
Topic 2: Introduction to spatio-temporal models

This topic introduces spatio-temporal point processes. This statistical model is used to describe randomly located points in time or space. We will start by discussing the basic theoretical foundations of this model. Then, we will learn several methods to investigate various properties of such processes with the R software. You will learn about the ppx format, which is used in R to represent spatio-temporal point datasets. You will also see how to simulate such data and create the corresponding R objects.

You will practice these methods with the R packages spatstat and stpp and their datasets.

Figure 2

Spatio-temporal association of SPREADs in cell division



https://commons.wikimedia.org/wiki/File:Spatio-temporal_association_of_SPREADs_in_cell_division.jpg

Spatio-temporal point process and their visualisation

First, in this part, we will introduce basic definitions and notations used to describe the statistical model called a satio-temporal point process. Then, you will learn how to create the corresponding objects in R using the function ppx. The obtained objects consist of spatial and time coordinates of points and the bounding box that defines ranges for these coordinates. Objects from the class ppx can also have marks attached to space-time points that are used to store additional information.

All approaches will be illustrated by using the data fmd that contains spatial locations and reported days of foot-and-mouth disease outbreaks in the county of Cumbria, UK.

Read

First, in the reading Spatio-temporal Point Processes, you will learn the definitions of the spatio-temporal point processes and several methods for their visualisation. You will practice these methods with the R packages spatstat snd stpp and the fmd dataset.

From the folder, open the document titled **Week_10_Topic_2** and read **slides 1–9**.

Spatio-temporal Poisson process

In this part, you will learn to simulate spatio-temporal Poisson processes. We will consider two cases, processes with constant intensities and inhomogeneous processes with intensities that depend on spatial or time locations. You will estimate the temporal intensities of such processes with R. As we simulate realisations of these processes using the known mathematical expressions for their intensities, you will see how the estimated intensities correspond to the true ones.

Read

In the second part of the reading Spatio-temporal Point Processes, you will learn how to simulate the spatio-temporal Poisson point processes. You will practice by simulating and plotting such data in the R package spatstat.

From the folder, open the document titled **Week_10_Topic_2** and read **slides 10–13**.

Revise key R commands used in the second topic.

Read

In the reading Key R commands, you will revise some of the key R commands that were used in this topic's materials.

From the folder, open the document titled **Week_10_Topic_2** and read **slide 14**.

Workshop

Activity

Workshop

This activity will be completed in R. Repeat the R programming content covered in Week 10. Modify the code and understand the impact of different R parameters on changes in results.

Your task

- Repeat R commands learnt in Week 10 prior to the two-hour workshop session.
- Try to modify the code and understand the impact and meaning of different R function parameters. Interpret the observed changes in plots and analysis results.
- Feel free to discuss questions with other students as you go in the forum, and please also take the time to help others. It is amazing how much we all can learn from each other's questions, and how in helping others we strengthen our own understanding.
- Come along to the two-hour scheduled workshop session and discuss any challenges, seek advice and work through some problems with your peers and facilitator.
- Revisit these problems in later weeks and challenge yourself to get a deeper understanding to build on what you learn later.

Guidelines

- This activity is not graded but is an essential part of your learning.
- You don't need to submit your R code; however, to be successful in this subject it is necessary to work through all R coding materials from this week and understand how to apply the corresponding R commands.
- You should repeat all R commands in this week's materials before the workshop. This will give you an opportunity to efficiently work with the facilitator during the workshop and get your questions answered.
- You should spend around two hours on this activity.

Summary

This week, we continued studies of statistical and data science models based on spatial point processes. We learned about different applications of Poisson processes. You also learned about the foundations of spatio-temporal modelling. We practised these point processes methods with the spatstat package.

Here's a list of tasks that you should be working on or have completed:

- **Required readings**
- **Workshop**

  The following resources provide you with this week's references and additional suggested readings.

Additional suggested readings and resources

While these readings and resources are not essential, they provide greater insight into the concepts covered in the week's lectures and give you the choice to enhance your learning or pursue an area of interest in greater detail.

Software and data:

- CRAN documentation for the spatstat package: https://cran.r-project.org/web/packages/spatstat/index.html
- northcumbria data: https://rdrr.io/cran/stpp/man/northcumbria.html

Theoretical concepts:

- Spatial point processes: https://www.apps.stat.vt.edu/leman/VTCourses/BaddeleyPointProcesses.pdf

Books:

- Bivand, R. S., Pebesma, E., & Gomez-Rubio, V. (2013). Applied spatial data analysis with R (2nd ed.). Springer. https://doi.org/10.1007/s12061-014-9118-y Avalilable on-line in La Trobe EBL ebook Library
- Baddeley, A., Rubak, E., & Turner, R. (2015). Spatial Point Patterns: Methodology and Applications with R. Chapman and Hall/CRC. https://doi.org/10.1201/b19708 Avalilable on-line in La Trobe EBL ebook Library
- Wikle C.K., Zammit-Mangion A., Cressie N. (2019). Spatio-Temporal Statistics with R. Chapman and Hall/CRC. Avalilable on-line from https://spacetimewithr.org/