Institute of Archaeology

ARCL0103
Spatial Statistics, Network Analysis and Human History

2023–2024, Term 1
Masters module, 15 credits

Co-ordinator: Prof Andrew Bevan
a.bevan@ucl.ac.uk
+44 (0)2076791508

Moodle: https://moodle.ucl.ac.uk/course/view.php?id=39786

The **coursework coversheet** is available on the course Moodle pages and here: https://www.ucl.ac.uk/archaeology/current-students under "Policies, Forms and Guidelines". Please enter **your five-digit candidate code on the coversheet and in the subject line** when you upload your work in Moodle.
Please use **your five-digit candidate code as the name of the file** you submit.
Please refer to https://www.ucl.ac.uk/archaeology/current-students/ioa-student-handbook/13-information-assessment
https://www.ucl.ac.uk/archaeology/current-students/ioa-study-skills-guide/referencing-effectively-and-ioa-guidelines
https://www.ucl.ac.uk/students/exams-and-assessments/academic-integrity
https://library-guides.ucl.ac.uk/referencing-plagiarism/acknowledging-AI
for instructions on coursework submission, IoA referencing guidelines and marking criteria, as well as UCL policies on penalties for late submission, over-length work, the use of text generation software (AI) and academic misconduct.

Contents

1 Module overview

1.1 Module description

This module provides a working knowledge of the statistical methods and theory used to comprehend spatial patterns, whether the latter be distributions of settlements across a landscape, densities of artefacts across a site or region, or different kinds of archaeological sampling procedure. Students learn the fundamental differences between spatial and non-spatial statistics, the design of appropriate sampling strategies for fieldwork, geostatistical methods (e.g. kriging), predictive modelling through logistic regression and more spatially-sensitive versions (e.g. geographically-weighted regression) as well as the multi-scalar analysis of point patterns or processes (e.g. K functions and related methods). They develop practical familiarity within the open source R statistical package, which is both the most popular and most advanced software environment for statistical analysis. The module is suitable for all those interested in more formal methods of spatial analysis, and hence assume a willingness to grapple with computational and quantitive methods. However, there are no pre-requisites and the module is open to those with no prior training in statistics or GIS.

1.2 Module aims

The course aims to provide:

- A working knowledge of non-spatial statistical methods that are widely used in conjunction with GIS;
- An understanding of the role of spatial sampling in archaeology
- A working knowledge of both basic and more advanced spatial statistics;
- A basic knowledge of grounded network analysis;

1.3 Learning outcomes

On successful completion of the course, students should:

- An understanding of the differences between scientific and other forms of reasoning;
- The ability to use quantitative data to support an argument;
- The application of acquired knowledge.

1.4 Methods of assessment

The course is assessed entirely by coursework, consisting of two assignments:-

	Weighting	Word Count	Submission Date(s)
1. Laboratory notebook	50%	-	19th Feb, 18th Mar, 1st Apr
2. Essay	50%	2500	29th Apr

1.5 Communications

- The Moodle pages are the main hub for this course.
- Important information will be posted by staff in the Announcements section of the Moodle page and you will automatically receive an email notification for these.
- Please post any general queries relating to module content, assessments and administration in the Moodle discussion forum, or via email if you prefer. The forum will be checked regularly.
- For personal queries, please contact the co-ordinator by email.

1.6 Week-by-week summary

The course will be taught in Term 1. The first class will be held on 11th January and there will be no taught class in Reading Week.

Classes will be held on Thursdays, commencing at 16:00 and lasting until 18:00, with further time for consultation in my office hours.

Week	Date	Subject
1	11 Jan	A rough guide to spatial analysis
2	18 Jan	Archaeological sampling and spatial inference
3	25 Jan	Regression models
4	01 Feb	Multivariate predictive models
5	08 Feb	Point pattern analysis
6	15 Feb	*Reading week*
7	22 Feb	Point process models
8	29 Feb	Network analysis
9	07 Mar	Spatial networks
10	14 Mar	Kriging and local spatial statistics
11	21 Mar	Uncertainty in spatial analysis

1.7 Lecturers

The course coordinator is:

Prof Andrew Bevan , who is available for consultation in room 108 from 12:00–14:00 on Thursdays, or by appointment.

Tel: +44 (0)20 7679 1508

Email / Teams calling: a.bevan@ucl.ac.uk

1.8 Weekly module plan

Teaching will be by a mixture of recorded lectures, online discussion and supervised practical exercises. Lectures and seminars will last for 1 hour whereas practicals may require up to two hours.

N.B. Participation in practical exercises is enabled via use of student's own laptops wherever possible, although suitably equipped computers can also be found in the AGIS laboratory.

1.9 Workload

This is a 15-credit module which equates to 150 hours of learning time including session preparation, background reading, and researching and writing your assignments. With that in mind you should expect to organise your time in roughly this way:

- 20 hours: staff-led teaching sessions (lectures, discussion, practical troubleshooting).
- 50 hours: self-guided preparation (tutorials, reading, listening), about 5 hours a week.
- 40 hours: completing the three assessments that make up the practical portfolio.
- 40 hours: reading for, and writing, the research essay.

2 Assessment

Each assignment and possible approaches to it will be discussed in class, in advance of the submission deadline. If students are unclear about the nature of an assignment, they should discuss this with the module co-ordinator in advance (via office hours or class Moodle forum). You will receive feedback on your written coursework via Moodle, and have the opportunity to discuss your marks and feedback with the co-ordinator in their office hours. For more details see the 'Assessment section on Moodle.

The coursework coversheet is available on the course Moodle pages and here: https://www.ucl.ac.uk/archaeology/current-students under "Policies, Forms and Guidelines". Please make sure you enter your five-digit candidate code on the coversheet and in the subject line when you upload your work in Moodle. Please use your five-digit candidate code as the name of the file you submit.

The IoA marking criteria can be found in the IoA Student Handbook (Section 13: Information on assessment). The IoA Study Skills Guide provides useful guidance on writing different types of assignment.

Please note that **late submission**, **exceeding the maximum word count** and **academic misconduct (unacknowledged use of text generation software and plagiarism)** will be **penalized and can significantly reduce the mark awarded for the assignment and/or overall module result**. Please do consult:

- https://www.ucl.ac.uk/archaeology/current-students/ioa-student-handbook/13-information-assessment with sections 13.7–13.8: coursework submission, 13.10: word count, 13.12–14: academic integrity.
- https://www.ucl.ac.uk/students/exams-and-assessments/academic-integrity for UCL's guidance on academic integrity.
- https://library-guides.ucl.ac.uk/referencing-plagiarism/acknowledging-AI for UCL's guidance on how to acknowledge the use of text generation software.

The use of software to generate content is not allowed for assessments for this course, except in a specific situation where the assessment rubric has asked for it.

The use of software for language and writing review and improvement is permitted, but the software and the way it has been used **must be indicated in the relevant boxes on the coursework coversheet**. UCL defines language and writing review as checking "areas of

academic writing such as structure, fluency, presentation, grammar, spelling, punctuation, and language translation".

Assessment 1, Laboratory notebook. A write-up of practical work which counts for 50% of your overall module grade. This is made up of 3 practicals which should be submitted individually, as follows:-

	Weight	Submission date
1a. Multivariate Regression	15%	19th Feb
1b. Point Process Models	20%	18th Mar,
1c. Network Analysis	15%	1st Apr

The weighting above is the proportion of the overall module result. Further detailed instructions and advice will be provided in tandem with the relevant class practicals, including word counts and dedicated assessment criteria. Note that all illustrations should have informative captions. Where appropriate, maps should include indicators of scale and orientation, as well as a legend (key) based on sensible ranges of data values. Graphs should include informative labels for the X- and Y-axes.

Assessment 2, Essay. A **2500 word** essay which counts for 50% of your overall module grade. You will be asked to critically evaluate existing archaeological literature covered in the course and its syllabus. A list of questions will be provided for you to choose from, with some starter readings. The IoA marking criteria for essays can be found in the IoA Student Handbook (Section 12.2).

3 Resources and preparation for class

3.1 Preparation for class

The practical element of teaching on this course makes heavy use of the R statistical package. This is available in the Institute of Archaeology AGIS lab., but you may wish to install it on your own computer as it is also freely available for most operating systems (MS Windows, MacOS, Linux). We will use the first class to troubleshoot installation on your own machines where necessary.

You are expected to read the essential readings as well as completing any online activities posted on Moodle each week. Completing the readings is essential for your effective participation in the activities and discussions that we will do, and it will greatly enhance your understanding of the material covered. Further readings are provided via the Online Reading List for you to get a sense of the range of current work on a given topic and for you to draw upon for your assessments. The online reading list is accessible through the Moodle page of the module and can be directly accessed here.

3.2 Recommended basic texts and online resources

There is no single textbook used for this module, but the following is nevertheless very useful and available online:-

Haciguzeller, P., Gillings, M. and G. Lock (eds.) 2020. *Archaeological Spatial Analysis: A Methodological Guide*, London: Routledge. [https://doi-org.libproxy.ucl.ac.uk/10.4324/9781351243858]

4 Syllabus

The following is an outline for the course as a whole. The syllabus identifies essential readings relevant to each session, which are also listed in the course .

Session 1: A Rough Guide to Spatial Analysis

A brief introduction to the module followed by familiarisation with the principal software package that will be used throughout the module.

Practical You will be introduced to the R statistical programming language. You will learn how to start R, load libraries, import data, conduct basic exploratory data analysis and produce plots.

Essential reading

Hodder, I. and C. Orton 1976. *Spatial Analysis in Archaeology*, Cambridge: Cambridge University Press [https://ucl-new-primo.hosted.exlibrisgroup.com/permalink/f/5qfvbu/UCL_LMS_DS21153309020004761]

Bevan, A. 2015. The data deluge, *Antiquity* 89.345: 1473-1484. [https://doi.org/10.15184/aqy.2015.102]

Gupta, N. 2020. In Haciguzeller, P., Gillings, M. and G. Lock (eds.) Archaeological Spatial Analysis: A Methodological Guide: 17-40. London: Routledge. [https://doi-org.libproxy.ucl.ac.uk/10.4324/9781351243858]

Session 2: Archaeological Sampling and Spatial Inference

The role of sampling is fundamental to archaeological practice, at scales from the regional to the microscopic. Archaeologists either sample in a deliberate way or they do so by accident, but in either case, these sampling decisions have important implications for what we can and cannot then infer from the recovered archaeological record. In this session, we both introduce the general idea of sampling and use case studies to focus on the specific issues raises by spatial samples.

Practical Types of sampling regime. Use of R to perform t-tests, Kolmogorov-Smirnov tests and Monte Carlo simulation.

Essential reading

Orton, C. 2000. *Sampling in Archaeology*. Cambridge: Cambridge University Press. Chapters 1, 2, and 4. [https://doi-org.libproxy.ucl.ac.uk/10.1017/CBO9781139163996].

Fisher, P. F., Farrelly, C., Maddocks, A. and Ruggles, C., 1997. Spatial analysis of visible areas from the Bronze Age cairns of Mull. *Journal of Archaeological Science* 24, 581–592. [https://doi.org/10.1006/jasc.1996.0142]

Banning,E.B. 2020. Spatial sampling, In Haciguzeller, P., Gillings, M. and G. Lock (eds.) Archaeological Spatial Analysis: A Methodological Guide: 41-59. London: Routledge. [https://doi-org.libproxy.ucl.ac.uk/10.4324/9781351243858]

Session 3: Regression Models

This week we begin a series of more analytical sessions by reviewing the use of linear regression to explore the relation between two variables, including measures of correlation and the distribution of residuals. We then introduce linear logistic regression, which is widely used for the construction of GIS-based predictive models.

Practical Use of R for linear regression analysis, including the study of residuals.

Essential reading

Hodder, I. and Orton, C., 1976. *Spatial Analysis in Archaeology*. Read the chapter on regression analysis. Cambridge: Cambridge University Press. [https://ucl-new-primo.hosted.exlibrisgroup.com/permalink/f/5qfvbu/UCL_LMS_DS21153309020004761]

Conolly, J. and Lake M. W., 2006. *Geographical Information Systems in Archaeology*. Cambridge: Cambridge University Press. Sections 8.1–3 and 8.8. [https://doi-org.libproxy.ucl.ac.uk/10.1017/CBO9780511807459]

Hacıgüzeller, P. 2020. Spatial applications of correlation and linear regression. In Haciguzeller, P., Gillings, M. and G. Lock (eds.) Archaeological Spatial Analysis: A Methodological Guide: 41-59. London: Routledge. [https://doi-org.libproxy.ucl.ac.uk/10.4324/9781351243858]

Session 4: Multivariate Predictive Models

This week is entirely devoted to a practical exercise in which you will use multivariate logistic regression to build a predictive model of archaeological site location.

Practical Use of R and GRASS GIS to build a predictive model.

Essential reading

Verhagen, P. and T.G. Whitley 2020. Predictive Spatial Modelling In Haciguzeller, P., Gillings, M. and G. Lock (eds.) Archaeological Spatial Analysis: A Methodological Guide: 231-246. London: Routledge. [https://doi-org.libproxy.ucl.ac.uk/10.4324/9781351243858]

Wescott, K. L. and Brandon, R. J. (eds), 2000. *Practical Applications of GIS for Archaeologists: A Predictive Modelling Kit*. London: Taylor & Francis. (Wescott incorrectly spelled as Westcott on cover) Chapter 2. [https://doi-org.libproxy.ucl.ac.uk/10.1201/b16822].

Woodman, P. E. and Woodward, M., 2002. The use and abuse of statistical methods in archaeological site location modelling. In D. Wheatley, G. Earl and S. Poppy (eds) *Contemporary Themes in Archaeological Computing*. Oxford: Oxbow Books, 22–27. [https://ucl-new-primo.hosted.exlibrisgroup.com/permalink/f/5qfvbu/UCL_LMS_DS21140652420004761]

Session 5: Point Pattern Analysis

This week, we consider a variety of methods for analysing data comprising the point locations, a common kind of evidence best-known to archaeologists in the form of 'distribution maps'. The simplest, nearest-neighbour and quadrat-based methods have been around in archaeology for nearly 50 years, while more complicated, multi-scalar methods such as K functions have only been introduced into archaeology more recently. We also consider the analysis of point distributions where there are likely to be directional patterns present, as well as the treatment of point distributions of multiple types or involving cases-and-controls.

Practical Use of R to analyse point patterns.

Essential reading

Orton, C. 2004 Point Pattern Analysis Revisited, *Archeologia e Calcolatori* 15: 299-315 [https://ucl-new-primo.hosted.exlibrisgroup.com/permalink/f/5qfvbu/UCL_EPR_DS11345].

Rosenberg, M.S. 2004. Wavelet analysis for detecting anisotropy in point patterns, *Journal of Vegetation Science* 15: 277-284 [https://shibbolethsp.jstor.org/start?entityID=https%3A%2F%2Fshib-idp.ucl.ac.uk%2Fshibboleth&dest=https://www.jstor.org/stable/3236762&site=jstor].

Bevan, A. 2020. Spatial point patterns and processes, In Haciguzeller, P., Gillings, M. and G. Lock (eds.) Archaeological Spatial Analysis: A Methodological Guide: 60-76. London: Routledge. [https://doi-org.libproxy.ucl.ac.uk/10.4324/9781351243858]

Session 6: Point Process Models

Modern approaches to point distributions do not just consider whether and how a pattern departs from a null hypothesis of complete spatial randomness. Instead, there is increasing

emphasis on fitting different kinds of model to obsrved point patterns with a view to understand when exteral variables might affect the overall density of points across a study area, as well as what kinds of interaction between points might be involved. Joint models of 'first-order' and 'second-order' characteristics are now possible and of great use in archaeology.

Practical Use of R to build an inhomogeneous point process model.

Essential reading

Vanzetti, A., Vidale, M., Gallinaro, M., Frayer, D.W. and Bondioli, L. 2010. The iceman as a burial, *Antiquity* 84: 681-692 [https://ucl-new-primo.hosted.exlibrisgroup.com/permalink/f/1klfcc3/TN_cdi_gale_incontextgauss_8GL_A238423228].

Bevan, A. 2020. Spatial point patterns and processes, In Haciguzeller, P., Gillings, M. and G. Lock (eds.) Archaeological Spatial Analysis: A Methodological Guide: 60-76. London: Routledge. [https://doi-org.libproxy.ucl.ac.uk/10.4324/9781351243858]

Baddeley, A. Rubak, E., and R. Turner *Spatial Point Patterns: Methodology and Applications with R*, New York: Chapman and Hall/CRC [https://ucl-new-primo.hosted.exlibrisgroup.com/permalink/f/5qfvbu/UCL_LMS_DS21129317250004761]

Session 7: Network Analysis

Network analysis has become increasingly popular across many different disciplines over the last decade or so. For archaeologists, networks have provided a useful, if rather loose, metaphor for thinking about human interaction in the past as well as, for some, an opportunity to try out more formal graph theoretic models. The simplifying assumptions that network structure typically imposes also bring an elegance to our analysis of social and natural phenomena that is very attractive.

Practical Construction of a network model based on cultural similarity in R.

Essential reading

Brughmans, T. and Peeples, M.A. 2023. *Network Science in Archaeology*, Cambridge: Cambridge University Press. (introductory chapters)

Mills, B. J. et al. 2013. Transformation of social networks in the late pre-Hispanic US Southwest, proceedings of the National Academy of Sciences, USA 110.15: 5785–5790. [https://doi.org/10.1073/pnas.1219966110]

Session 8: Spatial Networks

If abstract networks are sometimes good to think with in archaeology, where does that leave our modelling of more complex spatial networks such as those physical grounded in the actual landscape? Past and present transport systems, for example, potentially involve a bewildering array of directed, weighted, time-sensitive and/or multi-modal links that support an equally bewildering array of routine, officially regulated and/or effectively random interaction events by the humans and animals that use them.

Practical Simulation modelling of transport networks and site hierarchies.

Essential reading

Bevan, A., Wilson, A. 2013. Models of settlement hierarchy based on partial evidence, *Journal of Archaeological Science* 40.5: 2415-2427. [https://doi.org/10.1016/j.jas.2012.12.025]

Menze, B.H. and J.A. Ur. 2012. Mapping patterns of long-term settlement in Northern Mesopotamia at a large scale. *Proceedings of the National Academy of Sciences of the USA* 109: E778–E787 [https://doi.org/10.1073/pnas.1115472109].

Brughmans, T. and Peeples, M.A. 2023. *Network Science in Archaeology*, Cambridge: Cambridge University Press. (chapter 7)

Session 9: Kriging and local spatial statistics

In many cases, we are not dealing with a pattern of unmarked points (i.e. without attributes), but instead wish to analyse a spatial relationship between one continuously-measured variable and a range of others across a study area. Some of the simple forms of regression analysis introduced earlier in this module assume that the relations between independent variables are constant throughout space, but this is not always—perhaps not even usually—the case. This week we explore (a) ways to measure the degree of autocorrelation between point attributes in space, (b) ways to explore how statistical parameters can vary across a study area.

Practical Use of local statistics and kriging to understand patterns of spatial autocorrelation.

Essential reading

Lloyd, C.D and P. M. Atkinson 2020. Geostatistics and spatial structure in archaeology, In Haciguzeller, P., Gillings, M. and G. Lock (eds.) Archaeological Spatial Analysis: A Methodological Guide: 93-117. London: Routledge. [https://doi-org.libproxy.ucl.ac.uk/10.4324/9781351243858]

Premo, L. 2004. Local spatial autocorrelation statistics quantify multi-scale patterns in distributional data: An example from the Maya Lowlands. *Journal of Archaeological Science* 31, 855–866. [https://doi.org/10.1016/j.jas.2003.12.002]

Bevan, A. and Conolly, J. 2011. Terraced fields and Mediterranean landscape structure: an analytical case study from Antikythera, Greece, *Ecological Modelling* 222: 1303–1314. [https://doi.org/10.1016/j.ecolmodel.2010.12.016]

Session 10: Uncertainty in Spatial Analysis

This session looks at the kinds of classificatory, temporal and/or positional uncertainties inherent in most archaeological analyses. In particular, it address the issue of how we manage the very fuzzy spatial and chronological evidence with which archaeologists regularly work.

Practical Handling temporal uncertainty via R scripting

Essential reading

Crema, E. R. 2012. Modelling temporal uncertainty in archaeological analysis, *Journal of Archaeological Method and Theory* 19(3), 440-461 [https://doi.org/10.1007/s10816-011-9122-3].

Bevan, A., Conolly, J., Hennig, C., Johnston, A., Quercia, A., Spencer, L. and J. Vroom. 2013. Measuring chronological uncertainty in intensive survey finds. A case study from Antikythera, Greece, *Archaeometry* 55.2: 312–328 [https://doi-org.libproxy.ucl.ac.uk/10.1111/j.1475-4754.2012.00674.x].

Silva, F. et al. 2015. Modelling the Geographical Origin of Rice Cultivation in Asia Using the Rice Archaeological Database, *PLoS ONE* 10.9 [https://doi.org/10.1371/journal.pone.0137024].

5 Supplementary texts

In addition to the core texts listed above (3.2), the following may be useful, but should be read in consultation with the coordinator.

Pebesma, E. and R. Bivand 2021.Spatial Data Science with Applications in R [https://keen-swartz-3146c4.netlify.app/]