

Where did you go to my lovely? From punch card technology to Deep Learning. Tracing the development of statistical thinking in(to Computational) Archaeology.

Archaeology produces and deals with information collected and created by archaeologists. Just as there are many Archaeologies, there are also many ways to collect, interpret and analyse data and many approaches to archaeological thinking.

The use of statistical methods in Archaeology reaches back to the end of the 19th century (Petrie 1899) and became computer-based after the middle of the 20th century. The first applications of statistical-mathematical methods using computers transformed the handling of spatial and quantitative data (e.g. Goldmann 1979) and the view on Archaeology itself (e.g. Clarke 1968; Hodder and Orton 1976; Ihm and Zimmermann 1978) which facilitated the use and combinations of diverse data sources. This quantitative-statistical analytical view prepared archaeologists for the advent of publicly available, high-resolution digital data, which revolutionised and broadened Archaeology.

Through time, statistical approaches were adopted for a broad range of spatial analyses. The most impactful methods were applied on landscape scale, such as the conversion of paper map data to digital elevation data (e.g. by the Ordnance Survey of UK), along with the evolution of mapping itself. From this developed Landscape Archaeology, which adopted the use of remote sensing data, branching into a whole new discipline: Archaeological Remote Sensing (ARS). The new data sources, including geophysical platforms, led to the need for handling big spatial data and thence to the specialised use of GIS platforms (O'Sullivan and Unwin 2010; Wheatley 2004). The development and application of methods such as predictive modelling (Leusen and Kamermans 2005; Kamermans et al. 2009), along with the early realisation of the importance of sampling and the use of statistics (Banning 2020 in Gillings et al. 2020), followed. Such large amounts of detailed data have led the quest across *real* landscapes requiring the use and/or development of appropriate statistics (Lloyd & Atkinson 2020 in Gillings et al. 2020). These large individual 'scapes' became the bases for broad, cross-area relationship studies, representing human interaction.

For most areas of archaeology there has been a hand-in-hand development of scientific tools and statistical analyses. ARS has seen the sophistication of airborne platforms, sensors and imaging technologies, like LiDAR, hyper-spectral imagery and drone

derived imagery (Agapiou and Lysandrou 2015; Luo et al. 2019) which have helped the diversification of this sub-discipline's toolset. Such technical developments continuously push specialists to look for, borrow and adapt methods to analyse big data. We see machine learning (ML) as automated statistics becoming a common method for archaeological analysis, particularly in Landscape Archaeology (Orengo et al. 2021; Verschoof-van der Vaart and Lambers 2019). With significant developments in the last few years, ML has rapidly gained importance and is not likely to diminish in the foreseeable future. Although Automated ARS is still in its infancy (Opitz and Herrmann 2018), the use of scripting languages (Carlson 2017) and FAIR principles (also in other Archaeologies) point also towards a promising future.

This review brings to the fore some major statistical developments in archaeology, and despite its impact and heavy use in archaeology today, we have noticed that sessions *dedicated* to statistics rarely occur at the CAA in more recent times. Therefore, for the 50th anniversary of the CAA, this session would like to critically reflect on lessons learnt in the past or investigate the importance of statistical thinking today in Archaeology.

The main question we ask is: *are we there yet?*

Enfolded in this main enquiry are the following issues: are we heading in the right direction? Are we using the tools in the right way: have either qualitative or quantitative statistics let down researchers by misleading or confirming an archaeological 'truth' in the past that has since been overturned due to new data or approaches (Bergh et al. 2021)? Models and predictions are great tools - but where do the pitfalls lie? So, as archaeologists, are we mostly misled by the theory of statistics concerning the actual application? How to bridge the gap?

We request successful and cautionary tales to disseminate this topic and point to possible directions to counter this. Have we found "the" solutions to old questions with the ever renewing tool boxes or are we always facing new questions? Do we have standardised/formalised methods for specific problems? Do we use all tools available to also communicate and disseminate research for others to build upon? Are our methods FAIR and reproducible? If so, or not, why (not) (Berberi and Roche 2022)? What should we be doing about it?

So, ARE, we there yet? We invite the CAA community to consider and discuss the relevance of statistical thinking and application in Archaeology in the past, today and in the future.

Key references

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