A model of graphic diversity

in marks on Palaeolithic artefacts based on distance to neighbouring sites

Christian Westh Stenbro, 10-12-24, Introduction to Cultural Data Science

Data: SignBase

- An open source ‘sign base’ with *geometric* signs from mobile objects, stemming from excavations of the Aurignacian techno-complex (dating to ca. 43,000 to 30,000 years *before present*).
- Mainly includes artifacts from sites in the European continent. Currently the data base has 531 objects from 65 different sites.
- The data aggregates objects from different research efforts.
- The following information is encoded: geometric features; archeological information (dating, excavation data); and geographical data (latitude + longitude of the site).
- Original paper/data citation:

Dutkiewicz, E., Russo, G., Lee, S., & Bentz, C. (2020). SignBase, a collection of geometric signs on mobile objects in the Paleolithic. Scientific Data, 7(1), 364. https://doi.org/10.1038/s41597-020-00704-x

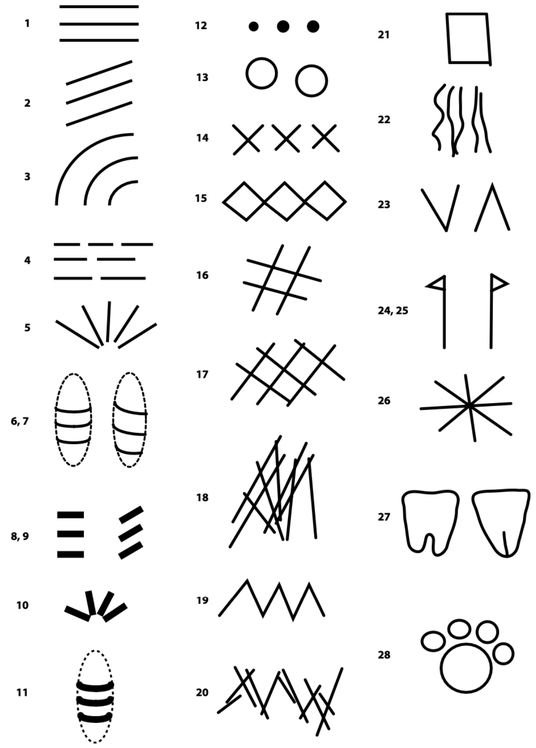

Figure 1:

An illustration from Dutkiewicz et al., 2020, showing examples of 28 different sign types encoded in the data set

Data: SignBase

This introduces some fundamental assumptions into the project

- Is the data representative?

- Possible problems include:
  (1) data sparsity due to uneven excavation efforts
  (2) data sparsity due to uneven preservation of artefacts

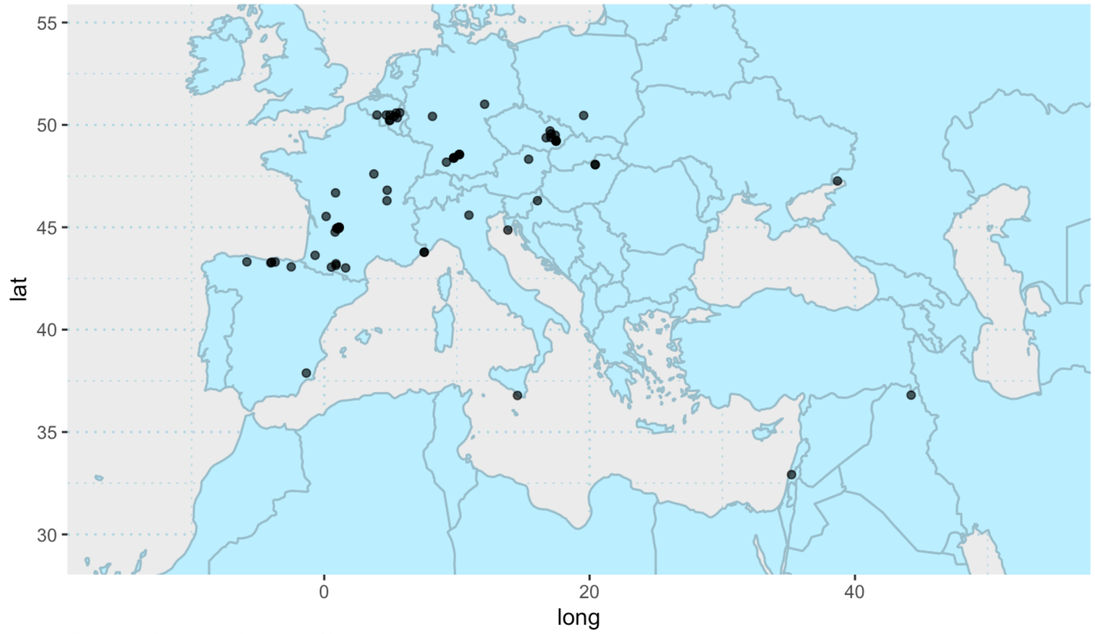

Figure 2: All sites plotted on a map

"Of course, both the distribution of sites and the distribution of objects are influenced by historical factors such as excavation and publication efforts of particular universities and researchers. Note, however, that many Aurignacian sites across Europe have not yielded artifacts with geometric signs. Hence, **while the picture can still change as new sites are discovered and new artifacts published, we expect to have uncovered the main tendencies of the Aurignacian.**"

Dutkiewicz et al., 2020, p. 3

Modelling the data

- The data presented an opportunity to test a model of the cultural evolution technology summarised by Boyd and Henrich in *The Cultural Evolution of Technology: Facts and Theories* (2013).

- The model proposes that larger populations and populations with more inter-group contact "*(...) will have more diverse and more complex toolkits than small, isolated populations*". (Boyd et al., 2013, p. 18).

- The analysis from Kline and Boyd, 2010, suggests that this model can account for the pattern between population size and ocean foraging tools of different island societies in Oceania.

- I wanted to test whether the **relative isolation/connectivity** of archeological sites could be used to predict the **graphic diversity** of the mobile objects of this site. The model is thus transferred to a slightly different domain, that could still be described as a part of the cultural evolution of technology.

- Concretely, I wondered whether **increased connectivity would lead to more graphic diversity**

References
Kline, M. A., & Boyd, R. (2010). Population size predicts technological complexity in Oceania. Proceedings of the Royal Society B: Biological Sciences, 277(1693), 2559–2564. https://doi.org/10.1098/rspb.2010.0452

Modelling the data

The following two operationalisations inform the model:

1. The relative isolation/connectivity of a site is operationalised as **the distance to the 3 nearest neighboring sites**.

   Based on the latitude/longitude information in the sign base a brute force Harversine distance computation is used to obtain a single log distance measure pr. site.

2. The **graphic diversity** is operationalised as the number of distinct features recorded in objects from each site.

   This results in a single integer number for each site, ranging from 1 to 18 features

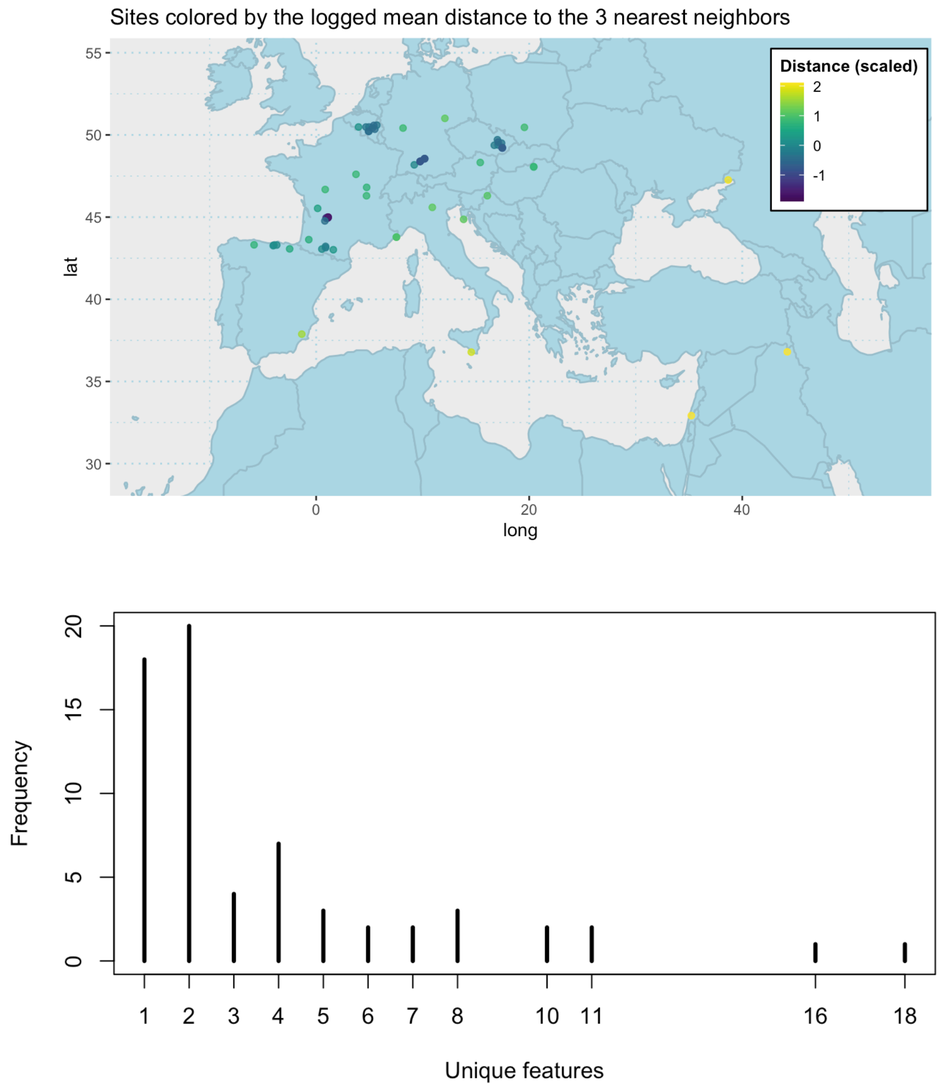

Figure 3; 4:

Sites colored by the log mean distance to the 3 nearest neighbors; distribution of unique features

Modelling the data

Model

- I fitted a Poisson regression model to the data, using a Bayesian framework (ULAM):

$$F_i \sim \text{Poisson}(\lambda_i)$$

$$log\lambda_i = \alpha + \beta \cdot D_i$$

- I used prior predictive simulation to estimate reasonable priors.

- The model implementation is heavily inspired by ch. 11 in McElreath, 2020, who reproduces Kline and Boyd's analysis from 2010.

Coefficients and predictions

	mean	sd	5.50 %	94.50 %	rhat	ess_bulk
α	1.258	0.064	1.155	1.358	1.000	969.222
β	-0.299	0.068	-0.407	-0.189	1.001	1089.777

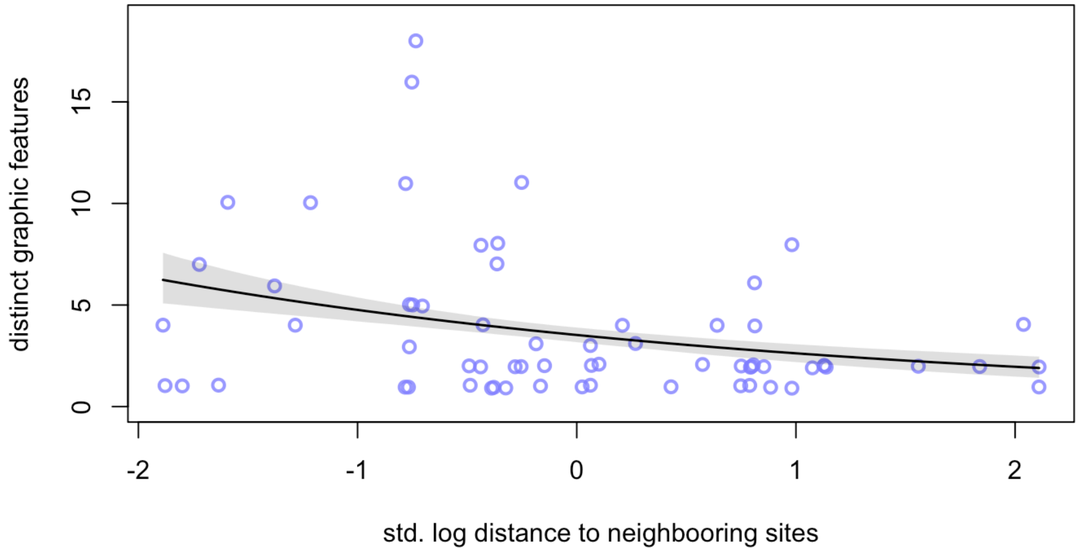

Figure 5; 6:

Coefficients from the regression model;
line and shaded area representing predictions based on the models, with data superimposed

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Kline, M. A., & Boyd, R. (2010). Population size predicts technological complexity in Oceania. Proceedings of the Royal Society B: Biological Sciences, 277(1693), 2559–2564. https://doi.org/10.1098/rspb.2010.0452

McElreath, R. (2020). Statistical Rethinking: A Bayesian Course with Examples in R and Stan (Second edition). CRC Press. https://doi.org/10.1201/9780429029608

Modelling the data

Interpreting the model

- The estimated beta coefficient indicates a negative relationship between the log distance of a site and the number of distinct graphic features observed in objects from the site.

- In other words, the data and the model suggests that the model of the cultural evolution of technology presented earlier also has explanatory value when it comes to systematic patterns in the graphic diversity in the sites recorded in the SignBase.

- It is important to be critical of this relationship – it is not necessarily causal, and there is still plenty of variation left in the data to explain!

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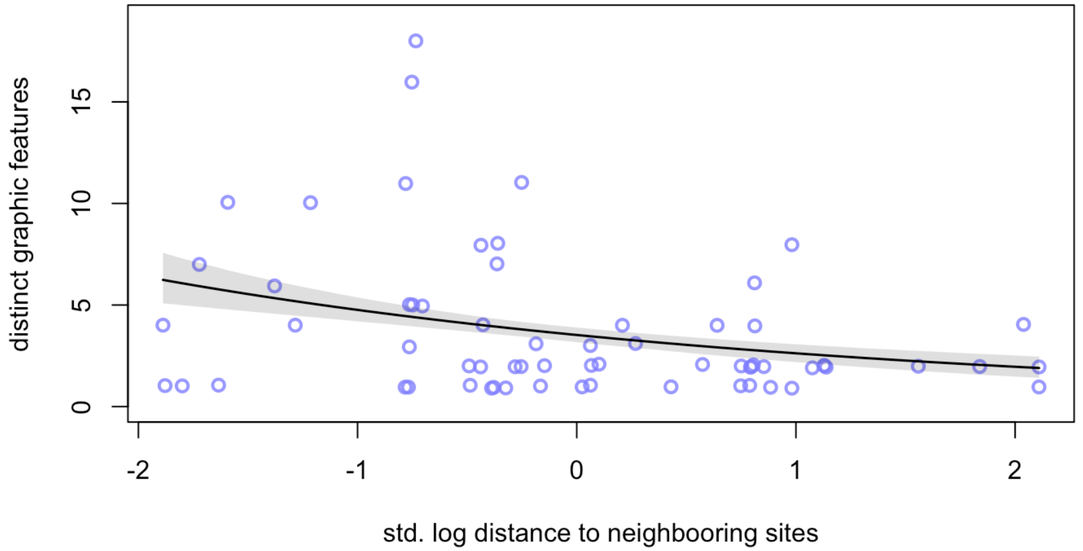

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