Computer models are bridges to the past

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Introduction

Research goal

- Document the impacts of climate change and geography on social networks.

- Focus on the Magdalenian (20,000-14,000 years ago).

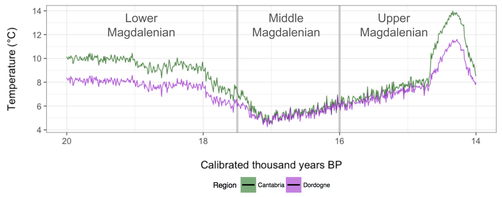

Figure 1. Global temperature change of the Magdalenian [1].

- Compare networks of two topographically different regions
  - Cantabria, Spain
    - Coastal mountains: high biodiversity
  - Dordogne, France
    - Inland plateaus and valleys: low biodiversity

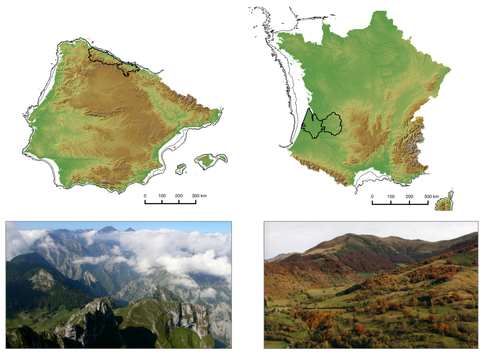

Figure 2. Geographical position and topography of the two study areas.

Methods

- Use an agent-based model (ABM) to simulate hunter-gatherers' interactions in a realistic landscape.
  - Run over 5000 simulations.

- Reconstruct the empirical Magdalenian social networks using multivariate statistics on portable art objects.
  - Artistic similarity is linked to shared cultural knowledge through social interaction [2].

- Combine ABM outputs to empirically-reconstructed networks to estimate the characteristics of Magdalenian social interactions.

References

[1] TraCE-21ka was made possible by the DOE INCITE computing program, and supported by NCAR, the NSF P2C2 program, and the DOE Abrupt Change and EaSM programs.

[2] Conkey, M.W., 1978. Style and information in cultural evolution: toward a predictive model for the Paleolithic, *Social archaeology: beyond subsistence and dating*:61-85

[3] Eerkens, J.W. & Lipo, C.P., 2005, Cultural transmission, copying errors, and the generation of variation in material culture and the archaeological record, *Journal of Anthropological Archaeology*, 24(4), pp. 316-34.

Agent-based model: Details

Simulation settings

- The model is set in a realistic landscape where each grid cell has:
  - Elevation, slope, resources, biome.

- The landscape can represent Cantabria or the Dordogne in the 3 Magdalenian subperiods (see Fig. 1)
  - Biome distribution and resource level vary per period.

- 10 camps are scattered randomly on the land. Each camp has:
  - 6 agents
    - Look for allies
  - 6 campers
    - Produce artifacts & share cultural traits

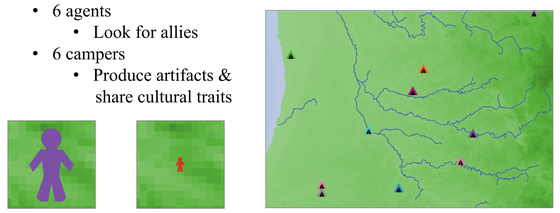

Figure 3. Agent, camper, and setting of a simulation set in the Dordogne.

- Campers' artifacts are modeled as a list of 5 numbers.
  - At setup, each number comes from a random normal distribution with the camp number as mean, and a standard deviation of 5.

- Each cycle represents 10 minutes. Days last 6 hours (36 cycles).

Resources and alliances

- Every day, each camp feeds its occupants by taking resources from cells located within a 10km radius.

- Camps send agents to form alliances when resources are low.
  - Agents walk to other camps until they find an ally.
  - Possible allies:
    - Enough food to feed its occupants + an extra agent and camper.
    - Located in a different biome.

- When alliances are created, one agent and one camper visit the allied camp for a given length of time.
  - This reduces the stress on the agent's camp of origin.

- The model records the features of alliances and how often they are used.

Cultural transmission (learning)

- Every day, campers located in the same camp learn from each other.

- Two transmission methods, based on Eerkens and Lipo [3]:
  - Conformism: take average of each values.
  - Prestige: copy values of prestigious camper (identified at setup).

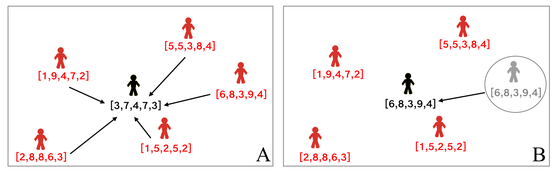

Figure 4. How cultural transmission occurs every day. A. Conformism, where a camper takes the average values of all campers located nearby. B. Prestige, where a camper copies only the values of the prestigious camper, if found nearby.

- 3% copying error is added to any transmission [3].

- The model outputs all campers' values every month.

Agent-based model: Outputs

Observed vs. reconstructed network

- Each simulation creates two outputs:
  - Alliances between camps (*observed* network)
  - Campers' artifacts (used to created *reconstructed* network)

Reconstructed networks from modeled artifacts

- Calculate Euclidean distance between all artifacts.
  - Artifacts with distance < 1 are deemed similar.
  - Sum the number of similar artifacts per pair of camps.

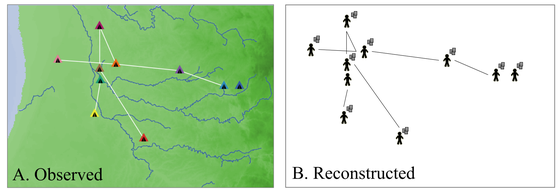

Figure 5. Example of observed and reconstructed networks from a single simulation. The nodes of the networks are the camps, and the links are the number of alliances (A) or the number of similar artifacts (B).

Comparing network characteristics

- The social network metrics of the observed and reconstructed networks differ significantly.

- This is due to *indirect* transmission, which leads to similar cultural traits being found between camps that had no *direct* contact, but were linked through another camp (e.g., camps 7 and 9 in Fig. 6).

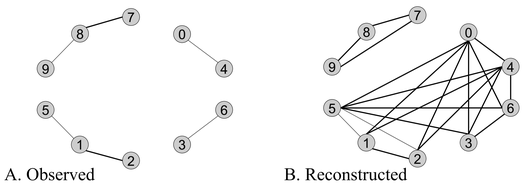

Figure 6. Example of the differences between observed (A) and reconstructed (B) networks of a single simulation. The nodes represent the camps, and the links represent the strength of the alliances (A. number of visits, B. number of similar artifacts).

Important remark

- Networks reconstructed through similarities of archaeological artifacts are inaccurate representations of real social interactions.

- Solution:
  - Use the ABM as a bridge between empirical and modeled networks to estimate the characteristics of the latent empirical networks.

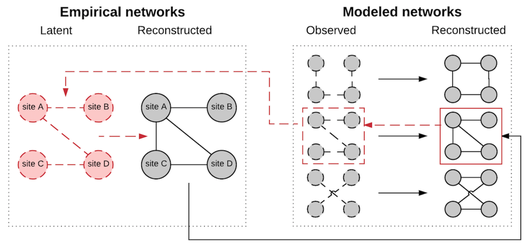

Figure 7. By comparing the characteristics of the Magdalenian empirically reconstructed networks to the characteristics of the modeled reconstructed networks, I can obtain an estimate of the archaeologically-invisible Magdalenian latent networks.

Reconstructing empirical social networks

Reconstructing Magdalenian networks from art

- Calculate stylistic similarities in 400 Magdalenian artistic representations

Table 1. Number of representations studied per region and period. The number in parenthesis represents the number of sites where those were found.

	Lower Magdalenian	Middle Magdalenian	Upper Magdalenian
Cantabria	50 (10)	36 (6)	41 (12)
Dordogne	0 (0)	26 (4)	247 (16)

- For each representation, identify the presence of design attributes.
  - Compute Gower dissimilarity coefficient between representation pairs.

- Link the sites where similar representations were found.

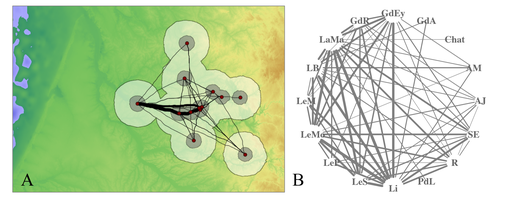

Figure 8. Upper Magdalenian networks reconstructed in the Dordogne. A. Geographically-informed, B. Spatially neutral.

Combining outputs

- Identify the ABM simulations that produced reconstructed networks similar to the empirical ones.

- Use the observed networks of these simulations as estimates for Magdalenian social networks (see Fig. 7).

Results

- Social network changed more in the Dordogne than in Cantabria.

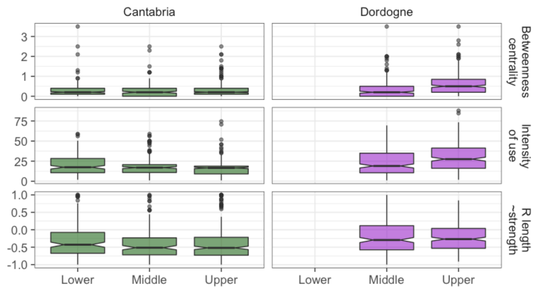

Figure 9. Social network metric estimates. Betweenness centrality refers to the interconnectivity of sites. Intensity of use refers to how often alliances were used. R length~strength is the Pearson r correlation for the distance between allied sites and the number of times they visited one another. Boxplot hinges show 95% CI around median (overlapping notches are not statistically significant).

Conclusions

- Topography impacts social networks, because it affects resource diversity.

- High biodiversity from rugged terrain increases resilience to resource fluctuations brought by climate change.

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