Use of Agent-Based Modelling to evaluate social food sharing behaviours in early hominins

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Introduction

Agent-Based Modelling is a computational technique that can be used to simulate behaviours of different individuals in complex systems. It is a powerful tool when the study of social and biological systems is a focus. An illustrative example of application is in archaeology, where rarefied human artefacts are ancient and very localised in space as compared to the scale of the (eco)system such that there is a need to simulate ancient behaviours to connect between archaeological observations and lifestyle interpretations.

The study of the ancient humans and their relatives, collectively known as hominins, is challenging for archaeologists in large part because of limited fossil traces and the vast differences in associated hominin behaviours, especially as related to social interactions and basic resource-use (Kingston, 2007). A good example is related to signs of cooperative behaviours, such as food sharing among those in need, and how it influenced the group as a whole. Consequently, predicting behaviours of early hominins is a complex system to model that features myriad distinct possible scenarios, contextual hypothesis, and emergent rules.

This study presents an Agent-Based Model (ABM) to simulate the foraging behaviour of early hominins on a complex environmental landscape. The model focuses on activities of gathering and scavenging food, with provisions for social food sharing at this point in human evolution. In particular, we extend the work of Griffith et al. (2010), who built an initial ABM that focused on simulating potential tool usage in a similar environmental context, but did not consider social interactions between agents.

Agent-Based Modelling in digital archaeology

Digital archaeology is a sub-discipline within archaeology that uses digital technologies in order to investigate the past (Morgan, 2022). Some examples are the usage of digital photography, Geographic Information Systems (GIS), 3D scanning, and virtual restoration (Costopoulos, 2016). ABMs also fall into digital archaeology since they are computer simulations that provide a bottom-up perspective of a complex system composed by individuals (**agents**) who interact with each other, as well as with their environment. In this context, a population of agents express behaviours represented by simple rules and likewise are influenced by the collective interactions with other agents. Although the model is built from individual points of view, its main properties and events observed during the simulations are generally visualized from a global perspective (Cuevas, 2020).

Some of the earliest use of ABMs in archaeology began in the late 1990s, when archaeologists were interested in questions about both the functioning of a complex system and the dynamic individual elements within the system (Romanowska et al., 2021). In this context, ABMs offer a unique opportunity to simulate representative ancient landscapes based on existing geologic evidence, fossils, artifacts and contemporary ecological analogues (Vahdati et al., 2019) to create a robust framework for making predictive assessments (i.e., hypothesis testing) of distinct behavioural drivers (Perry et al., 2016).

Early cooperative behaviours among hominins

The adaptive origins and further ontogeny of hominin cooperation is an evolutionary puzzle. Anthropological theory posits a direct link between the emergence of hominin cooperative activities and a shift towards more energy-rich dietary resources. Although debate continues about the specific composition of hominin diets (e.g., degree of incorporation of tubers and larger animal flesh), there nonetheless is emerging consensus about the importance of cooperative behaviours with respect to acquisition of 'high value' (i.e., calorie- and nutrient-rich) resources because of the cost to acquire and the value they have to other animals.

Despite uncertainties about the timing and dietary parallels associated with the rise of hominin cooperation, there emerges a consistent suite of behaviours suggested to coevolve with resource sharing such as division of labour, dedicated hunting, resource defense, and protection against predators (Smith et al., 2012). Cooperative behaviour correlates, in turn, include a shared dependence on ecological features and landscape composition (Kingston, 2007). But, the nature of sedimentary geologic archives limits spatial resolution at the scales of hominin foraging (100s m^2 to 10s km^2) (Wren et al., 2014; Magill et al., 2016).

Original HOMINIDS model

The *HOMINIDS* ABM model simulates the actions of two species of hominin agents living in the African savanna between 2.5 and 1.5 million years ago. These ancient human agents act to survive by foraging and nesting on a landscape composed by different topographic zones. The authors analysed how explicit foraging behaviours and subsistence strategies change in two distinct ecological layouts, and also the influence of the usage of digging tools.

Agents in this model are represented as: **hominins**, **plants** and **carcass**. Hominin agents are characterized by their hunger level, and, at each time step, either eat food available in their cell, move to a cell where they sense high probability of food, or move randomly. Plant agents and carcass agents provide calories for hominin agents, and are allocated stochastically in the environment.

When a hominin agent satisfies its daily caloric need, it moves automatically back to its nesting place. Agents may nest individually or collectively. Agents nesting individually will choose a new nest place every night, from nearby available nesting locations. Agents nesting collectively will only move their nest if a certain number of agents did not obtain sufficient food in that day. In this situation, the agents select a new nesting location that is close by the last scavenging location of the most successful agent in that nest.

This is an overview of the base *HOMINIDS* model, and the key characteristics necessary to understand the extensions proposed in this work. For more details, the reader should refer to the original paper (Griffith et al., 2010). Note that although the original paper mentions source code, it was lost to link rot, and we have re-implemented this model from the descriptions in the paper.

Extending the model for social food sharing

With the basic knowledge of the decision-making processes performed by the hominin agents in the original HOMINIDS work, we propose a new model in which hominin agents who are satisfied then can contribute in some way to the group. This approach tries to awake the importance of social interactions between agents, and through this, observe the main consequences to the group.

Since we are focused on observing social interactions when hominin agents share food with each other, we consider our agents to nest collectively (as opposed to individually). As well as in the original model, the hominin activity cycle is defined by scanning, eating and nesting during each day of the simulation year. Nevertheless, we included two new activities that are related to **collecting** and **carrying** food. Figure 1 shows the basic flowchart with the daily activities a hominin agent can perform. Highlighted parts indicate proposed new activities.

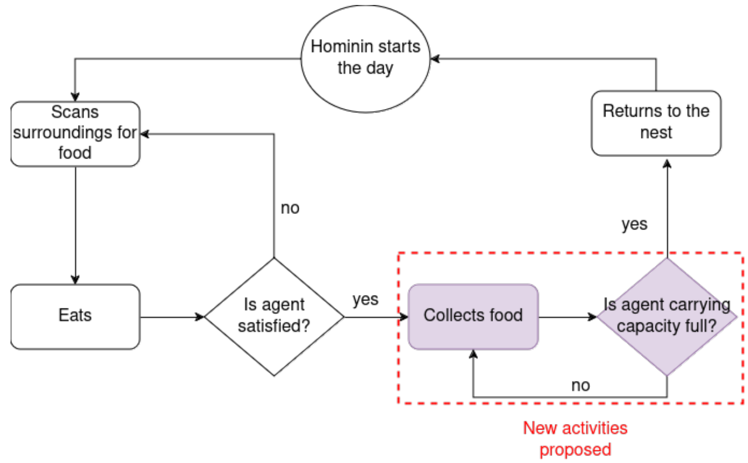

Figure 1: Daily activities of a hominin agent.

Thus, a hominin agent starts each day scanning surroundings for food. If a potential food is detected, it is implicit that the agent moves to that grid location and eats until it is satisfied. Otherwise, the agent will scan for food again. When the agent is ultimately satisfied, it then can start collecting food to share. If the agent's carrying capacity reaches its limit, the agent can return to the nest where surplus food is held and distributed among underfed hominin agents at the end of the day.

We intend to use, in principle, two different food distribution policies: distributing extra food equally to all hominins that did not reach the necessary amount of calories for the day; and distributing extra food prioritizing hominins most in need. This way, we can analyze how different procedures for the distribution of food among needy hominins affects the group as a whole, observing the average calorie consumption after they receive the extra food, and how this is reflected in the relocation of nests.

Conclusion

The work developed in the original HOMINIDS model has notable importance in the area of ABM for digital archaeology. Even so, social issues, such as food sharing among agents have not been explored in-depth. Through the incorporation of hominin social interactions into our model, here we expect to explore the effects of cooperative behavior on consumption and landscape exploration amid human evolution to inform further empirical and theoretical research on this topic.

Furthermore, we are also interested to provide a mechanism that facilitates the visualization of the model. One approach will be to use heat maps, indicating the region of the grid in which there was the highest concentration of hominins during the execution time of the simulation. This way, we will be able to observe how the issue of food distribution also influences the relocation of nests.

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