AncientS-ABM: A Novel Tool for Simulating Ancient Societies

Angelos Chliaoutakis and Georgios Chalkiadakis

Technical University of Crete, Greece
{angelos,gehalk}@intelligence.tuc.gr

Abstract. In this paper we demonstrate a tool that can be employed to build agent-based models (ABMs) for use in social archaeology. Specifically, our tool is based on the NetLogo modeling environment, and enables the creation of agent-based models of ancient societies, based on archaeological input. The models created by our tool can be used to obtain a better understanding of ancient societies, and assist archaelogists in testing the validity of existing or novel hypotheses and theories. We note that apart from assisting archaelogists in their work, the demonstrated tool can serve educational or recreational purposes as well: the ABMs created with the tool can, for instance, constitute the "backbone" of interactive platforms for use in schools or museums; and can conceivably be employed in history-focused digital strategic game environments.

Keywords: agent-based model · self-organization · social archaeology.

1 Introduction

Social archaeology seeks to understand the social organization of past societies at many different points in time [9]. For instance, do the main social units, individuals or groups, participate on a more-or-less equal basis, or do prominent differences in status or rank within the society (or perhaps even different social classes) exist? Answering these questions is very hard when exploring prehistoric communities, as written records in early societies are scant. The variety of methods used and the inherent uncertainty of the domain gives rise to a rich space of hypotheses regarding the social organization of early societies.

Over the past two decades, social and computational archaeology has utilized agent-based modeling for simulating ancient societies, in an attempt to answer such questions [5,7,8]. This is due to an ABMs' ability to represent individuals or societies, and encompass uncertainty inherent in archaeological theories. Moreover, incorporating ideas from multiagent systems (MAS) research in ABMs can enhance agent sophistication, and contribute on the application of strategic principles for selecting among agent behaviours [10].

Against this background, here we present *AncientS-ABM*, a NetLogo-based tool that serves the following purposes: *(a)* it can be employed for the study of practically any society of choice, and can easily incorporate and help test any theories proposed by archaeologists; and *(b)* it showcases how MAS-originating

concepts, techniques, and algorithms can be incorporated in archaeology ABMs. Unlike most existing ABM approaches in archaeology, which employ a simple reactive agent architecture, AncientS-ABM can be and has already been used to populate its models with *utility-based* agents. Our agents act autonomously towards utility maximization, and can build and maintain complex social structures. Furthermore, our models can (demonstrably) incorporate a number of different social organization paradigms and various technologies. Indeed, using agent-based models that were built on knowledge derived from archaeological research, but do not attempt to fit their results to a specific material culture, allows for the emergence of dynamics for different types of societies in different types of landscapes, and can help derive knowledge of socio-economic and socio-ecological systems applicable beyond a specific case study.

2 Main Purpose

We now describe the main purpose and present the basic functionality offered by *AncientS-ABM*. For interest, we describe briefly how we have employed the tool to create and study an artificial ancient society of autonomous agents residing at the *Malia* area of the island of Crete during the Early Bronze Age [2,3,4].

To begin, the tool was developed using the NetLogo modeling environment [1], which is a free, open source and cross-platform system that runs on the Java virtual machine and it is fully programmable using an extended Logo dialect to support agents. Model parameters values correspond to estimates found in archaeological studies and currently offered by the interface (Fig. 1): *number of agents per settlement's cell*, *agricultural strategy* (intensive or extensive), *level and distribution of resources*, *number of settlements* per scenario, *agent migration radius*, *proximity of a new location to an aquifer* or not, *resources amount stored* by an agent per year and agent decision-making based on different *social organization paradigms*: independent, sharing, egalitarian, self-organized and hierarchical (static). The modeler is able to visualize environmental information on-the-fly such as elevation, slope, aquifer density and level of resources, as well as river and spring features and locations of known archaeological sites.

In AncientS-ABM, an agent can correspond to either an individual, a household, or a settlement. For instance, in our research focusing on the Minoan society [2,3,4], *households* are utility-based autonomous agents who they can settle (or occasionally resettle) and cultivate in a specific environmental location. They also possess a knowledge of their environment that allows them to choose their forage sites, gain experience, and even plan future movements. Several agents may live and interact in a specific area. The tool allows their world to be a precise recreation of the landscape, using environmental information built from available archaeological and topographical data.

AncientS-ABM allows us to assess the influence of different *social organization paradigms* on land use patterns and population growth. Interestingly,

[1] https://ccl.northwestern.edu/netlogo

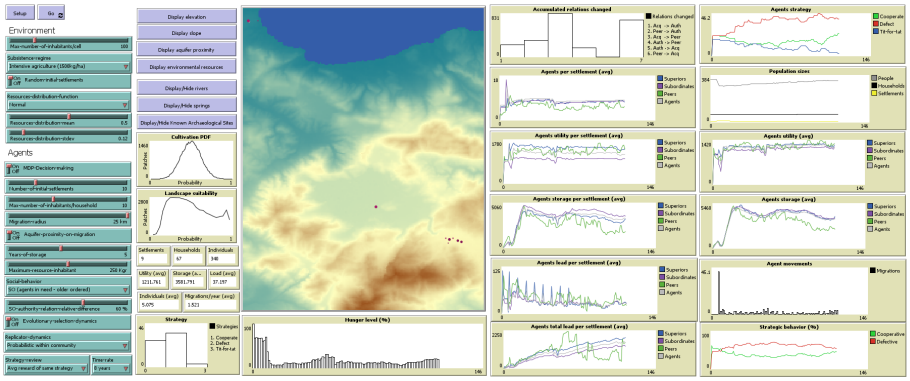

Fig. 1: AncientS-ABM interface and parameters.

AncientS-ABM incorporates a social paradigm of agents *self-organizing* into a "stratified" social structure, and continuously re-adapting the emergent structure, if required [2]. Moreover, in order to model societal transformation accurately, agent behaviour has to be analysed from a *strategic* perspective as well. AncientS-ABM provides the modeler with the ability of performing a "game-theoretic" study of the agents' society. This allows us to study the evolution and adaptation of strategic behaviours of individuals operating in the artificial ancient community, and the effect these have on the society as a whole [3].

AncientS-ABM has allowed us to obtain important intuitions regarding the evolution of early Minoan societies. Our simulation results [2,3] demonstrate that self-organizing agent populations are the most successful. The success of this social organization paradigm that gives rise to stratified, *non-egalitarian societies*, provides support for so-called *"managerial"* archaeological theories: these assume the existence of different social strata in Neolithic/Early Bronze Age Crete, and consider this early stratification a pre-requisite for the emergence of the *Minoan Palaces*, and the hierarchical social structure evident in later periods [1]. In many scenarios, populations converge to adopting cooperative strategies; in line with the view that, though complex societies emerge to a large extent due to conflict and competition, these social conditions seldom exist without cooperative agreements, alliances and cooperation networks [6].

Furthermore, in [4] we studied the extent by which the cataclysmic volcanic eruption of Thera (Santorini) impacted the Minoan social evolution. Our results support archaeological theories suggesting that the Theran eruption led to a gradual (and not immediate) breakdown of the Minoan socio-economic system.

3 Demonstration

The tool is based on the NetLogo (6) modeling environment. NetLogo runs on the Java Virtual Machine, so it works on all major platforms. Java 8 runime or later is required. "AncientS-ABM" source code is available for download at

the following link: `http://www.intelligence.tuc.gr/~angelos/PAAMS19_96.zip`. After download, extract content and run the following command:[2]

```
# java -jar AncientS-ABM.jar
```

When the "AncientS-ABM" user interface is available on the screen, you may set the available user-defined model parameters as you prefer or leave the default ones. Press the "setup" button to initialize the model and then the "Go" button to start running the simulation. Finally, you may find a demonstration video of the ABM at the following link: `https://youtu.be/Aa6mEsDqGfg`

4 Conclusions

In this work we intertwined MAS and EGT techniques to build a a generic ABM for simulating complex social systems interacting within a spatial environment. Our model uses existing archaeological evidence and it can readily incorporate any archaeological theory or historical data offered, in order to explore alternative hypotheses regarding the social organization of ancient societies.

References

1. Cherry, J.: Polities and Palaces: Some Problems in Minoan State Formation. In: Peer Polity Interaction and Socio–Political Change, pp. 19–45. Cambridge University Press (1986)
2. Chliaoutakis, A., Chalkiadakis, G.: Agent-based modeling of ancient societies and their organization structure. Autonomous Agents and Multi-Agent Systems **30**(6), 1072–1116 (2016).
3. Chliaoutakis, A., Chalkiadakis, G.: Evolutionary game-theoretic modeling of past societies' social organization. The 2018 Conference on Artificial Life: A Hybrid of the European Conference on Artificial Life (ECAL) and the Int. Conference on the Synthesis and Simulation of Living Systems (ALIFE) pp. 98–105 (2017)
4. Chliaoutakis, A., Chalkiadakis, G., Sarris, A.: Employing agent-based modeling to study the impact of the Theran eruption on Minoan society. In: Proc. of the 3rd Conference on Computer Applications and Quantitative Methods in Archaeology - Creece (in press 2019)
5. Crabtree, S.A., Bocinsky, R.K., Hooper, P.L., Ryan, S.C., Kohler, T.A.: How to make a polity in the central mesa verde region). American Antiquity **82**(1), 71–95 (2017)
6. Gumerman, G.J.: The role of competition and cooperation in the evolution of island societies. The Evolution of Island Societies pp. 42–49 (1986)
7. Heckbert, S.: Mayasim: An agent-based model of the ancient maya social-ecological system. Journal of Artificial Societies and Social Simulation **16**(4), 11 (2013)
8. Janssen, M.A.: Population aggregation in ancient arid environments. Ecology and Society **15**, 19 (2010)
9. Renfrew, C., Bahn, P.: Archaeology: theories, methods, and practice. Thames and Hudson, first edn. (1991)
10. Wellman, M.P.: Putting the agent in agent-based modeling. Autonomous Agents and Multi-Agent Systems (2016)

[2] Make sure there is no space or special characters on your path (pwd)