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THE ABADE ARTIFICIAL ARCHAEOLOGICAL SITE PROJECT

1. Introduction

Archaeology has undergone rapid changes in recent decades thanks to advances in technology. One key development is the ability to create detailed computer simulations and virtual models of archaeological sites and artifacts. These tools offer archaeologists an invaluable way to visualize, analyze, and experiment with the past in new ways. Since M. Aldenderfer's (1991) seminal article advocating the use of computer simulation as a tool for archaeological research, especially for studying, for example, the operation of the Analytical Engine, a mechanical device designed by Charles Babbage in the 19th century, considered the precursor of modern computers. He explains the basic principles of computer simulation, its benefits and limitations, and how it can be applied to the Analytical Engine, using a program called Simula to model the device's behavior and test different scenarios and hypotheses about its operation and performance. The Author concludes that computer simulation is a powerful and promising technique for archaeology, which allows exploring aspects of material culture that are not easily accessible by other means, and that the Analytical Engine is a fascinating example of a historical artifact that deserves more attention and study (Aldenderfer 1991).

On the other hand, M. Lake (2014) provides a history of archaeological computer simulation, starting from the early 1970s and focusing on the recent developments since 2001. It proposes a distinction between programmatic and mature simulation phases based on the emphasis on methodological issues or substantive results. The article reviews the main types of simulation models used in archaeology, such as cellular automata, network models, agent-based models, and evolutionary models. It discusses the advantages and challenges of each type, as well as the theoretical and empirical implications of their application. The article concludes that simulation is a valuable tool for exploring complex and dynamic archaeological phenomena, such as social change, cultural evolution, and human-environment interactions. It also suggests future directions for simulation research, such as integrating multiple models, incorporating spatial and temporal scales, and enhancing validation and verification (Lake 2014).

Today, computer simulations create artificial environments where researchers can test hypotheses, explore scenarios, and model complex dynamics like human interactions. They allow for countless experiment iterations that would be impossible in real-world archaeology. Simulations can incorporate climate, geography, architecture, artifact evidence, historical sources, and more to recreate ancient settings and societies. A great example is the Abade Artificial Archaeological Site Project in Brazil (Costa 2012). In 1887, Lavras do Abade, a village of gold miners in the Brazilian Midwest, was attacked for two consecutive nights and three days by the settlement of Meia Ponte, its neighboring village and now the city of Pirenópolis. According to local narratives, the mining was destroyed because of the pollution of the water of the Rio das Almas, which originates in the Serra dos Pireneus-GO. Nowadays, the site is considered a 'lost island' in society's collective, cultural, and social memory. The legacy of Lavras do Abade goes beyond the past conflict, as the environmental impact and the memory of the event are still present in the modern landscape, being a unique example of the history of human pollution in central Brazil.

This simulation combines laser scanning data of ruins, 3D modeling, historical photographs, and documents to recreate a 19th-century mining village. Researchers can immerse themselves in this virtual site to study details and test theories about how the settlement looked and functioned over time. Historical Data includes written documents, field reports, and local narratives that provide information about past events, such as the attack on the gold miners' village in 1887. Anthropological data are based on ethnographic studies and cultural analyses that help to understand the social practices and relationships between the communities of Meia Ponte and Lavras do Abade. Environmental Data involves the analysis of the impact of mining on natural resources, especially the Rio das Almas water pollution, and how this affected the local ecology. Archaeological data are obtained through excavations, surveys, and artifact analyses that reveal the physical structure of the village and mining activities.

The software also enables the creation of artificial intelligence agents who inhabit and interact within the simulations. Such a feature introduces more randomness and realism. The researcher can begin to model how individual and group decisions cascade over decades or centuries, like mapping the spread of technologies and ideas. Another benefit of simulations is using them to plan actual archaeological fieldwork. Virtual models help identify high-probability excavation zones and likely obstacles in advance. They provide analysis that sidelines do not offer, optimizing limited budgets. Of course, computer simulations have limitations. Factors like computing power, programming expertise, and underlying theory constraints impact accuracy. This technology should complement rather than replace traditional archaeological techniques.

However, virtual archaeology has tremendous potential to propel the field when used prudently. It facilitates collaboration as models are shared and expanded. Comprehensive databases integrate global site data. AI assistants can automate mundane tasks or suggest fresh research directions. Moreover, computer simulations bring archaeology full circle to its roots – the joy of discovery. What adventurer has not dreamed of unveiling a lost city? Virtual reality lets anyone unlock those wonders, whether a scholar or an aspiring

Indiana Jones. So, in summary, computer simulations enable archaeologists to conduct countless controlled experiments, gain insights difficult to achieve on-site, comprehensively plan expeditions, and share/expand models globally via computing networks. The sky is the limit as this technology keeps improving. With prudent application, virtual archaeology promises to complement traditional techniques and advance the field.

2. The Abade Artificial Archaeological Site Project (AAASP)

The Abade Artificial Archaeological Site Project (AAASP), which commenced in 2012, employed several distinct software programs throughout its different 4 phases. During phase 1 of the Abade Artificial Archaeological Site Project, 31 simulation software programs were researched and acquired. Subsequently, in phase 2, 18 of these programs underwent selection and testing for operability. As the project progressed into phase 3, 9 out of the initial 18 programs were chosen for simulation model testing. Finally, by phase 4, only three programs for simulation remained under consideration: AnyLogic, NetLogo, and MASON (Costa 2022). The project utilized a wide array of proprietary and open source software across its development to construct the virtual model of the Abade village and test various simulation approaches. One of these base models was the 'Serial Killers' model constructed by Haze B. Park and available in Serial Killers - AnyLogic Cloud. The 'Serial Killers' model is an example of a simulation created with AnyLogic software. It simulates a highly dangerous city district where criminals are looking for victims. In the model, a victim can be any person from the non-criminal population within the 'scan radius' of the criminal, with a certain probability. After choosing the victim, the criminal accelerates and begins to follow them. When the criminal approaches the victim at a 'kill distance', he is ready to murder the victim, but this only happens when there are no potential witnesses nearby within the 'scan radius'. After the murder, the killer remains with the victim for some time to appreciate what he has done and then moves away to look for a new victim. However, if the killer cannot find a good time to kill the victim, he gives up. This model exemplifies how simulation can be used to model and understand complex and dynamic behaviors in archaeological urban environments.

This model (Fig. 1) laid the groundwork for developing a more extensive and historically precise simulation. It integrated historical, anthropological, environmental, and archaeological data collected during the research phase. The resulting simulation accurately replicated the Lavras do Abade conflict within a constrained scale and observable timeframe. To elucidate the model construction process, I delineate the data parameters, variables, and action functions, including system dynamics, agents, connections, and the simulation experiment itself. In the virtual reconstruction of Lavras do Abade, agents

Fig. 1 – AAASP web page.

– labeled as 'criminals' – were programmed with a set speed of 5 KPH to navigate the continuous space of the simulation. Their movement was visually represented with rotation animations that aligned with their direction of travel, enhancing the realism of their actions. These agents were not designed to rotate along the Z-axis, maintaining a consistent vertical orientation. Advanced Java settings enabled detailed logging and automatic dataset creation, which facilitated the analysis of the agents' behaviors over time. The simulation did not limit the number of data samples, allowing for comprehensive data collection throughout the simulated period. This meticulous design allowed the 'criminal' agents to interact dynamically within the model, reflecting the complexity of human behavior in a historical context.

In the simulation of Lavras do Abade, the 'criminal' agents are equipped with a {scanRadius} of 10 m, allowing them to detect other entities within this range. Their {killRadius} is set to 2 m, defining the proximity required to affect other agents. When patrolling, these agents move at a {speedNormal} of 5 KPH and increase to a {speedFollowVictim} of 6 KPH when pursuing a target. The {decisionProbability} parameter, set at 0.2, dictates the likelihood

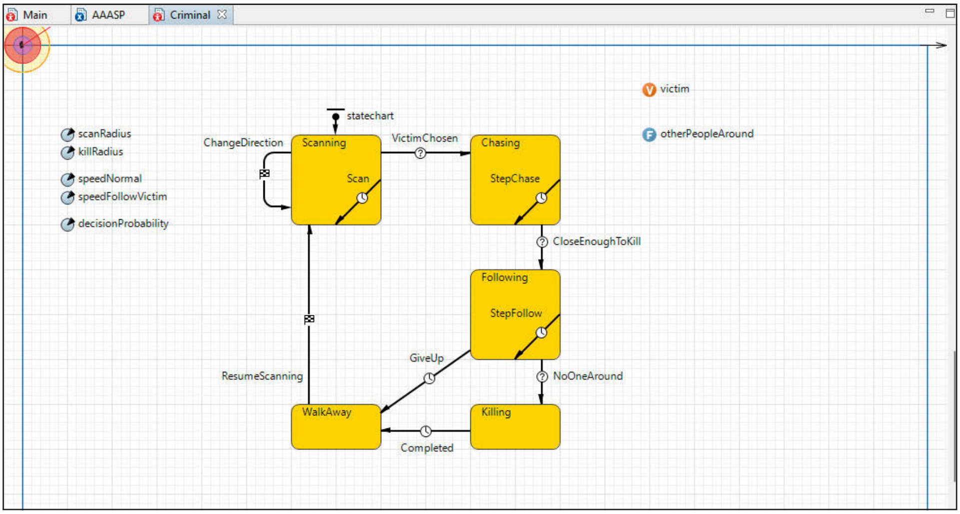

Fig. 2 – Criminal diagram (AnyLogic 2023).

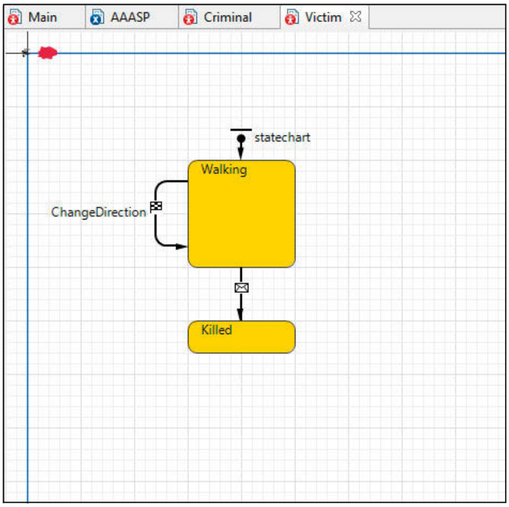

Fig. 3 – Victim diagram (AnyLogic 2023).

of making strategic decisions, such as engaging or disengaging with a target. All parameters are visible at runtime, ensuring transparency in the simulation process, and are saved in snapshots for consistent state restoration. The function {otherPeopleAround} is designed to determine if there are any other

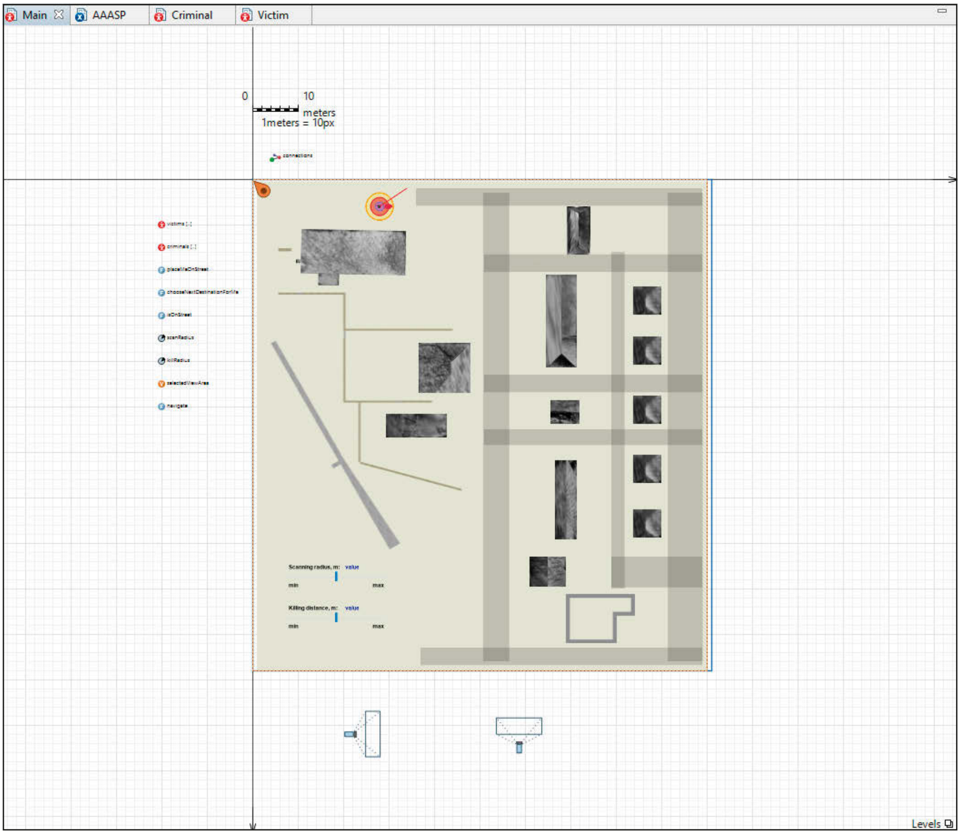

Fig. 4 – AAASP model at 50% (AnyLogic 2023).

individuals (victims) within the vicinity of a particular agent (criminal) in the simulation. This function iterates through a list of victims in the simulation. If a living victim is found within the {scanRadius} of the agent, the function returns {true}, indicating the presence of other people around. If no such victim is found, it returns {false}. This function is crucial for the agent's decision-making process, as it helps to determine whether they can proceed with their actions without being detected by others (Fig. 2).

In the simulation's framework, the victim variable is pivotal (Fig. 3), referencing the 'victim' class, which encapsulates the attributes and behaviors of individuals potentially interacting with 'criminal' agents. Declared with public visibility, it is accessible throughout the simulation, allowing various components to interact with it. Its mutable nature means it can represent different entities over time. The simulation's capability to save the victim's state

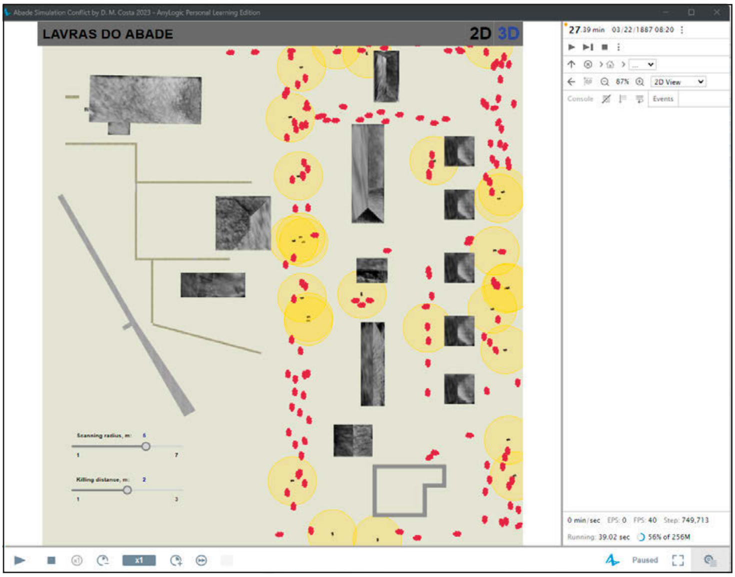

Fig. 5 – Run simulation (AnyLogic 2023).

in snapshots ensures that the simulation can be accurately restored to a previous state. Additionally, its visibility during runtime aids in monitoring and debugging, providing a transparent view of the simulation's inner workings as it progresses. In the simulation, 'victim' agents are integral components with a defined speed of 5 KPH and animations that rotate to match their movement direction, enhancing realism. They operate within a continuous space, allowing for seamless movement. These agents are not generic; they have specific attributes tailored for the simulation. With logging enabled, their actions and states are recorded, and datasets are auto-created for analysis without a limit on data samples. These parameters collectively shape the 'victim' agents' behavior, influencing the simulation's dynamics and outcomes.

Ultimately, the simulation is configured to run in real-time with a scale of 1.0 (Fig. 4), starting from March 22, 1887, at 08:00 GMT and concluding on March 24, 1887, at 18:00 GMT. It bypasses the initial simulation screen, has a maximum memory allocation of 256 Mb units, and uses the 'main' agent type. The simulation generates unique runs using a random seed, not allowing zooming or panning in the window. The developer panel is enabled but hidden at the start, and the simulation does not load from a snapshot, ensuring each run begins from the initial state as defined. This setup aims to provide a controlled environment to simulate the historical conflict at Lavras do Abade with precise time and randomness parameters (Fig. 5).

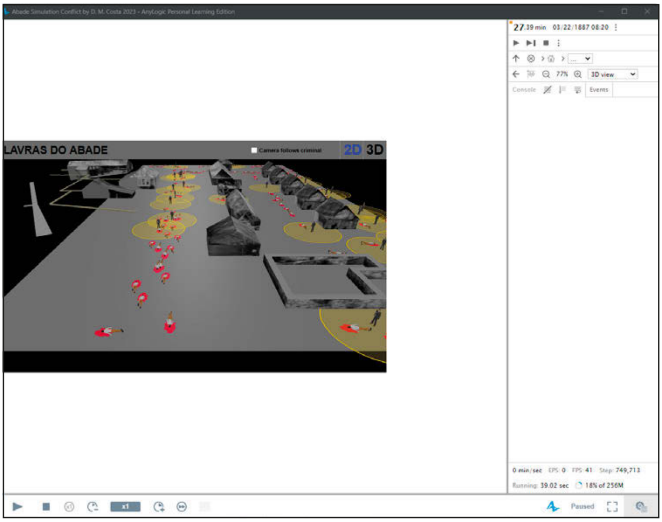

Fig. 6 – 3D view (AnyLogic 2023).

To accomplish this, we initiated the simulation with a quantitative representation of 150 victims, corresponding to the documented number of over 30 miners' families in historical records. Additionally, the model incorporates 27 criminals referred to as markers, black maskers, or Curucús, as documented in anthropological and archaeological accounts of assaults. The 3D environment was meticulously constructed using historical and archaeological data with millimetric precision. The predictive behavior of both miner victims and criminal agents is determined by a combination of physical and psychological training parameters (Fig. 6).

3. Final considerations

The simulations use actual archaeological data like scans, measurements, photographs, historical texts, environmental records, and material evidence to accurately recreate sites, artifacts, and environments. The models become more photo-realistic and detailed as computing power and graphic capabilities improve. The preliminary findings indicate that each simulation was completed within 30 minutes or less. Interestingly, in these simulations, all victims of criminal acts were fatally assaulted within this timeframe. This observation is particularly intriguing considering historical records, which suggest that the entirety of the conflict spanned over three days and two nights. This information aligns with documented instances of 2 or 3 minor assaults occurring within a 24-hour interval leading up to the village's destruction.

Another notable aspect of the AAASP is its commitment to being housed in an open repository upon completion Model direct link: https://cloud.anylogic.com/model/d2e01b6a-c8d7-4e86-9f6c-1f8e0c01241e. This approach allows other researchers to validate the model, adjust variables, and refine functions. Additionally, new historical, anthropological, environmental, and archaeological data can be incorporated to modify the initial parameters, ensuring the ongoing relevance and accuracy of the simulation. Many simulation projects are open source or available for researchers to use. As models expand to encompass more sites globally, the vision is an interconnected global database that archaeologists can share and enhance collectively to advance the field. Public contributions could be possible down the road via crowdsourcing efforts.

Simulations have reinforced theories about ancient innovations diffusing more rapidly across cultures connected by trade networks. Models also indicate that climate factors more strongly influence the development trajectories of ancient' civilizations than previously presumed. Most intriguing are models unveiling unexpected social dynamics, interactions, and behaviors in antiquity that differ from present-day assumptions. In the case of the AAASP, simulations are intricately linked with historical and archaeological facts. They not only serve to validate existing knowledge but also provide new avenues for research. Finally, it is an ongoing balance. Computing power and expertise still limit model complexity versus real-world dynamics (Lieto *et al.* 2023; Marras *et al.* 2023). But rapid improvements on both fronts are enabling more sophisticated theory-driven models. Close collaboration between technologists and archaeology/anthropology experts helps align capabilities and theory. Also, AI agents could interact within simulation environments – complying with cultural norms, group dynamics, resource constraints, etc. – introducing more realism and unpredictability versus pre-programmed behaviors. However, developers must be careful AI does not introduce modern biases. Continual tweaking based on emerging archaeological evidence refines fidelity. Ultimately, enabling students and enthusiasts to immerse themselves in virtual sites could revolutionize public understanding of ancient civilizations. Interactive models inspire more profound public interest and engagement. If integrated with classroom curriculums or museum tours, the public develops meaningful context about antiquity. This will undoubtedly advance preservation efforts.

In conclusion, the Abade Artificial Archaeological Site Project demonstrates the immense potential of computer simulation and virtual archaeology to advance our understanding of the past. The simulations can recreate ancient sites and societies with unprecedented detail and accuracy by integrating diverse data sources like laser scans, historical records, and archaeological evidence. The ability to test hypotheses, model dynamics like human behavior and interactions, and experiment with different scenarios provides invaluable insights that complement traditional archaeological methods. As computing power and software capabilities continue improving, the realism and complexity of these virtual environments will only increase further. Perhaps most importantly, initiatives like the AAASP that embrace open data-sharing and collaborative model-building can accelerate the field by enabling global cooperation and public participation. With an interdisciplinary approach combining technological prowess and theoretical archaeological expertise, virtual archaeology simulations offer a transformative way to analyze material culture, reconstruct our ancient heritage, and bring the wonders of the past vividly to life for academics and enthusiasts alike. The future impact is bound only by our intellectual curiosity to unlock the mysteries of humanity's origins through this powerful new lens.

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ABSTRACT

The Abade Artificial Archaeological Site Project (AAASP) employed computer simulations to recreate a 19th-century Brazilian mining village that was destroyed in an environmental conflict. The simulations integrate laser scans of ruins, 3D modeling, historical data, and material evidence to reconstruct the site in a virtual environment accurately. After researching 31 simulation programs, the project utilized AnyLogic software (https://www.anylogic.com/) for the final phase. One base model was the 'Serial Killers' simulation in AnyLogic, modeling criminal behavior in an urban setting. This laid the groundwork for the more extensive historically accurate 'Abade 10' simulation, precisely replicating the Lavras do Abade conflict within set parameters. The 'Abade 10' model incorporates system dynamics, agent behaviors, connections, and an experiment simulating the 3-day conflict timeline in 1887. Preliminary findings indicate all victim agents were fatally assaulted within 30 minutes in the simulations, aligning with historical records of intermittent attacks before the village's destruction. Upon completion, the AAASP aims to be an open repository that allows other researchers to validate, adjust, and enhance the model with new data. The project demonstrates the potential of virtual archaeology to test hypotheses, plan fieldwork, share models globally, and inspire public engagement by immersing users in accurate ancient environments.