Integration of an Agent-Based Model and Augmented Reality for Immersive Modeling Exploration

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Abstract

This work reports on the design and implementation of advanced geospatial simulations using an Agent-Based Model (ABM) integrated with an augmented reality solution for interactive and immersive modeling exploration. The multi-scenario modeling framework allows for emergent phenomena and provides flexible representation of biological and physical environmental factors associated with natural and man-made systems. Augmented reality is provided by a sandbox running Tangible Landscape, based on a customization of GRASS GIS. An integrated Microsoft Kinect sensor mounted over the sandbox captures real-time topography produced by physical interactions with sand and resulting digital elevation models are ingested into the Recursive Porous Agent Simulation Toolkit (Repast) as landscape definition input. We illustrate the implementation by presenting a model system that includes a classic predator-prey relationship over a grassland habitat where sheep and wolves coexist as agents. Food sources for sheep are scattered over the landscape and are consumed as agents forage. Wolves control sheep population by actively searching for sheep and chasing individuals when their presence is detected. We simulate natural conditions by defining that the presence and movement of agents over the landscape is controlled by elevation provided by the sandbox. For instance, the presence of agents and resources can be limited to specific elevation ranges and slope is used to incorporate movement cost (energy loss) while individual agents travel over the landscape. Ecological conditions are further simulated by the consumption and regrowth of food resources. Users interact with the sandbox and the modeling effort by manually moving sand and altering landforms. This effort brings together multiple technologies and data manipulation/visualization strategies and allows for feature-rich experimentation by supporting multiple co-located and georeferenced layers (e.g., land use/land cover, soil, hydrography).

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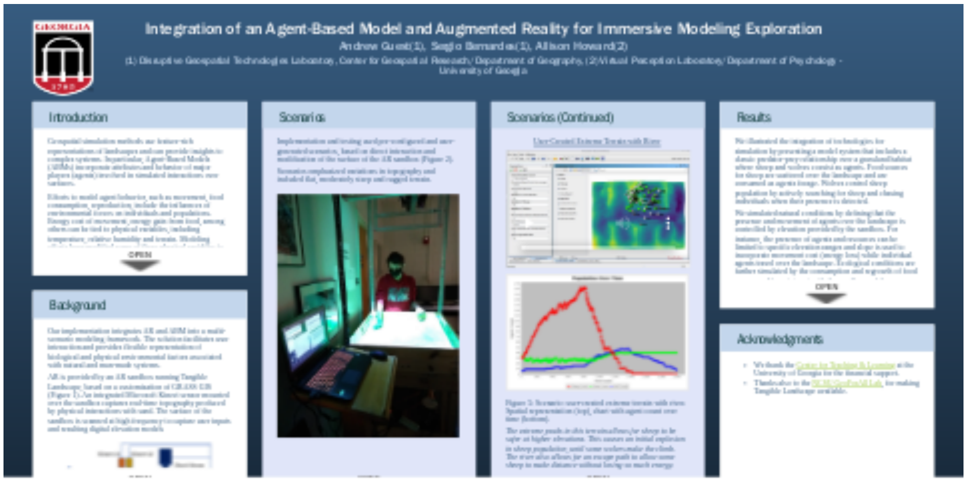

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INTRODUCTION

Geospatial simulation methods use feature-rich representations of landscapes and can provide insights to complex systems. In particular, Agent-Based Models (ABMs) incorporate attributes and behavior of major players (agents) involved in simulated interactions over surfaces.

Efforts to model agent behavior, such as movement, food consumption, reproduction, include the influences of environmental forces on individuals and populations. Energy cost of movement, energy gain from food, among others can be tied to physical variables, including temperature, relative humidity and terrain. Modeling efforts have modified some of these physical variables to conform to environmental changes. A less explored opportunity for landscape characterization and modeling involves the direct manipulation of topography by users and the near-real time presentation of associated modeling results.

This work explored a hands-on approach for modeling that includes manipulation of topography during modeling and geovisualization of results. Here, we report on the design, implementation and testing of advanced geospatial simulations using an Agent-Based Model integrated with an Augmented Reality (AR) sandbox for interactive and immersive modeling exploration.

BACKGROUND

Our implementation integrates AR and ABM into a multi-scenario modeling framework. The solution facilitates user interaction and provides flexible representation of biological and physical environmental factors associated with natural and man-made systems.

AR is provided by an AR sandbox running Tangible Landscape, based on a customization of GRASS GIS (Figure 1). An integrated Microsoft Kinect sensor mounted over the sandbox captures real-time topography produced by physical interactions with sand. The surface of the sandbox is scanned at high frequency to capture user inputs and resulting digital elevation models

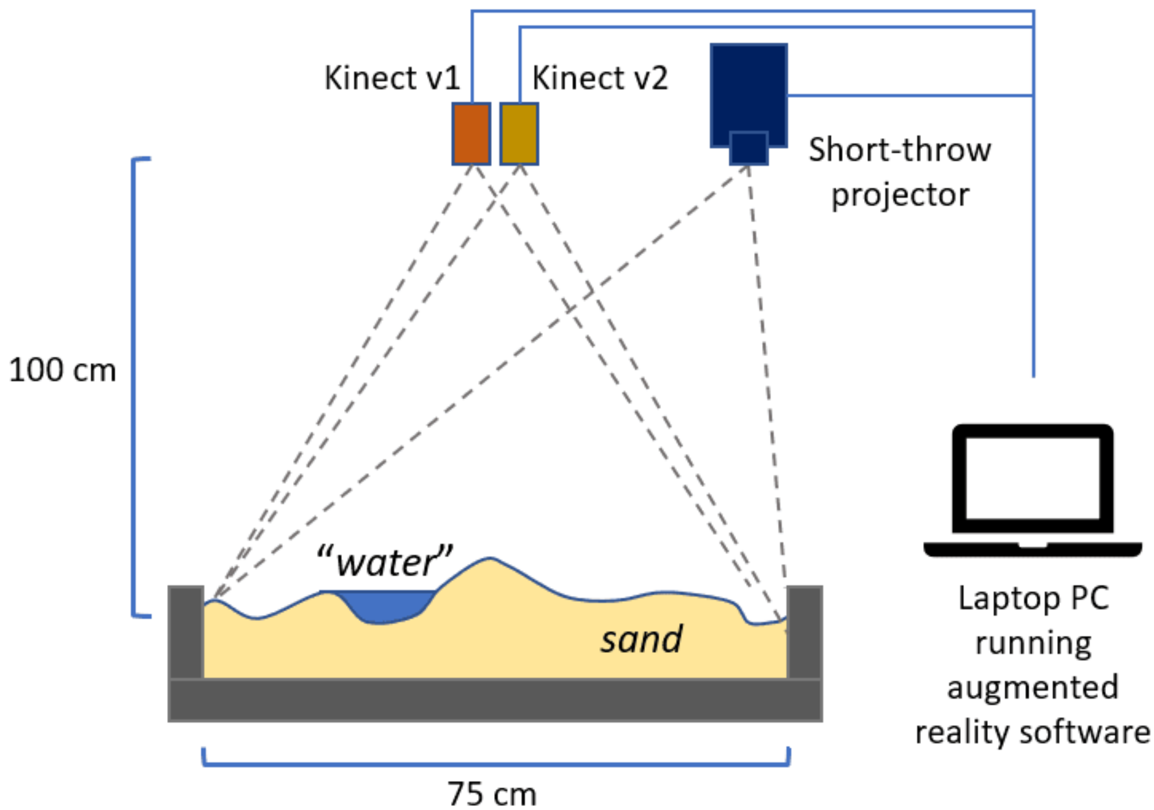


Figure 1: Diagram of the augmented reality sandbox, including Microsoft Kinect sensors, processing unit and projector.

A reformatted elevation file is ingested into the Recursive Porous Agent Simulation Toolkit (Repast) as landscape definition input. A Java-based proof-of-concept solution was implemented using Repast. The implementation uses a predator-prey simulation that includes sheep, wolves, and grass over different terrains.

SCENARIOS

Implementation and testing used pre-configured and user-generated scenarios, based on direct interaction and modification of the surface of the AR sandbox (Figure 2).

Scenarios emphasized variations in topography and included flat, moderately steep and rugged terrain.

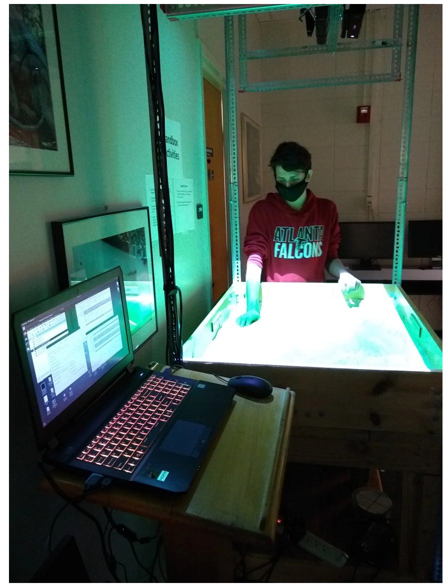
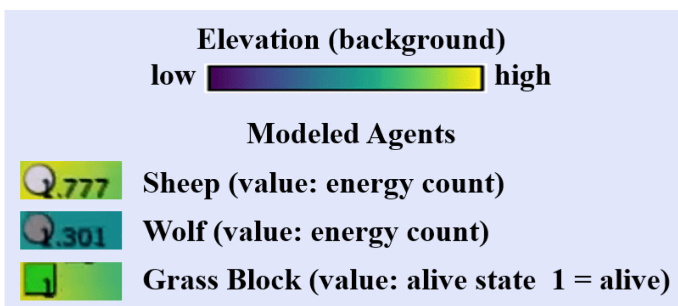


Figure 2: User interacts with the surface of the AR sandbox and reshapes terrain used by the ABM.

Figures 3 to 6 use the following conventions:



Scenarios included digital representations of existing terrain (Mount St. Helens, Figure 3) and user-defined topographies (Figures 4 to 6). In addition to spatial representations, we simulated energy consumption/gain and tracked the variation in number of agents over time.

Existing Terrain: Mount Saint Helens

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1639108075/agu-fm2021/61-E4-1B-40-75-F8-B8-6B-FF-10-31-B8-7A-32-0E-B7/Video/StHelens_nycxso.mp4

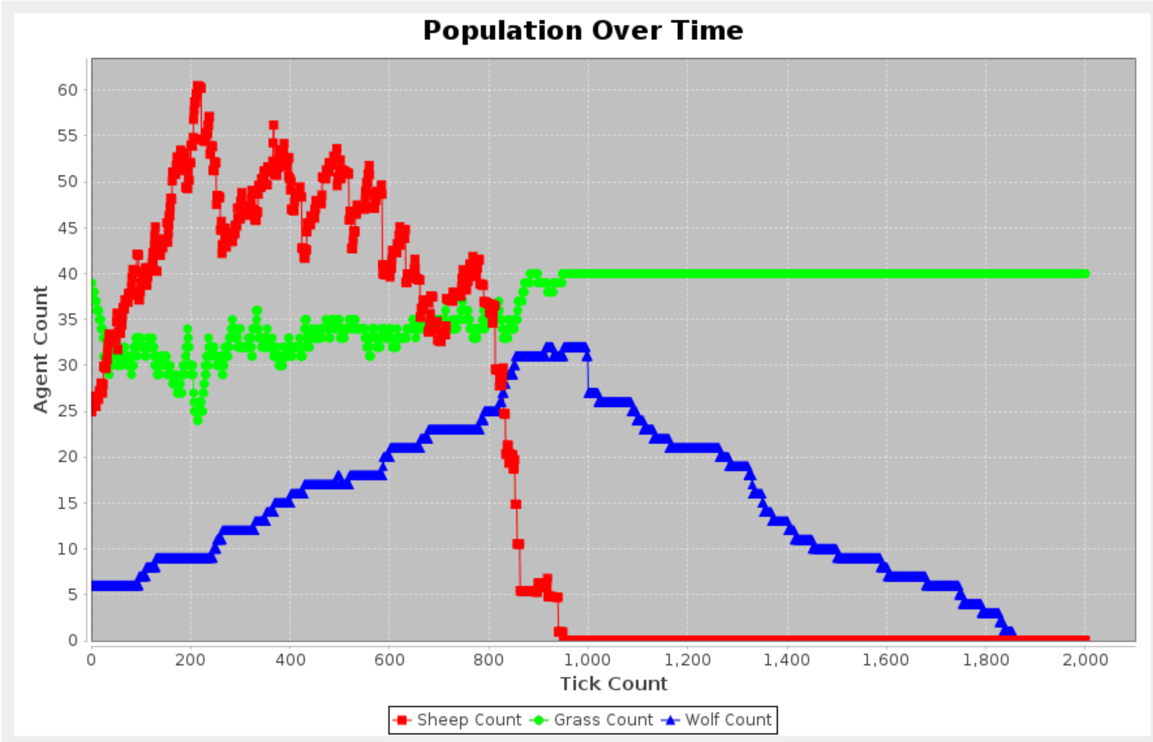


Figure 3: Scenario: existing terrain (Mount Saint Helens): spatial representation (top), chart with agent count over time (bottom).

Once the wolves descend upon the terrain with low energy costs, they find and eliminate the remaining sheep. This is not a favorable environment for sheep.

User-Create Moderate Terrain with Peaks

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1639110577/agu-fm2021/61-E4-1B-40-75-F8-B8-6B-FF-10-31-B8-7A-32-0E-B7/Video/ModeratePeaks_wxzf0t.mp4

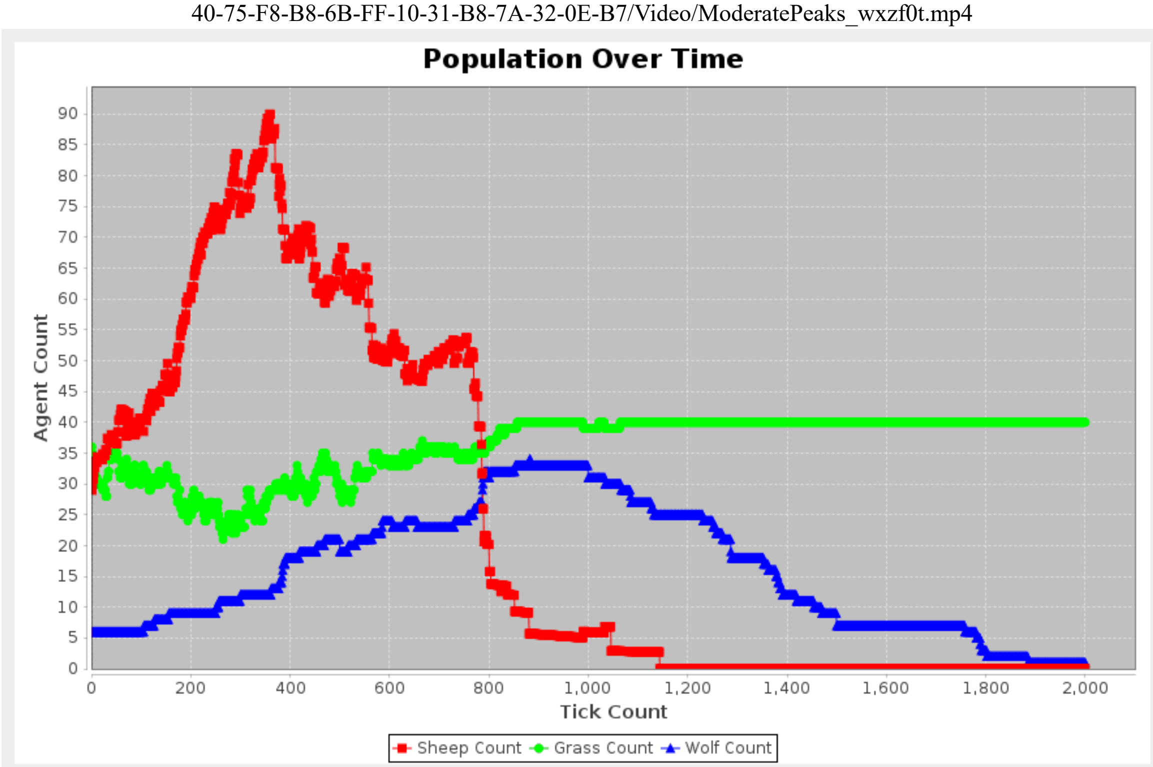


Figure 4: Scenario: user-created moderate terrain with peaks. Spatial representation (top), chart with agent count over

time (bottom).

Sheep who make it to higher elevations tend to live longer than sheep who stay on lower elevations. It takes a lot of energy to ascend terrain. Wolves who survive the climb, are greatly rewarded.

SCENARIOS (CONTINUED)

User-Created Extreme Terrain with River

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1639108090/agu-fm2021/61-E4-1B-40-75-F8-B8-6B-FF-10-31-B8-7A-32-0E-B7/Video/ExtremeRiver_qia9du.mp4

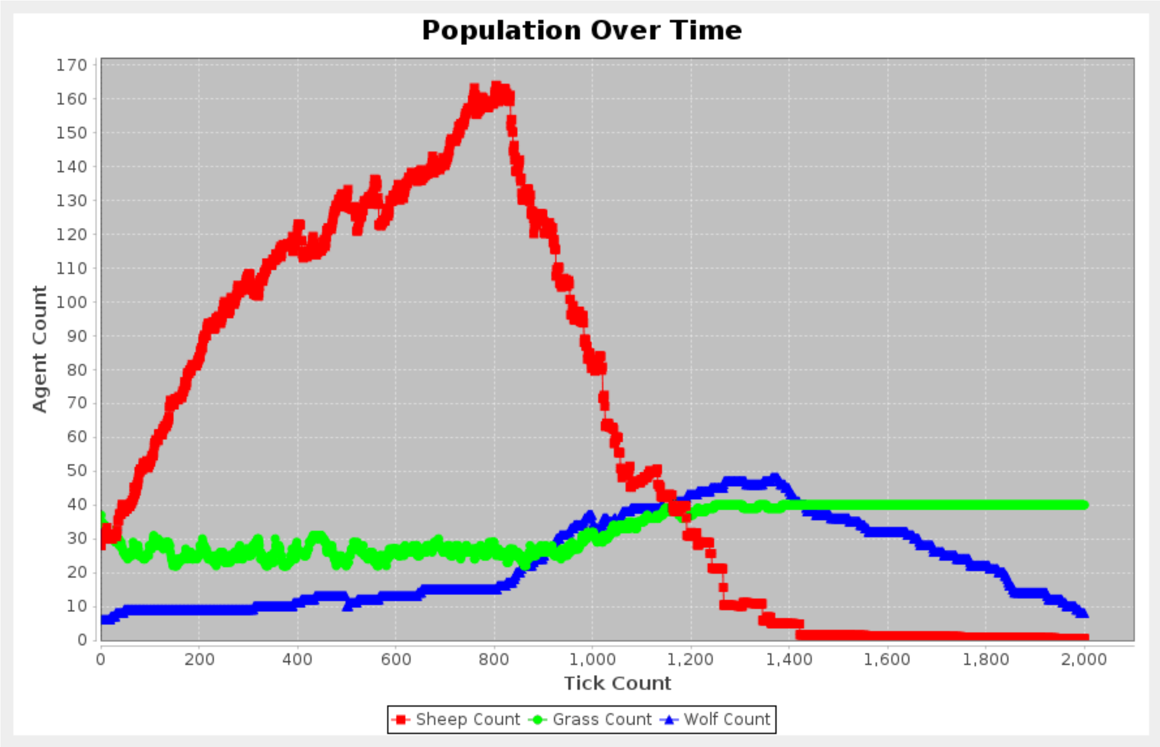


Figure 5: Scenario: user-created extreme terrain with river. Spatial representation (top), chart with agent count over time (bottom).

The extreme peaks in this terrain allows for sheep to be safer at higher elevations. This causes an initial explosion in sheep population, until some wolves make the climb. The river also allows for an escape path to allow some sheep to make distance without losing so much energy.

User-Created Mostly Flat Terrain with Hill

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1639110690/agu-fm2021/61-E4-1B-40-75-F8-B8-6B-FF-10-31-B8-7A-32-0E-B7/Video/FlatHill_kco2ai.mp4

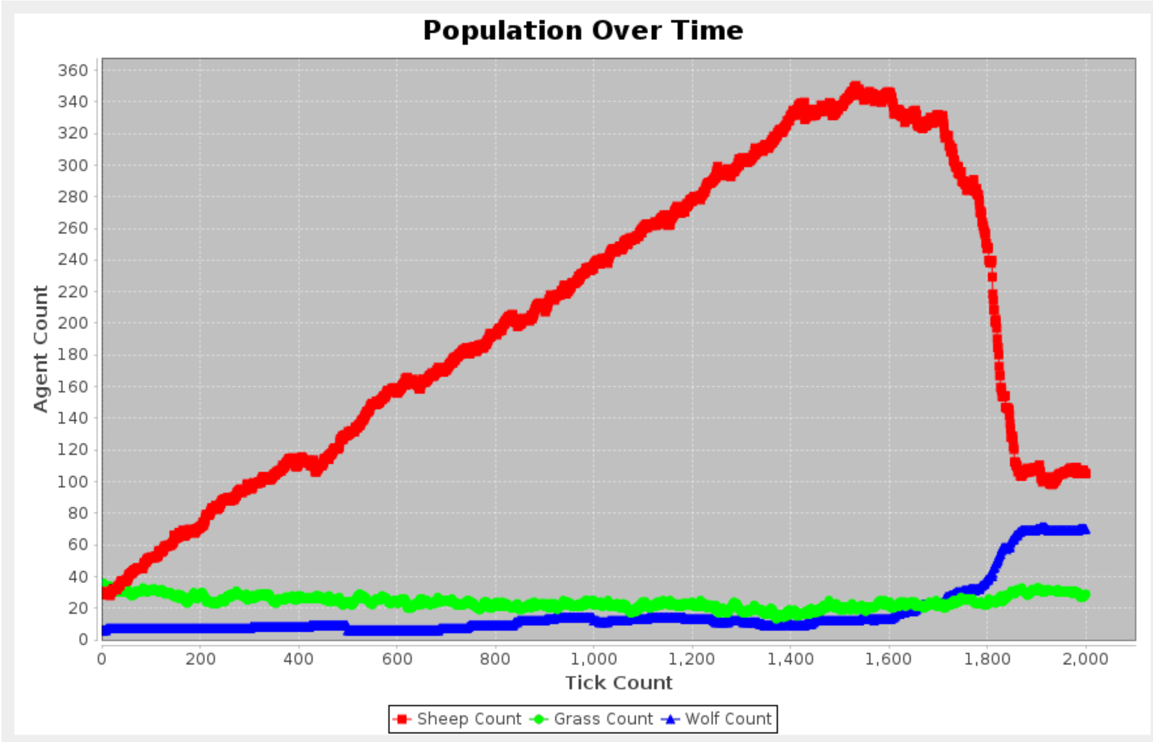


Figure 6: Scenario: user-created mostly flat terrain with hill. Spatial representation (top), chart with agent count over time (bottom).

Sheep have an easy time here. Some of the sheep are on lower terrain, meaning low energy consumption and more reproduction. An elevated percentage of wolves also attempt the hill climb causing an initial decline in population due to high energy costs.

RESULTS

We illustrated the integration of technologies for simulation by presenting a model system that includes a classic predator-prey relationship over a grassland habitat where sheep and wolves coexist as agents. Food sources for sheep are scattered over the landscape and are consumed as agents forage. Wolves control sheep population by actively searching for sheep and chasing individuals when their presence is detected.

We simulated natural conditions by defining that the presence and movement of agents over the landscape is controlled by elevation provided by the sandbox. For instance, the presence of agents and resources can be limited to specific elevation ranges and slope is used to incorporate movement cost (energy loss) while individual agents travel over the landscape. Ecological conditions are further simulated by the consumption and regrowth of food resources. Users interact with the sandbox and the modeling effort by manually moving sand and altering landforms.

This effort demonstrates the feasibility of AR-ABM integration and shows potential for further improvements in modeling and user-machine interface. In addition, the implementation supports teaching/learning, research and communication of results, as it creates immersive and hands-on experiences that support experimentation and discovery.

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REFERENCES

1. Sergio Bernardes, Allison Howard Eury, Andrea Presotto, Marguerite Madden, Thomas Jordan, Dorothy M. Fragaszy, Patricia Izar, Yuri Tavares-Rocha. 2011. “AN AGENT BASED MODELING APPROACH FOR REPRESENTING CAPUCHIN (Sapajusspp.) BEHAVIOR IN BRAZIL”. Center for Remote Sensing and Mapping Science-CRMS, University of Georgia Athens, GA 30602. http://www.asprs.org/a/publications/proceedings/Milwaukee2011/files/Bernardes.pdf

2. Crooks, A. (2007) The Repast simulation/modelling system for geospatial simulation. Working paper. CASA Working Papers (123). Centre for Advanced Spatial Analysis (UCL), London, UK. https://www.researchgate.net/publication/39065154_The_Repast_SimulationModelling_System_for_Geospatial_Simulation

3. North, M.J., Collier, N.T., Ozik, J. et al. Complex adaptive systems modeling with Repast Simphony. Complex Adapt Syst Model 1, 3 (2013). https://doi.org/10.1186/2194-3206-1-3

4. Collier N., North M. Repast Java Getting Started. Repast Development Team. https://bucchiarone.bitbucket.io/repast-material/RepastJavaGettingStarted.pdf

5. Petrasova, A., Harmon, B., Petras, V., Tabrizian, P., & Mitasova, H. (2018). Tangible Modeling with Open Source GIS. Second edition. Springer International Publishing. eBook ISBN: 978-3-319-89303-7, Hardcover ISBN: 978-3-319-89302-0, https://doi.org/10.1007/978-3-319-89303-7.