An agent-based modeling and simulation tool as a learning aid for diffusion of innovations

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Abstract: The diffusion of innovations describes how new technologies spread through a population. Agent-based modeling and simulation (ABMS) cover interactions among autonomous agents and the analysis of emergent outcomes from the behaviors, reactions, and interactions of these agents. Existing studies using ABMS aim to illustrate dynamic agent behavior and interaction with other agents and the environment in the context of diffusion of innovations. However, they do not extend the use of the simulators to teaching and learning. This study describes an ABMS built using NetLogo that allows students to explore the impact of various agent characteristics, behaviors, and interactions on adopting new innovations. Students can manipulate certain parameters involving the characteristics of these agents, such as their level of innovation propensity, social influence, and connectivity, to see how these factors in- fluence the adoption of the innovation. The outcome of each run is logged, analyzed, and presented to the students as meaningful feedback and suggestions for supplementary learning from an LMS in preparation for succeeding simulation iterations. The simulator preserves agent autonomy and adaptability while allowing the students to play with model parameters. As the simulator transitions to more empirical data for rules governing the behaviors of agents, future versions of the simulation may incorporate additional user interface and AI-based simulator elements.

Keywords: agent-based modeling, agent-based model simulation, computer simulation, entrepreneurship education, diffusion of innovations

1. Introduction

The diffusion of innovations describes how new ideas and technologies spread through a population (Rogers, 1983). In the context of a complex social system, the diffusion of innovations theory reflects adoption timing and decisions made by consumer groups classified based on the following adoption timing classification theme:(1) innovators, (2) early adopters, (3) early majority, (4) later majority, and (5) laggards (Rogers, 1983). Diffusion of innovations is relevant in entrepreneurship education (EE). However, traditional teaching approaches to entrepreneurship have been based on business management education, which is inflexible and ineffective (Fayolle & Gailly, 2008). Computer simulation (Roberts, 2011) helps develop, teach, and test entrepreneurship theory and helps entrepreneurs understand, predict, and explain the potential consequences of their decisions. Agent-based modeling and simulation (ABMS), a form of computer simulation, covers interactions among independent agents (Macal & North, 2008) and the analysis of emergent outcomes from the behaviors and interactions of these agents (Garcia, 2005). This paper is part of a larger set of studies using agent-based modeling and simulation for EE (Ilagan, 2022). The focus is on diffusion of innovations as a simulation scenario to understand the mechanisms that drive the adoption and spread of new ideas and technologies. The study also addresses the potential for integrating artificial intelligence at the agent level. How should the simulator allow students to play around with different characteristics of agents, impacting the adoption of innovations in the simulation while preserving the agents' autonomy to allow for emergent

outcomes? RQ1) How can autonomy and adaptability of agents be implemented while giving students the freedom to experiment with various model parameters? RQ2) What software architecture is needed for the ABM simulation to have ample validity for learning the concepts of diffusion of innovations? RQ3) In what ways can the ABM simulation support Artificial Intelligence at the agent level?

2. Related work

With the diffusion of innovations as the simulation scenario, students may experiment with various technology strategies: from pursuing technology leadership as an innovator to behaving as an early adopter or a fast follower. They can experience the respective advantages and drawbacks of these strategies (Stummer & Kiesling, 2021). Specific skills imparted by the simulation environment related to diffusion of innovations, as inspired by Stummer & Kiesling (2021), are market entry, global product launch strategies, pricing strategies, product lifecycle and portfolio management, and technology strategy. NetLogo (Tisue & Wilensky, 2004) is an open-source programming language and modeling environment specifically designed for agent-based modeling. While several studies have already featured diffusion of innovations implemented in ABMS, none have been explicitly tied to teaching or learning entrepreneurship. ABMS is argued to be either a subfield (Distributed AI) (O'Sullivan & Haklay, 2000) or an alternative of AI that takes advantage of the resulting emergence of interactions and the stochastic representation of intelligence (Luger, 2005). Machine learning (ML) and AI techniques may also enhance the behavior and capabilities of agents, as proposed by Rand (2006).

3. Approach

The parameters of the agent model representing different sensitivities or indexes (features, price, promotion, and social) influencing innovation adoption are based on the work of Schramm et al. (2010). The rules and formulas used in this study are simplified versions of those prescribed by Bass (1980, 2004). These include the consumer adoption threshold (CAT), a function of features, price, promotion, social influence, etc. The product price tends to drop over time. The expected S-curve related to adaption and the diminishing prices shall be reflected graphically and animated over time. The only form of relationship is when an agent is physically near another. Integration with a Learning Management System (LMS) can be done through file transfer of NetLogo logs or API callouts for content from LMS, where each simulation run is logged, analyzed, and presented to the students as meaningful feedback. Figure 1 shows the simulator's state before and after the run. The layout of consumer agents resembles a bell curve. A chart on the right shows an S-curve for the adaption of the innovations, with all green indicating full saturation. Another chart shows revenue per period, indicating tapering off revenues as the innovation matures and eventually declines.

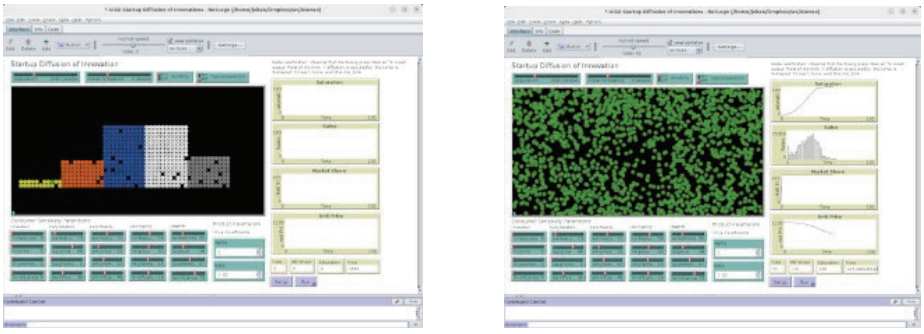

Figure 1. Simulator state before and after the run.

The Mobile switch allows agents to move around the screen to allow encounters with other agents and to influence their neighbors. Students can manipulate agents to observe how these factors influence the adoption of the innovation. Agents will behave autonomously based on the programmed rules, behaviors, and parameters set by the students.

4. Conclusion and Future Work

Future versions of this simulation will allow direct relationships and will not be constrained to proximity as the basis for being able to influence others. While this paper covers only rules-based methods for agent behavior, machine learning (ML) and AI techniques, in turn, will enhance the behavior and capabilities of agents (Rand, 2006) in future versions of this simulator. As the simulator transitions to more empirical data for rules governing the behaviors of agents, future versions of the simulation may incorporate additional user interface and AI-based simulator elements. In addition, rather than relying on formulas for consumer and agent behavior, external data fed into an ML model relied on by agents will allow more adaptive behavior in the simulator. Another shortcoming of this simulation is that the behavior of competitors is fixed and lacking. With the introduction of ML and AI techniques, adaptive competitor behavior will make the simulator more interesting to the technology entrepreneurship students as they will see consumer and producer (competitor) behavior. There also is an opportunity to take advantage of generative AI (GAI) and large language models (LLMs) to enable a conversational element to the educational interface.

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