Just a cog in the machine: participatory robotics as a tool for understanding collaborative learning and decision-making

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Abstract: We will demonstrate the integration of a software-based multi-agent modeling platform with a participatory simulation environment and a real-time control system for a physical robotic agent. Both real and virtual participants will be able to act collaboratively in a simulation that will control a physical agent. The backbone of this demonstration is a widely used, freely available, mature modeling platform (NetLogo). We posit that this technological platform can be of use for researchers interested in investigating collaborative learning and decision-making, as well as to design collaborative learning activities. We will present preliminary findings from pilot studies with the tool.

Introduction

Agent-based modeling has been increasingly used by scientists to study a wide range of phenomena such as the interactions of species in an ecosystem, the collisions of molecules in a chemical reaction, and the food-gathering behavior of insects (Bonabeau, 1999; Wilensky & Reisman, 2006). Such phenomena, in which the elements within the system (e.g., predators, molecules, or ants) have multiple behaviors and a large range of interaction patterns, have been termed *complex* and are collectively studied in a relatively young interdisciplinary field called *complex systems* (Holland, 1995). Typical of complex phenomena is that the cumulative (aggregate) patterns or behaviors at the macro level are not premeditated or directly actuated by any of the lower-level, micro-elements. For example, flocking birds do not intend to construct an arrow-shaped structure (Figure 1), or molecules in a gas are not aware of the Maxwell-Boltzmann distribution. Rather, each element (agent) follows its "local" rules, and the overall pattern arises as epiphenomenal to these multiple local behaviors i.e., the overall pattern *emerges*. In the late eighties and early-nineties, Wilensky & Resnick (1993, 1995) realized that agent-based modeling could have a significant impact on learning. They adapted languages and techniques heretofore used only with supercomputers and brought them to classrooms. Powerful ideas such as emergence, self-organization, and randomness were put in the hands (and minds) of children. To study the behavior of a chemical reaction, the student would observe and articulate *only* the behavior of individual molecules — the chemical reaction emerges from the interactions of these molecular agents. Once the modeler assigns agents their local, micro-rules, the system can be set them into motion and modelers can watch the overall patterns that emerge.

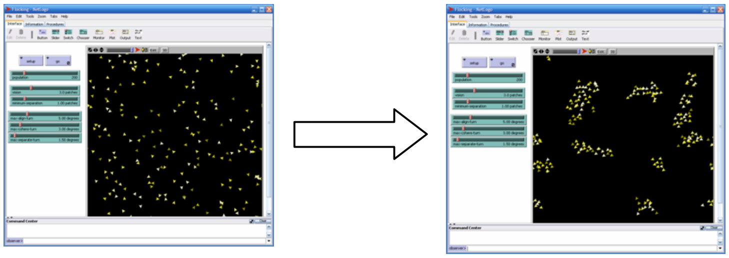

Figure 1. An agent-based model of the flocking behavior of birds.

Participatory simulations are similar to multi-agent simulation except that students play the role of the virtual agents, sometimes in combination with the virtual agents (Wilensky & Stroup, 2002a). In a typical participatory simulation, a server runs a computer model, and students connect to the server through a networked computer or calculator. The behavior of the whole system is not defined ahead of time but instead emerges from the participation of various individuals in the simulation. This emergent behavior can then be displayed to the participants through a central server with the results usually projected at the front of the room. Each of the participants will be assigned one agent on the screen, and would control its behavior. For example, in the traffic "Gridlock" (Wilensky & Stroup, 2002b) participatory simulation activity (PSA, Figure 2), each student controls a traffic light in a busy city. In the "Disease Spread" PSA (Wilensky & Stroup, 2002b), each student will be assigned different roles (doctors or patients).

We have also recently started to incorporate physical devices in agent-based models, using sensors and probes to gather data about the real-world phenomena under scrutiny. The presence of physical sensors enables students to ground their models in empirical data and further refine the models. This approach, *bifocal modeling*, permits a deeper understanding of the physical world than pure virtual modeling (Blikstein & Wilensky, 2006). This is particularly true within educational robotics, where research has shown that designing and controlling devices in the physical world introduces new challenges such as understanding error, noise, mechanical advantage, and mechanical failure, which cannot be explored in purely virtual environments (Martin, 1996).

Figure 2. A classroom ready for a participatory simulation (left), and students during the activity (right)

Rationale and technological design

The three aforementioned areas (agent-based modeling, participatory simulations, and bifocal modeling) are concerned with the creation, manipulation, and development of agents in one form or another. Thus combining these three systems in to one unified platform would be useful, since it would facilitate a synthesis of their main affordances: understanding of the role of locality and emergence (agent-based modeling), mapping human action to emergent, collective behaviors (participatory simulation), and controlling physical objects in noisy environments. We will demonstrate a novel technological based on the NetLogo/HubNet (Wilensky, 1999) architecture that supports simulated agents, participatory agents and physical agents. We have developed a methodological framework to help us understand this system, the "Human, Embedded, Virtual agents via Mediation (HEV-M)" framework (Rand, Blikstein, & Wilensky, 2006). Within this framework and the accompanying platform, designers can create participatory simulations in which each participant controls one element within a physical system (a car, a mini-factory, a robotic arm with multiple joints, etc). In the conference, we will show one instantiation of the platform (see Figure 3). It consists of a robot-car with four motors. Each motor is connected to a serial interface board (the GoGo Board), which communicates to the server. Each of the four users is assigned a motor to control, and turning the car is achieved by reversing the correct pair of wheels on each side of the car.

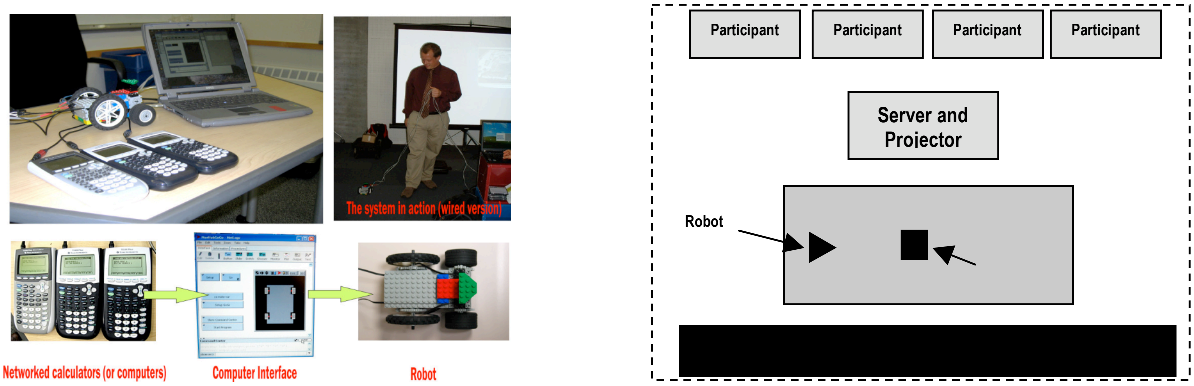

Figure 3. The system's components (left), and the schematic setup of the demonstration (right)

Preliminary User Studies

We have run three preliminary studies, two of them at professional conferences for computer scientists, and one at a research university with doctoral students and faculty. The setup was identical in every situation. The apparatus was setup on the floor (see Figure 3), and there were four notebook computers placed in front of the robot car. Each of the four participants could turn the motor on and off, reverse direction, and change the motor power level. They were given the simple task of moving the robot forward while avoiding an obstacle along the way. As these were proof-of-concept studies, our evidence is based on observations of the activity. At this stage of the development of our platform, the studies were exploratory, both to provide initial insight into participants' reactions and to improve our design. Nonetheless, the results were intriguing. Before the start of the activity, participants were very confident that they could accomplish the task with ease. However, as soon as the first turn of the robot was necessary, participants would start talking back and forth, asking who had control over which wheel, and which state (forward, backward, high power, low power) each wheel was in. At this point, participants started to report increasing frustration with their ability to solve the problem, and started complaining that the other participants were not helping them. In two of the groups, we observed some emergent strategies for optimizing the process, such as delegating leadership to one participant, or the formation of two groups each with two participants, which would then act fairly independently. In the end, the three groups were able to reach their goal, but often it took much longer than they expected, and several of them got stuck for long periods of time right around the obstacle. These preliminary runs of the platform seem to indicate that there were two levels of learning taking place. At the individual level, participants were trying to learn how to better control their own wheel. At the group level we saw evidence of strategy-generation, especially as participants appeared to learn that individual actions and groups actions are fundamentally different. For example, at the onset of the activity, they were unaware that an error from *any* of the participants would ruin the group's goal, no matter how well the other participants were doing. From our observations and interviews, it was noticeable that the "hands-on" experience in the participatory task challenged the initial strategies, and many participants claimed that they would use a different strategy if attempting the task again.

Conclusion

We have built a technological platform for investigating collaborative learning and decision making. Our platform seamlessly integrates three technologies: agent-based modeling, educational robotics, and participatory simulations. We believe that this tool has significant potential for three main reasons (1) it enables logging of participant's actions, as to identify patterns and match them to observations, (2) it offers researchers in the field of computer-supported collaborative learning an easy to-use tool to design engaging collaborative learning activities and, (3) it foregrounds the role of individual actions within the accomplishment of a collective goal, highlighting the connections between simple individual actions and the resultant macroscopic behaviors of the system.

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