Modeling on the Table: Agent-Based Modeling in Elementary School with NetTango

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ABSTRACT
In this paper we describe NetTango, an agent-based modeling environment designed for elementary school students to use on a multi-touch tabletop surface. We review literature on the use of interactive tabletops for learning and present examples from an exploratory study that we conducted with 28 children (ages 6-10). We also discuss two design challenges that emerged during our study and consider possible solutions.

Categories and Subject Descriptors
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Human Factors

Keywords
Children, multi-touch tabletops, scientific inquiry, discovery learning, agent-based modeling.

1. INTRODUCTION
A group of children stand around an interactive tabletop, eyes fixed on the screen, bodies leaning over the machine. They watch as little wolves and sheep roam across the surface. One of the kids screams, “Save yourself, little guy!” Another asks, “Why are our wolves dying out?” One child responds, “Old age!” while another replies, “No, they are not getting enough energy from food!” These children are exploring a simulation of a predator-prey ecosystem using NetTango, a multi-touch tabletop application that we are designing to engage elementary school children in collaborative explorations of agent-based models. In this paper we describe NetTango and present examples from an exploratory study that we conducted with 28 children (ages 6-10). Our observations revealed two design challenges for which we are currently exploring solutions.

2. BACKGROUND
2.1 NetLogo
NetTango is based on the popular agent-based modeling environment called NetLogo developed by the Center for Connected Learning and Computer-Based Modeling at Northwestern University [19]. NetLogo models describe sets of rules that govern the behaviors of individual agents (e.g. sheep, wolves, and grass) in a system. As a model runs, interactions between agents, all concurrently acting out their rules, can produce emergent phenomena that are often counter-intuitive to learners [20]. In the examples we describe in this paper, children explored an agent-based model called “wolf-sheep predation” from the NetLogo models library[1]. This model explores population dynamics and stability in a predator-prey ecosystem.

2.2 Tabletops and Learning
Studies have suggested that interactive tabletops have the potential to be productive tools for collaboration and learning [2], [10],[14],[17]. Specific applications have included: biodiversity, reading, fractions, the physics of light, quadratic equations, language learning, and genomics [5],[9],[11], [17],[13],[14],[18].

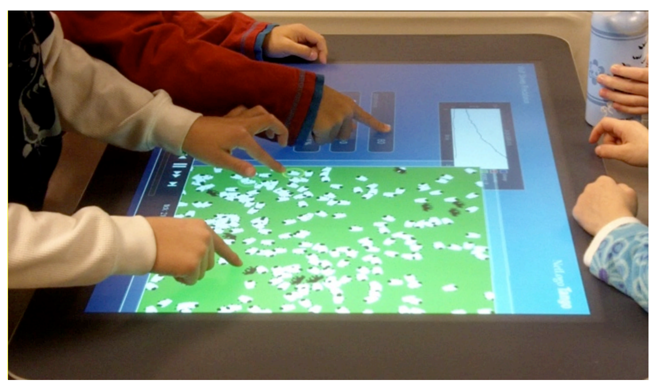

Figure 1: Children exploring the wolf-sheep predation model in NetTango

Research on tabletop-based inquiry has shown that the shared interactive surface leads to collective exploration and collaborative knowledge construction [11]. However, research also suggests that tabletop interaction tends to be fast-paced and that children tend to change configurations often, which may interfere with reflection [11]. Other studies suggest that interference in shared interfaces can be productive for learning, serving as a trigger for promoting argumentation and collective knowledge construction [4], [6]. Rick et al. [15] explored the use of single and multi-touch tabletops with children in a collaborative problem-solving task. They found that software

[1] http://ccl.northwestern.edu/netlogo/models/

design (e.g. single versus multi-touch) and children's positions around the work surface affect how different groups partition work and share in an activity.

A tabletop application, tested with undergraduate students, revealed four educational benefits: increasing physical participation, encouraging reflection, fostering effective collaboration, and facilitating more intuitive interaction [21]. However, will the same hold true for children in the area of scientific experimentation with agent-based models? Studies consistently demonstrate that children possess a fragmented understanding of the scientific method [8], [18]. On that account, what are the design affordances and challenges in supporting children in the process of scientific inquiry?

3. NET TANGO

NetTango is multi-touch tabletop modeling environment designed for elementary school children (Figure 1). NetTango is implemented in Java and currently runs on a Microsoft Surface. We use the NetLogo Java API as a modeling engine, allowing us to run existing NetLogo models with minimal modification. Similar to NetLogo, NetTango provides the following interface components (Figure 2):

- A world window provides an animated visual depiction of the model as it is being simulated. Children can move and resize this window using standard multi-touch pinch and drag gestures.
- A control toolbar enables users to play, pause, rewind, and fast-forward simulations. There is also a scrub bar that users can drag back and forth along a playback buffer.
- A set of slider controls enable children to adjust model parameters (e.g. sheep reproduction rate).
- And plot windows display graphs of the model's execution (e.g. a plot of the wolf and sheep population numbers over time).

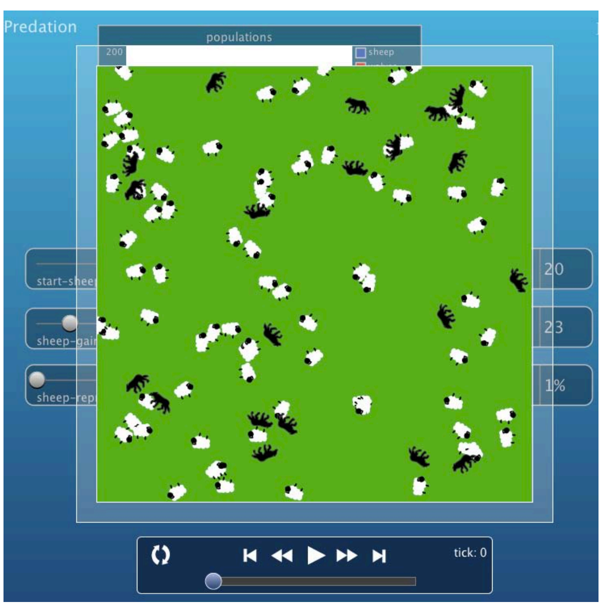

Figure 2: NetTango provides a world window, parameter sliders, plot windows, and a control toolbar.

4. EXPLORATORY STUDY

We conducted an exploratory study with 28 children (ages 6-10, grades 2-4) at a local elementary school. Children participated in groups of three or four for two hour-long sessions using the NetTango tabletop interface.

4.1 Preliminary Observations

In one of our sessions, the children playfully explored the model's parameter space:

> A: The choice is: who do you want to rule the world? Wolves or sheep?
> M: WOOOOOOOOOLVES!
> E: Sheep.
> D: Wolves.
> […]
> E: Wolves will eat people.
> A: Sheep. Sheep gives us wool to make our sweaters.
> E: Exactly! [Pointing at A.]
> […]
>
> [The kids press play and all the wolves die.]
> M: Sheep rules the world!

These playful explorations happened often, and although simple, seemed to provide group of children an opportunity to set shared objectives to accomplish with the model.

On other occasions, the children faced outcomes that were unexpected and puzzling. These outcomes led the children to reflect on their variables to understand what happened.

> N: Now, let's have everything zero.
> J: Yeah, let's see what happens if everything is zero besides the...
> N: No, besides the start [initial population setting].
> J: Yeah.
> N: Everything will start on 100 [the initial populations of both sheep and wolves].
> J: Yeah...and then delete everything else. [Change all the other settings to zero]
> […]
> [The kids look at the simulation.]
> J: What happened to our wolves? [Giggles.]
> N: [Giggles] yeah... [giggle] what happened?

The children were puzzled by the disappearance of the wolves, but when asked later, they were able to identify the problem. They realized they had set the wolves' gain from food at zero, which made the wolves die out at the very beginning of the simulation.

In general, the children were good at playfully exploring models' parameter spaces. However, they lacked a systematic approach to this exploration that we think would be necessary for them to develop a more in-depth understanding of the role of individual parameters in a model.

4.2 Agent Adoption

The children in our study enjoyed watching the simulations unfold in the world window. We observed multiple occasions on which children would name and track their agents and offspring:

> A: I'm gonna watch this sheep [points to the agent].
> N: I'm watching this one [points to the agent].
> J: Away Bob goes...
> B: I'm watching that one.
> A: Hey, the one I'm watching still hasn't died.
> N: Mine is being chased by a wolf. [J giggles.]
> A: Mine hasn't died yet.

B: Mine just had two babies.
A: Mine doesn't ... hasn't had.
[...]
N: Oh, mine just got eaten.
A: Oh mine just got eaten!!

Observing children's tendency to name and "adopt" agents, we added a tool to see if children could use agent adoption as a means to deepen their understanding of a model. To use the tool, children had to simply tap an agent (e.g. a sheep or a wolf) with their finger. A colored bubble would then appear around the agent (similar to *watch* and *follow* tools in available in the NetLogo environment).

Once we implemented the adoption tool, we observed a range of behaviors that varied by age. While younger children used the tool to relate to agents (i.e. to make it theirs), older children seemed to use the adoption tool to engage in more sophisticated problem-solving. These are preliminary results that we hope to explore more fully in future research.

5. CHALLENGES SUPPORTING INQUIRY

Below we discuss the challenges in our design, and how we may be able to solve these problems to help children engage in scientific inquiry.

5.1 Lack of systematicity in navigating the exploration space

It is easy for children to become lost or distracted while exploring an inquiry space [3],[8],[12]. The children in our study were comfortable manipulating variables and visualizing results; however, there was a lack of systematicity in the process of exploring variables. Younger children often randomly changed parameters, while older children often tried to set parameters to pre-determined numbers for one population and zero for another. However, there was no evidence-based approach in their exploring of the variables. Moreover, we observed several instances in which children would change parameters that had already been set by other children. These children were perhaps motivated by a desire to simply touch the table and feel part of the activity.

5.1.1 Possible Solutions

Children's lack of systematicity could be improved with a software restriction that limits children to change only one parameter at a time. Once they have experimented with all of the variables, and understood their effect on the system, a teacher could lift the restriction. This way, children could develop a better understanding of how to explore the space. Structured instruction around the model would be another obvious approach. Our exploratory study included only minimal instruction on scientific content and inquiry processes. A final strategy could be to assign roles to individual children in a group so that only one or two children are responsible for manipulating variables. This could be supported in software by creating smart badges (e.g. cards with computer vision fiducials) that *unlock* parameter sliders.

5.2 Interference due to excessive interactivity

Several studies have observed a tendency for children to interfere with one another while working together on tabletop applications [4],[6],[11]. Our design features a single simulation window (the world window) that is shared by all of the children participating in a group. In principle, children could decide together on a set of parameters for the model, press the play button, and then observe the results of the simulation. In practice, however, individual children were easily able to disrupt this process in several ways: A child could move or resize the world window; a child could press the pause, reset, or rewind buttons on the control toolbar; or a child could change a parameter of the model while the simulation was in progress. The work of Allen and Gutwill [1] on the design of interactive science museum exhibits is relevant in this context. They propose five common pitfalls in interactive exhibit design: (1) multiple options with equal salience; (2) features allowing multiple users to interfere with one another; (3) options that encourage users to disrupt the phenomenon being displayed; (4) features that make the critical phenomenon difficult to find; and (5) secondary features that obstruct the primary feature.

For our design, the interactivity of the graphs and world window obstructed the inquiry process. For example, children would play "hockey" with the interactive elements by making the world window small and throwing it from side to side, while other children were trying to focus on the simulation.

5.2.1 Possible Solutions

One solution to this problem would be making the graph and world window less interactive. Children seem to do two things with the world window: make it smaller (to move it out of the way) or bigger (to watch the simulation). Therefore, having only these two stages might prevent children from playing with the window, as well as keep them from getting in the way of others who want to watch the simulation. The same could be done with the graph windows, which could be kept fixed in one location to avoid it from causing further interference.

Offering different views of the entire modeling environment could be another effective way to indicate the salient features of both the exploration and experiment spaces. Users would have to toggle between views to use them, and the equal-saliency problem would be solved. As it is important to view the numerical values of the variables while visualizing the simulation, the current values of the parameters would be displayed (in a non-editable form) in the experiment view.

6. CONCLUSION

Tabletop learning environments are receiving increased from research and design communities. In this short paper, we introduced a new tabletop application, NetTango, and examined children's playful explorations within its discovery spaces. The novelty of this medium makes designing effective applications for educational use a challenge that may be overcome through research. We presented examples from an exploratory study we conducted with 28 children (ages 6-10) and discussed two design challenges that emerged during our study and consider possible solutions.

7. ACKNOWLEDGMENTS

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