NetLogo AR: Bringing Room-Scale Real-World Environments Into Computational Modeling for Children

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ABSTRACT

Computational modeling plays an important role in scientific research and education. However, many models do not communicate with the real world, which might limit their learning potential. In this proposal, we introduce the design of NetLogo AR, an authoring toolkit that transforms NetLogo agent-based computational models into room-scale AR experiences. We are inspired by studies that integrate real-world environments into computational models, including bifocal modeling and participatory simulation, and those that leverage Augmented Reality (AR) to create authoring tools for children. We describe our design goals that focus on raising the ceiling and lowering the threshold for potential AR designers: researchers, educators, and children. For the IDC conference, we propose an example learning activity to demonstrate the capabilities of NetLogo AR. By incorporating dynamic and unpredictable real-world inputs, NetLogo AR has the potential to inspire future designs of AR experiences and enrich the learning experiences of agent-based models for children.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing systems and tools**; **Systems and tools for interaction design**; **Mixed / augmented reality**.

KEYWORDS

Agent-based modeling; Computational modeling; Semantic-based Augmented Reality

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1 INTRODUCTION

Computational modeling plays an important role in contemporary scientific research and is recognized as an essential component of the learning and education of children [5]. Various technological advancements have been made in this area. One such platform is NetLogo [24], an agent-based modeling (ABM) environment that leverages simple computational rules for individual behaviors to generate complex macro-level phenomena. With its low-floor, high-ceiling design, NetLogo has been adopted extensively for both learning and teaching, as well as scientific research of complex systems in various fields (e.g. [15] in K-12 learning; [8] in social sciences; [18] in environmental science), thereby connecting the two domains.

While early studies in computer simulation tried to establish the superiority of the virtual modality over real-world elements, more recent studies have confirmed the benefits of combining virtual modeling and real-world elements [1]. However, many computational models are only "on-screen" and do not communicate with the real world, preventing them from realizing their full learning potential [1] To address this issue, two lines of design research for children have emerged: 1) Integrating real-world data as input to and as validating datasets for computational models (e.g. [1, 19]); 2) Participation simulation that invites learners, in particular children, to role-play as individuals in computational models of complex systems [4]. Both approaches have made progress in bringing the real world together with computational models. Yet, computational models still have little visible impacts on real-world environments [1, 19], or their impacts are limited to the wearables attached to participants [4].

In this paper, we introduce the technical demo of NetLogo AR (**Link To Demo Video**) that integrates the real world with computational models as a two-way street. NetLogo AR is an authoring toolkit capable of transforming many NetLogo models into AR experiences. Built with mobile AR technology, the first iteration of NetLogo AR is capable of integrating semantics and spacial information of real-world obstacles (e.g. a wall, a table, or a TV) at a room-scale; integrating the position and direction of participants; and augmenting computational models onto the real-world. Our design goals center around raising the ceiling and lowering the floor for AR designers: researchers, educators, and children. By embracing dynamic and unpredictable real-world inputs, NetLogo AR has the potential to inspire future AR experience designs and enhance the learning experiences of ABMs for a younger audience.

2 RELATED WORK

Our **first** design inspiration comes from the research that found learning benefits in integrating real-world data into model-based scientific inquiries [9, 11, 20]. Bifocal Modeling, for example, incorporates real-world sensor inputs for computational models, and compares the outputs of computational models with real-world

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phenomena [1] The MoDa platform employs real-world video data to validate models created by children [19] However, in many instances, this integration remains a one-way street. The outcomes of computational models and real-world phenomena are presented side by side for validation, often without the capability to influence or project into reality.

Based on ABM and Role-Play Games (RPG), participatory simulation provides the second inspiration for NetLogo AR's design. In this type of simulation, learners take on the roles of various elements within complex systems, either with or without technological support [4] Yet computational architectures, such as HubNet, have been argued for their potential in supporting learners' sense-making of complex systems [23]. By reacting to participants' behaviors, HubNet essentially integrates a type of real-world data into computational models through screen-based interaction. Wearable technology and Kinect-enabled Augmented Reality bring computational-enabled participatory simulation to physically co-located spaces and enable more embodied interactions. However, the potential influence of computational outcomes against real-world environments is still limited. While physical tags could present state changes for participants (e.g. [4]), other outcomes still have to go through abstract representations on computer screens (e.g. [6]).

How can we enhance the integration between computational models and real-world environments? One approach is through Augmented Reality (AR), a technology that augments physical environments with computer-generated information [2]. AR has been widely used in learning and education [17]. Yet, many of its applications still rely on markers or triggering objects, limited to enhancing existing learning materials [12]. A few recent studies have pushed the boundaries of AR, using it not only as a visualization tool but also as an authoring tool for learners to create their own artifacts. For example, Mathland MR [12] presents a Newtonian physics microworld where learners use their bodies to play with physics laws in their physical world; StoryMakAR [10] combines AR, programming and physics computing for children to create interactive stories; ExposAR [13] offers a cross-device AR authoring environment for playful content that help children build skills and critical thinking about AR; [16] leverages serious AR games to help children acquire basic programming skills.

Despite advancements in AR technology, there are still challenges when designing AR experiences for dynamic and unpredictable real-world environments. Our **third** inspiration comes from recent studies in semantic-based AR. For example, ScalAR [14] could identify the semantic meaning (such as refrigerators and dishwashers) and spacial relationships (how they are positioned together) of real-world objects and presents adaptive AR content that goes beyond pre-defined environments. ScalAR represents a significant step towards developing interactive AR experiences that are based on the meanings and connections of real-world inputs. However, its pre-trained machine-learning models work only in scripted settings, while we seek to leverage the power of complex systems to deal with more open-ended environments.

3 DESIGN GOALS

Inspired by the three lines of design research, we present the four design goals for NetLogo AR:

Dynamic integrating real-world inputs with computational models. Many classical NetLogo models (e.g. Wolf Sheep Predation, Fire, or Segregation) assume an ideal world: flat without obstacles. There are also models that combine simplicity with the power of real-world inputs: for instance, the Mammoth model [22] incorporates a map of the Western Hemisphere to explain the extinction of megafaunal species in the Americas, resulting in emergent phenomena that differ from ideal-world models. Similarly, participatory simulation experiences often lead to new findings for learners. Our design should facilitate the integration of both real-world sensory and participatory inputs, without limiting to a certain design pattern.

Enabling computational models to "influence" the real-world surroundings. With AR technology, computational agents can now be projected into learners' physical surroundings. Moreover, with input from real world, agents could now honor real-world constraints and behave as if they were real-world entities.

Encouraging and simplifying the switching between AR/abstract modalities. NetLogo AR introduces a new AR-enhanced modality where learners could "experience" computational models in real-world surroundings. While this immersion in a spatial context can aid in understanding micro-level behaviors and local emergence, it may hinder learners' perception of macro-level phenomena. As such, our design should encourage and simplify the switching between AR and abstract modalities to help learners generalize what they learn from the embodied experience.

Lowering the floor for authoring or transforming computational experiences with AR. NetLogo AR aims to empower researchers, educators, and young learners as designers of AR-based computational modeling experiences. To achieve that goal, the programming interface introduced by NetLogo AR should be relatable to existing concepts in NetLogo. Additionally, spatial-based models should have a clear and uncomplicated process for converting to AR, while leaving open-ended opportunities for further exploration and investigation with the technology.

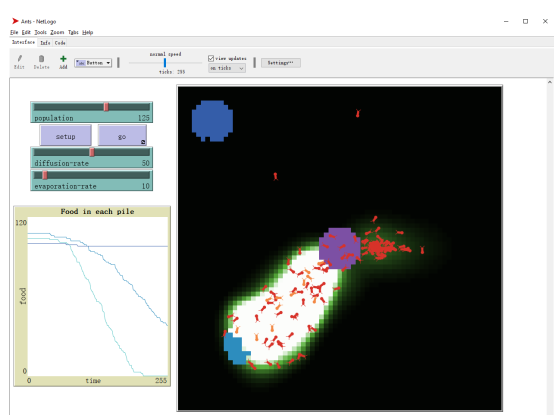

Figure 1: The original Ants model

4 DEMO ACTIVITY: ANTS

We intend to showcase the potential of NetLogo AR by demonstrating the Ants (AR) example activity at the IDC conference. Similar to the original Ants model (Fig 1) [21], Ants (AR) (Fig 2) simulates a colony of ants. While each ant is driven by simple computational rules, they collectively and collaboratively forage for food, manifesting swarm intelligence. However, there are also notable differences between the two models: 1) Instead of living in an ideal world, ants now share the same physical world with learners; 2) the nest and food piles are randomly placed in the physical environment, unlike in the original model where they are fixed; 3) ants have to navigate around obstacles; and 4) learners are invited to play as an ant, before diving into programming their behaviors. In 4), learners will first play as an "all-seeing ant" that reveals full information about the world, then as an "ant with a human brain" that receives similar information as other ants in the model. Through the 3-min activity, we hope that learners could progress from an all-mighty observer's perspective toward that of an individual ant, limited by biological constraints, thus prompting and scaffolding their further exploration of the computational model.

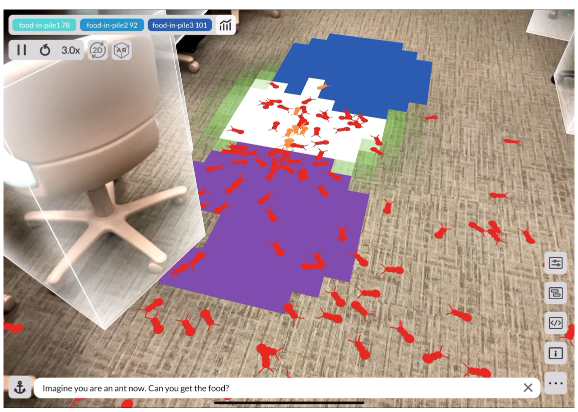

Figure 2: The Ants (AR) model

Although NetLogo AR can function in various indoor settings, the optimal experience can be attained by securing a physical space that: 1) has distinct boundaries (walls/windows/doors) and regular-shaped obstacles (tables/chairs/sofas); 2) allows the audience to walk around without obstructing the traffic; 3) accommodates the projection of iPad screen onto monitors or TVs, so that other participants can observe the activities on the device.

5 NETLOGO AR SYSTEM

Transforming a spacial-based NetLogo model into an AR-enhanced one generally takes three steps (Fig 3). Here, we use the Ants model to briefly explain the process. The **first** step is automatic: when the learner launches the Ants model in the AR mode, the model's view is projected into reality. However, the model lacks awareness of its surroundings, thus necessitating the **second** step: aligning the computational ants' world with the real world. For example, every meter in the real world maps to 10 patches in our demo activity. Then, we could set up computational agents that represent obstacles around the world, as the model will receive information

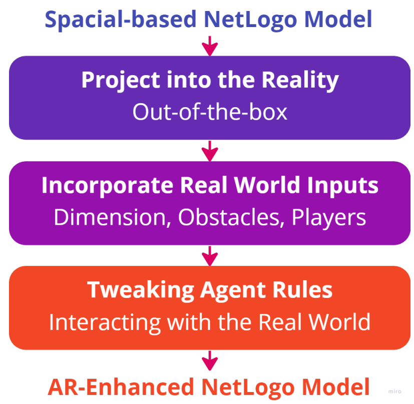

Figure 3: Steps to transform NetLogo models into AR

about the nature of each obstacle: whether it is a wall, a table, a chair, or a storage space. The model visualizes them and gives them meanings accordingly. In the **third** step, the computational rules of ants also need to be tweaked: once an ant runs into an obstacle, it turns 180 degrees back. We also changed the rules of the nest and food piles so that they would randomly scatter around the world (both computationally, and in the real world). Finally, as the model also has information about the device's location and direction, we "possessed" an ant to mimic the device's movement, allowing the learner to play as an ant.

While it might take a workshop rather than a demo session to go into the technical details, visitors at IDC will be able to go through the modified source code - with around 20 lines of code changes - and if they so wish, to edit the demo activity on the fly.

NetLogo AR runs on and inherits its cross-platform capabilities from Turtle Universe [3] that works on computers, phones, and tablets. However, most of them do not have room-scale AR scanning capability (which at this time relies on Apple's LiDAR-based RoomPlan framework); many of them do not support AR at all (such as Chromebooks). To ensure maximal flexibility in learning implementations, fig 4 presents our tiered support for NetLogo AR. While the accessibility of first-tier devices (with built-in LiDAR) might be limited, the scanned data could be easily synchronized to second-tier devices. As long as ARKit/ARCore is supported, those devices would receive similar authoring or immersion experiences. Both types of devices support a one-click switching between AR and non-AR modalities without additional coding. Finally, for the third-tier non-AR devices, we provide full authoring capabilities. Learners can create, test, and debug their NetLogo AR program in the non-AR modality using spatial scan data from other devices, and later transfer it to AR-enabled devices for live experiences. As such, it is our hope that NetLogo AR could be leveraged in a diversity of learning contexts, ranging from classrooms, after-school programs, to online and other informal settings.

6 DISCUSSION AND FUTURE WORK

In this demo proposal, we present the first technical design that leverages AR to integrate computational models with dynamic and unpredictable real-world environments. While our demo activity

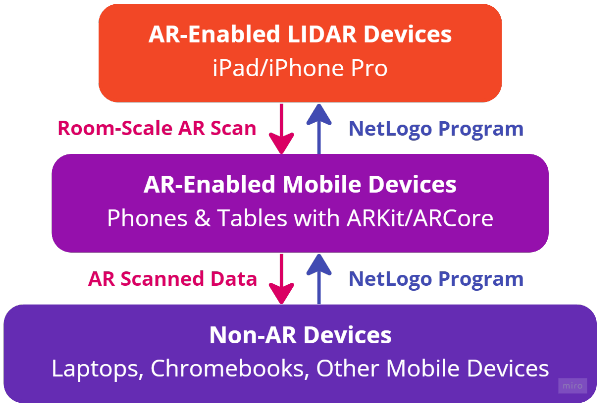

Figure 4: Tiered support for different devices

has only gone through internal testing, our participants have started to feel the potential of AR in computational models. For example, while the computational ants in the original Ants model would always succeed in foraging, they often had trouble finding food blocked by a table or chair. This, in turn, could prompt young learners to reflect on their living experiences and the computational rules built into the model.

We believe that the boundary of NetLogo AR could go beyond scientific modeling. Our design made a step toward [7]'s imagination of a technology-infused child's room: it is now entirely possible to have a "dynamic cellular automaton design on one wall, playing a programmable game of Life" [7] NetLogo AR could also be used for a "wallpaper that periodically changes its design to cycle" [7]: the design elements could not only be controlled by the child from "a desktop computer", but also from their phones or tablets as well. As such, we anticipate NetLogo AR to support other genres of computational experiences: games, interactive arts, and more.

We also reflect on our techno-centric stance when designing and implementing the first (proof-of-concept) iteration of NetLogo AR. To shift towards a more learner-centric stance, we plan to hold participatory design sessions with a local school, where children would imagine beyond and build on existing NetLogo AR technology to create learning experiences. Together with our proposed demo session in IDC, we hope to learn more from participants about where the technology should go next. We believe that by empowering children to create their own learning activities with AR, they will be able to develop more creative, relevant, and meaningful experiences for themselves and their communities.

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