Paper to Parameters: Designing Tangible Simulation Input

Tia Shelley
University of Illinois at Chicago
tshell2@uic.edu

Leilah Lyons
University of Illinois at Chicago
llyons@uic.edu

Jingmin Shi
University of Illinois at Chicago
jshi7@uic.edu

Emily Minor
University of Illinois at Chicago
eminor@uic.edu

Moira Zellner
University of Illinois at Chicago
mzellner@uic.edu

ABSTRACT

We present a new low-cost paper-based user interface strategy (Paper-to-Parameters) for making interaction with simulations of complex systems pragmatic within an Environmental Science curriculum. Students specify initial simulation conditions by sticking pieces of paper to a wall, and can experiment with the simulation by repositioning the pieces of paper. Computer vision recognizes the paper-based symbols and converts them into parameters used by the simulation. This tangible input approach contrasts with current slider- and programming-based approaches for interacting with simulations. We hypothesize that the affordances of this interaction strategy better supports manipulations of spatial simulation parameters. We report here on the initial prototype of the system, and present plans for future work studying its impact on spatially-rooted understandings

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General Terms Design, Human Factors

INTRODUCTION

Educational bodies like the National Academies have been encouraging the utilization of educational tools, like simulations, to aid students in understanding scientific systems. One simulation type, Agent-Based Modeling (ABM), is frequently used to explore, hypothesize, and test the interaction of policy and scientific processes in integrated human-natural systems [1010]. The spatial properties of human-natural systems, like the location and connectivity of "green infrastructure" in an urban setting, strongly influence phenomena like flooding and animal population persistence and genetic diversity [44]. Thus, if students are to use ABMs to learn about human-natural systems, they need to be able to perceive and interact with the spatial characteristics of the systems.

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Figure 1. Left: *Paper-to-Parameters* input to *EcoCollage* simulation. Right: ARToolKit bounding on input

Our *Paper-to-Parameters* input strategy allows students to directly interact with the spatial characteristics of a simulation by manipulating the placement of paper stickers. The stickers are in fact fiducial symbols recognized via computer vision (see Figure 1), and then converted into variables used as input to a complex system simulation. It thus combines elements of Augmented Reality (AR) and tangible user interfaces to create a new way for learners to interact with ABMs. The system as a whole is called *EcoCollage.*

RELATED WORK

Our work builds on three strands of computing research: ABMs, augmented reality, and tangible user interfaces in education. Agent-based simulations have a long history of incorporation in K-12 science curricula, like the *NetLogo*-based *Connected Chemistry* [33] curricula. However, they typically require a 1:1 or 2:1 child:computer ratio and some understanding of computer programming, which can reduce the adoption of such simulations by schools.

Some prior work has been done with computer vision in the classroom, although not as an input strategy for simulations. One research group that designed an Augmented Reality (AR) toolkit to teach children about material sciences determined that, from a usability perspective, AR was appropriate for all age groups, since it does not require advanced motor skills [88].

Much of the published work on Tangible User Interfaces (TUIs) presents exploratory designs, but one prior study found that when children solved a two-dimensional problem (a jigsaw puzzle) with tangibles they actually used different (and better) solution strategies than when they used a touch screen to solve the same problem [11]. The students took advantage of the physical affordances of the tangible pieces to more systematically explore the spatial constraints, behavior we hope to see in our implementation.

ECOCOLLAGE DESIGN

We developed the *Paper-to-Parameters* strategy to support the *EcoCollage* simulation we are designing for Advanced Placement Environmental Science classes. In guided inquiry activities students will be asked to design "yards" in urban and suburban neighborhoods by placing stickers representing different types of terrain, structures, and plants on sheets of paper. These "yards" are then combined to form a "neighborhood" wherein ecological and hydrological processes (like animal and water movement) are simulated.

While the use of tangible stickers provides a *physical* affordance for spatial manipulations, we suspect that it also provides a cognitive affordance by quite literally representing the spatial relationships critical to the systems being studied. If a student wishes to discover the maximum foraging distance of an animal, rather than converting plant placements into Cartesian coordinates the student need only inch the tangible symbols further apart. This supports a constructivist "bricolage" pattern of experimentation that non-programmers might find to be more natural (and which may be better-suited to female students [99]).

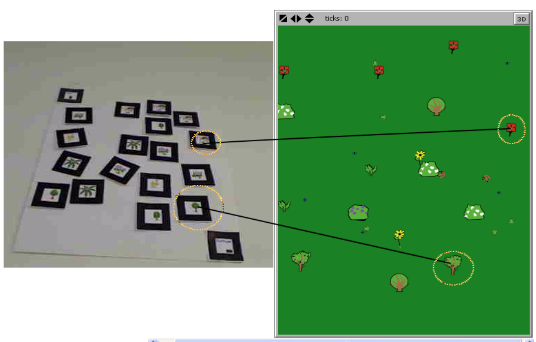

Figure 2. Left: *Paper-to-Parameters* input. Right: *EcoCollage* simulation.

PAPER-TO-PARAMETER IMPLEMENTATION

The webcam directs a live video feed to the Fiducial Position Recorder program that was designed for *EcoCollage,* written using *ARToolKit[2]*. Users place special "Top-Left" and "Bottom-Right" markers on a wall to define the extents of a "yard," and then populate the yard with plants by placing black-bordered human-recognizable markers (see Figure 2). The program draws boxes around recognized markers in a screen capture of the user's input. When the image selection is confirmed by the user, the Fiducial Position Recorder translates the markers into the coordinate system relative to the "Top-Left" marker and outputs those coordinates to a file that is used to integrate with the NetLogo supported simulation.

In creating the simulation, we are looking to published animal movement models developed for studying ecology.

We intend to preserve the salient characteristics of these models, such as the perception range of the animals, foraging patterns, as well as the response to other animals.

DISCUSSION & FUTURE WORK

To illustrate *Paper-to-Parameters'* usability benefits a small laboratory test was conducted. An investigator arranged a yard with 16 items in two ways (1) using the *Paper-to-Parameters* method and (2) manually inputting the coordinates for the same yard layout into *NetLogo*, timing the two activities. It took the investigator 1 minute, 11 seconds to arrange the yard using *Paper-to-Parameters*, and 8 minutes, 18 seconds to manually input the data (which amounts to 19 lines of code)..

To develop a fully integrated and functional version of *EcoCollage,* we have discovered that several changes will need to be made. First, *ARToolkit [2]*'s thick black borders and grayscale-only recognition mechanisms are limited. In nature, color is a critical element in animal decisions, and thus it is also critical for color to be usable in our system. Rather than modifying core *ARToolkit [2]* code, we are looking to use *OpenCV [6],* an open source computer vision toolkit. Second, while *NetLogo [5]* is free, it is not open source, making seamless integration difficult. The complete version of *EcoCollage* will use an open source simulation toolkit such as *Repast [7]*.

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