NetLogo HotLink Replay: A Tool for Exploring, Analyzing and Interpreting Mathematical Change in Complex Systems

Michelle Hoda Wilkerson-Jerde and Uri Wilensky, Northwestern University, Evanston, IL
{m-wilkerson;uri}@northwestern.edu

Abstract: Some of the most important patterns of change that we encounter in our everyday world – global warming, fluctuations in the unemployment rate, voter trends – are produced by the interactions and accumulation of many different individuals and events. This interactive poster will demonstrate NetLogo HotLink Replay, a computational tool designed to provide students a context to reconcile large-scale patterns of mathematical change with the interactions and events that contribute to and are reflected by that change.

Introduction

One of the primary goals of education should be to equip students with the tools to make sense of and act within an increasingly interconnected and changing world. Whether reading a newspaper report about increasing global temperatures due to individual consumption and feedback cycles, or learning about the dynamics of a predator-prey system (Wilensky & Reisman, 2006), the mathematical patterns we observe in the world are often reflective of *complex systems* – systems that are comprised of a number of individual *agents* (such as consumers, employees and employers, or voters) that interact with one another and their environment to produce large-scale outcomes. In this sense, mathematical change is not produced by a single entity or phenomenon, but by the interactions and accumulations of many. *NetLogo HotLink Replay* is an environment designed to help students link the behavior of complex systems to the mathematical trends they generate.

Background

The *NetLogo HotLink Replay* software environment leverages findings about the kinds of experiences that help students to make sense of both *mathematical change over time* and *complex systems*. For example, although the mathematics of change is often considered a difficult topic (Leinhardt, Zaslavsky, & Stein, 1990), research has shown that educators can leverage students' real-world experiences to address these difficulties – primarily in the context of motion (Nemirovsky, Tierney, & Wright, 1998; Roschelle, Kaput, & Stroup, 2000). From this literature we know that students can benefit especially from activities such as *controlling* a phenomenon that produces change over time (Kaput, 1994; Wilhelm & Confrey, 2003); interacting with time-series *plots* and other representations of a value its rate of change (Confrey, Maloney, & Castro-Filho, 1997); and making linkages between *intervals* and *shapes* of plots and the events they represent (Yerushalmy, 1997).

At the same time, complex systems are becoming increasingly important in education (Jacobson & Wilensky, 2006). One way to provide students a context within which to think and learn about complex systems from the perspective of embodied experience is with *agent-based modeling* environments such as NetLogo (Wilensky, 1999). An agent-based model is built by defining the *agents* or individual entities of a system (such as voters), and the *behaviors* and *interactions* of those agents that make that system work (such as the ways that friends may influence on another's vote). By interacting with and building agent-based models, students can reconcile behavior and outcomes on multiple levels of a system (Wilensky & Resnick, 1999), and develop generative and deep understandings of complex systems in a number of domains (Wilensky & Reisman, 2006).

The NetLogo HotLink Replay Environment

NetLogo HotLink Replay is designed to leverage the strengths of agent-based modeling, which provides students a means to connect large-scale complex systems to more personal, individual actions; as well as the strengths of dynamic, controllable mathematics environments, while providing opportunity and context for student *interpretation and meaning-making* through modification and annotation. NetLogo HotLink Replay includes a number of features intended to foster a deeper understanding of the mathematics of complex systems:

Dynamically Linked Representations. The two primary representations included in the environment are visuospatial agent-based models and time-series plots. These two representations are dynamically linked, such that students can click on critical features of a plot and observe that corresponding point in time in the simulation, or play the simulation over time as a cursor indicates the corresponding area on the plot.

Annotation Tools. Students are able to identify any intervals on a plot, and annotate that interval with respect to the aggregate (whole-system) or agent-based (individual actors) behavior that it reflects.

Numerical Approximation Tools. In addition to plots and visuospatial representations, the environment also calculates a user-defined piecewise linear approximation of change on any area of a featured model plot.

Recording Function. Students can opt to run a model in the NetLogo modeling environment, modifying parameters (for example, infection or illness mortality probabilities in the model featured in Figure 1) and observing the outcomes. These interactions can be captured and replayed, so that students can then reflect on their own modifications to the system and the resulting mathematical patterns.

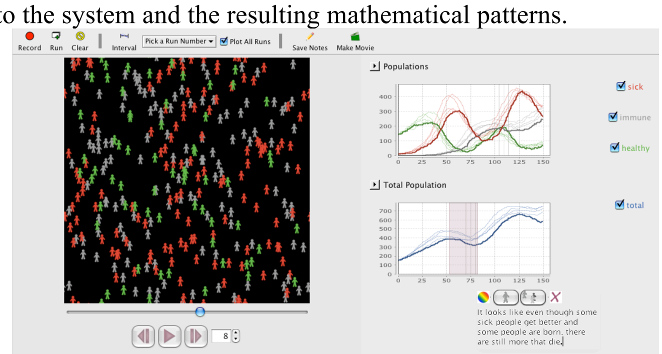

Figure 1. *NetLogo HotLink Replay*, featuring an annotated set of "runs" of an agent-based model of virus spread in a population

Pilot and Future Work

The design of the HotLink environment is informed by preliminary interviews with 12, 10th and 11th grade students enrolled in a precalculus course at a high-performing, urban public school. In one-on-one interviews, they were asked to interact with a simple NetLogo model of exponential population growth and describe their understanding of rate of change and accumulation in terms of results of the model, as well as their understanding of the individual behaviors and their implications for the system. They were then asked these same questions as they constructed their own models by including different behavior patterns of interest. Each interview was analyzed along a number of dimensions: to determine which representations students leveraged (and, at times, coordinated) to think about different properties of systemic change; to identify when students "slipped between levels" (Wilensky & Resnick, 1999) and how those conflicts were resolved; and to explore how students' conceptualizations of notions of rate and accumulation changed during those activities.

We found that by noticing and attempting to resolve differences between conventional (aggregate trends and smooth graphs) and computational (individual behaviors and noisy graphs) representations of population growth, students began to consider how factors such as randomness, heterogeneity, and feedback effect systems and how they might or might not manifest in different representations, as well as how mathematical notions such as "rate of change" could include or reveal information about some real world events, such as a catastrophic event or shift in the behavior of individuals. We hope that the *NetLogo HotLink Replay* environment will leverage these findings, to provide students a more integrated way to interpret and connect the events and mathematical patterns that characterize complex systems across representations.

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