Tabletop Process Modeling Toolkit: A Case Study in Modeling US Postal Service Mailflow

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ABSTRACT
Powerful simulation software packages often produce results that are counter-intuitive. These results are therefore hard to internalize for the target audience who needs to use these results in making nontrivial choices in setting up and managing complex systems with intricate real-time dynamics. We are developing a tangible modeling toolkit to allow novices to set up physical representations of the process that they are interested in modeling and collaboratively interact with it in real time. We will demonstrate our current implementation of this toolkit and the simulation tool that we, in collaboration with the United States Postal Service, developed to help postal managers figure out how to balance work hours to workload and increase throughput of time-sensitive mails through hands-on manipulation of various operations modeled in the simulation.

Keywords
System dynamics, tangible user interface, simulation model, workplace research, mailflow analysis

INTRODUCTION

The field of system dynamics has provided valuable methods for understanding the structure and behavior of complex systems through the use of computer models. [1] This has provided a framework for understanding and improving the way that organizations adapt to changing conditions [11] and a means of analysis for data collected by workplace observation studies. [3] Yet developing an understanding of these models and simulations remains a significant challenge both for learning researchers and toolbuilders who attempt to address this area. [2, 9, 10, 12]

Our work to develop a tabletop system for building models of dynamic systems has evolved as a close collaboration between the Grassroots Invention Group at the MIT Media Lab and the United States Postal Service (USPS), a major Media Lab sponsor. This demonstration will present our work thus far with the Postal Service while suggesting more general applications of this system. This collaboration has allowed us to further develop our tool based on insights provided by interactions in this real world context. A closer look at the problems in this context help show how this approach can provide solutions to challenges that are inherently associated with how we learn, think, and communicate using simulation tools rather than with technical limitations of the tools themselves.

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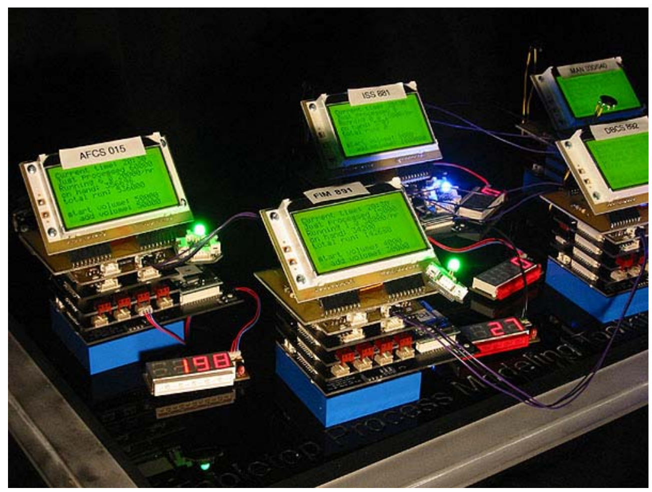

Figure 1: Second-generation prototype of Tabletop Process Modeling Toolkit model of a USPS mailflow

CHALLENGES FACING THE POSTAL SERVICE

The Postal Service manages 38,000 post office locations, 700,000 employees, and dozens of processing facilities. Each facility contains as many as a hundred mail-processing machines. Systems modeling plays a major role in the management of the postal service on every level; however, the effectiveness of these simulations is limited due to the challenges in communicating their results to the managers who need to utilize these results in real-time decision-making. There is a great deal of anecdotal evidence from engineers and managers within USPS that managers find the results of these simulations counter-intuitive and untrustworthy, and, as a result, often ignore them entirely.

It is important to note that the problem is not with the existing simulation tools' technical merits or fidelity in capturing the subtleties of the situations they are used to model but rather the accessibility of their results to decision makers. At the root of the problem, the interaction between the engineering team and the management team often consists largely of opaque written reports because the simulations models used are too abstract and inaccessible for non-experts to understand or manipulate.

OUR APPROACH

In order to overcome the difficulties in allowing non-experts to develop their intuition of such complex simulations, we are guided by the constructionist theory, which asserts that individuals learn most effectively when constructing artifacts in the domain under study. [7] Thus, we have focused on developing a toolkit to allow managers to be an integral part of designing and manipulating these dynamic simulations. This has the potential to overcome the disconnect between the abstract specifications on which engineers base these simulations and the concrete experiences and tacit knowledge of the managers for whom the results of these simulations are intended.

Another dimension of the problem is that most of the current simulation packages are based on advanced mathematical representations and are therefore inaccessible to most non-engineers. We overcome this limitation by developing programming languages and design environments that are based on different ways of thinking about simulations. We aim to take advantage of intuitive representations that are grounded in the practices of the managers in their daily work. This involves a direct mapping of the computational elements in the simulations to objects in the process under study.

It is important to keep in mind that supporting alternative representational choices does not guarantee that non-experts will be able to transparently understand and manipulate the relevant parameters in the simulations. To address this issue, we insist that these simulations not be "black-boxed" and can be opened up so that their inner mechanisms can be examined and tinkered with in easily accessible interfaces and programming languages.

Another drawback of many existing simulation packages is that they are not well suited to collaboration among a group of engineers and/or managers. The use of a single computer screen, keyboard and mouse makes it difficult for multiple users to engage with an onscreen model. Our approach to overcoming this issue is to provide physical representations of the objects in a simulation so that a group of people can gather around a tabletop to collaboratively construct and manipulate dynamic simulations.

A CONCRETE CASE: ***Modeling the flow of mail at a United States Postal Service Facility***

Individuals at various levels of the Postal Service have suggested a variety of potential uses for this approach in their organizations. In order to ground our work in a specific scenario, we have chosen to focus on the problem of modeling the flow of mail at a USPS processing facility, such as the one at Fort Point Channel in Boston. This has allowed us to tap a wealth of local expertise and interact directly with those facing this problem on a daily basis.

The Problem Statement

Analyzing the flow of mail in the Postal Service is very challenging due to the varying ways that mail moves through a processing plant. Different types of mail (e.g. advertising mail, first class mail, parcels, periodicals, etc.) have different delivery standards, and thus these different types of mail have separate streams within a facility.

All of these mailflows, which move through automation and mechanization within a postal facility, create a complicated web of physical and information flows.

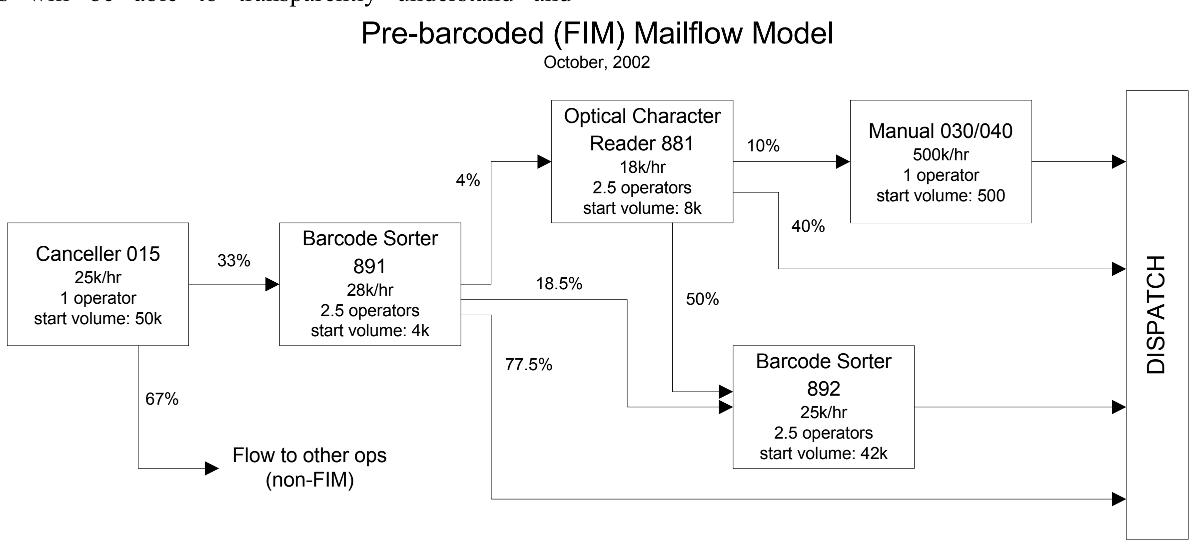

Figure 2: United States Postal Service Mailflow Model

The Existing USPS Simulation Model

The existing simulation model used in the Postal Service requires a week of training to learn to use and requires someone who already has a very good understanding of mailflow. The user enters volumes of each mail type, operation numbers, arrival profiles, maintenance schedules, percentages of mail that flow from one operation to another, and so on. The simulation produces equipment requirements in order to process the associated volumes of mail. The user must trust the simulator since it produces only the final results in table format, without any way for a user to build his intuition about the underlying model. Additionally the tool does not calculate people requirements (staffing), let alone attempt to optimize staffing according to varying workloads.

The Prototype

The flowchart in Figure 2 was the basis of our prototype that only dealt with one mail type, pre-barcoded letters. This mail type is referred to as FIM (Facing Identification Mark). An actual volume arrival profile for FIM mail was used based on a high volume Monday in the Boston Processing and Distribution Center in South Station.

Figure 3: USPS Engineer Benny Penta (seated) discusses the model with a colleague at the Fort Point Channel USPS Facility in Boston.

Each operation that FIM mail might flow to, depending upon the letter's address, was designated as a node in the system and the associated characteristics were assigned to it. A separate embedded computer system, called a Tower, represented each node, and these nodes were connected with wires for communication between them. Each Tower transferred the mail flowing from one operation to another and statistics were stored at each node. The characteristics were treated as parameters (operational throughput, operational staffing, threshold on-hand volumes etc.) that could be varied by the user in a hands-on manner while the simulation was running.

The result of each simulation run produces the work-hours and start/end times of each operation. This will allow the managers of a particular operation to staff each operation.

Our evaluation of this prototype has been largely informal to date. We have demonstrated this system to many engineers and managers from the United States Postal Service and other sponsoring companies of the MIT Media Lab. Many of these visitors quickly pointed out that the simulation capabilities of our prototype were limited compared to the software packages used in their organizations, but many were also extremely enthusiastic about this approach's possibilities for improving internal communication and involving non-technical members of their organization in designing and exploring simulations used in their fields. Their feedback has been invaluable for developing our ideas and focusing our work.

TECHNOLOGICAL INFRASTRUCTURE

Over the past year, we have developed two iterations of our prototype for the Tabletop Process Modeling Toolkit.

Initial Prototype: *The Cricket System*

The initial prototype of the Tabletop Process Modeling System, seen in Figure 4, was constructed using the Cricket system, utilizing several Cricket bus devices, including the tricolor LED devices and LCD display devices, to display relevant information about the simulation's state. [4] We achieved communication between Crickets using pairs of infrared communication bus devices, though this method severely limited the amount of data that we could reliably send between Crickets in the system. This model was based on a similar FIM model as the current system, but did not allow the user to interact with the nodes in the system to adjust parameters. Despite its limitations, this prototype served well as a means of obtaining feedback on our approach from a variety of visitors to the Media Lab.

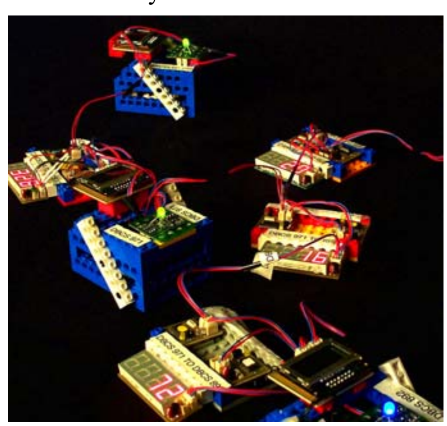

Figure 4: Initial Prototype of Tabletop Process Modeling Toolkit

Second-generation Prototype: *The Tower, a Modular Computation System*

Our current prototype of the Tabletop Process Modeling System, shown in Figure 1, was constructed by extending a modular computational prototyping system developed by our research group at the MIT Media Lab called the Tower. [5] The Tower consists of a set of Foundations with increasing computational capabilities, the first of which was based on a Microchip PIC microcontroller. Connectors on each Foundation provide the physical and electrical architecture for stacking layers to add functionality to the system, including data storage, infrared and RF communication, sensors, displays, and other layers. For this project we developed both a new, more powerful Foundation based on the Rabbit Semiconductor RCM2300 processor module and a new layer that uses serial ports and cables to communicate with other Towers in the simulation.

Each Foundation runs a compact interpreter for the Logo language, which enables novices to quickly write programs to control the capabilities of the Foundation and attached layers. These Logo programs, written on a desktop computer, are downloaded to the foundation via a serial cable. We have developed Logo libraries to handle packet communication and routing between Towers in the tabletop network, providing a robust communication infrastructure upon which users can rapidly build their simulations.

Our growing collection of Tower layers enables us to easily add a variety of capabilities to these tabletop models. We use the sensor layer to add buttons, sliders, and dials to control the simulation's parameters. LCD display layers and tri-color LED boards allow us to display relevant information about the state of the simulation on each Tower, providing both detailed information and important visual cues about the simulation as a whole.

Related Work

Approaches to enabling novices to build intuition of dynamic systems have been the subject of intense work. Forrester has stressed the importance of immersive explorations as a means to developing understanding such systems [2], and his System Dynamics in Education project at MIT has produced *Road Maps*, a series of exercises using STELLA software to build understanding of this field. [6] Resnick developed *StarLogo* for creating and exploring complex systems, using a massively parallel variant of the Logo language to program vast numbers of individual "turtles" and their shared environment. [10] Patten et al. have developed *Sensetable,* upon which they projected an on-screen representation of a dynamic simulation and manipulated parameters of the model by moving physical objects. [8]

DEMONSTRATION

At CSCW 2002, we will demonstrate and reflect on the application developed in collaboration with the USPS. We will discuss the architecture of the prototyping toolkit that we developed to construct this demonstration and a much wider range of applications that this system can support, including workflow modeling, tabletop network modeling, and system dynamics in general.

ACKNOWLEDGMENTS

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