Simulation for Computer Science Majors: A Preliminary Report*

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Abstract

The author is revising and restructuring an existing simulation course designed primarily for senior computer science majors by: 1) developing an integrated set of laboratory exercises based on computer science topics using commercially available software (GPSS/H); 2) incorporating these materials into a formal laboratory manual along with related computer science reference materials and instructions in the use of the software; 3) implementing a pilot course using this manual together with a single text in the theory of simulation; 4) preparing a syllabus and a detailed annotated course outline for the instructor, keyed to the manual and the text. The materials developed will be flexible and highly modular allowing their adoption or adaptation at other institutions.

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1 Introduction

With the support of the National Science Foundation under Grant DUE-9554863, the author is revising and restructuring an existing simulation course designed primarily for senior computer science majors by: 1) developing an integrated set of laboratory exercises based on computer science topics using commercially available software (GPSS/H); 2) incorporating these materials into a formal laboratory manual along with related computer science reference materials and instructions in the use of the software; 3) implementing a pilot course using this manual together with a single text in the theory of simulation; 4) preparing a syllabus and a detailed annotated course outline for the instructor, keyed to the manual and the text. The materials developed will be flexible and highly modular allowing their adoption or adaptation at other institutions.

This project is being undertaken at the University of the District of Columbia (UDC).

The instructional materials are designed to be especially helpful to computer science students by providing them with marketable skills in computer simulation which can be expected to enhance their ability to obtain professional positions with a bachelor's degree.

2 The Problem and Computer Science Curriculum Needs

In Computer Curricula 91, a major report on the problems and needs of computer science curricula, Tucker (Curricula 91 1991) notes that existing computer science curricula often lack an established infrastructure for the senior year. He identifies a number of special needs in the computer science curricula, including: the need for a capstone course; the need for more hands-on laboratory experience; the need to integrate abstraction, theory and practice at an upper division level in the curriculum for computer science majors; and the need for collaborative learning, small teams, and learning by doing. The report also defines knowledge units and subject areas of the field of computing.

Tucker recommends establishing an advanced undergraduate elective course in Modeling and Simulation, but does not establish syllabus and content for the course.

The proposed senior course in simulation for computer science majors has been specifically designed and focused on meeting the needs of a capstone course, as well as the other requirements discussed above.

Most computer science majors have very limited exposure to simulation. When they elect a course in simulation, the course is often largely theoretical. When hands-on experience in use of simulation software is provided, it is often limited to applications to business and manufacturing. Computer Science graduates are thus not adequately prepared for employment opportunities involving the use of simulation as a tool in solving problems that require a computer science background, e.g., problems in networks, operating systems, computer architecture, performance analysis and scheduling.

Optimized instructional materials are needed for an updated course in simulation for senior computer science majors. Suitable instructional materials also need to be made available nationally, so instructors will not be required to develop their own materials.

The author has examined available instructional materials in the areas of simulation and simulation software for use with the course she teaches at the University of the District of Columbia.

She has been unable to locate a single text that covers both theoretical and experimental aspects in a comprehensive fashion. Schriber (Schriber 1990), for example, which is aimed at graduate students in business, has coverage of GPSS/H (General Purpose Simulation Software), but does not cover the theoretical material. In contrast, Ross (Ross 1990) covers the theory but has no software coverage.

The usefulness of the available texts on the theory of simulation for courses for computer science seniors would be improved if they were used with a brand-new substantial laboratory component based on the use of simulation software on personal computers, with an emphasis on applications of the computer science "knowledge units" recommended in Computing Curricula 91 which will meet the special needs of computer science majors.

The most pressing need is for a laboratory manual containing carefully selected experiments which would furnish hands-on computer science applications of computer simulation theory. It should be usable either with a text or as an independent instructional aid that would stress practical applications of simulation to areas of computer science rather than to business and manufacturing. The manual needs to include sufficient summarized reference material on operating systems, computer architecture, and other computer science areas to enable students to develop the simulation models and run them on simulation software.

The manual needs to have the experiments based on a simulation package such as GPSS/H. Also, the laboratory manual needs to have step-by-step guidance in use of the software, at least to the level of modeling queues.

Also needed are instructor's materials for this enhanced course, including a syllabus and a detailed outline, keyed to the theoretical text and the laboratory manual. In addition, a workshop for instructors is needed, to furnish aid in teaching both the software and the technical material.

3 Goals

The author proposes to meet the needs outlined above by developing a new course in computer simulation with GPSS/H for computer science seniors. As discussed in more detail below, the major goals of this pilot project are:

- to develop a laboratory manual
- to establish a syllabus and detailed outline for the course

The overall goal of this project is to provide instructional materials which will be key components of a capstone course in computer simulation with GPSS/H for senior computer science majors. These materials will integrate the student's previous experience in computer science, mathematics, physics and engineering.

The first major goal is to develop a new laboratory manual containing computer simulation exercises of special interest and value to majors in computer science. The manual will be designed for use either as a supplement to existing simulation texts or as a stand-alone manual for students and professionals who already have a background in simulation.

The manual will contain laboratory exercises which encourage computer science students to apply their knowledge to specific, constrained problems and to produce solutions. Section 5.2 provides further details concerning the proposed exercises.

The manual will incorporate enough introductory and background material on the use of GPSS/H to obviate the need for a textbook for teaching use of the software. The manual will also incorporate a summary of background information and reference materials on the knowledge units defined in Computer Curricula 91 in areas such as operating systems, computer architecture and computer networks, to the extent that they are relevant to the laboratory exercises and helpful in solving the problem presented.

The second major goal of the project is to prepare an annotated course syllabus and outline showing appropriate integration of the accompanying laboratory exercises with the material in a theoretical text. The laboratory exercises must be synchronized both with the theory of simulation and the simulation software experience.

Emphasis will be placed on the following innovative aspects of this proposal:

- development of a new laboratory manual which is usable with existing textbooks, so that the novel aspects of the manual can be easily and quickly incorporated into existing courses
- incorporation of theory and practice in computer science, into the laboratory exercises linked to "knowledge units" in major subject areas
- orientation of the laboratory exercises towards applying the techniques of simulation to topics of interest and value to computer science majors
- incorporation of qualities desirable in a capstone course which will summarize and reinforce the student's undergraduate experience.

4 Potential Impact and Significance

The optimized computer simulation course is expected to be a strong pedagogical tool because the processes of theory, abstraction and design, as used in simulation, require that students integrate their knowledge of mathematics, probability, computer science and physics. In addition students will gain experience in hypothesis formation and testing, evaluating alternatives and trade-offs, costs and performance, written presentation of findings and technical writing, and statistical analysis of results in computer science problems, while learning simulation and simulation software.

The proposed manual will provide students with hands- on experience in applying the theory of simulation and will reinforce computer science knowledge units from throughout the curriculum. Student problem-solving ability, analytic skills and professional judgment will also increase as a result of laboratory exercises based on the computer science curriculum.

Because this manual will be based on a low-cost, widely used and easily available commercial software, it will be of particular value to students and educators in underfunded colleges. The additional proposed course materials will support teachers in integrating software into current simulation courses. This will avoid the labor-intensive need for teachers individually to develop their own laboratory materials which would otherwise be necessary because of the lack of a comprehensive computer science oriented laboratory manual.

This project will also have a major impact on the overall computer science curriculum. Student laboratory experience in the upper division computer science curriculum will extend and consolidate students' knowledge and improve their ability to apply the information gained during their four years of study. The author believes that an enhanced simulation course using the instructional materials produced in this project will be a model for the type of computer simulation course that might be required for all computer science majors.

Ultimately, the improvement of courses in simulation and computer science curricula is expected to contribute to the placement of Bachelor's degree candidates in better professional positions.

See Section 5.3 for a further discussion of the impact of this course on students, including underrepresented groups.

5 Procedures and Methods

5.1 The Plan and Specific Products

The overall plan is to create optimized instructional materials for an expanded and revised course in simulation with GPSS/H for computer science seniors. The starting point for this project is course in computer simulation.

The course will be thoroughly revised as the laboratory manual is developed and integrated with the course work during this project.

The two major products to be prepared during this project are a laboratory manual and other instructional materials.

The laboratory manual will contain: 1) introductory material about GPSS/H software, including new implementations of the software; 2) exercises using GPSS/H; 3) reference material in relevant computer science knowledge units. The manual will be designed for use with current published textbooks in the theory of simulation.

The other instructional materials will include a course guide, a detailed course outline, and keys linking the theory of simulation, the level of use of GPSS/H and the appropriate knowledge units.

A preliminary draft of the table of contents for the proposed laboratory manual in Appendix A identifies the major knowledge units to be included in the manual.

In each exercise in the laboratory manual the student will: start with a problem; clearly define and analyze the problem, developing a "lumped model" or abstraction; solve the problem; implement the solution by writing the GPSS/H program file to run the simulation; use the GPSS/H software to run the program file; and answer questions about the simulation. Appendix B is a preliminary draft of a sample laboratory exercise.

The exercises will be designed for use by groups of two or three students so as to promote collaborative learning and experience in working as a team.

5.2 The Current Status of the Course at UDC

The current version of the simulation course with GPSS/H for computer science majors was developed by the author, and has been taught at UDC for the last several years.

The prerequisites for the current course are: the calculus, physics and upper division standing in computer science. To avoid additional prerequisites, the author includes sufficient material on probability and statistics before presenting the core material on queueing theory. Our curriculum includes probability and statistics in the second semester of the senior year. By my including this material in the course, I am able to allow juniors to take the course as well as seniors. This gives UDC more flexibility in scheduling the course.

For the laboratory part of the course, the author selected GPSS/H, (Wolverine 1995), because the manufacturer of this widely used simulation software has been very cooperative with academic institutions. The textbook used with the GPSS/H software is Schriber, which includes diskettes for IBM-compatible machines with the book. No site license need be purchased by the college. However, this book is aimed at candidates for a master's in business administration, rather than undergraduates in computer science, and it contains little material on the theory of simulation.

Aburdene (Aburdene 1988), an undergraduate text for science majors, was previously used for the more theoretical aspects of simulation. However, since it is currently out of print, beginning Fall 1993, the author has substituted Ross.

The pair of books selected encompassed the material for the course. However, the textual and laboratory emphasis on computer science material needs to be significantly expanded to fulfill Computing Curricula 91 guidelines.

The current version of the simulation course is integrated into the curriculum at UDC as an upper division elective for computer science majors.

5.3 Impact of the Course on Students

This course is expected to be especially beneficial to those students who have a protracted undergraduate experience, helping them to improve their skills and integrate their knowledge. However, this integration of knowledge is an important reason why every computer science major should take the course.

Most of our graduates go directly to industrial jobs or to teaching, since they lack the resources for full-time graduate study. This course will enhance their marketability for employment. The low cost exposure to important commercial simulation software is expected to be of major benefit to students in underfunded colleges, giving them a marketable skill.

6 Anticipated Results

The goal is to produce instructional materials which improve instruction in computer simulation at UDC and will furnish instructors in computer science departments throughout the United States with a defined method for teaching computer science seniors simulation with GPSS/H.

The specific instructional materials to be produced are:

1. A student laboratory manual consisting of laboratory exercises for a semester of computer simulation instruction. The laboratory manual will include; background information from courses in operating systems, architecture and algorithms; and an introduction to GPSS/H; sufficient for students to do the exercises. A study of Proof Animation (Wolverine1992) may be included in the final course. The background material will summarize the reference information from other computer science courses so that students with limited exposure in a particular area will be able to perform the exercises. This is intended to make the material more flexible for use in departments with various objectives and curricula.

2. A course guide for instructors including: an annotated course syllabus, an outline correlating the laboratory exercises to the specific knowledge units proposed for computer science majors in Computing Curricula 91; and suggested teaching time frames. The background material and course guide will be organized in a fashion that will facilitate their use with standard texts in the theory of simulation.

3. Preliminary and final results will be presented at meetings such as ACM SIGSCE and ACM SIGSIM.

7 Dissemination of Project Results

During the implementation of the project, the initial results will be disseminated informally via world wide web and internet news groups journals such as comp.simulation, along with input from participants. As the project progresses, preliminary and final results will be presented at professional meetings.

The laboratory manual and teaching materials will be disseminated to schools nationally, both through bookstores (publisher) and as above.

The author plans to apply for funding under the NSF UFE (Undergraduate Faculty Enhancement) Program to organize a faculty workshop which will be designed to enhance the skills of faculty who are teaching or who plan to teach computer simulation. This workshop could be scheduled for the summer of 1998, when the written materials for the current project are complete.

Arrangements will be made for publication of the laboratory manual by established publishing companies.

Appendix A

Preliminary Table of Contents

for "A Laboratory manual for Simulation with GPSS/H for Computer Science Majors: an Integrated Approach"

Section 1. Getting started with GPSS/H simulation software

Introduction to GPSS/H. Software installation; transactions, generate and terminate blocks.

Continuation of GPSS/H. Advance, Seize and Release blocks; practice in setting up and running program files. Modelling a server: queues.

Section 2. Laboratory exercises using GPSS/H
A preliminary draft of a sample exercise is shown in Appendix 2.
Section 3. Computer Science Reference Material: subject areas and knowledge units

Operating Systems; Tasking and Processes
Scheduling and Dispatch
Device Management
Communications and Networking

Distributed and Real-time Systems

Computer Architecture; Interfacing and Communication
Alternative Architectures

Algorithms and Data Structures; Complexity Classes
Recursive Algorithms

Computer Networks
Performance Prediction and Analysis

Appendix B

Preliminary Draft of a Sample Laboratory Exercise in Simulation with GPSS/H

Exercise

Topics: Networks, Scheduling, Queues

Problem. An office has a local area network. There are 20 workers on the staff, each with a PC on the LAN. However, there is only one printer. Each worker will want to print 1 file. Assume the files are of various lengths. Make any reasonable assumption about printer speed. Refer to your materials on queues and modeling of single servers, both in your text and in handouts, to answer the questions in Part I. Only then, proceed to Part II.

Part I. Setting up model and theory.

1. Draw a spatial representation of the system, showing arrivals, waiting time, server and departures.
2. Choose a suitable distribution for your arrival times from: deterministic, random. Explain your choice.
3. When you model the server, should you use FCFS (first come, first served) or should you establish priority levels? Explain your choice. Make any reasonable assumptions about the office use of the printer. You might want to solve the problem both ways.

Part II. Build and run a GPSS/H model file for this system.

1. Consider the GPSS/H operations: Generate, Advance, Seize, Release, Transfer. What is the sequence of steps for your model file? What are suitable values for your Operands?
2. What is the default distribution in GPSS/H? Should you use that distribution, or is there a better one for this problem? What is the server and what are the transactions for your system?
3. Set up your GPSS/H file.
4. Simulate your model (run GPSS/H) until all 20 files have left the system. Run your system three times, and furnish statistical data about the runs: show file arrival times at the printer, start of printer time, end of printer time, and average waiting time for each file.

Hand in your results.

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