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TEACHING SIMULATION TO UNDERGRADUATE LIBERAL ARTS STUDENTS

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ABSTRACT

Few colleges and universities in the United States teach simulation courses to undergraduate liberal arts students. Simulation was born and grew up in engineering, but it may attain its greatest sophistication in a new realm, the liberal arts. This paper suggests that a course in simulation for undergraduate liberal arts students is important and presents a course outline for it. Our experience with teaching the course is presented.

INTRODUCTION

Society has become increasingly complex. The graduate today needs to be able to deal with a variety of issues and cannot do it without sophisticated analysis. This analysis can be done with a computer.

The purpose of this article is to describe a way for the educator to provide liberal arts students with computer skills and problem solving skills to deal with the complex economic, social and political problems facing them.

To help the educator meet student needs, we propose a course in computer simulation. Simulation is building a simplified model to represent a complex situation and then experimenting with it to see how it behaves. If we build a flight simulator, for example, we can "test fly" it to see what happens to the "airplane" in a storm. In just the same fashion, we can build a simplified computer model to represent a complex economic system. Rather than sit in the cockpit of a flight simulator, we can sit at the computer and investigate whether raising the interest rates and inventory levels results in higher or lower capital investment. The model building involved in this simulation helps the student to better conceptualize the world around him and to solve complex problems more effectively.

THE SIMULATION COURSE

To meet the students' need for sophisticated computer skills and problem solving skills, a simulation course can be implemented by either liberal arts or engineering faculty. The course should have a number of student objectives, so that by the end of the course, the student should be able to:

- Identify the important relationships or laws governing the behavior of a social or behavioral system,
- Make a reasonable approximation as to the importance of each factor as it relates to the other variables in the system,
- Construct a mathematical or logical model of the relationships and their importance,
- Make hypothesis about how the model will predict or represent the problem, use a computer simulation package DYNAMO (Dynamic Models)[12] to gather quantitative results that verify or confirm the hypothesis, and write a computer program to represent a simple simulation problem.

These courses objectives can be met using a single semester lecture-oriented course with computer "labs" given during the week.

To help the student identify the important relationship or laws governing behavior of a social, engineering, economic, or behavior system, we distinguish between the physical sciences and engineering. In the physical sciences, many of the laws governing the behavior of these systems have been well formulated, for example, Newton's Laws and Kirchoff's Laws. On the other hand, in engineering and the social sciences, the student is trying to formulate an empirical relationship describing the system as he sees it. This corresponds to J. W. Forrester's view that physical sciences model natural phenomena whereas engineers and social scientists model man-made systems.[2]

To deal with the relative importance of each of the simulation factors, we sought to emphasize the purposes and uses of the simulation. We wanted to include the essential factors and avoid including superfluous details in order to abstract an ideal representation of real systems. We emphasized analysis of the problem and the interaction of the components with the system. At this point, we examined internal (endogenous) and external (exogenous) variables to clarify the input/output and functional relationships.

To construct a mathematical model, we used the two earlier objectives to develop differential and difference equations, and the logical relationships. If possible, an analytical solution was sought to interpret the results. Often the equations were nonlinear and simulation was required. However, even if an analytical expression could be obtained, we found it beneficial to do the simulation. Based on our as yet incomplete understanding of the total system, we could make some tentative hypotheses about its behavior. The students then verified their hypotheses according to statistical procedures.

To simulate systems, we used two approaches: first, we used high-level languages familiar to the students (e.g., FORTRAN, BASIC, APL, and PL-1) for the introductory part of the course. Then, second, we used simulation languages [1,3,10,11,12,13]. We used DYNAMO, ACSL, or CSMP for differential equation models and we used GPSS and/or SLAM for difference equation models.

We encouraged the students to write simple simulation programs using each of these languages so that, by the end of the semester, each was familiar with the full range of simulation tools available. For a semester project, each student or group of students submitted a simulation of a large-scale system.

A SIMULATION COURSE OUTLINE

The course should progress from simple and informative simulations through more elaborate simulations and eventually to complex simulations such as world models.

Week 1 Simulation in the social sciences and physical sciences, elements of simulation, uses of simulation, features of simulation, model construction, pitfalls of simulation, and areas of simulation in the social sciences.

Week 2 Simulation of stochastic (random) systems, computer simulation using a programming language such as BASIC, FORTRAN, PASCAL, mind simulation, and actual simulation. Example: sales person calling on a customer to sell his company's product.

Week 3 Introduction to a simulation language. (SIMAN, GPSS, SLAM, DYNAMO, ACSL, or CSMP)

Week 4 Simulation of deterministic system. Examples: spread-of-rumor model, economic models, price models.

Week 5 Discrete and continuous systems, equilibrium. Introduction of delays, oscillation, stability of simulation models. Cobweb models, voting models.

Week 6 System theory, basic concepts of probability, applications.

Week 7 Expected value, variance, sampling, regression analysis, and correlation analysis. Experimental design.

Week 8 Monte Carlo simulation, random number generators, scatter diagrams, testing random number generators. Poisson Processes, exponential processor generators, queueing models, time between conflict models. Validation, verification.

Week 9 Discrete systems and Markov Processes. Naive subject model, repeated balloting, recovery from cancer model. Validation, verification.

Week 10 Simulation of continuous systems, arms-race models, growth models, world models, system dynamics. Validation, verification.

Week 11 Parameter identification of deterministic and stochastic systems.

Week 12 Optimization, single-variable optimization, several variable optimization.

Week 13 Simulation methodology. Validation and verification.

Week 14 Presentation of term projects.

EXPERIENCE IN TEACHING THE COURSE

We have taught this course to a small class twice. The students were sophomores, juniors, and seniors majoring in political science, history, economics, linguistics, mathematics, biology, psychology, and engineering. The prerequisites were a familiarity with a programming language and the motivation for active participation in classes. The students were all active contributors to the model construction stage of the simulation process. They were encouraged to present their ideas and concerns and to draw upon their experience and background in their discipline.

A colleague used our class notes at another institution and taught the course to mathematics and computer science students. He reported that his students were enthusiastic about the course and became aware of the difficulties and uncertainties of the "soft sciences." The students particularly appreciated the application of their mathematics and computer skills to social science problems.

One of the most difficult aspects of this course was the availability of a suitable text for the instructor. The references provided material for course development.

REFERENCES

[1] Aburdene, Maurice, F. and D. Finkel, "An Approach to Teaching Simulation to Undergraduates," Proceedings of the 1983 Winter Simulation Conference, S. Roberts, J. Banks, and B. Schmeiser (eds), pp. 375-377.

[2] Forrester, J. W., Indirected Dynamics, MIT Press, Cambridge, Massachusetts, 1961.

[3] Gordon, G.. The Application of GPSS V to Discrete Systems Simulation, Prentice-Hall, Englewood Cliffs, New Jersey, 1975.

[4] Graybal, Wayne, and U. W. Pooch, Simulation: Principles and Methods, Winthrop Publishers, Inc., Cambridge, Massachusetts, 1980.

[5] Kochenburger, R. J. and C. J. Turcio, Computers in Modern Society, Hamilton Publishing, Santa Barbara, California, 1974.

[6] Lave, C. A. and J. G. March, Introduction to Models in the Social Sciences, Harper and Row, New York, 1975.

[7] Law, A. M. and W. D. Kelton, Simulation Modeling and Analysis, McGraw Hill Book Co., New York, 1982.

[8] Lewis, T. G. and B. J. Smith, Computer Principles of Modeling and Simulation, Hamilton Publishing, Santa Barbara, California, 1974.

[9] Payne, J. A., Introduction to Simulation, McGraw Hill Book Co., New York, 1982.

[10] Pegden, C. D., Introduction to SIMAN, System Modeling Corporation, State College, Pennsylvania, 1982.

[11] Pritsker, A. A. B. and C. D. Pegden, Introduction to Simulation and SLAM, Halstead Press, New York, 1979.

[12] Pugh, A. L., Dynamo II User's Manual, The M.I.T. Press, Cambridge, Massachusetts, 1970.

[13] Roberts, S. D., "Teaching Simulation to Undergraduates." Proceedings of 1982 Winter Simulation Conference, IEEE, New York, New York, 1982.

[14] Russell, E. C., Building Simulation Models with SIMSCRIPT II.5, CACI, Inc., Los Angeles, California, 1983.

[15] Shannon, R. E., System Simulation the Art and Science, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1975.

[16] Simulation, Journal, SCS, LaFolla, California.

[17] Summer Simulations Conference, Proceedings.

[18] Vogt, W. G. and M. H. Mickle, (editors), Modeling and Simulation, Volume 1-16, Proceedings of Annual Conference 1970 - 1984, University of Pittsburgh, Pennsylvania.

[19] Winter Simulation Conference, Proceedings.

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