Fundamentals and Case Studies for a Modeling and Simulation Model Curriculum

Dietmar P. F. Möller[1)]
Roy E. Crosbie[2)], Ralph C. Hilzer[2)] , John J. Zenor[2)]
[1)]University of Hamburg, Faculty of Computer Science, Chair Computer Engineering
Vogt-Kölln-Str. 30, D-22525 Hamburg, Germany
[2)]College of Engineering, Computer Science, and Technology
California State University,
Chico, CA95929-0003, USA

ABSTRACT

Since several years, the authors suggests that the development and publication of a Model Curriculum for MS programs in Modeling and Simulation would facilitate the development of such programs. This paper presents a first draft of a Model Curriculum developed on the basis of a recent published textbook of Mathematical and Computational Modeling and Simulation at the University of Hamburg (UHH), Germany and the California State University, Chico (CSUC). The aim of the draft is to stimulate further discussion in the M&S community with the goal of arriving at a generally acceptable outline that can serve as a guideline for new Modeling and Simulation programs.

1 INTRODUCTION

As the demand for Mathematical and Computational Modeling and Simulation professionals continues to increase, much attention has been focused recently on what constitutes a proper educational preparation for a career in Mathematical and Computational Modeling and Simulation. At the Western Simulation Conference in 2000 (WSC 00) Dr. Roy Crosbie proposed the development of a Model Curriculum for a MS degree in Modeling and Simulation (M&S) to assist schools planning new programs in the field. This suggestion was based on experience in the 1980s of developing a new BS program in Computer Engineering, a task that was greatly facilitated by the availability of a model curriculum for Computer Science and Engineering (CSE) published by IEEE-CS and ACM.

The task of defining a curriculum for a MS degree in Mathematical and Computational Modeling and Si mulation is particularly difficult, partly because M&S is normally not seen as a discipline in its own right in most universities. It is usually regarded as a fragmented subject with concepts in a range of disciplines including, but not necessarily restricted to computer science, various engineering disciplines, mathematics, business, natural and physical sciences, medicine, pharmacy and social sciences. Furthermore, the range of applications of M&S is so wide that almost any university department could possibly offer a course on M&S applied to it's particular discipline. This results in a situation in which course offerings relevant to M&S, and that might be included in an M&S degree program, tend to be scattered throughout the university, with no central responsibility for M&S as a discipline.

A recent White House report identified computational modeling and simulation as one of the key enabling technologies of the 21st century. Its application is universal.

One way of handling this various individual courses will go through departments of interdisciplinary degree, which is the mechanism currently used at US universities, which can offer a flexible MS in Interdisciplinary Studies (MSIS) that allows a student, with faculty support, to devise a program of study from the course offerings of multiple departments that can address specific academic goals not provided for in the regular graduate programs of the university. The MSIS in Simulation Science at CSUC requires 9 semester units (3 courses) of M&S fundamentals covering methodology and tools and techniques, and a project of at least 3 units on a topic related to M&S. The student selects the remaining courses without specific restrictions as to department or discipline as long as they conform to the student's academic goals and receive faculty approval. In comparison to the CSUC model at UHH students enrolled in Computer Science or Engineering can select special courses on Modeling, Simulation and Optimization, each of which have 3

Proceedings 18th European Simulation Multiconference
Graham Horton (c) SCS Europe, 2004
ISBN 3-936150-35-4 (book) / ISBN 3-936150-36-2 (CD)

credit units, as well as specific seminars and projects on M&S topics.

Another approach is for universities to combine forces, and UHH and CSUC are also pursuing this route in a consortium of 3 European and 3 US universities that are together running an international graduate program in M&S making use of on-line based course material, faculty exchange and student exchanges in order to broaden the base of M&S courses available to students from a particular campus. The basis for such a graduate program in M&S is based on the textbook "Mathematical and Computational Modeling and Simulation: Fundamentals and Case Studies" published by Springer Pub. Heidelberg.

Some choices have been made in selecting the material of this book. First the methodology of mathematical and computational modeling is described, because this represents the largest portion of system analysis. In addition, the mathematical background describing real-world systems is introduced on a basic level as well as on a more advanced one and its correspondence with the respective modeling methodologies. Second the most interesting simulation software systems at the language and logic level are described, as well as their use in several case study examples. However, a textbook can not describe all available simulation software systems in detail, for this reason students are referred to use the specific written material such as textbooks, reference guides, user manuals, etc., as well as the web based information addressed to the several simulation software systems. Thirdly, an algorithmic approach to ill defined and distributed systems based on the respective mathematical frameworks are introduced.

The purpose of this book is to expose undergraduate and graduate students to the use of mathematical and computational modeling and simulation as a basis for developing an understanding of the response characteristics of a broad class of real-world systems. Mathematical and computational modeling is based on systems theory as a mathematical form of representation while building models of real-world systems. The simulation methodology behind is used for a better understanding of the time dependent transient behavior of the complex models developed, which are in relation to the continuous-time and discrete-time description. The subject matter of the textbook can be considered to form an introduction to the methodology of mathematical and computational modeling of real-world systems, as well as into simulation software systems, to gain experience, which result from the different application domains introduced as case study examples in this book.

The nature of the material in the book can be seen more or less difficult, if the reader is new to such approach, which also is due to the fact, that mathematical and computational modeling and simulation is a multi-disciplinary domain, founded in computer science, engineering, mathematics, physics, chemistry, biology, life science, etc. The material may not be read and comprehended either quickly or easily. This is why specific case study examples, from the various disciplines, have been embedded due to the related topics of system theory representation of the material, to master the material, at least for most individuals of the several scientific disciplines. It is assumed that the reader has some previous background in mathematics through calculus, differential equations, Laplace transforms, and matrix fundamentals. The most common simulation software systems will be introduced and their performance will be discussed based on several case study examples. But real-world systems often are ill defined and the important parameters which should be known for modeling may not be known and/or not measurable, which call for parameter identification methods to estimate unknown parameters. Moreover, virtual reality and soft computing methods show up recently which are now are being add on as part of the methods used for modeling and simulating real-world systems, which are used for the respective examples and case studies.

Whatever the administrative basis for a graduate program in M&S, it can only be helped by the availability of a set of generally agreed guidelines on the structure and composition of the degree. Having said this, it is important that the guidelines should be capable of flexible interpretation, avoiding a "*one size fits all*" approach. This was achieved in the CSE guidelines by specifying course content in the form of subject areas rather than complete courses. This allows the program developers to mix and match different subject areas to produce individual courses that best fit the needs and resources of a particular institution. As long as the mix of courses provides for all of the subject areas that are required, and adequately provides for those that are optional, the program conforms to the guidelines.

2 COMPONENTS OF THE M&S DEGREE

The referenced WSC 00 paper of Dr. Roy Crosbie (Crosbie, 2000) recommended that the M&S degree contain the following four major components:

- *Fundamentals of M&S;*
- *Simulation Tools and Techniques;*
- *Applications of M&S;*
- *M&S Project.*

This initial draft assumes an MS program of 30 semester units (equivalent to approximately 10 semester courses). Students entering the program are assumed to have an adequate background in basic topics in

computer science, mathematics, physics and their primary BS discipline.

Although the guidelines do not prescribe the number of units to be allocated to each of the above areas, it is recommended that at least two courses (6 semester units) be allocated to each of the first three areas and 3 semester units to the project. This accounts for 21 units and leaves 9 units (3 courses) at the discretion of the program or for use as electives.

Henceforth the textbook covers the previous mentioned scopes due to the content and time schedule. It can be used in courses in various ways. It contains more material than could be covered in detail in a quarter-long (30-hour) or semester-long (45-hours) course, leaving instructors with the possibility of selecting their own topics and add on own case study examples. Sections denoted with an asterisk report on advanced topics and can be skipped in a first reading or in undergraduate courses. Moreover, it covers the fundamentals of M&S, as well as simulation tools and techniques, applications of M&S and several M&S projects, introduced as case study examples for the variety of M&S application domains.

The book can also be used for self-study or as a reference for graduate engineers, scientists and computer scientists for training on the job or in graduate schools.

3 DETAILS OF PROGRAM CONTENT

The four Subject Areas (SA) for a MS in M&S are as follows:

1. SA1: Fundamentals of Modeling and Simulation
2. SA2: Tools and Techniques for Modeling and Simulation
3. SA3: Applications of Modeling and Simulation
4. SA4: Modeling and Simulation Project

Each subject area is divided into a number of sub-areas. Each sub-area can be regarded as the basis for a single course, part of a course, or even more than one course. Topics can be taken from different sub-areas and combined to form a course and the topics in a given sub-area may be distributed between different courses. The aim is to produce a general topology for the material that should fit into the course content of the actual degree program. Because of the wide variety of simulation applications, as covered by the textbook, it is likely that individual programs will emphasize different aspects of the material, and may find it necessary to include additional material.

We make no claim that these subject area definitions are complete. They are merely offered as a starting point for discussion and elaboration. We would welcome all comments, both positive and negative, including suggestions for alternate ways of arriving at a set of guidelines that are both sufficiently prescriptive to provide positive guidance to program developers and sufficiently flexible to avoid undue restrictions on the development of innovative programs in an area that has so many facets and multi-disciplinary aspects.

4 CONCLUSIONS

A first version of a model curriculum for a graduate degree in Modeling and Simulation is proposed. We hope that this can be used as a basis for wide-ranging discussions that will lead to a published version sponsored by interested professional bodies such as ACM, SCS and IEEE-CS.

5 REFERENCES

Crosbie, R. E. 2000. A Model Curriculum in Modeling and Simulation: Do We Need It? Can We Do It? In *Proceedings of the 2000 Winter Simulation Conference*, Piscataway, New Jersey:Institute of Electrical and Electronics Engineers.

Möller, D.P.F. 2003. Mathematical and Computational Modeling and Simulation: Fundamentals and Case Studies. Springer Publ. New York

6 AUTHOR BIOGRAPHIES

DIETMAR P. F. MÖLLER is a Professor of Computer Science and Computer Engineering at University of Hamburg, Germany. He is Director of the McLeod Institute of Simulation Sciences at UHH. His current research interests include simulation methodology, virtual and augmented reality, embedded systems, mobile autonomous systems and robots, and e-Learning and e-work.

ROY E. CROSBIE is a Professor of Electrical and Computer Engineering at California State University, Chico. He is Director of the McLeod Institute of Simulation Sciences at CSUC. His current research interests include simulation methodology and distributed and real-time simulation.

RALPH C. HILZER is a Professor of Computer Science at California State University, Chico. His interests include simulation of parallel systems.

JOHN J. ZENOR is a Professor of Electrical and Computer Engineering at California State University, Chico. He is Associate Director of the McLeod Institute for Simulation Sciences at CSUC. His interests include distributed simulation and real-time operating systems.