Simulation Foundations, Methods and Applications

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Modelling and Simulation

Exploring Dynamic System Behaviour

Second Edition

Springer

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To our wives, Suzanne and Monique, and to
the next and future generations:
Christine, Jennifer, Alison
Amanda, Julia, Jamie, Aidan
and
Mika

Preface

Overview

Modelling and simulation is a tool that provides support both for the planning, design and evaluation of dynamic systems as well as the evaluation of strategies for system transformation and change. Its importance continues to grow at a remarkable rate, in part because its application is not constrained by discipline boundaries. This growth is also the consequence of the opportunities provided by the ever widening availability of significant computing resources and the expanding pool of human skill that can effectively harness this computational power. However the effective use of any tool, and especially a multi-faceted tool such as modelling and simulation, involves a learning curve. This book addresses some of the challenges that lie on the path that ascends that curve.

Consistent with good design practice, the development of this book began with several clearly defined objectives. Perhaps the most fundamental was the intent that the final product provide a practical (i.e., useful) introduction to the main facets of a typical modelling and simulation project. This objective was, furthermore, to include projects emerging from both the discrete-event and the continuous-time domains. In addition, the work was not to evolve into a treatise on any particular software tool, nor was it to be overly biased towards the statistical notions that play a key role in handling projects from the discrete-event domain. To a large extent, these objectives were the product of insights acquired by the first author over the course of several decades of teaching a wide range of modelling and simulation topics. Our view is that we have been successful in achieving these objectives.

Features

We have taken a project-oriented perspective of the modelling and simulation enterprise. The implication here is that modelling and simulation is, in fact, a collection of activities that are all focused on one particular objective; namely, providing a credible resolution to a clearly stated goal, a goal that is formulated within a specific system context. There can be no project unless there is a goal. All the constituent sub-activities work in concert to achieve the goal. Furthermore

the ‘big picture’ must always be clearly in focus when dealing with any of the sub-activities. We have strived to reflect this perspective throughout our presentation.

The notion of a conceptual model plays a central role in our presentation. This is not especially significant for projects within the continuous time domain inasmuch as the differential equations that define the system dynamics can be correctly regarded as the conceptual model. On the other hand, however, this is very significant in the case of projects from the discrete event domain because there is no generally accepted view of what actually constitutes a conceptual model in that context. This invariably poses a significant hurdle from a pedagogical point of view because there is no abstract framework in which to discuss the structural and behavioural features of the system under investigation. The inevitable (and unfortunate) result is a migration to the semantic and syntactic formalisms of some computer programming environment.

We have addressed this issue by presenting a conceptual modelling framework for discrete-event dynamic systems which we call the ABCmod framework (*A*ctivity *B*ased *C*onceptual *mod*elling). While this book makes no pretence at being a research monograph, it is nevertheless appropriate to emphasize that the ABCmod conceptual modelling framework presented in Chap. 4 is the creation of the authors. This framework has, furthermore, evolved substantially from the version presented in the first edition of this book.

The basis for the ABCmod framework is the identification of relevant ‘units of behaviour’ within the system under investigation and their subsequent synthesis into individual behavioural components called ‘activities’. The identification of activities as a means for organizing a computer program that captures the time evolution of a discrete-event dynamic system is not new. However in our ABCmod framework the underlying notions are elevated from the programming level to an abstract and hence conceptual level. A number of examples are presented in the text to illustrate conceptual model development using the ABCmod framework. Furthermore we demonstrate the utility of the ABCmod framework by showing how its constructs conveniently map onto those that are required in program development perspectives (world views) that appear in the modelling and simulation literature.

The Activity-Object world view presented in Chap. 6 is a recent outgrowth of continuing development of the ABCmod concept. This world-view preserves the activity perspective of the ABCmod framework and makes the translation of the conceptual model into a simulation model entirely transparent and simplifies the verification task.

Audience

This book is intended for students (and indeed, anyone else) interested in learning about the problem solving methodology called modelling and simulation. A meaningful presentation of the topics involved does necessarily require a certain level of technical maturity on the part of the reader. An approximate measure in this regard

would correspond to a science or engineering background at the senior undergraduate or the junior graduate level.

More specifically our readers are assumed to have a reasonable comfort level with standard mathematical notation which we frequently use to concisely express relationships. There are no particular topics from mathematics that are essential to the discussion, but some familiarity with the basic notions of probability and statistics play a role in the material in Chaps. 3 and 7. (In this regard, a Probability Primer is provided in Annex 1.) A reasonable level of computer programming skills is assumed in the discussions of Chaps. 5, 6, and 9. We use Java as our programming environment of choice in developing simulation models based on the Three-Phase world view and the Activity-Object world view. The GPSS programming environment is used to illustrate the process-oriented approach to developing simulation models. (We provide a GPSS Primer in Annex 2). Our discussion of the modelling and simulation enterprise in the continuous-time domain is illustrated using the numerical toolbox provided in MATLAB. A brief overview of relevant MATLAB features is provided in Annex 3.

Organization

This book is organized into three parts. The first part has two chapters and serves to provide an overview of the modelling and simulation discipline. It provides a context for the subsequent discussions and, as well, the process that is involved in carrying out a modelling and simulation study is presented. Important notions such as quality assurance are also discussed.

The five chapters of Part II explore the various facets of a modelling and simulation project within the realm of discrete event dynamic systems (DEDS). We begin by pointing out the key role of random (stochastic) phenomena in modelling and simulation studies in the DEDS realm. This, in particular, introduces the need to deal with data models as an integral part of the modelling phase. Furthermore there are significant issues that must be recognized when handling the output data resulting from experiments with DEDS models. These topics are explored in some detail in the discussions of Part II.

As noted earlier, we introduce in this book an activity-based conceptual modelling framework (the ABCmod framework) that provides a means for formulating a description of the structure and behaviour of a model that originates within the DEDS domain. An outline of this framework is provided in Part II. A conceptual model is intended to provide a stepping stone for the development of a computer program that will serve as the ‘solution engine’ for the project. This transition from an ABCmod conceptual model to simulation models based on both the Three-Phase and the process-oriented perspectives (world views) is outlined in Chap. 5. The presentation in Chap. 6 shows how the transition task to a simulation model based on the Activity-Object world view is considerably more straightforward and transparent.

There are three chapters in Part III of the book and these are devoted to an examination of various important aspects of the modelling and simulation activity within the continuous time dynamic system (CTDS) domain. We begin by showing how conceptual models for a variety of relatively simple systems can be formulated. Most of these originate in the physical world that is governed by familiar laws of physics. However, we also show how intuitive arguments can be used to formulate credible models of systems that fall outside the realm of classical physics.

Inasmuch as a conceptual model in the CTDS realm is predominantly a set of differential equations, the 'solution engine' is a numerical procedure. We explore several options that exist in this regard and provide some insight into important features of the alternatives. Several properties of CTDS models that can cause numerical difficulty are also identified.

Determining optimal values for some set of parameters within a CTDS model is a common project goal in a modelling and simulation study. The last chapter in Part III explores this task in some detail. We outline two particular numerical procedures that can be applied to optimization problems that arise in this context.

Web Resources

A website has been established to provide access to a variety of supplementary material that accompanies this book. Included is:

1. A set of PowerPoint slides from which presentation material can be developed.
2. An ABCmod tool that supports the development of discrete event conceptual models based on the framework.
3. A methodology for organizing student projects.

It is anticipated that the material at this site will not remain static and will instead be updated on a regular basis.

Acknowledgements

We would, first of all, like to acknowledge the privilege we have enjoyed over the years in having had the opportunity to introduce so many students to the fascinating world of modelling and simulation. In many respects, the material in this book reflects much of what we have learned in terms of 'best practice' in presenting the essential ideas that are the foundation of the modelling and simulation discipline.

We would also like to acknowledge the contribution made by the student project group called Luminosoft whose members (Mathieu Jacques Bertrand, Benoit Lajeunesse, Amélie Lamothe and Marc-André Lavigne) worked diligently and capably in developing the initial version of a software tool that supports the ABCmod conceptual modelling framework that is presented in this book. Our many discussions with the members of this group fostered numerous enhancements and refinements that would otherwise not have taken place. Their initial work has

necessarily evolved to accommodate the continuing evolution of the ABCmod framework itself. The current version of the support tool can be found at the website that has been established for material relating to this book.

The extensions and refinements that are embedded in this second edition of our original work have consumed substantial amounts of time. To a large extent this has been at the expense of time we would otherwise have shared with our families. We would therefore like to express our gratitude to our families for their patience and their accommodation of the disruptions that our preoccupation with this book project has caused on so many occasions. Thank you all!

Finally we would like to express our appreciation for the help and encouragement provided by Mr. Wayne Wheeler, Senior Editor, (Computer Science) for Springer. His enthusiasm for this project fuelled our determination to maintain a high level of quality in the presentation of our perspectives on the topics covered in this book. Thanks also to Mr. Simon Rees (Associate Editor, Computer Science) who always provided quick responses to our concerns and maintained a firm but nevertheless accommodating oversight over the timely completion of this project.

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