SYSTEM SIMULATION TECHNIQUES WITH MATLAB® AND SIMULINK®

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Foreword

It is a pleasure for me to write a foreword for this book by Dingyü Xue and YangQuan Chen. Dingyü came to the University of Sussex in 1988 to study for his DPhil with me. At the time, computing, relating to control engineering, was starting to move from Fortran to MATLAB, first on terminals connected to a central mainframe computer and then to standalone desktop machines. Digital simulation languages, which had replaced analog computers, were also heading in the same direction. The original version of MATLAB used on the mainframe was written in Fortran, followed by the much faster C version a few years later. One great advantage of MATLAB was that its fundamental data type was the matrix, the concept of which I first came across in the now little known language APL. APL was a very efficient coding language, so much so that a fair comment would be that it required as many lines of commenting as coding for a person to understand a program, and it also required a special keyboard. Other major features of MATLAB were the very good graph plotting facilities and the tools available for providing an excellent graphical user interface for a program. The graphical features provided for programming and for the display of results in Simulink were also a major improvement over the features of existing digital simulation languages.

In the early days of MATLAB, I had several general programs on the mainframe computer which used a question and answer interface and gave the output as a printed plot of points. Dingyü, in doing his research, developed a deep understanding of MATLAB and the capabilities of the GUI, one eventual result of which was the program CtrlLAB which is freely available from the MathWorks library. The genesis of this was a program described in my 1962 doctoral dissertation written in Manchester Autocode, which used paper tape to provide the data input and the values of points as output. Intermediate stages had seen its coding in APL and MATLAB using a question and answer format. Dingyü has therefore used MATLAB and Simulink avidly for the past 25 years, including, I suspect, most of the versions issued over that period. He has spent thousands of hours writing new code and modifying existing routines to be compatible, or to take advantage of new features in the changing versions of MATLAB and Simulink. I have known YangQuan Chen – whom Dingyü first met in Singapore about twenty years ago – for the past ten years. Since they first met, they have cooperated a lot with their complementary research interests being united by their use of MATLAB and Simulink.

This book is therefore written by two people who have had a wealth of first-hand experience of using MATLAB/Simulink in control engineering research and teaching its use to students in China and the USA in both mathematical and control-related courses for over two decades. Also, much of the material has been available in earlier versions of the book in Chinese, where it has been extremely well received, and it is used at many universities. Feedback from these publications has provided suggestions for improvements which have been incorporated here.

The coverage of the book is such that it provides a basic introduction to the use of MATLAB/Simulink before going on to address their usage in many facets of mathematics and engineering. After

covering the general aspects of programming and computation in MATLAB, details of applications in many areas of scientific computation are given, covering areas such as differential equations and optimization. Chapters 3–6 are primarily devoted to Simulink, starting from consideration of the functions of the various blocks and continuing to describe a variety of applications covering topics such as linear and nonlinear system simulations, multivariable systems, vectorized blocks, output blocks, the animation of results, linearization of nonlinear systems, S-functions and optimization in simulations. Chapter 7 discusses the more specific engineering application blocks for electronic systems, electrical drive systems and so on, that are available in Simscape, and in chapter 8 some simulation applications for non-engineering systems, image processing and finite state machines are described which show the wide applicability of modeling and simulation techniques.

I'm sure that this book with its many examples and problems will prove a major asset to you, the reader, in learning the simulation capabilities of MATLAB/Simulink, but as Dingyü and YangQuan would no doubt confirm, the only way to really learn is by the hard work of "doing". So attempt the exercises and also design your own to possibly clarify certain points and gain greater understanding.

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March 2013

Preface

As Confucius has said, "*The mechanic, who wishes to do his work well, must first sharpen his tools*", so MATLAB/Simulink is the right tool to solve problems in the field of systems simulation. It can free the scientist and engineer from tedious, laborious and error-prone work in low-level computer programming, and it is obvious that by the use of MATLAB and Simulink, the efficiencies of researchers can be significantly improved. In communities such as systems simulation and control engineering, MATLAB/Simulink is the de facto international computer language, and the importance of such a tool is being taught in universities worldwide.

Although MATLAB itself was developed and advocated by mathematicians, it was in fact first acknowledged by researchers in the engineering community, and in particular, by the researchers in the field of control engineering. The development of MATLAB and Simulink received a significant amount of innovative contribution from scholars and researchers in the field of control engineering. Already, a significant number of toolboxes and blocksets are oriented to control problems. MATLAB itself has extremely strong capabilities for solving problems in scientific computation and system simulation, with its handy graphical facilities and integrated simulation facilities. It is being used by researchers in more and more engineering and other scientific fields, and it has huge potential and great applications possibilities in related fields.

The authors have been consistently using MATLAB in education and scientific research since 1988, and have had some of their MATLAB packages added to MATLAB Central. A significant amount of first-hand knowledge and experience have been accumulated.

The first author started introducing MATLAB into education more than twenty years ago, and has tried to instruct students in the use such tools. For instance, the book "Computer-aided control systems design — MATLAB languages and applications" published by Tsinghua University Press was regarded as the first of its kind and one of the best in China and has been cited by tens of thousands of journal papers and books. The second author has had more than ten years of experience of scientific research and education in universities in the United States, after his work in industry. He has built up a lot of experience in MATLAB/Simulink based simulation as well as hardware-in-the-loop simulation and real-time design of control systems. Two other books have also been written by the authors and introduced into English world, concentrating on, respectively, the fields of automatic control and scientific computation.

The first edition of this present book was published by Tsinghua University Press in Chinese in 2002, and the second edition was published there in 2011. It has been used as a textbook and reference book by many universities in China. With evolution of MATLAB, Simulink and related products, a lot of new material and innovative work has emerged. It is not possible to cover all the material in one book, so the material here was carefully chosen, and tailored to meet the demands of engineering students and researchers in the revelent disciplines. The current shape of this book was finalized in the course at the Northeastern University, China, and also by offering seminars and

series lectures at Utah State University in the USA, at Baosteel Co. Ltd and at Harbin Institute of Technology in China. Based on the programming and educational experiences of over twenty years, the authors have finally debuted the book to the English-speaking world, and we feel sure that this book will be welcomed by readers worldwide.

The educational work in this book, together with other related educational work, was directed and encouraged by the former supervisors, Professors Xingquan Ren and Xinhe Xu of Northeastern University, China, and Professor Derek P Atherton at Sussex University, UK. It was they who guided the first author into the field of system simulation and, in particular, into the paradise of MATLAB/Simulink programming and education.

A lot of suggestions were received during the preparation of related books, and among them, the authors are in particular grateful for the help given by Professor Hengjun Zhu of Beijing Jiaotong University, the late Professor Jingqing Han of the Institute of System Sciences of Academia Sinica, Professor Xiaohua Zhang of Harbin Institute of Technology, China, and Professor Igor Podlubny of the University of Kosice, Slovakia.

Fruitful discussions with colleagues Drs Feng Pan, Dali Chen, Ying Wei, Jianjiang Cui, Liangyong Wang, Zheng Fang resulted in some new ideas and material in this book, and Zhuo Li in proofreading a draft of the book.

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