
Book Review

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Analytical Methods for Dynamic Modelers

by: Hazhir Rahmandad, Rogelio Oliva and Nathaniel D. Osgood

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Model-based analysis and optimisation plays an important role in a wide range of applications, such as architecture design of engineering systems, efficiency improvement of healthcare services, decision support of public strategies, etc. To complete such tasks, practitioners have to handle a series of problems, from model building to simulation, analysis, and optimisation. *Analytical Methods for Dynamic Modelers* edited by Hazhir Rahmandad, Rogelio Oliva, and Nathaniel D. Osgood, is a perfect book for audiences who are interested in the theories, techniques, or tools to solve the problems mentioned above. Both practitioners and theorists can benefit from this book.

The first step is to build a proper model that can reflect the dynamics of the targeted system, which is called *model building*. Techniques such as system identification, parameter estimation, state estimation, model calibration, or even simulation are involved in this step. This is exactly the content of the first section of this book, which is introduced using the first five chapters as below:

- Chapter 1 by Jeroen Struben, John Sterman, and David Keith discusses parameter estimation for a typical scenario in which the system structure is known but the system parameters are not. Likelihood maximum method and bootstrapping method are widely used techniques for parameter estimation and are introduced in detail in this chapter. The related theory, algorithm, codes, and a case study are also presented, which are especially helpful for practitioners.
- Chapter 2 by Mohammad S. Jalal, Hazhir Rahmandad, and Hamed Ghoddsi is about system identification for a scenario in which the system structure is also waiting for recognition. Although many techniques are developed for system identification in the literature, the method of simulated moments is emphasised in this chapter. A detailed recipe of this method and an application example are also introduced. These can help practitioners to understand and apply this method in practice.
- Chapter 3 by Peter S. Hovmand and Nishesh Chalise focuses on a statistical method called structural equation modelling that is also useful for parameter estimation. With this chapter, audiences can learn how to investigate the parameter estimation from the point of view of statistics. The relationship of multiple variables of systems, such as covariance analysis, is the emphasis of this chapter. Audiences can learn some statistical techniques that are definitely useful for model building in practice.
- Chapter 4 by Robert Eberlein talks about Kalman filtering, which is probably the most important progress of control theory over the past half century. With this chapter, audiences can learn how to apply Kalman filtering to recursively estimate the system state from a sequence of noisy observations. Data filtering techniques can help practitioners to compare and calibrate their estimated models even if only noisy observations are available.
- Chapter 5 by Nathaniel D. Osgood and Juxin Liu is mainly about simulation techniques, which is very important for model building especially when the system is too complicated or the available information is too little to build an accurate enough model in mathematical form. The Markov chain Monte Carlo method is one of the simulation techniques, which is often used to generate more samples when the available real samples are limited in practice. In some sense, we can view the sample generating source by Markov chain Monte Carlo as a special form of model building.

The second step is *model analysis* after a system model is built up. The system behaviour analysis, such as stability analysis, and the model calibration and validation are conducted in this step. We have to validate if the output of the model constructed complies with the system behaviours observed, thus model calibration may be conducted based on output comparison. The stability analysis or the performance evaluation can be investigated after the system

model is derived. There are many other topics that deserve discussion during the model analysis step. This book uses two chapters to introduce some key techniques.

- Chapter 6 by Gönenç Yücel and Yaman Barlas is mainly about model testing, calibration, and behaviour analysis. Audiences can learn technical methods for pattern recognition of system behaviours, including the widely used methods for clustering. Examples and detailed algorithm procedures are also included for easy understanding.
- Chapter 7 by Rogelio Oliva introduces a method called eigenvalue elasticity analysis to assess the effect of structure on behaviour in dynamic models, where eigenvalues are used as indicators to link the relation between the system structure and behaviour. With this technique, audiences may get some ideas about how the system will behave if the system structure or parameters are changed.

Decision support and optimisation is the third step, also the most useful techniques for practitioners, since most of their final objectives of investigation are to improve the system efficiency. This is a cross-discipline field. There are many different topics about optimisation, from mathematical programming to simulation-based optimisation, game theory, optimal control, data-driven learning, etc. The third section of this book has five chapters devoted to this field, to which audiences should pay great attention.

- Chapter 8 by Erling Moxnes gives an introduction to deterministic optimisation and stochastic optimisation for dynamic systems. Basic concepts and widely used methods of optimisation are introduced in this chapter, which are helpful for fresh practitioners to step in this field.
- Chapter 9 by Nathaniel D. Osgood, Karen Yee, Wenyi An, and Winfried Grassman studies a planning problem in a dynamic environment with uncertainty. Simulation modelling and decision tree are the main techniques to handle this dynamic decision problem. Audiences can learn how to construct a decision tree for a specific decision problem, through the demonstration of several practical examples in this chapter.

- Chapter 10 by Burcu Tan and Edward G. Anderson Jr. gives another case study about the application of decision tree. Audiences can learn how to use the decision tree method to solve a financial engineering problem, the valuation of managerial real options. From this case study, audiences can find how to organise the data, construct the decision tree, and derive the optimal policy under the framework of decision tree method.
- Chapter 11 by Edward G. Anderson Jr. and Nitin R. Joglekar investigates the topic of optimisation from the viewpoint of optimal control. Optimal control can be viewed as a counterpart of optimisation in the field of control theory, where the system state and optimisation variables are usually continuous and differentiable. Some key concepts, such as the LQG problem, reinforcement learning, policy iteration and value iteration, are also introduced in this chapter. This can be a good start for audiences interested in optimal control.
- Chapter 12 by Hazhir Rahmandad and Raymond J. Spiteri introduces the differential game that handles the optimisation problem of multiple players with competing interests among them. The basic concepts of differential games, including the problem formulation and Nash equilibrium, are introduced in this chapter. Algorithms for solving an example of differential game are also presented in detail, which may give audiences specific experiences about applying the model of game theory to practical problems.

In summary, this book gives a comprehensive introduction about the key techniques during the procedure of model building, analysis, and optimisation. The organisation of the book is clear and the relationship among chapters is consistent. The book is written in an easy to understand way, where many examples, case studies, tools, and exercises are included. The supplements of each chapter, such as R, MATLAB, Mathematica, and Vensim code files, are also available online. Audiences can easily understand and apply the techniques in this book to their own problems in practice. If you want to become a skilful modeller for handling practical problems, this book is definitely a very good recommendation.