Preface

The autopilot and main engine governor of a ship are typical examples of feedback systems that have a long history. Autopilot systems to maintain the heading angle of a ship in order to hold a desired course were developed by the Sperry Corporation in the 1910s, and since then helmsmen have become free from the arduous task of steering in course navigation. A governor mechanism to maintain the revolution rate of the engine shaft was invented much earlier than the autopilot system and can be traced back to the centrifugal governor invented by James Watt for regulating a steam engine in the eighteenth century. The classical control theory for designing these analog control systems has contributed to control in numerous mechanical systems.

In the latter half of the twentieth century, however, the circumstances of control engineering have changed rapidly due to dramatic developments in digital computers and microelectronics, and digital computers have overtaken analog systems in several fields. In the first stage of digital control, the analog control law was digitized to realize a digital control system. However, a more essential innovation in control system design was to apply the modern control theory based on the state-space model of the control system.

In the 1970s, modern control theory was also introduced, allowing innovations in ship autopilot systems. The critical problem in designing an autopilot system, however, is to obtain a model of the ship that can properly represent the complicated and inherently stochastic behavior of a ship at sea. Without a reasonable model of the control system, it is not possible to apply modern control theory, which is a bottleneck when applying modern control theory to complicated large systems with strong disturbance noise.

As a practical solution to this problem, Dr. Hirotugu Akaike proposed the use of the autoregressive (AR) model in the analysis and control of complicated systems. The crucial problem in statistical modeling was the identification of the model, including the selection of variables, model type, and model orders, and the estimation of unknown parameters. For this problem, he proposed final prediction errors (FPE) for identifying the stochastic behaviors of a cement rotary kiln system using a multivariate autoregressive (MAR) model, and generalized FPE to the

Akaike information criterion (AIC) for evaluating a more general statistical model. Many successful applications of analysis and control of complicated stochastic systems through statistical modeling based on AIC have appeared in the literature.

The purpose of this book is to present an appropriate time series modeling method for the analysis and control of complicated systems, for which it is difficult to obtain a precise model that can express the behavior of a controlled system based on the theory of the domain. Throughout this book, we will use multivariate autoregressive modeling with exogenous variables based on AIC. However, we will also consider a nonstationary version and a nonlinear version of the model to cope with real problems. A special feature of this book is to consider modeling, analysis, and control of a real ship's behavior at sea, and we herein develop various types of autopilot systems. We present not only the results of simulation studies, but also many results of actual sea tests. Although we treat only applications related to ships, we hope that the readers of this book will gain a deeper general knowledge and useful tools for the analysis and control of complicated systems and will be able to apply these methods to solve problems in their own fields.

This book is the result of long and intensive collaboration of three researchers who have different research fields. Kohei Ohtsu's research interests include the analysis, monitoring, and control of ship motions at sea using time series modeling techniques. He developed a novel autopilot system using an autoregressive model in cooperation with Genshiro Kitagawa in the 1970s. Hui Peng's research interests include nonlinear system modeling, nonlinear optimization, and optimal control. He developed a practical modeling technique for nonlinear time series using a radial bases function ARX model and, together with the two other authors of this book, recently succeeded in developing tracking control of a ship using this model. Genshiro Kitagawa's primary interests are in statistical modeling, nonstationary time series analysis, and optimal control of stochastic systems. He developed a Monte Carlo filter technique for a nonlinear state-space model which is now referred to as a "particle filter".

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