Preface

We are living in an era of rapidly developing technology. Dynamic systems control is not a new methodology, but it is heavily influenced by the development of technologies for sensing and actuating devices, data storage and communication. All these advances create new opportunities for the control based on data-driven models.

Systems control, especially systems control design, relies on mathematical models. These can be developed from an understanding of the underlying relations in the systems or from measurement data. The term for data-driven modelling used in the control community is system identification.

Increasingly complex systems have to be controlled, and this means that we are dealing with increasingly complex models. Examples of such systems are coming from the fields of biological systems, environmental systems, transportation networks, energy grids and others. This increased complexity triggers a strong need for new methods that deal with data in a scalable and robust way. System identification methods are usually based on statistical analyses, resulting in parametric or nonparametric mathematical models that can be used for systems analyses and control design. System identification methods are well established in the control community.

Large data sets provided with ever-better sensing devices require new identification methods, and this book is written with purpose of demonstrating a type of nonparametric model, coming mainly from the machine-learning community, for use in the applications of the engineering community. On the other hand, small data sets where larger amount of data is required for system identification is another border situation met in practice that also needs appropriate attention.

The particular aim of the book is to describe how Gaussian process (GP) models can be used for the design of dynamic systems control. System identification based on GP models is an integral part of the control design and its description as such also forms an integral part of this book. Using GP models for system identification is a relatively recent approach, where the research activities are very lively. Consequently, this book cannot give a complete picture of the application field,

rather it attempts to provide an overview of the current situation and opens up directions for further applications as well as further research options.

The book is intended to open up new horizons for engineers and researchers in academia and industry and all those who are dealing with, or who are interested in, new developments in the field of system identification and control. It addresses issues, some of which are of more interest to engineers and others to researchers. The emphasis is on guidelines for working solutions and on practical advice for their implementation. The emphasis is not on the theoretical background of GP models, for which other books exist, nor does it describes the basics of nonlinear systems identification; instead it shows the potential of the selected modelling method for use in dynamic-systems identification and control design. It is not written in a theorem/proof style. The mathematics is kept to a minimum. The emphasis of the book is on an intuitive understanding of the topic and on providing guidelines and case studies to facilitate practical applications.

An introductory course in nonlinear system identification, probability, statistics and computation intelligence methods is considered as the most appropriate prerequisite for reading this book.

The book was inspired by many years of research and involvement in applications using GP models. I thought it necessary to convey my experience and fascination with the topic to the audience in an integrated form. Since my first introduction to GP modelling more than a decade ago, I see GP modelling as a very handy tool for engineers working with dynamic systems and my wish is that this book conveys this fact.

The content of the book was developed over a few years, but the last three were focused on the book preparation itself. Research on this topic is very dynamic and I am well aware of the fact that I was not able to include everything that relates to GP models, system identification and control design. However, I hope I have enough content to convey the main features of using GP models when modelling dynamic systems and design control system with these models.

The book consists of five chapters that lead the reader from a basic understanding of GP models, via their application for system identification, to the use of the obtained models for system control. Real-life examples are presented to illustrate the explained concepts in the last chapter.

I wish to express my gratitude to the many people I have interacted with during my research on the topic and the writing of this book. I wish to thank Martin Stepančič, Kristjan Ažman, Dejan Petelin, Matej Gašperin, Bojan Likar, Djani Juričić, Stanko Strmčnik, and all my other colleagues from the Department of Systems and Control at the Jožef Stefan Institute. In addition, I would like to thank Alexandra Grancharova, Gregor Gregorčič, Jan Přikryl, Roderick Murray-Smith, David Murray-Smith, Douglas Leith, Bill Leithead, Agathe Girard, Carl Rasmussen, Joaquin Quiñonero Candela, Keith Thompson, Keith Neo and many others. They all helped me by proofreading draft material, or discussed the topic with me, or had a strong influence on my research.

I am very grateful to the Jožef Stefan Institute and the University of Nova Gorica for providing a highly stimulating research environment and for giving me the freedom to write this book. Thanks to Springer for all their support.

I would like to thank Miroslav Štrubelj for assisting me with drawing the figures and Paul McGuiness for improving the English language of the book.

Finally, I would like to thank my entire family for all their support throughout the years it has taken me to write this book.

Ljubljana Juš Kocijan
March 2015

http://www.springer.com/978-3-319-21020-9

Modelling and Control of Dynamic Systems Using Gaussian Process Models

Kocijan, J.

2016, XVI, 267 p. 117 illus., 17 illus. in color. With online files/update., Hardcover
ISBN: 978-3-319-21020-9