Springer Tracts in Advanced Robotics

Volume 46

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Probabilistic Reasoning and Decision Making in Sensory-Motor Systems

Springer

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ISBN 978-3-540-79006-8 e-ISBN 978-3-540-79007-5

DOI 10.1007/978-3-540-79007-5

Springer Tracts in Advanced Robotics ISSN 1610-7438

Library of Congress Control Number: 2008923577

Typesetting by the authors and Scientific Publishing Services Pvt. Ltd.

Printed in acid-free paper

5 4 3 2 1 0

springer.com

STAR (Springer Tracts in Advanced Robotics) has been promoted under the auspices of EURON (European Robotics Research Network)

To Edwin T. Jaynes

Foreword

At the dawn of the new millennium, robotics is undergoing a major transformation in scope and dimension. From a largely dominant industrial focus, robotics is rapidly expanding into the challenges of unstructured environments. Interacting with, assisting, serving, and exploring with humans, the emerging robots will increasingly touch people and their lives.

The goal of the new series of Springer Tracts in Advanced Robotics (STAR) is to bring, in a timely fashion, the latest advances and developments in robotics on the basis of their significance and quality. It is our hope that the greater dissemination of research developments will stimulate more exchanges and collaborations among the research community and contribute to further advancement of this rapidly growing field.

Probabilistic Reasoning and Decision Making in Sensory-Motor Systems by Pierre Bessire, Christian Laugier and Roland Siegwart provides a unique collection of a sizable segment of the cognitive systems research community in Europe. It reports on contributions from leading academic institutions brought together within the European projects Bayesian Inspired Brain and Artifact (BIBA) and Bayesian Approach to Cognitive Systems (BACS). This fourteen-chapter volume covers important research along two main lines: new probabilistic models and algorithms for perception and action, new probabilistic methodology and techniques for artefact conception and development. The work addresses key issues concerned with Bayesian programming, navigation, filtering, modelling and mapping, with applications in a number of different contexts.

The thorough discussion, extensive treatment, and wide span of the work unfolding in these areas reveal the significant advances in the methodologies and technologies. The two projects culminate with this important reference to the robotics and cognitive systems community on the current developments and new directions in the area of probabilistic reasoning. A fine addition to the STAR series!

Naples, Italy
February 2008

Bruno Siciliano
STAR Editor

Preface

Over the next decades, probabilistic reasoning will provide a new paradigm for understanding neural mechanisms and the strategies of animal behaviour at a theoretical level. This will raise the performance of engineering artefacts to a point where they will no longer be easily outperformed by the biological examples they are imitating.

The coordinated works presented in this book are motivated by this conviction and aim to advance in this direction.

The twin common scientific objectives are:

- to reconsider in the light of Bayesian probabilistic reasoning our methodology, models, algorithms and techniques for building artefacts for the "real world". We gain inspiration from the way living beings have evolved and adapted to the properties of their natural environments, and constructing robots that use these principles;
- to provide a firm Bayesian basis for understanding how biological systems may use probabilistic logic to exploit the statistical properties of their environments, both at the level of neural mechanisms and at the level of strategies, and to use robots to test the validity of these ideas.

To reach these objectives, three axes of research and development have been addressed:

- *Neural basis of probabilistic inference:* The objective of this first axis of research is to identify how the nervous system does (or at least may) implement probabilistic inference. This hypothesize to propose well-defined models of how probabilities are represented and manipulated, and to test predictions with psychophysical performance measures and studies of regional brain activation. The goal is to improve our understanding of neural mechanisms and derived new ideas for the implementation of probabilistic inference in engineering systems.
- *New probabilistic models and algorithms for perception and action:* The main goal of this second axis is to illustrate how probabilistic computation may

account for global behaviours of organisms in interaction with their environment. In this book, the focus is on specific questions concerning multisensory perception and motion control. New probabilistic models that explain the observed behaviours in humans and animals are proposed and some are implemented on autonomous robots.

- *New probabilistic methodology and techniques for artefact design and development:* The third axis' aim is to explore how the Bayesian inference and learning paradigm may be used to develop robots that acquire repertoires of reactive probabilistic behaviours (synergies) and build combinations, hierarchies and temporal sequences of these behaviours (strategies).

Using a common formalism and modeling methodology called *Bayesian Programming*, this book describes the main outcomes of the last two axes of research. The first axis, concerning the neural basis of Bayesian inference, is another story and is not addressed here.

This book is an outcome of two successive European projects: *BIBA*[1] (Bayesian Inspired Brain and Artifact) and *BACS*[2] (Bayesian Approach to Cognitive Systems).

The scientific results presented in this book mainly relies 12 PhD theses initiated during the BIBA project. They are also the result of strong collaborations with academic partners from both information sciences and life sciences: The Autonomous System Laboratory (ASL) from the Ecole Polytechnique Fdrale de Lausanne (EPFL) in Lausanne, Switzerland; the Gatsby Neuroscience Unit and the Department of Physiology of the University College of London (UCL) in London, United Kingdom; the E-Motion group, affiliated with the Centre National de la Recherche Scientifique (CNRS) and the Institut National de Recherche en Informatique et Automatique (INRIA) in Grenoble, France; the Nonlinear System Laboratory (NSL), affiliated with the Massachusetts Institute of Technology (MIT) in Boston, USA; the Laboratoire de Physiologie de la Perception et de l'Action (LPPA) from the Collge de France in Paris, France, the Department of Physiology of Cambridge University in the United Kingdom and The Institut de la Communication Parle (ICP), affiliated with CNRS in Grenoble, France.

Our first thanks go to the authors of the different papers appearing in this book and especially to the PhD students who did the essential work with much enthusiasm and cheerfulness: Miriam Amavizca, Francis Colas, Christophe Cou, Carla Cavalcante Koike, Julien Diard, Jean Laurens, Olivier Lebeltel, Ronan Le Hy, Kamel Mekhnacha, Cdric Pradalier, Guy Ramel, Jihene Serkhane, Adriana Tapus, Christopher Tay and Manuel Yguel.

We also would like to give a special thanks also to the scientific leaders of the different research groups who contributed through scientific discussions but who do not appear as authors of chapters of this book: Horace Barlow, Alain Berthoz, Peter Dayan, Tony Gardner-Medwin and Jean-Jacques Slotine. They were the instigators and inspirers of a large part of this work.

[1] IST-2001-32115
[2] FP6-IST-027140

Finally, we would like to thank Carole Bienvenue, Olivier Malrait and Jean-marc Bollon who took great care of all the administrative financial and technical edition questions related to the work presented in the book..

Grenoble, France
February 2008

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