Springer Tracts in Advanced Robotics
Volume 59

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Electroactive Polymer Gel Robots

Modelling and Control of Artificial Muscles

Springer

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ISBN 978-3-540-23955-0 e-ISBN 978-3-540-44705-4

DOI 10.1007/978-3-540-44705-4

Springer Tracts in Advanced Robotics ISSN 1610-7438

Library of Congress Control Number: 2009941047

Typeset & Cover Design: Scientific Publishing Services Pvt. Ltd., Chennai, India.

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)

Foreword

By the dawn of the new millennium, robotics has undergone a major transformation in scope and dimensions. This expansion has been brought about by the maturity of the field and the advances in its related technologies. From a largely dominant industrial focus, robotics has been rapidly expanding into the challenges of the human world. The new generation of robots is expected to safely and dependably co-habitat with humans in homes, workplaces, and communities, providing support in services, entertainment, education, healthcare, manufacturing, and assistance.

Beyond its impact on physical robots, the body of knowledge robotics has produced is revealing a much wider range of applications reaching across diverse research areas and scientific disciplines, such as: biomechanics, haptics, neurosciences, virtual simulation, animation, surgery, and sensor networks among others. In return, the challenges of the new emerging areas are proving an abundant source of stimulation and insights for the field of robotics. It is indeed at the intersection of disciplines that the most striking advances happen.

The goal of the 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 wider dissemination of research developments will stimulate more exchanges and collaborations among the research community and contribute to further advancement of this rapidly growing field.

The monograph written by Mihoko Otake combines ideas from chemistry and physics, material science and engineering for the revolutionary development of the so-called "gel robots". Electroactive polymers are introduced to build new types of muscular-like actuation for deformable robots. The coverage spans from modelling and design to the development, control and experimental testing. A number of methods are proposed for describing the shapes and motions of such systems. The results are demonstrated for beam-shaped gels curling around an object and starfish-shaped gel robots turning over.

This book is the outcome of the author's doctoral work and constitutes the first comprehensive monograph ever published in this fascinating new area. As such we warmly welcome it into the STAR series!

Naples, Italy
August 2009

Bruno Siciliano
STAR Editor

Preface

Electroactive polymers are candidate material to build artificial muscles. Performance of electroactive polymers is improving rapidly from the early 1990s, which attracts wide attention especially in the fields of robotics and polymer science. Artificial muscles, which generate force and change shapes, can potentially form a basis for the development of deformable robots. This will change the assumption of robotic design. For example, traditional robots with rigid bodies basically should not hit upon outer world, while deformable robots can interact with the environment gently and safely. Power assist suits, which are consisting of artificial muscles, will have affinity to human bodies. Different kinds of intelligence should be implemented for robots with active materials, because they are open system capable of exchanging matter and energy with external environments.

The main focus of this book is to propose methods for deriving a variety of shapes and motions of such machines, using a particular electroactive polymer gel. Mechanisms consisting of the gel, hereafter called 'gel robots', were designed, developed, and controlled experimentally. It includes: (1) a mathematical model of the gel to be applied for design and control of distributed mechanisms, (2) gel robots manufacturing and their driving systems, (3) control of gel robots for dynamic deformations. The results are demonstrated for beam-shaped gels curling around an object and starfish-shaped gel robots turning over. This book is the first comprehensive monograph in the world on deformable robots utilizing electroactive polymers with full of original simulation and experimental results.

Most studies on electroactive polymers (EAP) have been focusing on improving the material properties in the field of polymer science or on replacement of the conventional actuators in the field of robotics. In contrast, this book discusses the technical problems for developing novel class of deformable robots utilizing EAP instead of just replacing actuator parts. Varieties of shape and motion patterns are derived without changing material properties. Original model is proposed by the author and examined through numerous

simulations and experiments. The proposed motion control method based on the model actively using the nonlinearity of the material, which is unique.

This book is based on the Ph.D. dissertation of the author "Modeling, Design and Control of Electroactive Polymer Gel Robots" supervised by Professor Hirochika Inoue with the Department of Mechano-Informatics, the University of Tokyo. This book is open to wide range of readers who are interested in advanced science and technology. The concept of gel robots was proposed by the author, whose results have been presented at related research area: cybernetics, robotics and automation, autonomous systems, polymer science, electroactive polymers, smart materials and structures, and nonlinear chemical dynamics. The research was conducted by the author, from setting up the chemical facility for fabrication, to developing original hardware and software for building and controlling gel robots. Therefore, this book helps researchers in chemistry and physics, material science and engineering, mechanical, electrical, computer science and engineering.

This book is intended to be used for references of classes and courses which include but not limited to: physically based modelling, modelling and simulation, advanced robotics in computer science classes; advanced motion control, system identification in mechanical engineering classes; smart materials and structures in aerospace engineering classes; advanced materials, electroactive polymers in material science classes; electrochemistry in physical chemistry classes; nonlinear phenomena, nonlinear chemical dynamics in chemical physics classes. Of course, researchers and practitioners who start or have been to work on electroactive polymers will be benefited from this book. This book will also be utilized for computer aided design software which can design mechanical devices utilizing electroactive polymers. The author is looking forward to seeing and collaborating with the readers of this book in the future.

Kashiwa, Japan
August 2009

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