



Key Techniques of Navigation Control for Mobile Robots under Unknown Environment

Zixing Cai et al.

(TP-7422.31)

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科学出版社互联网入口

能源与动力分社: (010) 64003075 销售: (010) 64031535

E-mail: gengjianye@mail.sciencep.com

销售分类建议: 自动化 / 机电工程 / 电子信息

www.sciencep.com

ISBN 978-7-03-049864-9



定 价: 188.00 元

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China Science Press

2016

Responsible Editors: Jianye Geng Zhou Wu

图书在版编目(CIP)数据

未知环境中移动机器人导航控制理论与方法 = Key Techniques of Navigation Control for Mobile Robots under Unknown Environment; 英文 / 蔡自兴等著. —北京: 科学出版社, 2016. 9

ISBN 978-7-03-049864-9

I. ①未… II. ①蔡… III. ①移动式机器人-导航-自动控制系统-英文 IV. ①TP242
中国版本图书馆 CIP 数据核字(2016)第 212269 号

Published by Science Press
16 Donghuangchenggen North Street
Beijing 100717, P. R. China
Printed in Beijing

Copyright © 2016 by Science Press
ISBN 978-7-03-049864-9

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Preface

The issue of the navigation control theory and method for mobile robot in unknown environments is one of the international frontier research topics and is also one of the hot spot issues and the most difficult problems in the development of the intelligent robotics. The intelligent mobile robot is a kind of robotic system that can release autonomous navigation motion towards its object in the environment with obstacles and completes the desired tasks by means of sensing its environment and itself situation through sensors and other advanced techniques.

The contents of this book deal with the navigation control theory and method for mobile robot in unknown environments including the architecture, localization and mapping, obstacle detection, navigational strategy and fault diagnosis of mobile robot system etc. The breakthrough of these technologies in the book will produce positive influence in many fields. It will promote the research of many frontier discipline such as cognition science, pattern recognition, nonlinear control. It will drive the development of mobile robot navigation control system for spaceflight, ocean, military, architecture, traffic, industry and service and so on. It will also build theoretical and technical foundation for the application of mobile robot system such as unmanned exploring vehicles, unmanned emission car, unmanned transporter in the field of spaceflight, military, under ocean and nuclear industry.

During 2003 to 2008, I presided over the key project of National Natural Science Fund of China (NSFC), titled as "Navigation Control Theory and Method of Mobile Robot under Unknown Environment" (Grant No. 60234030) and the key project of National Basic Research Fund of China, titled as "Research on Theories and Methods of Synergetic Searching and Reconfiguration for Heterogeneous Multi-mobile Agents" (Grant No. A4120060159), which have passed the concluding acceptance checks and were comprehensive evaluation of outstanding in January 2007 and May 2009 respectively. During January 2009 to December 2012, I have also cooperatively presided over another key project of National Natural Science Fund of China, titled as "Key Scientific Issues of Vehicle's Intelligent Driving in Expressway" (Grant No. 90820302) in this area, and invited experts

at home and abroad to visit our research center and group. We also had exchanges and cooperation in-depth academic with the domestic and foreign counterparts. For about 10 years study, a number of achievements have obtained in fund project support and under the joint efforts of group members. More than 200 papers have been published in IEEE and other international journals and the important international conferences (ICRA, IROS, ICPR, etc).

These achievements are scattered in various magazine or in the form of the proceedings, which is not convenient to access and exchange for readers. Therefore, it is necessary to organize the project results as a book for presenting to the general robotic researchers home and abroad. Every authors of the book have been the key researchers engaged in and devoted to the projects for long years.

In this book the authors present mainly the research results in the navigation control theories and methods of mobile robot in unknown environments. The book exists 8 chapters. Chapter 1 gives A brief survey of mobile robot navigation theory and technology in unknown environments and some research progress of machine learning theory and approach in mobile robot navigation. Chapter 2 presents the architecture of mobile robot system in unknown environments and its examples. Chapter 3 studies the dynamic models and control of mobile robots, especially wheeled mobile robots, under unknown environments and several examples for stabilization and tracking control design. Chapter 4 discusses mobile robot localization and mapping such as dead reckoning localization and simultaneous localization and mapping, SLAM. Chapter 5 introduces the methods of obstacle detection for mobile robot in unknown environments. Chapter 6 inquires into the navigational strategy and path planning for mobile robot under the unknown environment. Chapter 7 investigates fault diagnosis by using the technique of computational intelligence for wheeled mobile robots under unknown environments. Chapter 8 prospects the mobile robot navigation control research in unknown environments. General speaking, this book should not be limited to, but at least possess the following features:

- (1) Put forwards one four-level system architecture of the hierarchical intelligent navigation control. The architecture possesses the feature of multi-resolution in the time and space, has shown good adaptability and has gotten successfully application to the high-speed unmanned driving system with structured environment, the safe driving of autonomous SUV in the environment of moderate relief, and the autonomous navigation of the mobile robot MORCS-1 in unknown

environment.

(2) Two effective solutions have been proposed for navigation and fault diagnosis of mobile robot. Firstly, proposed a topological modeling method based on approximate Voronoi boundary network (AVBN), and generate a method with virtual obstacle, and so provided one effective solution for connectedness of boundary network in complex environment with non-convex set. Secondly, aiming at the problem of the fault diagnosis and compensation a framework of adaptive particle filtering that combined two adaptive mechanisms, the proposal distribution adaptation with domain dependent and the particle number adaptation with domain independent, and so provided an efficient solution for solving the contradiction between estimated accuracy and efficiency of the particle filter.

(3) Created new control strategy and control theory for mobile robot in unknown environment. Put forwards a tracking control strategy in moving horizon, which enables the controller to automatically decrease the control performances to satisfy constraint when the unforeseen large disturbance appeared in the system, and when the large disturbance disappeared the controller enable to increase the control performances. In the aspect of non-holonomic control theory three control laws have been obtained which include the robust unified law of unicycle model in the uncertain quadratic curve, the unified law that completes practical calm and track task simultaneously in the case of slipping, and calm control law with limited time for single-chain type system. Besides, based on differential flatness theory a generated method of trajectory satisfied the non-integrity constraint and controlled variable constraint has been proposed.

(4) In the aspect of control with respect to nonholonomic constraints, a unified control law which can tackle stabilization and tracking control problems simultaneously is proposed using transverse function and Lyapunov redesign method. A path generation method based on differential flatness is proposed where both nonholonomic constraints and control constraints are satisfied. In order to deal with input constraints, exogenous disturbances and model uncertainties, receding horizon tracking strategy is proposed which can trade off the conflict of disturbances attenuation and constraints satisfaction.

(5) The contents of the book go from the easy to the difficult and complicated that could be educational and entirely self-contained, i. e. , potential readers not working in the field of the navigation control of mobile robot can appreciate the literature therein without prior knowledge and exposure.

Although there are many textbooks currently available in the fields of intelligent robots, robot localization and mapping, path planning, navigate control, we are proud to claim with our knowledge that our presented book possesses the following characteristics:

(1) Novel academic ideas reflect the latest progress of research in the field of mobile robot navigation control in unknown environment.

(2) More comprehensive and informative contents, including most aspects of research for mobile robot navigation control in unknown environment.

(3) Systematic and structured, unlike the general scientific or academic papers.

(4) The main authors have extensive experiences in book writing. The book connects the related theory with practice closely, and with good readability.

We greatly appreciate for the experts and scholars home and abroad who have given us much help during the book writing and publishing process. The special thanks would send to the National Science Foundation of China, NSFC, and its support. Besides, we are grateful to the graduates who have attended the national key projects and with or without writing the book, they have devoted their intelligence and power to the projects and the book.

The book has been written by Professors Zixing Cai, Hong Chen, Zhuohua Duan, Meiyi Li, Zhiqian Wen, Jinxia Yu and Doctors Xiaobing Zou, Baifan Chen, Ping Tan, Lu Wang, Linai Kuang as well as Yong Wang, Xingquan Gao, Binlu Wu and Xieyu Long etc. Zixing Cai charges of the chief editor, syllabus design and draft revision of the book. Ping Tan charges of the assistant of chief editor. The division of the written tasks are as follows: Chapter 1 by Lu Wang and Zixing Cai, Chapter 2 by Xiaobing Zou and Zixing Cai, Chapter 3 by Hong Chen and Zhiyong Liu, Chapter 4 by Baifan Chen and Xiaobing Zou, Chapter 5 by Jinxia Yu and Zhiqian Wen, Chapter 6 by Meiyi Li and Linai Kuang, Chapter 7 by Zhuohua Duan and Ping Tan, Chapter 8 by Lu Wang and Zixing Cai, Index by Zixing Cai. In my project working and book writing periods I have had the good fortune to work with many excellent people who have worked with me in my guidance and devoted their knowledge and efforts.

Owing to the time pressing and lack of experience in English monograph writing the misgivings and even mistakes in the book would be existed, and any suggestion and critical corrections are sincerely welcome.

We have found that the most literature on the navigation control of mobile

robot has been currently involved in mathematical model, which makes it hard for readers not working in this field or academia to follow and appreciate. For this reason, the book is primarily intended to be a bridge between professors and graduate students in universities, engineers practicing in industries, and also scientists working in research institutes. At the same time, many universities have established programs and courses in this new field, with many cross-faculty and inter-discipline research going on in this arena as well. Many graduate schools have established courses in this field, and many graduate students are engaging in the dissertation about the mobile robots also in some universities in China and the world. The book has provided and summarized new ideas and methods of mobile robot navigation control, which could be taken as reference for the research and design of mobile robots navigation control, and can also serve as a textbook for an intermediate to advanced module as part of control engineering, mechatronics, pattern recognition, machine learning, fault diagnosis and tolerant, etc. This book can also put used as an introductory material to fresh graduates joining the industry workforce to work on advanced machine control, machine failure analysis and prediction. We strongly believe that a significant number of potential readers exist for our proposed book among the professionals working in the engineering. We hope that this book can be fully appreciated by researchers and scientists working in research institutes, engineers working in industries, as well as professors and students working in universities.

Zixing Cai

July 17, 2016

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