

Closed-Loop Motion Control for Mobile Robotics

Rich recently came up with two closed-loop drive train designs for mobile robots. All it took were some inexpensive permanent magnet motors and a simple feedback scheme. In this article, he covers everything from PID control and tuning to trajectory generation and operational space control for two robot bases. He also explains the software.

The mechanical components that make up robots aren't getting much cheaper. That's the bad news. The good news, of course, is that electronics and processors continue their steady march toward higher performance and lower cost. As an engineer, you have to figure out how to use the extra resources and capabilities most effectively. In some cases, extra processing allows you to use lower-cost mechanical components, which can effectively reduce the system's overall cost.

With this idea in mind, I'll tackle the robot drive train armed with a modest amount of computing power. When I'm done, you'll have two different closed-loop drive train designs that would make R2-D2's head spin with envy. I'll show you how to accomplish this using inexpensive permanent magnet motors and a clever feedback scheme that requires no mechanical overhead. Let's begin by addressing the topic of motors.

MOTOR OPTIONS

Clearly, selecting a motor is one of the most important decisions to make when designing the drive train. If you've played with motors and gears, you've certainly developed the following intuition: more gear reduction results in less speed and more torque, and less gear reduction results in more speed and less torque. Modified RC servomotors, which are often used in robot drive trains, have large gear reductions (typically 300:1) resulting in high torques and low speeds. As a

result, robots that use them are typically slow. Large gear reductions make some problems easier, as you'll see, but no one wants a slow robot if they can help it. If you've used these motors, you might have wanted to trade in some torque for some speed.

The 9-V Lego motors shown in Photo 1 are readily available. They are part of the Mindstorms kit, so you can build the rest of your robot base out of Legos, which is a good thing for the mechanically challenged like me.

Fortunately, the Lego motor has much less gear reduction (14:1) and is well suited for attaching a wheel directly to the output shaft. If you've done this, you know that you get a quick robot, but it's difficult to control. Particularly, when you shut off power

to the motor, the robot takes much longer to stop. With less gear reduction, the robot will coast!

Sometimes stopping quickly is important (e.g., stairs ahead), or your robot may do something hazardous to its health. This brings up an important point: motors with high gear reductions stop quickly when power is removed. But this is a silly reason to use these motors. It's like telling a beginning driver to drive only in first gear to avoid getting into an accident. What the driver really needs is better driving skills. Similarly, what you need is a better motor controller.

CLOSING THE LOOP

A motor controller that doesn't receive any feedback information from the motor is an open-loop controller. The main advantage of open-loop controllers is simplicity. All that's required is a way to control the voltage or current going to the motor. The Lego Mindstorms RCX controller, for example, uses an open-loop motor controller that allows you to select from several voltages (by varying the pulse-width modulator duty cycle) depending on how much speed and torque you want to deliver to your robot's wheels.

A disadvantage of open-loop control is inaccuracy. Others include the inability to deal with uncontrollable variables such as bumps in a floor, inclines, and low batteries, which can create an undesirable situation by slowing or stop-



Photo 1—Lego is an excellent medium for implementing robots such as the four-wheeled HUMR. The Gameboy Advance acts as the controller and provides 32-bit RISC processing performance, a color LCD, and sound.

Closed Loop Motion Control For Mobile Robotics

Frank L. Lewis, Shuzhi Sam Ge



Closed Loop Motion Control For Mobile Robotics:

Mobile Robot: Motion Control and Path Planning Ahmad Taher Azar, Ibraheem Kasim Ibraheem, Amjad Jaleel

Humaidi, 2023-06-30 This book presents the recent research advances in linear and nonlinear control techniques. From both a theoretical and practical standpoint, motion planning and related control challenges are key parts of robotics. Indeed, the literature on the planning of geometric paths and the generation of time-based trajectories while accounting for the compatibility of such paths and trajectories with the kinematic and dynamic constraints of a manipulator or a mobile vehicle is extensive and rich in historical references. Path planning is vital and critical for many different types of robotics, including autonomous vehicles, multiple robots, and robot arms. In the case of multiple robot route planning, it is critical to produce a safe path that avoids colliding with objects or other robots. When designing a safe path for an aerial or underwater robot, the 3D environment must be considered. As the number of degrees of freedom on a robot arm increases, so does the difficulty of path planning. As a result, safe pathways for high-dimensional systems must be developed in a timely manner. Nonetheless, modern robotic applications, particularly those requiring one or more robots to operate in a dynamic environment (e.g., human robot collaboration and physical interaction, surveillance, or exploration of unknown spaces with mobile agents, etc.), pose new and exciting challenges to researchers and practitioners. For instance, planning a robot's motion in a dynamic environment necessitates the real-time and online execution of difficult computational operations. The development of efficient solutions for such real-time computations, which could be offered by specially designed computational architectures, optimized algorithms, and other unique contributions, is thus a critical step in the advancement of present and future-oriented robotics.

Adaptive Mobile Robotics Abul K. M. Azad, 2012 This book provides state-of-the-art scientific and engineering research findings and developments in the area of mobile robotics and associated support technologies. The book contains peer-reviewed articles presented at the CLAWAR 2012 conference. Robots are no longer confined to industrial and manufacturing environments. A great deal of interest is invested in the use of robots outside the factory environment. The CLAWAR conference series, established as a high-profile international event, acts as a platform for dissemination of research and development findings and supports such a trend to address the current interest in mobile robotics to meet the needs of mankind in various sectors of the society. These include personal care, public health services in the domestic public and industrial environments. The editors of the book have extensive research experience and publications in the area of robotics in general and in mobile robotics specifically, and their experience is reflected in editing the contents of the book.

Autonomous Mobile Robots in Unknown Outdoor Environments Xiaorui Zhu, Youngshik Kim, Mark A.

Minor, Chunxin Qiu, 2017-12-15 Mobile robots have been increasingly applied in many different scenarios such as space exploration and search and rescue, where the robots are required to travel over uneven terrain while outdoors. This book provides a new framework and the related algorithms for designing autonomous mobile robotic systems in such unknown

outdoor environments **Path Planning of Cooperative Mobile Robots Using Discrete Event Models** Cristian Mahulea, Marius Kloetzer, Ramon Gonzalez, 2020-01-09 Offers an integrated presentation for path planning and motion control of cooperative mobile robots using discrete event system principles Generating feasible paths or routes between a given starting position and a goal or target position while avoiding obstacles is a common issue for all mobile robots This book formulates the problem of path planning of cooperative mobile robots by using the paradigm of discrete event systems It presents everything readers need to know about discrete event system models mainly Finite State Automata FSA and Petri Nets PN and methods for centralized path planning and control of teams of identical mobile robots Path Planning of Cooperative Mobile Robots Using Discrete Event Models begins with a brief definition of the Path Planning and Motion Control problems and their state of the art It then presents different types of discrete models such as FSA and PNs The RMTTool MATLAB toolbox is described thereafter for readers who will need it to provide numerical experiments in the last section The book also discusses cell decomposition approaches and shows how the divided environment can be translated into an FSA by assigning to each cell a discrete state while the adjacent relation together with the robot's dynamics implies the discrete transitions Highlighting the benefits of Boolean Logic Linear Temporal Logic cell decomposition Finite State Automata modeling and Petri Nets this book also Synthesizes automatic strategies based on Discrete Event Systems DES for path planning and motion control and offers software implementations for the involved algorithms Provides a tutorial for motion planning introductory courses or related simulation based projects using a MATLAB package called RMTTool Robot Motion Toolbox Includes simulations for problems solved by methodologies presented in the book Path Planning of Cooperative Mobile Robots Using Discrete Event Models is an ideal book for undergraduate and graduate students and college and university professors in the areas of robotics artificial intelligence systems modeling and autonomous control

Autonomous Mobile Robots: Vehicles With Cognitive Control Alex Meystel, 1991-03-29 This book explores a new rapidly developing area of robotics It describes the state of the art in intelligence control applied machine intelligence and research and initial stages of manufacturing autonomous mobile robots A complete account of the theoretical and experimental results obtained during the last two decades together with some generalizations on Autonomous Mobile Systems are included in this book

Emerging Trends in Mobile Robotics Hideo Fujimoto, Mohammad Osman Tokhi, 2010 This book provides state of the art scientific and engineering research findings and developments in the area of mobile robotics and associated support technologies The book contains peer reviewed articles presented at the CLAWAR 2010 conference Robots are no longer confined to industrial manufacturing environments A great deal of interest is invested in the use of robots outside the factory environment The CLAWAR conference series established as a high profile international event acts as a platform for dissemination of research and development findings and supports such a trend to address the current interest in mobile robotics to meet the needs of mankind in various sectors of the society These include personal care public health and

services in the domestic public and industrial environments The editors of the book have extensive research experience and publications in the area of robotics in general and in mobile robotics specifically and their experience is reflected in editing the contents of the book

Control Problems in Robotics Antonio Bicchi, Henrik Christensen, Domenico Prattichizzo, 2007-07-12 The field of robotics continues to flourish and develop In common with general scientific investigation new ideas and implementations emerge quite spontaneously and these are discussed, used, discarded or subsumed at conferences in the reference journals as well as through the Internet After a little more maturity has been acquired by the new concepts then archival publication as a scientific or engineering monograph may occur The goal of the Springer Tracts in Advanced Robotics is to publish new developments and advances in the fields of robotics research rapidly and informally but with a high quality It is hoped that prospective authors will welcome the opportunity to publish a structured presentation of some of the emerging robotics methodologies and technologies The edited volume by Antonio Bicchi, Henrik Christensen and Domenico Prattichizzo is the outcome of the second edition of a workshop jointly sponsored by the IEEE Control Systems Society and the IEEE Robotics and Automation Society Noticeably the previous volume was published in the Springer Lecture Notes on Control and Information Sciences The authors are recognised as leading scholars internationally A number of challenging control problems on the forefront of today's research in robotics and automation are covered with special emphasis on vision, sensory feedback control, human centered robotics, manipulation, planning, flexible and cooperative robots, assembly systems

The navigation of mobile robots in non-stationary and non-structured environments Victor Vladareanu, Gabriela Tont, Luige Vladareanu, Florentin Smarandache, The paper presents the navigation of mobile walking robot systems for movement in non-stationary and non-structured environments In the first approach are presented main elements for the successful completion of intelligent navigation

Modeling and Control of a Tracked Mobile Robot for Pipeline Inspection Michał Ciszewski, Mariusz Giergiel, Tomasz Buratowski, Piotr Małka, 2020-03-18 This book describes the design, mathematical modeling, control system development and experimental validation of a versatile mobile pipe inspection robot It also discusses a versatile robotic system for pipeline inspection together with an original adaptable tracked mobile robot featuring a patented motion unit Pipeline inspection is a common field of application for mobile robots because the monitoring of inaccessible long and narrow pipelines is a very difficult task for humans The main design objective is to minimize the number of robots needed to inspect different types of horizontal and vertical pipelines with both smooth and rough surfaces The book includes extensive information on the various design phases, mathematical modeling, simulations and control system development In closing the prototype construction process and testing procedures are presented and supplemented with laboratory and field experiments

Adaptive Mobile Robotics - Proceedings Of The 15th International Conference On Climbing And Walking Robots And The Support Technologies For Mobile Machines Mohammad Osman Tokhi, Noah J Cowan, Abul K M Azad, Gurvinder S Virk, Roger D Eastman, 2012-07-11 This book provides

state of the art scientific and engineering research findings and developments in the area of mobile robotics and associated support technologies The book contains peer reviewed articles presented at the CLAWAR 2012 conference Robots are no longer confined to industrial manufacturing environments A great deal of interest is invested in the use of robots outside the factory environment The CLAWAR conference series established as a high profile international event acts as a platform for dissemination of research and development findings and supports such a trend to address the current interest in mobile robotics to meet the needs of mankind in various sectors of the society These include personal care public health services in the domestic public and industrial environments The editors of the book have extensive research experience and publications in the area of robotics in general and in mobile robotics specifically and their experience is reflected in editing the contents of the book

Emerging Trends In Mobile Robotics - Proceedings Of The 13th International Conference On Climbing And Walking Robots And The Support Technologies For Mobile Machines Hiromi Mochiyama, Mohammad Osman Tokhi, Hideo Fujimoto, Gurvinder S Virk, 2010-08-23 This book provides state of the art scientific and engineering research findings and developments in the area of mobile robotics and associated support technologies The book contains peer reviewed articles presented at the CLAWAR 2010 conference Robots are no longer confined to industrial manufacturing environments A great deal of interest is invested in the use of robots outside the factory environment The CLAWAR conference series established as a high profile international event acts as a platform for dissemination of research and development findings and supports such a trend to address the current interest in mobile robotics to meet the needs of mankind in various sectors of the society These include personal care public health and services in the domestic public and industrial environments The editors of the book have extensive research experience and publications in the area of robotics in general and in mobile robotics specifically and their experience is reflected in editing the contents of the book

Informatics in Control, Automation and Robotics Joaquim Filipe, Jean-Louis Ferrier, Juan Andrade Cetto, 2008-09-27 The present book includes a set of selected papers from the fourth International Conference on Informatics in Control Automation and Robotics ICINCO 2007 held at the University of Angers France from 9 to 12 May 2007 The conference was organized in three simultaneous tracks Intelligent Control Systems and Optimization Robotics and Automation and Systems Modeling Signal Processing and Control The book is based on the same structure ICINCO 2007 received 435 paper submissions from more than 50 different countries in all continents From these after a blind review process only 52 were accepted as full papers of which 22 were selected for inclusion in this book based on the classifications provided by the Program Committee The selected papers reflect the interdisciplinary nature of the conference The diversity of topics is an important feature of this conference enabling an overall perception of several important scientific and technological trends These high quality standards will be maintained and reinforced at ICINCO 2008 to be held in Funchal Madeira Portugal and in future editions of this conference Furthermore ICINCO 2007 included 3 plenary keynote lectures given by Dimitar Filev

Ford Motor Company Patrick Millot Universit de Valenciennes and Mark W Spong University of Illinois at Urbana Champaign

Intelligent Robotics and Applications Xuguang Lan,Xuesong Mei,Caigui Jiang,Fei Zhao,Zhiqiang Tian,2025-01-24 The 10 volume set LNAI 15201 15210 constitutes the proceedings of the 17th International Conference on Intelligent Robotics and Applications ICIRA 2024 which took place in Xi an China during July 31 August 2 2024 The 321 full papers included in these proceedings were carefully reviewed and selected from 489 submissions They were organized in topical sections as follows Part I Innovative Design and Performance Evaluation of Robot Mechanisms Part II Robot Perception and Machine Learning Cognitive Intelligence and Security Control for Multi domain Unmanned Vehicle Systems Part III Emerging Techniques for Intelligent Robots in Unstructured Environment Soft Actuators and Sensors and Advanced Intelligent and Flexible Sensor Technologies for Robotics Part IV Optimization and Intelligent Control of Underactuated Robotic Systems and Technology and application of modular robots Part V Advanced actuation and intelligent control in medical robotics Advancements in Machine Vision for Enhancing Human Robot Interaction and Hybrid Decision making and Control for Intelligent Robots Part VI Advances in Marine Robotics Visual Linguistic Affective Agents Hybrid augmented Agents for Robotics and Wearable Robots for Assistance Augmentation and Rehabilitation of human movements Part VII Integrating World Models for Enhanced Robotic Autonomy Advanced Sensing and Control Technologies for Intelligent Human Robot Interaction and Mini Invasive Robotics for In Situ Manipulation Part VIII Robot Skill Learning and Transfer Human Robot Dynamic System Learning Modelling and Control AI Driven Smart Industrial Systems and Natural Interaction and Coordinated Collaboration of Robots in Dynamic Unstructured Environments Part IX Robotics in Cooperative Manipulation MultiSensor Fusion and Multi Robot Systems Human machine Co adaptive Interface Brain inspired intelligence for robotics Planning control and application of bionic novel concept robots and Robust Perception for Safe Driving Part X AI Robot Technology for Healthcare as a Service Computational Neuroscience and Cognitive Models for Adaptive Human Robot Interactions Dynamics and Perception of Human Robot Hybrid Systems and Robotics for Rehabilitation Innovations Challenges and Future Directions *Advanced Mobile Robotics* DaeEun Kim,2020-03-06 Mobile robotics is a challenging field with great potential It covers disciplines including electrical engineering mechanical engineering computer science cognitive science and social science It is essential to the design of automated robots in combination with artificial intelligence vision and sensor technologies Mobile robots are widely used for surveillance guidance transportation and entertainment tasks as well as medical applications This Special Issue intends to concentrate on recent developments concerning mobile robots and the research surrounding them to enhance studies on the fundamental problems observed in the robots Various multidisciplinary approaches and integrative contributions including navigation learning and adaptation networked system biologically inspired robots and cognitive methods are welcome contributions to this Special Issue both from a research and an application perspective **Motion Control** Federico Casolo,2010-01-01 The book reveals many different aspects of

motion control and a wide multiplicity of approaches to the problem as well. Despite the number of examples, however, this volume is not meant to be exhaustive; it intends to offer some original insights for all researchers who will hopefully make their experience available for a forthcoming publication on the subject.

Wheeled Mobile Robotics Gregor Klancar, Andrej Zdesar, Saso Blazic, Igor Skrjanc, 2017-02-02. Wheeled Mobile Robotics: From Fundamentals Towards Autonomous Systems covers the main topics from the wide area of mobile robotics, explaining all applied theory and application. The book gives the reader a good foundation, enabling them to continue to more advanced topics. Several examples are included for better understanding, many of them accompanied by short MATLAB script code, making it easy to reuse in practical work. The book includes several examples of discussed methods and projects for wheeled mobile robots and some advanced methods for their control and localization. It is an ideal resource for those seeking an understanding of robotics mechanics and control and for engineers and researchers in industrial and other specialized research institutions in the field of wheeled mobile robotics. Beginners with basic math knowledge will benefit from the examples, and engineers with an understanding of basic system theory and control will find it easy to follow the more demanding fundamental parts and advanced methods explained. Offers comprehensive coverage of the essentials of the field that are suitable for both academics and practitioners. Includes several examples of the application of algorithms in simulations and real laboratory projects. Presents foundation in mobile robotics theory before continuing with more advanced topics. Self-sufficient to beginner readers, covering all important topics in the mobile robotics field. Contains specific topics on modeling, control, sensing, path planning, localization, design architectures, and multi-agent systems.

Handbook Of Industrial Automation Richard Shell, 2000-08-29. Supplies the most essential concepts and methods necessary to capitalize on the innovations of industrial automation, including mathematical fundamentals, ergonomics, industrial robotics, government safety regulations, and economic analyses.

Advances in Robots Trajectories Learning via Fast Neural Networks Jose De Jesus Rubio, Yongping Pan, Jeff Pieper, Mu-Yen Chen, Juan Humberto Sossa Azuela, 2021-05-14.

Autonomous Mobile Robots Frank L. Lewis, Shuzhi Sam Ge, 2018-10-03. It has long been the goal of engineers to develop tools that enhance our ability to do work, increase our quality of life, or perform tasks that are either beyond our ability, too hazardous, or too tedious to be left to human efforts. Autonomous mobile robots are the culmination of decades of research and development, and their potential is seemingly unlimited. Roadmap to the Future: Serving as the first comprehensive reference on this interdisciplinary technology. Autonomous Mobile Robots: Sensing, Control, Decision Making, and Applications authoritatively addresses the theoretical, technical, and practical aspects of the field. The book examines in detail the key components that form an autonomous mobile robot: from sensors and sensor fusion to modeling and control, map building and path planning, and decision making and autonomy, and to the final integration of these components for diversified applications. Trusted Guidance: A duo of accomplished experts leads a team of renowned international researchers and professionals who provide detailed technical

reviews and the latest solutions to a variety of important problems They share hard won insight into the practical implementation and integration issues involved in developing autonomous and open robotic systems along with in depth examples current and future applications and extensive illustrations For anyone involved in researching designing or deploying autonomous robotic systems Autonomous Mobile Robots is the perfect resource Engineering Providing of Industrial Development Wen Jin,2014-09-12 Selected peer reviewed papers from the 2014 2nd Asian Pacific Conference on Mechatronics and Control Engineering APCMCE 2014 August 8 9 2014 Hong Kong

The book delves into Closed Loop Motion Control For Mobile Robotics. Closed Loop Motion Control For Mobile Robotics is a vital topic that must be grasped by everyone, from students and scholars to the general public. This book will furnish comprehensive and in-depth insights into Closed Loop Motion Control For Mobile Robotics, encompassing both the fundamentals and more intricate discussions.

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 - Chapter 2: Essential Elements of Closed Loop Motion Control For Mobile Robotics
 - Chapter 3: Closed Loop Motion Control For Mobile Robotics in Everyday Life
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 - Chapter 5: Conclusion
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 6. In chapter 5, this book will draw a conclusion about Closed Loop Motion Control For Mobile Robotics. This chapter will summarize the key points that have been discussed throughout the book.
- The book is crafted in an easy-to-understand language and is complemented by engaging illustrations. It is highly recommended for anyone seeking to gain a comprehensive understanding of Closed Loop Motion Control For Mobile Robotics.

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