Precision Programming of Roving Robots

Project-Based Fundamentals of Wheeled, Legged and Hybrid Mobile Robots

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Series Editor's Preface

Dear Reader,

The ASME Press Robotics Engineering Book Series continues to present research and engineering accomplishments in the key areas of robotics. I am delighted to introduce a book by Dr. Francis Nickols and Dr. Yueh-Jaw Lin from the University of Nottingham Ningbo China. Entitled *Precision Programming of Roving Robots*, this book has launched a new area of our robotics publications, namely textbook supplements for undergraduate students. As specified in the subtitle, this book concerns with project-based fundamentals of wheeled, legged and hybrid mobile robots.

The authors has a notable experience of undergraduate and graduate teaching that is multiplied by engineering work in the automotive industry. A distinguished feature of the book is a mechatronics-based approach to mobile robots that is presented in a form of a lab operation manual to assist students with their projects and, thus, to comprehend a lecture course on roving robots. Remarkably, the book focuses on precision sensorless actuation of robot movements. Hence, the learning outcome of the book is the precision programming of robots to perform accurate behavior pattern movements.

The book can serve as a supplement to undergraduate courses on robotics engineering that allows students to learn course material "in action" by doing actual projects in the lab environment.

The Robotics Engineering Book Series is committed to both assisting eminent scholars in publishing their findings and introducing outstanding new researchers and educators to the world of books in Robotics. We look forward to close collaboration with researchers, engineers and academia around the world.

Vladimir V. Vantsevich, ScD, PhD, ASME Fellow
Founding Editor, ASME Press Robotics Engineering Book Series
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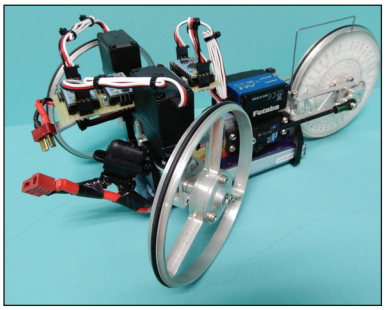
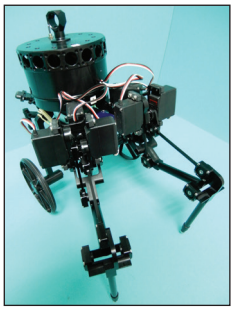
Preface

Project-Based fundamentals of wheeled, legged and hybrid robots

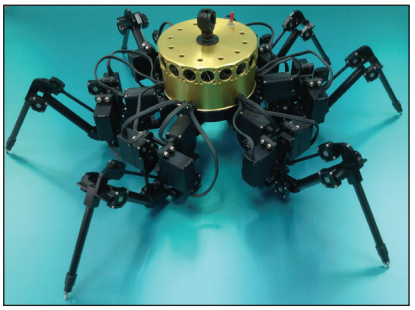
This book is designed primarily as a mechatronics and robotics textbook supplement for undergraduate students. More precisely it serves as a project-based laboratory operations manual for an academic course related to mobile roving robots. The book explains how to programme precision behaviour pattern motions in a ground plane using these three roving robots shown below.



The 'Tricycle' Robot
A 3-wheeled Robot



The 'Rickshaw' Robot
A 2-wheeled, 2-legged Robot



The 'Hexapod' Robot
A six-legged omnidirectional Robot

The three roving robots are graded in complexity from the all-wheeled Tricycle Robot through to the hybrid wheeled and legged Rickshaw Robot up to the most complex of the three, the all-legged Hexapod Robot. The precision programming of behaviour patterns for the three robots is demonstrated, evaluated and measured with a 'figure-of-eight' pattern that is marked out on to a 4.8metre × 2.4 metre table as shown below. Robots are programmed to travel consecutively from node 1 to node 2, then nodes, 5, 4, 3, 2, 5, 6 and back to node 1. Target 'bulls-eyes' at each node are given accuracy marks from 1 to 10 such that 10 marks are given for the robot stopping at the centre of the bulls-eye. *Sensor-less* dead-reckoning precision programming is used to programme the robot to travel through the figure-of-eight path. The book does not cover the design and programming of robots with sensors that measure quantities in the outside observed world. This is an important aspect since the authors believe that sensorless behaviour patterns are fundamental to actuated reactionary patterns that are built into biological systems. Sensors such as vision and touch sensors serve mainly to learn, to correct, or to fine-tune, built-in behaviour patterns.

Based on such a premise, this book solely concentrates on sensorless actuation of robot motion. For example, we as human beings are exercising sensorless behaviour patterns all the time; for example, the act of getting off our chair to stand up is to execute a particular actuated routine. Yes, your senses adjust the routine based on height of the chair and other factors, but largely it is a set muscular routine that is executed. So this is the flavour of the book, i.e. precision sensorless behaviour pattern actuation. You can imagine that this means your robot is blind-folded. As soon as your blind-folded robot can perform behaviour patterns accurately then sensors can be added further to improve its performance. Such programmed actuation is fundamental to robotics and forms the basis of the learning outcomes from this book.

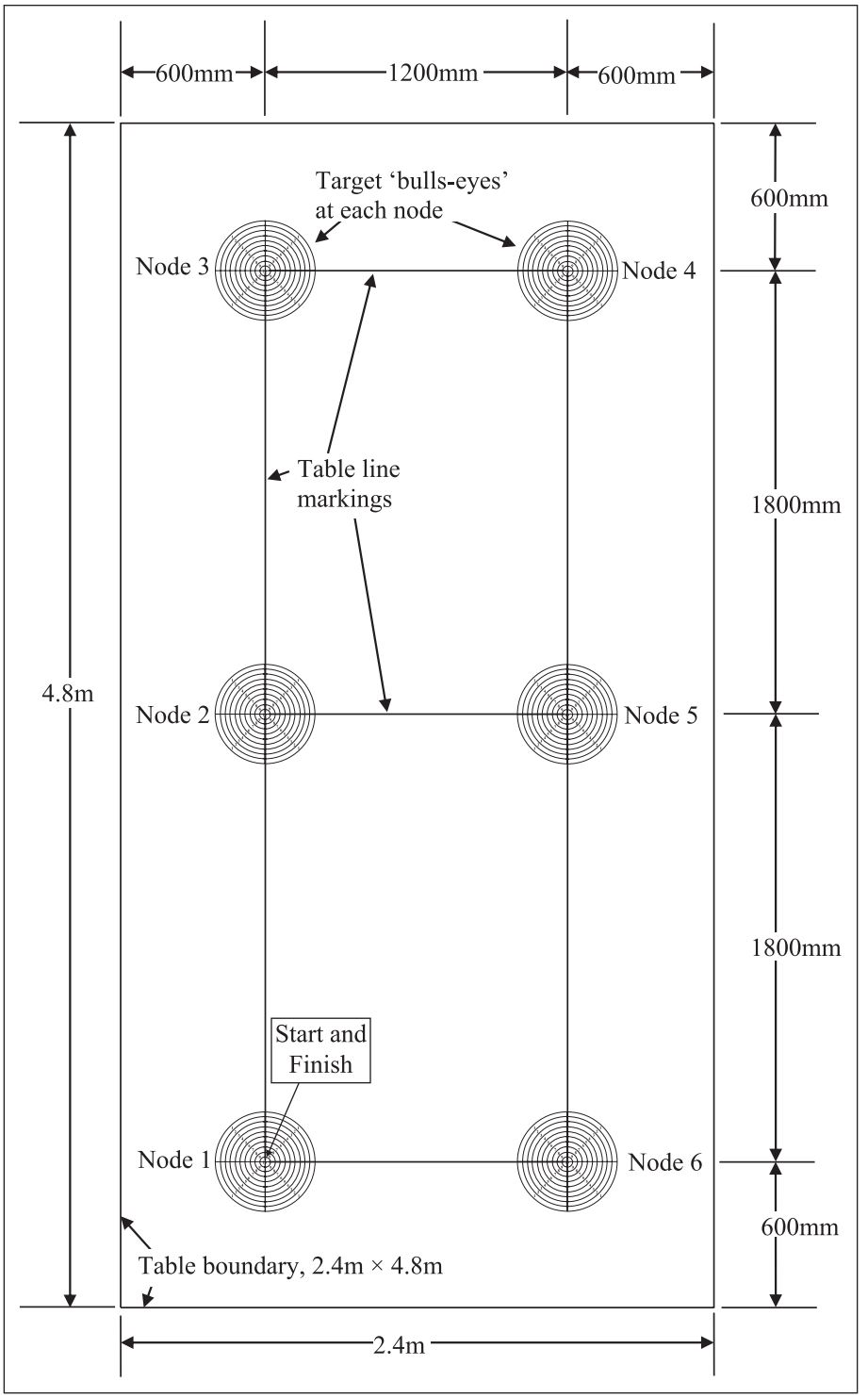


Diagram of the 'Vehicle Motion in a Ground Plane' table' showing nodes and target 'bulls-eyes'. This table is used to evaluate robot motion computer programmes.

The book is designed primarily as a mechatronics and robotics experiential and project-based teaching and learning platform for tertiary students. It is also graded in that starting with the Tricycle Robot, students build up their knowledge and experience of programming to be able to tackle the Rickshaw Robot and finally the most complex robot, i.e., the Hexapod Robot. As regards the academic level, the book is aimed at university and college students. However, nowadays the authors are seeing robotics curricula extending down into schools so this book can also be very useful for giving ideas to teachers at school level. Furthermore, the book provides useful ideas for driverless vehicles and robots as well as for educationalists who are developing practical project-based teaching and learning modules.

The book covers the concept of a robot turning about an Instantaneous Centre of Rotation, ICofR, and how a wheeled and/or legged robot is programmed to achieve such motion in a ground plane. Programming concepts move on to creating behaviour and motion patterns in legged robots eventually leading to the design of a hierarchical central pattern generator, CPG, for the hexapod robot. Early chapters are concerned with wheeled vehicles and how Taylor series equations are used to simplify complex inverse kinematic control equations. Wheeled vehicles serve as a smooth introduction to legged motion which suddenly becomes complex. Understanding wheeled motion lessens the sudden jump in understanding the complexity of programming legged motion.

The real time programming code is executed on Parallax.com Basic Stamp2 series microcomputers using the PBasic language which means 'Parallax Basic'. The language is very easy to learn and you get your robot up and running and operational very fast. Even though the programming language is straightforward, almost like writing short English instructions, you can develop complex real-time, parallel processing, interconnected, multi-cored microcomputer systems tailored to your own application. The book gives the code at all stages of the robot motion and behaviour pattern programming. Since the code is given in PBasic it is easy for students and readers to alter the code to use an alternative microcomputer to their liking. The choice of microcomputer and programming language is like politics and religion meaning that every robot constructor and programmer has his or her own views together with preferences as to the best hardware and software to use.

The robots featured in this book have all been created by the author and used in experiential project-based teaching and learning classes. Hence the book is tried and tested. The authors see themselves as teachers, mentors and coaches. This means that students are taught with both theoretical and experiential learning concepts and then as they gain proficiency, mentoring is gradually lessened. Students then begin to exhibit problem solving abilities, sometimes in novel ways, thus becoming promising inventors and autonomous learners and only needing teachers as sounding boards. This has certainly been the case when using the Tricycle Robot, the Rickshaw Robot and the Hexapod Robot in our classroom.

Acknowledgements

The authors would like to thank Dr. Mani Le Vasan, an expert in pedagogy, for her help, advice, persistence and encouragement in getting this book written. In fact, the book would always have been on 'Planet Procrastination' until she directed 'nose to the grindstone'. Not only has Mani, a prolific author herself, been a tower of strength in the book's creation but she has also been an inspirational coach who has constantly provided guidance and gems of advice every step of the way.