

# Contents

|   |               |
|---|---------------|
| <b>1 Mobile Robot Navigation .....</b>  | <b>1</b>      |
| 1.1 Autonomous Mobile Robot Navigation .....  | 1             |
| 1.2 Why Vision in Navigation?.....  | 1             |
| 1.3 Vision-Based Navigation .....   | 3             |
| 1.3.1 Vision Based Indoor Navigation .....  | 4             |
| 1.3.1.1 Map-Based Navigation .....  | 4             |
| 1.3.1.2 Map-Building-Based Navigation.....  | 4             |
| 1.3.1.3 Mapless Navigation .....  | 5             |
| 1.3.2 Vision Based Outdoor Navigation.....  | 6             |
| 1.4 State of the Art .....  | 6             |
| 1.5 Obstacle Detection and Avoidance .....  | 12            |
| 1.6 Summary .....   | 14            |
| References .....  | 14            |
| <br><b>2 Interfacing External Peripherals with a Mobile Robot .....</b>                               | <br><b>21</b> |
| 2.1 Introduction .....  | 21            |
| 2.2 PIC Microcontroller Based System for Interfacing a Vision System<br>with a Ready-Made Robot ..... | 23            |
| 2.3 The Integrated System Employing KOALA Robot with a PC<br>and a Vision System .....                | 34            |
| 2.4 Real-Life Performance Evaluation .....  | 39            |
| 2.5 Summary .....   | 45            |
| Acknowledgement.....  | 45            |
| References .....  | 45            |
| <br><b>3 Vision-Based Mobile Robot Navigation Using Subgoals .....</b>                                | <br><b>47</b> |
| 3.1 Introduction .....  | 47            |
| 3.2 The Hardware Setup.....   | 49            |
| 3.3 A Two-Layer, Goal Oriented Navigation Scheme .....  | 52            |
| 3.4 Image Processing Based Exploration of the Environment in Layer 1 .....                            | 53            |
| 3.5 Shortest Path Computation and Subgoal Generation .....  | 58            |
| 3.6 IR Based Navigation in Layer 2 .....  | 62            |
| 3.7 Real-Life Performance Evaluation .....  | 63            |
| 3.8 Summary .....   | 80            |
| Acknowledgement.....  | 81            |
| References .....  | 81            |

|          |  |            |
|----------|--|------------|
| <b>4</b> | <b>Indigenous Development of Vision-Based Mobile Robots.....</b>                         | <b>83</b>  |
| 4.1      | Introduction .....   | 83         |
| 4.2      | Development of a Low-Cost Vision Based Mobile Robot.....                                 | 84         |
| 4.3      | Development of Microcontroller Based Sensor Systems<br>for Such Robots .....             | 85         |
| 4.3.1    | IR Range Finder System with Dynamic Range Enhancement.....                               | 85         |
| 4.3.1.1  | The Dynamic Range Enhancement Algorithm.....   | 88         |
| 4.3.1.2  | Experimental Results .....   | 89         |
| 4.3.2    | Optical Proximity Detectors Using Switching-Mode Synchronous<br>Detection Technique..... | 89         |
| 4.3.2.1  | PIC Microcontroller Based Optical Proximity<br>Detector .....                            | 90         |
| 4.3.2.2  | Switching Mode Synchronous Detection (SMSD)<br>Technique .....                           | 94         |
| 4.3.2.3  | Experimental Results .....   | 96         |
| 4.4      | The Intranet-Connectivity for Client-Server Operation .....                              | 97         |
| 4.5      | Summary .....  | 99         |
|          | References .....   | 100        |
| <b>5</b> | <b>Sample Implementations of Vision-Based Mobile Robot Algorithms.....</b>               | <b>101</b> |
| 5.1      | Introduction .....   | 101        |
| 5.2      | Lesson 1 .....   | 102        |
| 5.3      | Lesson 2.....  | 108        |
| 5.4      | Lesson 3.....  | 113        |
| 5.5      | Lesson 4.....  | 116        |
| 5.6      | Lesson 5.....  | 119        |
| 5.7      | Lesson 6.....  | 124        |
| 5.8      | Lesson 7.....  | 129        |
| 5.9      | Lesson 8.....  | 132        |
| 5.10     | Lesson 9.....  | 134        |
| 5.11     | Lesson 10.....   | 137        |
| 5.12     | Summary.....   | 141        |
|          | References .....   | 142        |
| <b>6</b> | <b>Vision Based Mobile Robot Path/Line Tracking .....</b>                                | <b>143</b> |
| 6.1      | Introduction .....   | 143        |
| 6.2      | A Preview of the Proposed Scheme.....  | 144        |
| 6.3      | A Fuzzy System for Vision Based Robot Navigation.....                                    | 146        |
| 6.4      | The IR-Sensor Based Obstacle Avoidance by Employing a Fuzzy<br>Algorithm .....           | 155        |
| 6.5      | Real-Life Performance Evaluation .....   | 158        |
| 6.6      | Summary.....   | 165        |
|          | Acknowledgement .....  | 165        |
|          | References .....   | 165        |

|  |            |
|--|------------|
| <b>7 Simultaneous Localization and Mapping (SLAM) in Mobile Robots .....</b>   | <b>167</b> |
| 7.1 Introduction .....   | 167        |
| 7.2 Extended Kalman Filter (EKF) Based Stochastic SLAM Algorithm .....   | 170        |
| 7.3 Neuro-fuzzy Assistance for EKF Based SLAM .....  | 176        |
| 7.4 The Neuro-fuzzy Architecture and Its Training Methodology<br>Employing Particle Swarm Optimization (PSO) .....           | 180        |
| 7.4.1 Architecture of the Neuro-fuzzy Model .....  | 180        |
| 7.4.2 Training the Neuro-fuzzy Model Employing PSO .....   | 181        |
| 7.4.3 Performance Evaluation .....   | 184        |
| 7.5 Training a Fuzzy Supervisor Employing Differential Evolution<br>(DE) Based Optimization .....                            | 193        |
| 7.5.1 Performance Evaluation .....   | 194        |
| 7.6 Summary.....   | 203        |
| Acknowledgement .....  | 203        |
| References .....   | 203        |
| <b>8 Vision Based SLAM in Mobile Robots.....</b>   | <b>207</b> |
| 8.1 Introduction .....   | 207        |
| 8.2 The Dynamic State Model for the Differential Drive Koala Robot.....  | 208        |
| 8.3 Vision Sensing Based Image Feature Identification, Feature Tracking<br>and 3D Distance Calculation for Each Feature..... | 211        |
| 8.4 Real-Life Performance Evaluation .....   | 215        |
| 8.5 Summary.....   | 220        |
| Acknowledgement .....  | 221        |
| References .....   | 221        |
| <b>Index .....</b>   | <b>223</b> |