Embedded Robotics

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From Mobile Robots to Autonomous Vehicles with Raspberry Pi and Arduino

Fourth Edition

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Preface

This book gives a practical, in-depth introduction to embedded systems and autonomous robots, using the popular Raspberry Pi and Arduino microcontrollers. We demonstrate how to build a variety of mobile robots using a combination of these controllers, together with powerful sensors and actuators. Numerous application examples are given for mobile robots, which can be tested either on the real robots or on our freely available simulation system *EyeSim*.

This book combines teaching and research materials and can be used for courses in embedded systems as well as in robotics and automation. We see laboratories as an essential teaching and learning method in this area and encourage everybody to reprogram and rediscover the algorithms and systems presented in this book.

Although we like simulations for many applications and treat them in quite some depth in several places in this book, we do believe that students should also be exposed to real hardware in both areas, embedded systems and robotics. This will deepen their understanding of the subject area and, of course, create a lot more fun, especially when experimenting with small mobile robots.

We started this robotics endeavor over twenty years ago, when we first interfaced a digital image sensor to our own processor board. The *EyeBot-1* was based on a Motorola 68332 and our own operating system *RoBIOS*. The controller was soon followed by a variety of driving, walking, flying, swimming and diving robots that we called the EyeBot family. More powerful (and more expensive) controller architectures followed, until the availability of cheap, powerful boards like the Raspberry Pi and the Arduino Uno let us reconsider our approach. We redesigned our robot family around these popular controllers, but maintained the look and feel of our easy-to-use operating software.

Even on the simulation side, we have gone new ways. Our original stand-alone robot simulation has now been replaced by our new *EyeSim VR* package, which uses the Unity game environment with a much more realistic physics engine. The companion book *Robot Adventures in Python and C* (Springer 2020) concentrates on the software aspect of mobile robots and extends the hardware/software approach of this book.

For any embedded application, the processor power (and cost) needs to match to the given problem. For low-level control of a mobile robot with two DC motors and a few simple sensors, an 8-bit controller such as the Arduino might be sufficient. However, if we want to do image processing or learning, we need a more powerful controller like the 32-bit Raspberry Pi.

The EyeBot family consists of mobile robots with all sorts of propulsion systems. We and numerous other universities use these robots and simulation systems for laboratory experiments in embedded systems as part of the computer engineering, electrical engineering and mechatronics curriculum.

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Working on the RoBIOS robot operating system were Remi Keat (base system), Marcus Pham (high-level control), Franco Hidalgo (low-level control) and Klaus Schmitt (driving routines).

The EyeBot controller board layout was done by Ivan Neubronner, and the EyeSim VR simulator was implemented by Travis Povey (Unity), Joel Frewin (robot models and applications), Michael Finn (terrain, underwater, swarms) and Alexander Arnold (VR).

The following colleagues and former students contributed to this book: Adrian Boeing on the evolution of walking gaits, Mohamed Bourgou on car detection and tracking, Christoph Braunschädel on PID control graphs, Louis Gonzalez and Michael Drtil on AUVs, James Ng on Bug and Brushfire algorithms, David Venkitachalam on genetic algorithms, Joshua Petitt on DC motors, Bernhard Zeisl on lane detection, Alistair Sutherland on balancing robots, Jordan King on traffic sign recognition and Nicholas Burleigh on deep learning for autonomous driving.

Additional Materials

All system software discussed in this book, the RoBIOS operating system, C/C++ compilers for Windows, MacOS and Linux, system tools, image processing tools, simulation system, and a large collection of example programs are available free from:

http://robotics.ee.uwa.edu.au/eyebot/

http://robotics.ee.uwa.edu.au/eyesim/

Software specific to the Raspberry Pi and Arduino (Nano) controllers can be downloaded from:

http://robotics.ee.uwa.edu.au/rasp/

http://robotics.ee.uwa.edu.au/nano/

As further reading, please refer to our companion book on programming of mobile robots: *Robot Adventures in Python and C*. This book makes heavy use of the EyeSim simulator, so it can be used for practical experiments without the need for a physical robot.

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