Adaptive Behavior 2001, 9(2), 000-000

Book Review

Unifying Artificial Intelligence Robotics: An Undergraduate Textbook

Introduction to AI Robotics. Robin R. Murphy. MIT Press/Bradford Books (2000). Hardcover, 466 pages, $50.00

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Robotics as a discipline has been active for more than 40 years and encompasses a wide range of disjoint subfields. Although there is a surfeit of undergraduate-level textbooks in robotics, history has checked the development of texts appropriate for an undergraduate course from the artificial intelligence (AI) perspective. Robin Murphy's *Introduction to AI Robotics* (*IAIR*) is a new undergraduate text that partially succeeds in remedying this omission.

Historically, by far the most developed subfield of robotics is engineering robotics, characterized by a precise mathematical description of the physical properties of the robot (kinematics), and techniques for using this description to execute planned sequences of motions (control theory). The approach is successful for controlling manipulator arms to perform precise, repeatable actions, making them ideal for manufacturing, but engineering robotics never really addresses the problem of enabling the robot to select actions in unforeseen situations. This can be problematic once a robot has a means of locomotion and can get itself into serious trouble. AI robotics developed in parallel to engineering robotics to address this question: How should a mobile robot make decisions for itself?

AI robotics is generally regarded to have begun in the 1960s with AI planning techniques still in use today. A robot using these techniques senses the environment, builds a model of the environment, searches for an optimal plan, and then acts based on that plan. Despite numerous difficulties with this approach, it continued to dominate until the 1980s, when several researchers (most visibly Rodney Brooks at MIT) began to point out that we could mitigate many of these difficulties by taking inspiration from biology. The result of this activity was behavior-based (or reactive) robotics, a subfield of AI Robotics, where the robot is controlled by a collection of miniature programs, each of which is a tightly coupled mapping from a subset of sensor input to a motor output. The inspirations that led to the establishment of behavior-based robotics were the same ones that led to the development of the field of adaptive behavior. The genesis of these fields and the revolution centred around them splintered AI robotics with such force that only now is the dust beginning to settle.

Unsurprisingly given this volatile history, there has been a lack of an appropriate undergraduate textbook for teaching robotics from the computer science and artificial, intelligence perspective. Such a text would need to take into account that few undergraduates can be assumed to have already taken AI courses; allow flexibility in the robotic platform used; and most importantly, it must unify and put in perspective the recently fractured field of robotics. The vast majority of texts in robotics are in engineering robotics. One popular text [*Introduction to Robotics* by McKerrow, (1991)] spends 431 pages on kinematics, 200 pages on the engineering of sensors and control theory, and only 114 pages on issues connected to mobile intelligent robotics. Some texts, such as Jones and Flynn's *Mobile Robots: Inspiration to Implementation* (Jones & Flynn, 1993), cover appropriate AI material but focus on a single robotic platform (in this case the Rug Warrior). Collections of papers, such as *Artificial Intelligence and Mobile Robots* (Kortenkamp, Bonasso, & Murphy, 1998) can be successful as a text because of their flexibility, but they lack cohesion and are more suitable for

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a second course in a particular topic. Consensus on Usenet[1] is that Ronald Arkin's *Behavior-Based Robotics* (Arkin, 1998) is the best textbook from the AI perspective. In many ways it is a great book, but it is geared more for a graduate course, and it has a narrow focus on behavior-based robotics.

Recently, MIT Press introduced *IAIR*, which appears to fill this textbook gap. *IAIR* certainly has the proper pedigree to be the standard text. Robin Murphy, a former student of Arkin's at Georgia Tech, has been a prominent researcher in robotics for a decade. Besides establishing an impressive research record[2] she has also been an active organizer of robot events and competitions, including acting as the chair for three AAAI robot competitions. Her book both succeeds and fails in its mission; it contains some major flaws, yet still manages to fill most of the gap it set out to fill.

The book is divided into two parts: robotic paradigms, and navigation. At first, this seems an odd division, much like classifying food into separate categories: fruit and yellow, but in retrospect it makes a certain sense. Robotic paradigms is essentially a mini-book on software engineering for robotics. Navigation is then presented as a fundamental skill necessary for all mobile robots, regardless of architecture, and the one skill we know the most about. *IAIR* actually opens with a brief synopsis of part I, which serves to sever part I from part II conceptually, and then much of it is promptly repeated in Chapter 1. It would have been better to have the opening material emphasize the connections between the major parts. This aside, the introductory chapters, including the de rigeur history of robotics, persent a solid motivational foundation of the text.

Chapter 2 begins the serious content with a discussion of traditional AI robotics using planning techniques. Calling it the "hierarchical paradigm," the chapter presents the planning model with a clear example with enough detail to allow even the most inattentive student to follow along. Chapter 3 presents some of the ideas form biology that are developed into the reactive paradigm in Chapter 4. Here the core of the Behavior-based approach is presented, including the ideas of subsumption architecture and potential fields, followed by an entire chapter of examples and case studies of building reactive robots. At this point, there is a digression into sensors and how they affect the robot, followed by a return to the paradigms, with a discussion of hybrid architectures that combine behavior-based and planning controllers. Part I ends with a discussion of social robotics, that is, managing teams of robots working together.

Navigation in Part II is broken into path planning (figuring out how to get from here to there) and localization and map making (figuring out where the robot is on a map and building a map from scratch). The former is broken into topological path planning (essentially the use of landmarks in navigation) and metric path planning (converting maps to graphs and searching them). The chapter on map making and localization is the most in-depth of the book, performing a side-by-side comparison of Bayesian, Dempster-Shafer, and Histogramic In-Motion Mapping techniques. The chapter "On the Horizon" concludes Part II and the book with a discussion of the possible futures of AI robotics.[3] The final chapter emphasizes robots that can change their morphology, and applications of robots to the real world where they interact with (non-computer-science) people.

The key contribution of *IAIR* is its broad coverage of all AI robotics, touching on all the major issues, putting the pieces in perspective, and unifying the field in a way a typical undergraduate can grasp. It presents the material so that it can be easily understood, and that material is consistently accompanied by well-chosen, detailed examples, and interesting case studies. In addition, the book has other enjoyable features. Each chapter begins with a list of objectives, which helps students focus for exams. The exercises are interesting and creative, including simple chapter summary questions, numerical problems, advanced reading, web searching; some even require students to watch science fiction movies. The book often breaks up the technical material with bits of humor and pop-culture references to keep the students interested (though many, like the reference to Jones and Flynn's book as *Inspiration to Perspiration*, will be over their heads). In the same manner, each chapter's end notes are filled with interesting anecdotes about the people, places, and robots that make up the field. Finally, in a few places are true gems of exposition, such as the recasting of Brook's subsumption architecture in terms of the more general behavior-based model.

The book is not without its flaws, however. There are a number of errors of fact or judgment. For example, the use of the term "hierarchical paradigm" to describe the planning-based approach not only is incorrect in that there is nothing hierarchical about them, but also distracts the reader from true hierarchies, such as Rosenblatt's or Tyrell's action selection mechanisms, (Payton, Rosenblatt, & Keirsey, 1990; Tyrrell, 1993). A second example occurs in

the discussion of A* search, where the meaning of the notation $f^*(n)$ is reversed from the long-established standard notation. When discussing the limitations of A*, Murphy says that "gaining energy going down hill is essentially having an edge in the graph with a negative weight," which is only true if cost factors such as time are ignored.

A further distraction, more annoying than anything else, is persistent sloppy editing. Lapses in grammar abound, from the subtle (using "recurse" as the verb form of "recursion," pp. 50, 364) to the incoherent ("For the purposes of this book, this will be referred to as the stategic vector the robot want to go" p. 145). Related but more problematic are the few times a new named concept is discussed well before it is defined (e.g., holonomicity is discussed on p. 132, explicitly defined on p. 354). Serious editing problems include errors in equations such as equations 11.1 and 11.2, where the probability of a sensor returning a particular reading given that a location is occupied, $P(s|O)$, is incorrectly labeled as the prior probability of the location being occupied, $P(O)$.

Often disappointing is the uneven depth of the description of various algorithms. The chapter on path planning describes in detail the A* algorithm, but for the algorithms that generate the graphs that A* searches, we're given remarkably little. For example, the only thing we're told about how to construct a generalized Voronoi graph is that "a GVG can be constructed as the robot enters a new environment, thereby creating a topographical map." Similarly, a more in-depth treatment of planning, complete with some more current algorithms, would have resulted in a more complete book.

Finally, in an effort to teach to all levels of students, *IAIR* sometimes goes too far toward simplicity. There are many examples in C that are simplistic pieces of advice. For example, when discussing how a behavior could be made to take an action only occasionally when other conditions are met, we are informed that, "this could be done with an if-else statement" (p. 80). Later we are told that if we implement schemas using object oriented programming, a "schema class in C++ or Java would contain both data … and methods."[4] Mathematical treatments are also often too basic. On p. 128, there is a definition of the formula of a line, complete with a discussion of "slope." Then on p. 135, the reader is presented with the definitions of both associativity and commutativity, complete with examples for the confused: "a + b + c + d can be performed as ((a + b) + c) + d." This is not to say that all such examples are so basic, and these digressions into simplistic programming and mathematics are mostly well contained and easy to skip.

When it comes to undergraduate AI robotics, *IAIR* is essentially the only game in town. No other book even attempts to be broad and basic enough to be used as an undergraduate text, and *IAIR* is likely to enjoy some success on that fact alone. It is not, however, an ideal textbook. It contains errors and omissions enough to try the patience of the professor, and its tone can be condescending enough to try the patience of the student. But for all the little things it gets wrong, it gets many of the big things right. Most importantly, it unifies the field in a simple way that can appeal to a diverse group of students. It would have been a better book by far if more time was spent editing and test-teaching it, but it is still a useful book.

NOTES

1 Primarily comp.ai and comp.robotics.misc.
2 See http://www.csee.usf.edu/~murphy for a complete listing.
3 Again, this is odd placement, having nothing to do with navigation.
4 Nevermind that they're called functions in C++.

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