Pyro: An Integrated Environment for Robotics Education

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Introduction

Pyro, which stands for Python Robotics, is a Python-based robotics programming environment that enables students to explore topics in robotics. Programming robot behaviors in Pyro is akin to programming in a high-level general purpose programming language; Pyro provides abstractions for low-level robot-specific features much like the abstractions provided in high-level programming languages. Consequently, robot control programs written for a small robot (such as K-Team's hockey puck sized, infrared-based Khepera robot) can be used, without any modifications, to control a much larger robot (such as ActivMedia's human-scale, laser-based PeopleBot). This represents an advance over previous robot programming methodologies in which robot programs were written for specific motor controllers, sensors, communications protocols and other low-level features. Programming robot behaviors is carried out using the programming language Python, which enables several additional pedagogical benefits. We have developed an extensive set of robot programming modules, modeling techniques, and learning materials that can be used in graduate and undergraduate curricula in a variety of ways.

Currently, Pyro supports K-Team's Kheperas, ActivMedia's Pioneer class robots (including PeopleBot and AmigoBot robots), Player/Stage based robots (including Evolution's ER1 and many others), the Handyboard, RWI's Mobility-based B21R, and simulators for all of these. Currently, many other robots are also being ported to Pyro, including Sony's Aibo, K-Team's inexpensive Hemisson, and the Robocup Soccer Server Simulator.

Use of Pyro in the Curriculum

The Pyro library includes several modules that enable the exploration of robot control paradigms, robot learning, robot vision, localization and mapping, and multi-agent robotics. Within robot control paradigms there are several modules: direct/reactive/stateless control, behavior-based control, finite state machines, subsumption architectures, and fuzzy logic. The learning modules provide an extensive coverage of various kinds of artificial neural networks (ANNs): feedforward networks, recurrent networks, self-organizing maps, etc. Additionally Pyro has modules for evolutionary systems, including genetic algorithms, and genetic programming. The vision modules provide a library of the most commonly used filters and vision algorithms enabling students to concentrate on the uses of vision in robot control. The entire library is open source, well documented, and can be used by students to learn about the implementations of all the modules themselves. We have also provided tutorial level educational materials for all of the modules. This enables instructors to tailor the use of Pyro for many different curricular situations.

Pyro has been incorporated in the undergraduate curriculum at Bryn Mawr College, Swarthmore College, and the University of Massachusetts Lowell. Additionally, it has been used at several other institutions. At the University of Massachusetts Lowell, it has also been used in the graduate level courses. Specifically, Pyro has been incorporated into the following courses:

Introduction to Artificial Intelligence: A standard elective course in the computer science curriculum. This course is offered at Swarthmore College and Bryn Mawr College.

Cognitive Science: An elective in computer science and psychology. This course is offered at Bryn Mawr College.

Emergence: An elective course that studies emergent computation and emergent phenomena. Additional Python code has been developed to explore related topics, such as bird flocking behavior, and cellular automata. This course is offered at Bryn Mawr College.

Androids: Design & Practice: An upper-level elective on recent advances in robotics. This course is offered at Bryn Mawr College.

Developmental Robotics: Another upper-level elective on recent advances in robotics. This course is offered at Bryn Mawr College and Swarthmore College.

Robotics II: This is a second undergraduate course in Robotics at the University of Massachusetts Lowell.

Mobile Robotics: This is a graduate-level course offered at the University of Massachusetts Lowell.

Senior Theses: Students at several institutions have used Pyro as a part of their capstone projects.

Summer Research: Students at several institutions have used Pyro as a part of their summer research projects at the undergraduate and graduate levels. Additionally, some high school students have also used Pyro in their summer research projects.

Goals of Pyro

We believe that the current state-of-the-art in robot programming is analogous to the era of early digital computers when each manufacturer supported different architectures and programming languages. Regardless of whether a computer is connected to an inkjet printer or a laser printer, a computer today is capable of printing on any printer device because device drivers are integrated into the system. Similarly, we ought to strive for integrated devices on robots. Our attempts at discovering useful abstractions are a first and promising step in this direction. We believe that discoveries of generic robot abstractions will, in the long run, lead to a much more widespread use of robots in education and will provide access to robots to an even wider range of students.

Our goal is to reduce the cost of learning to program robots by creating uniform conceptualizations that are independent of specific robot platforms and incorporate them into an already familiar programming paradigm. Conceptualizing uniform robot capabilities presents the biggest challenge: How can the same conceptualization apply to different robots with different capabilities and different programming API's? Our approach, which has been successful to date, has been shown to work on several robot platforms, from the most expensive research-oriented robot to the lowest cost LEGO-based ones. We are striving for the "write-once/run-anywhere" idea: robot programs, once written, can be used to drive vastly different robots without making any changes in the code. This approach leads the students to concentrate more on the modeling of robot "brains" by allowing them to ignore the intricacies of specific robot hardware. More importantly, we hope that this will allow students to gradually move to more and more sophisticated sensors and controllers. In our experience, this more generalized framework has resulted in a better integration of robot-based laboratory exercises in the AI curriculum. In addition, our system is not only accessible to beginners, but is also usable as a research environment for our own robot-based modeling.

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For more information on the Pyro project, see http://www.pyrorobotics.org

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