Demonstrating the Capabilities of MindStorms NXT for the AI Curriculum

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Abstract

We demonstrate the possibilities offered by the new NXT platform for CS artificial intelligence curricular development. The NXT provides a number of hardware improvements over the RCX, including a faster processor and more memory. We demonstrate the curricular materials developed in the LMICSE archive, including autonomous mobile robot localization and SLAM.

Introduction

In the summer of 2006 Lego released its successor to the popular MindStorms RCX robotics platform – MindStorms NXT. In many ways this new release is a major improvement over the RCX, containing a more powerful processor, more memory, and employing an enhanced sensor and effector suite. We believe it will make an effective platform for integrating robotics topics into the CS curriculum, particularly within the Artificial Intelligence course.

With the NXT release being so recent, the development of third-party programming environments for it, such as Java and Lisp, are lagging behind with no projected release dates set at the time of this writing. Obviously, curricular materials based on these languages have not yet been developed. Our curricular development project, Lego MindStorms in Computer Science Education (LMICSE) – see http://www.mcs.alma.edu/LMICSE – is dedicated to the development of such materials. We are currently exploring the NXT and its capabilities and will demonstrate the state of our materials at AAAI SSS '07.

Contrasting the NXT to the RCX

Lego released RCX MindStorms in 1997. Its programmable brick offered a 16MHz H8 CPU with 32 KB onboard RAM for firmware and user programs. Since the firmware had a 26 KB footprint, user programs were limited to approximately 6 KB of bytecodes. Its I/O complement featured three sensor ports, an infrared (IR) transceiver port for program download, and three motor ports. The RCX supported "immediate command" and "program command" modes, which meant it could be controlled remotely through IR signals or controlled directly through an onboard program. The immediate command mode allowed third-party packages such as LeJOS (Bagnall 2002) and RCXLisp (Klassner 2004) to support AI projects such as robotic navigation or planning by running memory intensive, floating point portions of system code on a PC while running smaller remote-control programs on the RCX.

Nine years later Lego released the NXT. The hardware and firmware of the new kit's programmable brick feature several advances over the RCX design. These include a local file system on 256KB flash RAM, 64KB RAM for program execution, a 48MHz ARM7 CPU with support for Bluetooth radio frequency (RF) communication, a large 100x64 pixel LCD display, a USB 2.0 port for program download, and four sensor ports. User programs can be as large as 160 KB (more if system sound files are removed from the flash RAM drive). NXT firmware uses the 64KB onboard RAM to allocate memory for programs in execution. The NXT supports "immediate command" and "program command" modes, but because it uses RF communication, line-of-sight issues with the RCX's IR technology have been eliminated.

Demonstration

LMICSE is currently porting current RCX-based curricular materials to the NXT platform. We demonstrate projects under development, drawing from the following materials:

Odometry: A great first robotics project in an AI or mobile robots course, the NXT offers a much more accurate platform than the RCX for odometry. The RCX rotation sensor was limited to 16 clicks per revolution (or 22.5 degrees per click). The integrated servo motors of the NXT count 360 clicks per revolution (or 1 degree per click), while not tying up sensor ports. Improved tire design allows more accurate turning. We demonstrate an NXT odometry laboratory assignment.

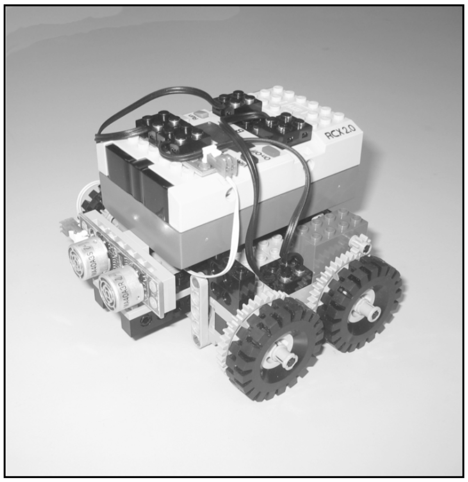

Figure 1: RCX with Sonar and Rotation Sensors

Figure 2: NXT with Sonar Sensor

Path Planning: Well developed for the RCX (McNally 2006), occupancy-grid based solutions to the path planning problem can be employed in the CS curriculum as early as CS 2 (given a provided odometry solution). Experience with classical path search algorithms such as depth and breadth-first search on the RCX was described in (Kumar 2004). Our RCX materials incorporate options to use such methods or to use wave-front propagation, either with a known environment map or without one. With NXT's increased memory and its motors' more accurate odometry support, much larger occupancy-grids will be possible

Localization: Monte Carlo Localization (MCL) methods are well suited for the fast and accurate localization of autonomous mobile robots. Our robust RCX materials employ the particle filtering approach described by (Fox 2003), whose linear example was implemented by (Greenwald et al 2006). Due to memory constraints it is not feasible to do localization on-board the RCX, but this is not a problem for the NXT. We demonstrate MCL on the NXT.

Mapping: 1-d and 2-d mapping projects are under development for use in this sequence of NXT laboratory materials. We demonstrate these materials' current status, which should include one and two-dimensional solutions.

Simultaneous Localization and Mapping (SLAM): The end point of this sequence of laboratory materials, these materials are under development as well. Not developed for the RCX, this approach should be possible for NXT. We demonstrate the current state of the art for NXT.

Conclusion

Lego MindStorms NXT provides enhanced opportunities for incorporating appropriate robotics projects in the undergraduate AI course or for a course in autonomous mobile robotics. LMICSE is a repository for MindStorms-based CS curricular material, and in this presentation we describe the possibilities provided by the new MindStorms NXT platform and the materials being developed for LMICSE for NXT.

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