An Affordable Platform for Robotics Education Driven by Open Source Hardware and 3D Printers

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Abstract

Our method for creating robotic learning environments is novel. Printouts, which are open-source 3D-printable robots, allowed us to simply design and build one-of-a-kind robots. The Ausubo, a cheap robot with sufficient capabilities for use in various educational settings, was created by us using this innovative technique. We constructed the robot with our newly developed electronics platform, which is built on the Print shield and Arduino. A wide variety of sensors and actuators, including those for light, distance, and lines, may be included into this system (motors, lights and speaker). Further development by both academics and students is also easy. We present our plans together with the outcomes of workshops that included students from various academic backgrounds. Here we lay out our strategy and suggest some ways that printout-based lectures might be improved in the future.

Keywords:

Printout, 3D printing, robotic platform, Arduino, open hardware, open source, inexpensive.

INTRODUCTION

Robots have played a significant role in schools across the world for many years. Robotics mainly benefits educators since it is an interdisciplinary field that includes computer science, electrical engineering, and mechanical engineering. Collaboratively building robots may be a fun way for students to learn about many different subjects. The platform has to be cheap, readily repairable, and scalable because we'll be dealing with a lot of robots (as stated in [1]). Even in their most basic versions, educational robots should have enough capability to facilitate study, as stated in [2]. Some authors [3] argue that real robots, not virtual ones, are the way to go in a first-year robotics class, showing that even with very modest gear, students can achieve a great deal. Skybot1, our own little, custom-built robot, has been used effectively in classrooms since 2004. It is possible to classify robotic platforms into two main groups: commercial and customized. Teachers now have a plethora of commercial educational robot alternatives from which to choose, making it easy for them to find the ideal one for their classroom [2]. You may spend anything from €100 to €4,500 on a single robot. There are many different parts to a design, including powerful processing, many sensors, simple logic, and so on. The responsibility of evaluating these resources in relation to the required skills and financial constraints is with the educator. Lego's NXT2 platform has a large user base [1,4,5]. The main issue with commercial platforms is that they are proprietary and closed. Students won't be able to benefit from the manufacturer's design choices, but they may be used as black boxes in the classroom. This makes it harder for students to try to change or enhance preexisting business concepts. Another negative aspect is that the company could decide to stop making that specific kind of robot (after they've developed a new version, for instance). If that's the case, they'll have to come up with a new curriculum and choose a different robot.

A RDUINO FOR ELECTRONICS

The autonomous central processing unit is standard equipment on all robotic bases. Some examples of electronic components that are available for purchase are the Leggott NXT block, Parallax's BasicStamp6 [3], and the Dwengo-board7 [1]. Also, specific circuit boards based on microcontrollers (from companies like Atmel and Microchip) do exist. This explains why there is a wide variety of electronic boards used in robotics education. The popularity and availability of Arduino8, a general-purpose electronics platform, is growing at a fast pace. It offers a wide variety of boards based on Atmel micro-controllers with a standardized programming interface, making it easy for newcomers to use while yet giving power users what they need. The authors make a number of interesting conclusions in [9].

Due to the widespread availability of Arduino kits, excellent documentation, and support forums, it first shows that, in comparison to other platforms, Arduino encourages students to think creatively. Second, it's a warning that the Arduino community isn't always concerned with the best way to execute ideas; sometimes, they just want things to function. Transferring to different platforms is usually the best option for teaching specialized low-level optimization. For example, by substituting an Arduino board for the electronics (and programming) of the Boa-sophisticated Bot, the authors of [10] build upon the Boa-Bot results from [3] and demonstrate how to use Arduino with educational robots. Moreover, open-hardware is the foundation of the Arduino platform. Any of the designs are at your disposal to use, study, or modify as you choose. Furthermore, there is a large community of people that contribute to Arduino by creating tools (hardware and software), sharing projects, and offering help. We have chosen to use Arduino in our robots for these reasons.

Integration improvements by the use of shields.

As mentioned before, Arduino is a very adaptable board. Its I/O ports aren't compatible with our sensors and actuators, so we'll need to design our own circuits to incorporate it into our robots. Using prototype boards typically leads to a maze of wires and connections, as seen in Figure 2.1. Although these methods work well for teaching basic electronics, the resulting circuits are seldom tiny and dependable. Numerous "shield" designs have been created by the Arduino community. These PCBs are one-of-a-kind and designed to perfectly fit atop an Arduino board. Figure 2.1 shows an example of plugging these shields. This essay will mainly focus on the Arduino UNO board as it is the most popular and extensively used board in its category.

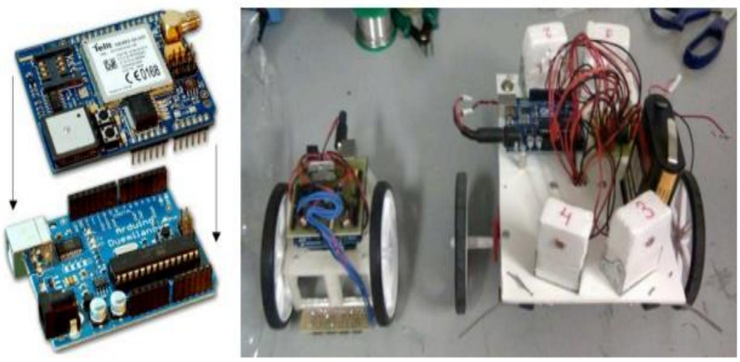

Fig. 1 Example shield (left) and a practical case of compacting circuitry (right)

All sorts of peripherals may be electrically connected with the help of these shields, which include a WIFI shield, motor shield, GPS shield, and a plethora of others. We regret to inform you that we were unable to find any presently available robotics-specific shields. None of them can handle the amount of sensors, motors, and extension connections required to build a little robot with all the features. The following part will go into more detail about our strategy, which included employing custom-made shields (such as the CRM-Shield depicted in Fig. 2.1 coupled to the HKTR-9000).

Building the Robotic System

One great thing about printouts is how well they can adapt to different materials and settings. The inaugural robotics workshop was going to make use of all the sensors, Arduino UNO boards, Palolo micro-motors10, wheels, casters, screws, and the like that the Robotics and Mechatronics Club members had on hand. We thought the best course of action for the electronics would be to construct our own robotics-centric shield from the ground up. The main objectives were to reduce overall size and complexity via integration and to manufacture dependable electronics that could endure frequent usage. We favored Cicada, a free and open-source program, for board design. We have used traditional toner transfer technologies for designing all of our printed circuit boards. Our first plan gave rise to the CRM-Shield. Installing a line sensor is a piece of cake when you use this shield. A motor driver (L298), two light sensors, and an LED are all housed in its small form factor. A fully operational prototype of the HKTR-900011 robot (Fig. 3.1) was constructed in about one week after our custom 3D-printable chassis was created in a matter of hours. By the end of the next week, all five of these robots were completed. Since our robotics club had all the required parts on hand and the 3D-printed plastic was inexpensive, we didn't have to spend a dime on our project. The CRM-Shield did not come with any pushbuttons or other ways for the user to submit data. The light sensors' connection to a pin header makes disassembly a breeze. A considerable amount of space and pins on the board have been taken up by the motor operator as well.

Arduino board. The CRM-Shield worked effectively, even though this was just our first session (see Section 4.1).

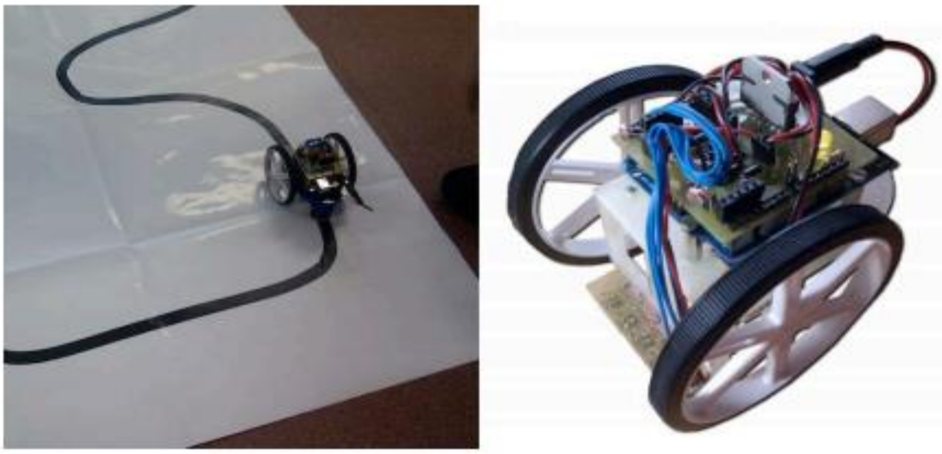

Fig.2 HKTR-9000 possible usage as a line follower (left) and detail view (right)

The promising outcomes achieved with the CRM-Shield motivated us to redesign it with the aim of addressing its current issues: It was because of our hard work that the Print shield (Fig. 3.2) came to be. Since they can be operated by a single digital pin instead of a motor driver, we opted to return to the continuous rotation servos utilized in the original Minsky. Motors that are both simple to operate and have a common hookup make expansion a breeze. We improved the design by adding two push-buttons (function and reset) and by swapping out the pin headers for a screw terminal, which allows for much more secure attachment of light sensors.

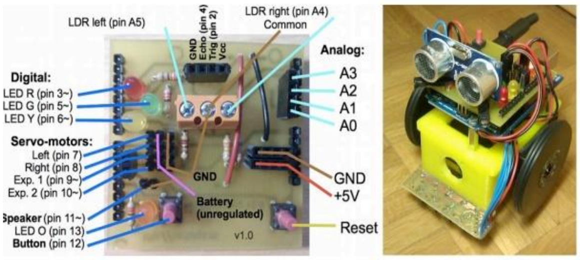

Fig. 3.Print shield (left) and usage connection diagram example in the Ausubo (right)

Ideal for teaching programming and debugging principles, the print shield combines a broad selection of light and distance sensors as well as a simple manner of adding peripherals (LEDs). Because it uses common electrical components, print shield is cheap (approximately 5€ per board). You may easily reuse it for other prints as well. The Minsky v2.013 3D-printed chassis and wheels are used by ArduSkybot12. We were able to integrate a speaker, LED lights, two continuous rotation servos, a number of sensors (distance, light, and line), and a few other components into a small, easy-to-transport platform by using the Print shield.

We managed to maintain the production cost at around 55€, which is similar to the Minsky's pricing mentioned in [7]. We later verified the Ausubo's efficacy as a pedagogical tool in a small workshop.

PROOF THAT THE NEW SYSTEM WORKS

We have tested the feasibility of our printed ideas in two workshops, one with high school and college students and another with primary and secondary school students. The HKTR-9000 4.1: An Introduction to Robotics 4.1 On May23,24,25,28, and 29, 2012, the Robotics and Mechatronics Club at Universidad Autonomy de Madrid held an introductory robotics course.

Aims and demographics

The workshop's target audience consisted of 20 engineering students (18 to 23 years old). It was intended as a primer on robotics fundamentals. There was no prerequisite expertise for this session; the participants constructed five HKTR-9000 robots after learning the fundamentals (electronics using Arduino and the CRM-Shield, and basic mechanics). They were proficient in some kind of computer programming.

Time and procedure

This workshop lasted for 15 hours, split into five 3-hour blocks. The process began with a 20-minute introduction, following which students were tasked with completing the recommended tasks. They divided into five groups and worked together to complete the tasks. For our materials, we had access to a lab with PCs, a presentation projector, and five pre-existing HKTR-9000 sets.

Material presented at the workshop

We learned the basics of robots and Arduino in the first two courses. Students gained a solid grounding in sensor and motor operation with the use of prototype boards. Then, the code was updated to include the instructions needed to run the motors. The next two courses went over the HKTR-9000's assembly language and provided some rudimentary examples of programming. In order to teach the robot to follow a light source or a black line, students learned basic PD control methods. They equipped the students with distance sensors and headphones and let them decide what to learn in the last class. After programming the robot to make sounds and avoid obstacles, some students set it to follow a light and adjust its pitch according to the distance it had traveled, as detected by a sensor. Our Discoveries, Version 4.1.4 While some students thought the workshop contained too much theory, others thought the exercises should have been more demanding. The plan was to make the content more concise while still giving students who required it more difficult tasks to complete. It was somewhat difficult to install the distance sensor on the HKTR-9000. For this reason, the Print shield subsequently gained this sensor. The attendees expressed satisfaction, and the workshop achieved all of its goals. It was also promising since it got a number of students involved with the robotics club. From July 30th to August 2nd, 2012, Carlos GarciSaurav sponsored the Ausubo 2012 Summer Workshop in Palo Alto, California.

Aims and demographics

The goal was to introduce robotics to four students, aged 12 to 14. They constructed their own Ausubo and made their own adjustments to the software after learning the fundamentals of robotics (electrical using Arduino and Print shield, programming, and mechanics).

Time and procedure

Ten hours were spent on this workshop, split up into four 2-and-a-half hour sessions. The process began with a brief introduction (about 15 minutes), followed by the distribution of sample code and straightforward activities for the students to complete with our guidance (extra exercises were provided for advanced students based on our experience with the first workshop). In terms of hardware, we used two tables, a presentation screen, and four Ausubo starter kits. A laptop and an Arduino board with a USB connection were also needed of each student.

Material presented at the workshop

The first session covered the fundamentals of robotics. In this activity, students learnt about the Print shield and Arduino. They then constructed and tested basic circuits using LEDs and sounds. In the two lectures that followed, the Ausubo was both presented and put together. To begin, they modified many pre-existing code samples to initiate robot movement. We tested their abilities in more challenging situations, such as responding to light or avoiding obstacles. In the more challenging task, a few astute students managed to program the robot to follow the light while avoiding obstacles. In the prior lesson, we covered how to program the robot to travel in a straight path using the line sensor. Getting back onto a straight path after avoiding an obstacle was the intended objective. Oh, seriously? Some youngsters pulled this off? We were astounded!

Results

The modules of the workshop were developed in accordance with the recommendations made in [4] for the instruction of elementary school pupils, who pose distinct problems than college students and need a different approach. We mapped out the course of study for the pupils in advance using an example-based, uncomplicated approach. On the other hand, younger children said that everything was somewhat challenging. Maintaining complete simplicity is key when interacting with young children. Giving the kids control over the speed of the offered song added an unexpected element of fun while also revealing something about the speaker's ability to engage its intended listeners. Another feature that wowed them was the new instrument's capacity to generate tones using distance data. There were buzzer-like sounds played throughout the show, and the host was there the whole time to help set a good example for the kids. Every student is expected to have brought their own Arduino board, as mentioned before. We arrived at this conclusion after seeing that they possessed an Arduino kit. It turned out that this was their parents' botched effort to introduce them to electronics. The cost to produce each robot was reduced by more than half, or roughly 25€, since the Arduino board is the most expensive component. The students were ecstatic because, since the components were inexpensive, they got to retain the robot they had constructed at the end of the course.

Fig 4. Robotics introductory course (left) and Ausubo 2012 summer workshop (right)

DISCUSSION

We were surprised by how easy it was to set up the HKTR-9000 and the Ausubo for our sessions. Taken into consideration, we were able to design, develop, and produce five HKTR-9000 robots in the two weeks it took to build the massive robot seen in Fig. 2.1. Perhaps even more remarkable has been our experience with the Ausubo: the whole process of developing and producing five of them (including the prototype) took only one week. Since the Ausubo is an exact replica of the original Minsky, its pricing (approximately 55€) is very close to that of the original. This is why it's important to emphasize the modifications:

• The robot may now be directly connected to a computer by USB, thanks to the Arduino UNO platform. Since many people already own one of these boards, using a line sensor and the really cheap Print shield lowers the robot's entry price. The production cost of its four infrared sensors was CNY70.

FINAL REMARKS AND FUTURE STUDIES

Students in robotics courses no longer need store-bought robotics kits or to construct their own robots from the ground up, proving the usefulness of our novel printout-based method. It takes very little time and effort to design unique educational robots from prints, and the results are fantastic. We addressed the lack of specialized Arduino shields for robots with the Print shield, and using this innovative method, we built the Ausubo. It's a space-saving way to add the usual sensors and actuators to robots that run on Arduino, like the Ausubo. We want to keep pushing forward with efforts to improve these robots down the road. A more stable design with tracks instead of wheels and an infrared link in the next Print shield version will let robots communicate with one other and learn more complex algorithms. All of the documentation and drawings from our design process are available online for free. Every single activity and handout from the session is now accessible online.

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