A Low-Cost Robotics Education Platform Based on Open-Source Software and 3D Printers

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Abstract

Here, we provide a fresh approach to the design of robotic learning environments. We were able to quickly and easily design and fabricate unique robots using printouts (open-source 3D-printable robots) as a foundation. Using this novel approach, we developed the Ausubo, a low-cost robot with enough functionality for use across a range of pedagogical contexts. We built the robot using our new electronics platform, which is based on Arduino and the Print shield. Light, distance, and line sensors are only some of the many types of sensors and actuators that may be used with this system (motors, lights and speaker). It's also simple for academics and pupils to develop further. We detail our designs and the results of workshops with students at all educational levels. Our approach is laid out, and recommendations for future printout-based seminars are offered.

Keywords:

Keywords: printout, robotic platform, 3D printing, Arduino, open source, open hardware, affordable.

INTRODUCTION

For decades, robots have been an integral part of classrooms throughout the globe. The fact that Robotics is an interdisciplinary discipline that encompasses mechanical engineering, electrical engineering, and computer science is its primary benefit for educators. Students may have fun while gaining knowledge in a wide range of disciplines by working together to construct robots. We will be dealing with a huge number of robots, thus the platform must be inexpensive, easily repaired, and scalable, as described in [1]. As mentioned in [2], it is recommended that educational robots include sufficient functionality to enable research even in their most basic forms. Other writers [3] strongly advocate for the use of actual robots rather than simulated settings, demonstrating that a substantial amount of work can be accomplished even with very basic hardware in a first-year robotics course. Our own modest, custom-designed robot (called Skybot1) has been utilised successfully in classroom settings since 2004. Two primary categories of robotic platforms may be identified: commercial and bespoke. Due to the abundance of options on the market, educators may quickly and easily choose the best commercial educational robot for their classroom [2]. A single robot might cost anything from €100 to €4,500. Different designs have various components, such as robust processing power, a variety of sensors, straightforward logic, and so on. The onus is on the educator to assess these tools in light of the necessary capabilities and budgetary limitations. Lego's NXT2 platform [1,4,5] is widely used. Commercial platforms have the major

drawback of being closed and proprietary. They can be used as black boxes in classrooms, but students will not be able to learn from the manufacturer's design decisions. Students are therefore hampered in their attempts to improve upon or otherwise alter existing commercial designs. A further drawback is that the corporation may decide to no longer produce that particular kind of robot (when they create a new version, for example). If that's the case, they need to choose a different robot and create a new curriculum.

A RDUINO FOR ELECTRONICS

Each robotic base comes with its own central processing unit. Commercially available examples of electronic components include the Leggott NXT block, the BasicStamp6 from Parallax [3], and the Dwengo-board7 [1]. There are also specialised boards built around microcontrollers (Atmel, Microchip and so forth). Because of this, the landscape of electronic boards used in teaching about robots is rather diverse. When it comes to general-purpose electronics platforms, Arduino8 is quickly becoming one of the most well-known and rapidly expanding options. Based on Atmel micro-controllers, it provides a large selection of boards with a standardised programming interface, making it accessible to beginners while yet providing the power for advanced users. In [9], the authors draw several intriguing findings.

To begin, it demonstrates that Arduino encourages students to think outside the box when compared to other platforms (this is due to the high availability of Arduino kits, good documentation and support forums). Second, it serves as a cautionary tale, showing that the Arduino crowd is more concerned with getting things to work than picking the best method to implement them. In most cases, it is preferable to transfer to other platforms when instructing on specialised low-level optimization. In [10], for instance, the authors take the Boa-Bot findings from [3] and show how to utilise Arduino with educational robots by replacing the Boa-sophisticated Bot's electronics (and programming) with an Arduino board. Furthermore, the Arduino platform is open-hardware. You may use, examine, or alter any of the designs anyway you choose. In addition, Arduino has a sizable community of tool-developers (both software and hardware), project-sharers, and support-providing volunteers. It is for these reasons that we have opted to employ Arduino in our robots.

Integration improvements by the use of shields.

Arduino, as we've said previously, is a very flexible board. We can't just plug sensors and actuators into its I/O ports, so we have to build our own circuitry to utilise it in our robots. A tangled web of wires and connections is often the result of using prototype boards (an example is shown in Fig 2.1). While these kinds of approaches are effective and may be used to teach elementary electronics, the resultant circuits are seldom small and reliable. The Arduino community has produced a plethora of "shield" designs9. These printed circuit boards are made specifically to sit atop an Arduino board. Plugging these shields is shown as an example in Fig. 2.1. The Arduino UNO board will be the primary subject of this article since it is the most popular and widely used.

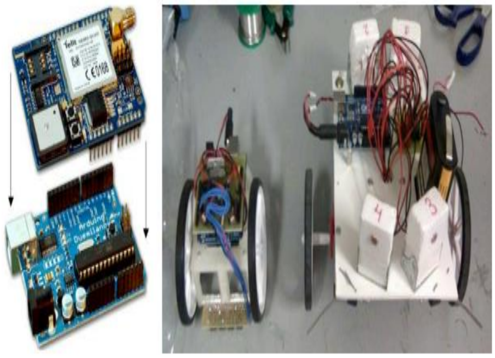

Fig. 1 Example shield (left) and a practical case of compacting circuitry (right)

This wide selection of shields (including a WIfi shield, motor shield, GPS shield, and many more) is meant to facilitate electrical connections with a wide range of peripherals. Unfortunately, we were unable to locate a robotics-specific shield that is currently on the market. The quantity of sensors, motors, and extension connections needed to construct a small fully-featured robot cannot be accommodated by any of them. Our approach consisted of using specially made shields (like the CRM-Shield shown in Fig. 2.1 attached to the HKTR-9000), which will be discussed in more depth in the next section.

Building the Robotic System

Printouts' adaptability to new environments and materials is a major strength. The members of the Robotics and Mechatronics Club intended to employ the many sensors, Arduino UNO boards, Palolo micro-motors10, wheels, casters, screws, and so on that were already in their possession for their first robotics workshop. We decided that building our own robotics-centric shield from scratch was the best option for the electronics. The primary goals were to produce reliable electronics that could withstand regular use, and to integrate well to decrease overall size and complexity. Cicada was used to design the boards since we prefer free and open-source software. All of our printed circuit boards have been designed utilising conventional toner transfer methods. The CRM-Shield is the product of our first strategy. With this shield, connecting a line sensor is a breeze. It has two light sensors, an LED, and a motor driver (L298) all in one compact package. Our bespoke 3D-prinable chassis was designed in only a few hours, and within a week, a fully functional prototype of the HKTR-900011 robot (Fig. 3.1) had been built. The next week, we had five of these robots fully built. Our robotics club had no out-of-pocket expenses since we already had all the necessary components, and the cost of the 3D-printed plastic was minimal. No pushbuttons or other user input mechanisms were included with the CRM-Shield. The light sensors may be disassembled with ease due to their connection to a pin header. The motor operator has also occupied a significant portion of the board's pins and area.

Arduino. While this was just our first session, the CRM-Shield performed well (view Section 4.1).

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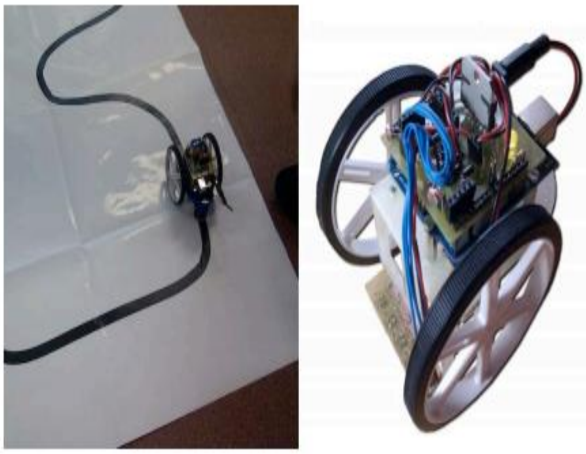

Fig.2 HKTR-9000 possible usage as a line follower (left) and detail view (right)

Encouraging results obtained with the CRM-Shield prompted us to re-design it trying to fix existing problems: The Print shield (Fig. 3.2) was the result of our efforts. We decided to switch back to continuous rotation servos (like the ones used in the original Minsky) since they don't require a motor driver, but only one digital pin to be driven. Easy to use motors and a standardized connector allow an easy expandability. Two push-buttons were added (reset and function) and we found a much robust way to attach light sensors using a screw terminal instead of pin headers.

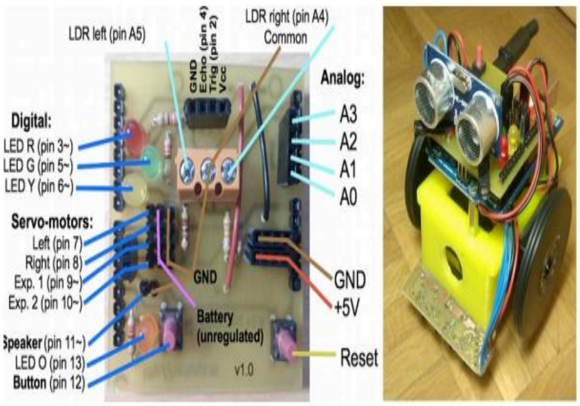

Fig. 3. Print shield connection diagram (left) and usage example in the Ausubo (right)

Print shield incorporates a wide variety of sensors (light and distance) and a simple method of connecting peripherals (LEDs), making it ideal for teaching fundamentals of programming and troubleshooting (servo motors, speaker, line sensors and more). Print shield is inexpensive (about 5€ per board) since it employs widely available electrical components. Also, it's simple to recycle and use again in other printouts. The 3D printed chassis and wheels of the Minsky v2.013 are used by ArduSkybot12. Since the Print shield includes many sensors (distance, light, and line sensor), two motors (continuous rotation servos), LED lights, push-buttons, and a speaker, we were able to design a simple transportable platform with all of these features.

We were able to keep the manufacturing cost down to roughly 55€, which is comparable to the price of the Minsky described in [7]. Later, in a little workshop, we confirmed the Ausubo's usefulness as a teaching tool.

PROOF THAT THE NEW SYSTEM WORKS

We have held two workshops, one with college students and one with elementary and secondary school kids, to explore the viability of our printout concepts. A First Course in Robotics Using the HKTR-9000 4.1 The Robotics and Mechatronics Club at Universidad Autonomy de Madrid hosted an introduction course in robotics on May 23, 24, 25, 28, and 29, 2012.

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

In the first two classes, we covered robot fundamentals and were introduced to Arduino. With the help of prototype boards, students learnt the fundamentals of working with sensors and motors. Afterwards, the necessary commands for operating the motors were written into the code. The HKTR-9000's assembly and some basic programming examples were covered in the next two classes. Students learnt fundamental PD control techniques in order to have the robot follow a black line and how to have the robot follow a light source. They gave the pupils free reign over the final lesson's content, equipping them with distance sensors and headphones. Some students programmed the robot to avoid obstacles while producing noises, while others had it follow a light and change its pitch based on the distance it had travelled as measured by a sensor. What We Found, Version 4.1.4 Some students complained that there was too much theory covered in the session, while others felt there should have been more challenging activities provided. The approach was to condense the material presented and to provide extra challenging activities for those students who needed them. The HKTR-9000's distance sensor proved very challenging to install. This is primarily why this sensor was added to the Print shield later. All of the workshop's objectives were met, and the participants reported feeling pleased. Additionally, it encouraged several pupils to join the robotics club, which is encouraging. 4.2 Summer Workshop on Ausubo 2012 In Palo Alto, California, Carlos GarciSaurav hosted the Ausubo 2012 Summer Workshop15 between July 30 and August 2.

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

In the first class, we learned the basics of what makes a robot tick. Students learned about Arduino and the Print shield, then built and tested simple examples that used LEDs and beeps. The Ausubo was introduced and assembled in the following two lectures. They started by changing some existing code samples to get the robot moving. We gave them progressively more complicated scenarios, such reacting to light or navigating around barriers. Some bright pupils figured out how to get the robot to follow the light while avoiding obstacles in the more difficult activity. The line sensor was introduced in the previous unit, allowing students to programme the robot to move in a straight line. The planned task was navigating around an obstruction and back onto a straight course. Some kids really managed to do this? We couldn't believe it!

Results

The workshop's modules were designed using the guidance provided in [4] for teaching young children; this demographic presents unique challenges that need a different strategy than teaching college students. Using a straightforward method based on examples, we laid out what students would be taught up front. Kids of a younger age, however, said that everything was really difficult. When dealing with young children, it is crucial to keep things extremely straightforward. Fun was found simply by allowing children to choose the tempo at which the provided melody was played, revealing an unexpected fact about the speaker's appeal to its target audience. They were also impressed by the new musical instrument's ability to make tones based on distance readings. Buzzer-like noises were played throughout the programme, and the presenter was there the entire time to assist set a positive tone for the youngsters. It has been previously stated that each student must have brought their own Arduino board. As we saw that they already had an Arduino kit, we came to this conclusion (we confirmed this was their parents failed attempt to get them into electronics). Since the Arduino board is the costliest component, this lowered the cost to manufacture each robot by more than half (about 25€). The students were overjoyed that, at the conclusion of the course, they could keep the robot they had built themselves due to the relatively modest cost of the components.

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

DISCUSSION

Setting up the HKTR-9000 and the Ausubo for our sessions required surprisingly little effort. To put this in perspective, it took us approximately two weeks to assemble the huge robot shown in Fig. 2.1; in that time, we were able to successfully plan, develop, and manufacture five HKTR-9000 robots. Arguably more impressive has been our time with the Ausubo: Five of them (including the prototype) took around one week to develop and produce from start to finish. The Ausubo is extremely comparable in price (about 55€) to the original Minsky since it is a direct descendant of that product. This is why we have to highlight the changes that were made:

• The Arduino UNO platform now powers the robot, allowing for direct USB connectivity. Incorporating a line sensor and the very inexpensive Print shield reduces the robot's entry price, since many people already have one of these boards. It has four infrared sensors that cost CNY70 to produce.

FINAL REMARKS AND FUTURE STUDIES

The efficacy of our new printout-based technique has been demonstrated: students in robotics classes are no longer need to utilise off-the-shelf robotics kits or to build their own robots from scratch. Designing unique instructional robots from printouts requires little time and effort but yields excellent outcomes. Using this new approach, we were able to create the Ausubo, and Print shield is our solution to the dearth of dedicated robotics-focused Arduino shields. It's a space-saving option for incorporating Arduino-based robots' standard sensors and actuators, such the Ausubo. We plan to continue working to advance such robots in the future. Tracks, rather than wheels, will improve stability, and the next iteration of the Print shield will feature infra-red connection, enabling robots to talk to one another and facilitating the study of more sophisticated algorithms. Our whole design process, including all paperwork and blueprints, is freely accessible online. We have also made available online all of the workshop's handouts and activities.

REFERENCES

[1] Waffles, F., Herman's, M. &Schreuder, B. (2010), "Building robots as a tool to motivate students into an engineering education", In Proceedings of the 1st international conference on Robotics in Education, RiE2010. September 2010. pp. 49-52. FEI STU, Slovakia.

[2] Moncada, F., Banani, M., Raemy, X., Pugh, J., Cianci, C., Klaptocz, A., Magnenat, S., Zufferey, J.-C., Floreano, D. and Martinoli, A. (2009), "The e-puck, a Robot Designed for Education in Engineering", Proceedings of the 9th Conference on Autonomous Robot Systems and Competitions, 1(1) pp. 59-65.

[3] Balogh, R. (2008) "Basic Activities with the Boe-Bot Mobile Robot", In DidInfo2008. 14th International Conference. FPV UMB, Banská Bystrica, Slovakia.

[4] Peter van Lith (2007), "Teaching Robotics in Primary and Secondary schools", ComLab Conference 2007, November 30 - December 1, Radovljica, Slovenia.

[5] Carter, J. & Coupland, S. (2010), "Teaching Robotics at the Postgraduate Level: Delivering for On Site and Distance Learning Students", In Proceedings of the 1st international conference on Robotics in Education, RiE2010. September 2010., pp. 149-154. FEI STU, Slovakia.

[6] J. Mateos, A. Sánchez, Luis J. Manso, Pilar Bachiller, Pablo Bustos (2010), "RobEx: an openhardware robotics platform". Proceedings, Workshop en Agentes Físicos (WAF2010), Valencia, Spain.

[7] Juan Gonzalez-Gomez, Alberto Valero-Gomez, Andres Prieto-Moreno, Mohamed Abderrahim (2011), "A New Open Source 3D-printable Mobile Robotic Platform for Education", Proc. of the 6th International Symposium on Autonomous Minirobots for Research and Edutainment, May, 23-25, Bielefeld, Germany.

[8] A. Valero, J. González-Gómez, V. Gonzalez, M.A. Salichs (2012), "Printable Creativity in Plastic Valley UC3M". IEEE Educon 2012. Marrakech. Morocco. Apr, 2012.

[9] P. Jamieson (2011) "Arduino for teaching embedded systems. Are computer scientists and engineering educators missing the boat?", International Conference on Frontiers in Education: Computer Science and Computer Engineering.

[1 0] Balogh, R. (2010), "Educational Robotic Platform based on Arduino", In Proceedings of the 1st international conference on Robotics in Education, RiE2010. September 2010., pp. 119-122. FEI STU, Slovakia.