Reaching new audiences through "RoboSlam!" workshops

T. Burke
Lecturer
School of Electrical and Electronic Engineering
Dublin Institute of Technology
Dublin, Ireland
E-mail: ted.burke@dit.ie

D. Berry
Lecturer
School of Electrical and Electronic Engineering
Dublin Institute of Technology
Dublin, Ireland
E-mail: damon.berry@dit.ie

S. Chance
Associate Professor
Hampton University
Hampton, Virginia, USA
E-mail: smchan@wm.edu

Conference Key Areas: Attract youngsters to engineering education; Engineering education research; Novel education tools for engineering programs.

Keywords: robotics, workshop, awareness raising.

INTRODUCTION

This paper reports on the development of an inexpensive and scalable workshop that will lead to the creation of a community of young robotics enthusiasts. "RoboSlam!" is a robotics workshop for beginners, which aims to stimulate interest in engineering and raise awareness of the role of engineers in society. The primary audience is young people who are curious about robotics, but have no prior experience.

With scalability in mind, the overarching design objective is to produce a robust *recipe* which others can replicate. Specifically, it is hoped that participants with some prior technical experience can themselves go on to deliver the workshop to new audiences. To facilitate this, the RoboSlam robot is built from low-cost materials that can be sourced widely with relative ease. The electronic components used are off-the-shelf devices. Free instructional materials (both for participants and facilitators) are provided online.

Fig. 1. Facilitators and participants discuss design details of a RoboSlam robot. Typically, a participant-facilitator ratio of approximately 6:1 is used.

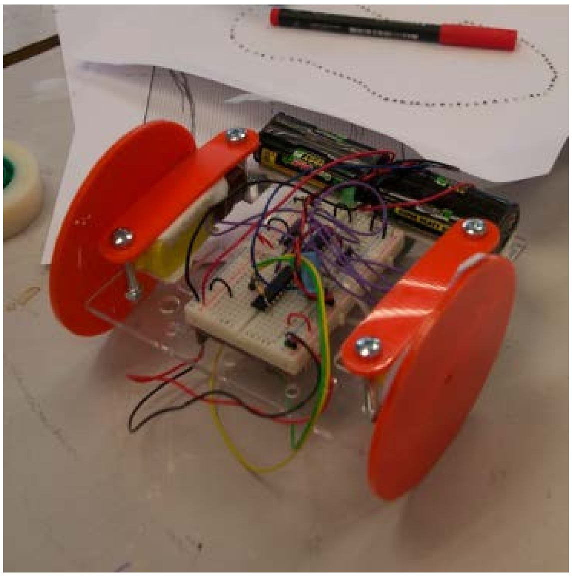

Fig. 2. A RoboSlam robot with laser-cut acrylic chassis and wheels. Also visible is the breadboard and battery pack. The LaunchPad is under the chassis

Each RoboSlam workshop takes place over a 6-8 hour period, either as a one-day workshop or spread over two sessions. Each participant receives a standard kit of electronic components and other materials, using which they construct and program an autonomous robot. Participants work alone, in pairs, or in teams, according to their own preference, assisted by experienced facilitators (see Fig. 1). Aggressive cost-saving in the design of the robot kit means that participants can take away their working robots and development tools at the end, so that the workshop becomes the induction phase of an ongoing learning process.

A novice can construct and program a working robot from scratch within a single well-structured workshop, but he or she cannot become an expert in that time. In fact, the technical learning which takes place during those few short hours is likely to be quite superficial. The emphasis in RoboSlam is therefore not on making participants experts, but rather on making them *enthusiasts*. Those who begin curious should ideally emerge as active hobbyists, capable of progressing onwards as self-directed learners with the support of additional resources and an on-line community.

The ultimate aim of the RoboSlam project is to strengthen the STEM pipeline by increasing awareness of engineering among young people and providing an enjoyable and supportive entry point into robotics as a hobby. Others have also used robotics development for this purpose, albeit typically in longer formats, e.g. [1, 2].

Here, we begin by describing how the workshop is delivered in practice. The philosophy which underpins it is then outlined. In particular, four key design principles are discussed in detail. The proposed method of evaluation, which forms an integral part of the iterative process of refinement of RoboSlam, is also described.

1 WORKSHOP DESCRIPTION

In the workshop, participants construct a small autonomous robot using a kit of very low-cost components and then program it to perform a set of tasks. The work undertaken by the participants includes mechanical construction, electronic circuit construction and programming. Ideally, participants should have some interest in engineering, robotics or programming, but no prior technical expertise is assumed. To date, young children, adults, engineers, teachers, artists and others have all taken part with universally positive results. A ratio of approximately one facilitator to every six participants works well, making the experience enjoyable for all concerned.

Normally, each participant builds a separate robot, but occasionally participants choose to work with a partner (or in a team) on a single robot. Either way, all participants work at tables which comfortably accommodate four people. Those sharing a table tend to form what might loosely speaking be regarded as a team, working together and helping each other to overcome problems.

1.1 Workshop induction

At the beginning of the workshop, each participant receives a plastic bag containing the following components and materials:

MSP430G2452 microcontroller	Mini breadboard
MSP430 LaunchPad	Battery holder (4 x AA)
SN754410NE driver IC	2 x geared DC motors
RPR-220 reflective optical sensor	Solid-core wire (several colours)
Resistors (1 x 220Ω, 1 x 10kΩ)	Foam board (A4-sized piece)
2 x green LEDs	Wheel material (e.g. paper coasters)
2 x 1N4001 diodes	Double-sided sticky tape
1 x 1000µF capacitor	

A facilitator presents a short introduction to explain the role of each component and to outline the overall structure of the workshop. Additional presentations are used at the beginning of each major section, but the majority of the time is reserved for participants to work on their robots, while facilitators circulate, helping out as needed.

The cost of each kit is approximately €20 (at time of writing). All components used are standard off-the-shelf devices available from on-line suppliers. Additional materials can be obtained in most art supply stores. A selection of tools, such as pliers, snips, screwdriver and scissors, are useful, but these are not used extensively and can be shared between participants. A PC is required to view the instructions and to program the robot, but this can also be shared between several participants. Indeed, during the mechanical and circuit construction, it is arguably preferable to share a single PC since it encourages interaction and collaboration.

1.2 Mechanical construction

The mechanical structure of the robot comprises a chassis plate to which two geared DC motors are attached. A disc wheel is attached to the shaft of each motor. An additional strut on the underside of the chassis provides a third point of contact with the ground, balancing the robot. The strut is also the mounting point for a reflective optical sensor which is used to detect the colour of the surface under the robot.

In our pilot workshops, a variety of materials were used for the chassis and other mechanical parts, including the laser-cut acrylic design shown in Fig. 2. Although this material is very easy for participants to assemble, the parts need to be pre-cut using specialist machinery. To ensure that third parties can easily stage the workshop without needing access to specialist facilities, the current design uses foam board which participants can easily cut by hand.

1.3 Circuit construction

The circuit for the robot is constructed on a mini breadboard. Rather than following conventional circuit schematics, participants are guided through the circuit construction process by a series of near photo-realistic illustrations showing the components positioned on the breadboard. An example illustration is shown in Fig. 3.

Although conventional circuit schematics might arguably provide a deeper insight into the operation of the circuit, these simple breadboard illustrations have proven remarkably effective in propelling participants with no prior electronics experience to complete working circuits in a very short time. A quick inspection by a facilitator is usually sufficient to resolve any minor errors in component placement.

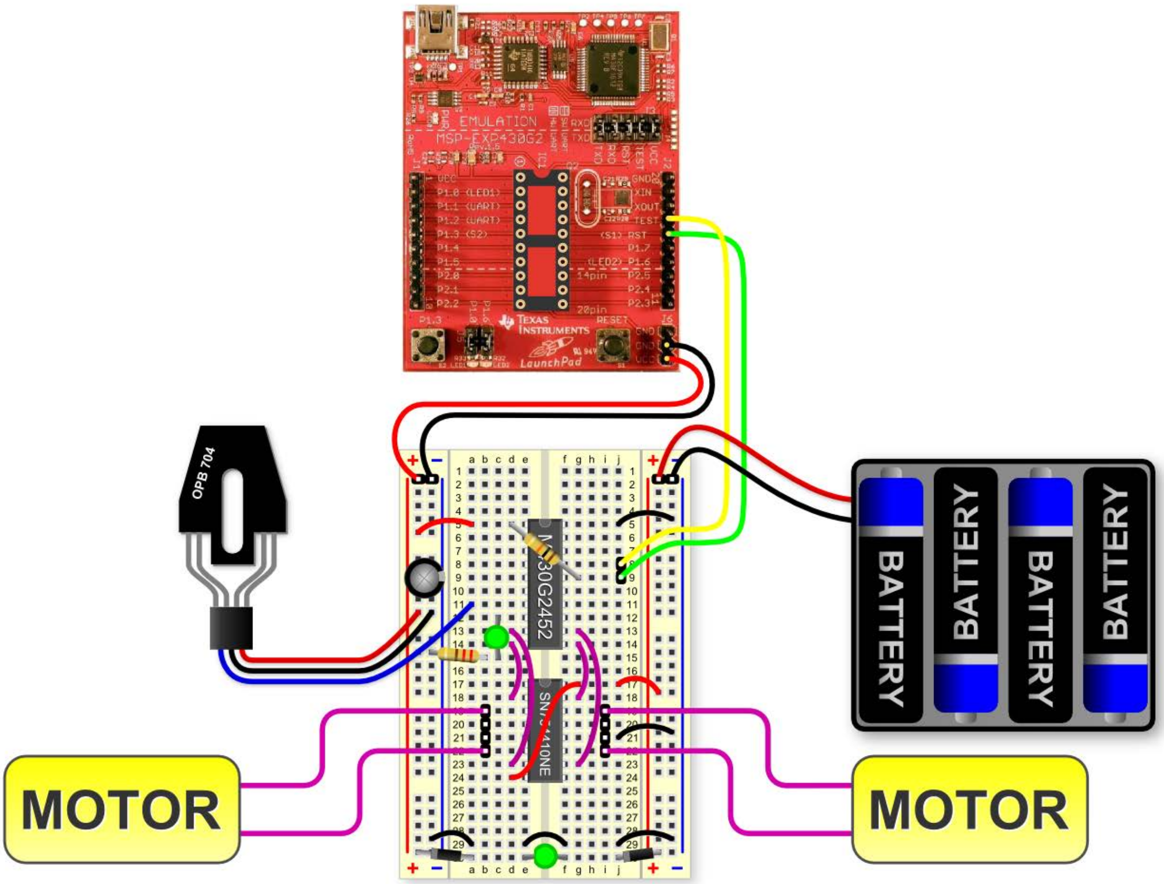

Fig. 3. An example image from the series of illustrations which guide participants through the circuit construction process. In this image, the complete circuit is shown.

1.4 Programming

Once the robots are fully built, a number of sample tasks are carried out, each of which involves downloading a new program onto the microcontroller. In each case, the participants copy example C code from the RoboSlam web site and compile it themselves. These example programs provide a high level introduction to digital input and output on the microcontroller, and demonstrate how these simple operations can be used to implement bi-directional control of each motor, and to respond to sensor input.

Each participant requires access to a PC, which may be shared between more than one if necessary. Four software applications are used:

- A web browser is used to view the robot-building instructions, which are publicly available on the RoboSlam web site [3].
- A free text editor, Notepad++, is used to edit the C code which will control the robot.
- An open source compiler, MSPGCC, is used to compile the C code.
- Another open source utility, MSP Flasher, is used to transfer the compiled program onto the microcontroller, via the LaunchPad USB programmer.

Apart from the web browser, all software tools are deployed as so-called *portable* applications. They are stored in a single folder which can be copied to a participant's own computer for use either during the workshop or subsequently at home. These applications were chosen in preference to an integrated development environment because their open source licensing facilitates very simple deployment on participants' computers in minutes, without installation and free of charge.

The formal content of the workshop concludes with a sensor navigation task in which the robot drives around on a smooth black surface with a white border, turning whenever it meets the edge. Once this task has been performed, participants are encouraged to explore the possibilities of modifying the C code to change the behaviour of the robot. Our experience has been that once their own robot is complete, many participants also naturally adopt the role of peer instructor, assisting other participants who are progressing more slowly.

2 HISTORY

The origins of the RoboSlam workshop can be traced to a module called Engineering Practice and Design (referred to hereafter by its informal title, *RoboSumo*) in which undergraduate electrical engineers in the Dublin Institute of Technology work in teams to design and build a robot to compete in a robot sumo tournament. This module is taken by students in year 1 of the 4-year BE degree and by students in year 2 of the 3-year BEngTech degree. Two of the authors have been members of the teaching team on this module for a number of years.

The RoboSumo module is designed as a highly student-centred project-based learning experience, in which students work in groups on a relatively open-ended problem. Although a great deal of very useful technical learning takes place, the most important learning outcomes are those related to group work and project management. However, above all else, it is the extraordinary motivational effect of the module that has most impressed the teaching staff involved in it. Anecdotally, students report that the module is not only very rewarding, but also that it helps to situate electrical engineering in a more meaningful real-world context.

Given the remarkable degree of student engagement that emerges spontaneously in this module each year, it seemed reasonable to consider whether some of the same ingredients might be recombined in a different way to create a tool for promoting engineering (and related disciplines) to second level students as a career choice.

3 DESIGN PRINCIPLES

In the course of developing RoboSlam, we have delivered the workshop several times (as we will continue to do in the future). However, our primary objective is not simply to *deliver* workshops, but rather to produce a *recipe* which is relatively easy for others to replicate, which transforms participants from interested novices into enthusiastic hobbyists, and around which a community of enthusiasts can form. Specifically, we envisage that those who enjoy the workshop as participants may themselves go on to deliver the workshop to others. The establishment of a community around the workshops will do two things:

- Facilitate those participants who wish to expand their learning in the weeks and months that follow their participation in the workshop,
- Provide support to those interested in becoming facilitators.

The RoboSlam recipe is founded on four core design principles:

1. Eliminate barriers,
2. Achieve critical affect,
3. Guide towards independence,
4. Ensure scalability.

3.1 Design principle 1: Eliminate barriers

The first principle of RoboSlam is to eliminate barriers to entry in robotics and engineering, which might otherwise derail an interested novice.

Unfortunately, a young person who is curious about electronics or robotics faces significant practical difficulties if they wish to take it up as a hobby. Unless he or she has convenient access to a supply of components and equipment (e.g. through a relative or school workshop), it can be difficult to get started. The number of high street retailers stocking electronic components is dwindling and although everything required by a hobbyist can be acquired from suppliers on-line, the delay involved in obtaining new parts that way, as well as the added expense of postage, can prove a very significant impediment. Since novices frequently experience uncertainty about exactly which parts to order, the situation is further complicated.

RoboSlam’s workshop format is intended to eliminate this barrier by providing access to an environment in which a young person can take his or her first steps in robotics with the support of more experienced facilitators and with a reasonable expectation that everything required to complete the project will be close at hand. Part of the RoboSlam recipe is a comprehensive shopping list for facilitators, which includes an allocation of spare parts so that replacements are on hand if a problem arises.

Another important barrier is cost. RoboSlam has been designed from the outset to use inexpensive components so that the per-participant cost of staging a workshop is as low as possible. With volunteer facilitators and a modest level of financial subvention from a commercial sponsor, school, or other organisation, the workshop can even be made available free of charge to participants (as has been our practice).

As a point of entry into robotics, RoboSlam marks *one clear path*. When people are confronted by a dilemma, there is a danger of hesitation taking hold and motivation waning. Each decision that a novice is obliged to make in uncertainty creates a possible point of abandonment. With this in mind, decisions are carefully avoided in the RoboSlam process. When people register to take part in a workshop, they are not obliged to make any further decisions until their first robot is complete.

The structure of the workshop is intended to allow people to work in a way that is comfortable for them. Some people prefer to work in a team, while others prefer to work alone. Both are perfectly acceptable within the RoboSlam structure. The loosely defined team with whom each participant shares their table provides access to peer support if it is desired.

3.2 Design principle 2: Achieve critical affect

Suppose you ask an engineer "*Is computer programming a critical skill for engineers in industry?*" Rather than providing a purely rational response, it is likely that he or she will unconsciously substitute the simpler question "*Do I like programming?*" and provide a response based on that. This tendency for a person's ostensibly rational views to be determined primarily by his or her emotional attitudes has been termed the *affect heuristic* by Slovic et al. [4].

This is of critical importance when introducing novices to a new subject with the aim of persuading them that it merits further study. Exposing a novice to a deeply unpleasant experience, such as feeling confused or inadequate, may create lasting *negative affect*, with potentially disastrous consequences for the person's ongoing learning in that subject. The novice is likely to unconsciously concoct a quasi-rational justification for avoiding that discipline.

In sharp contrast to this, when a person *likes* something, the job of persuading them that it is useful is substantially easier, since they are instinctively predisposed to embrace arguments which align with their existing emotional perspective. With this in mind, perhaps the most important attribute of the RoboSlam workshop is that participants should achieve *critical affect.* Provided that they look back on the workshop as an enjoyable and rewarding experience, they will be more likely to appreciate the value of learning robotics. For the complete novice, the long-term educational impact of learning to love robotics is much greater than any specific technical learning which can be imparted in a 1-day workshop.

3.3 Design principle 3: Guide towards independence

Although the workshop itself is essentially prescriptive in nature, it is intended to prepare participants for continued self-directed learning in the weeks and months that follow it, supported by the supplementary learning resources on the RoboSlam web site.

At the end of the workshop, all participants take away their robot, together with any remaining parts from the kit, to continue experimenting and learning at home. The kit uses off-the-shelf real-world electronic components, similar to those widely used in undergraduate engineering projects as well as in industry, which have been specifically selected for their adaptability to a wide range of applications. Furthermore, the development software is freely available, allowing work on the robot to continue without any obstacle.

3.4 Design principle 4: Ensure scalability

The primary objective of the RoboSlam project is to create a *recipe* which others can easily deliver to new audiences. All workshops to date have been organised by the core project team, but most of the facilitators have been people who previously took part in a workshop as an ordinary participant, and it is envisaged that workshops will soon begin to take place independently of the project team. The use of off-the-shelf components and materials, and the publication of all required documentation on-line, facilitates the delivery of the workshop by third parties.

4 EVALUATION

Feedback from participants in our previous workshops has been universally positive. For example, in a survey carried out at the conclusion of our most recent workshop, of the 34 participants, 21 rated it as "excellent", 12 rated it as "very good" and just one rated it as only "good".

Our formal evaluation of the effectiveness of the RoboSlam workshop is at a very early stage. In the coming months, as well as recording simple metrics (e.g., number of workshop participants and number of website visitors), we will:

- Conduct focus groups and individual interviews with several dozen participants (collecting after one week as well as two months following the workshop) and analyse these data qualitatively,
- Collect survey data at the start and end of each workshop, and again one month later, from all participants and analyse these data quantitatively, seeking statistically-significant gains.

Our research will probe two major topics: learning gains; and ideas for enhancing the program, materials and experience. We will seek to assess:

- How perceptions about engineering, technology, and career options changed,
- Levels of hands-on engagement or experimentation following the workshop,
- Amount of post-workshop dialogue participants had on associated topics,
- What participants learned,
- What they found valuable, enjoyable or frustrating.

5 CONCLUSIONS

In the pilot workshops carried out to date, RoboSlam has proven to be an effective tool for promoting interest in engineering. The current design, while still being refined, already provides a tried and tested means of delivering a practical introduction to robotics for beginners in a single day. The current format has proven very popular with participants and facilitators alike.

Formal evaluation of the effectiveness of the workshop, both in terms of learning and subsequent participation by workshop participant in robotics, programming or other engineering activities, will take place over the coming months, informing further refinement of the design.

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