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An Open Source Hardware and Software Platform for Interdisciplinary Design

Electronics, Interfacing and Programming for the Designer

PHILIP BREEDON, LESLIE ARTHUR AND FERGAL COULTER

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AN OPEN SOURCE HARDWARE AND SOFTWARE PLATFORM FOR INTERDISCIPLINARY DESIGN: ELECTRONICS, INTERFACING AND PROGRAMMING FOR THE DESIGNER

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Leslie Arthur, Nottingham Trent University, Nottinghamshire, UK
Fergal Coulter, Nottingham Trent University, Nottinghamshire, UK

Abstract: The integration of the appropriate pedagogic methods for incorporating technology-based disciplines can be challenging within the design curriculum. However designers and design students who also possess the appropriate technological skills are being viewed by an ever increasing number of commercial organisations as valuable company assets. This paper discusses how the design team within NTU is using this platform to enhance the technological experience and knowledge of undergraduate, postgraduate and research degree students. A number of case studies demonstrate how such a relatively inexpensive and simple programming platform is being successfully utilised for a wide variety of design and research applications.

Keywords: Pedagogic Methods, Product Design, Electronics Prototyping, Arduino Platform

INTRODUCTION

From their inception, there has been a widely held belief that computers and microcontrollers were difficult and unforgiving things to program, requiring abstract logic, an understanding of non-intuitive computer syntax and a firm grasp of electronics. Such preconceptions meant their widespread use remained firmly in the realm of engineering, mathematics and science. Rarely were they seen in the domain of the artist or non-technical product designer.

In recent years it has become clear that a radical shift in opinion has taken place, and now rather than perceiving inaccessibility, many design students are embracing microcontrollers and embedded systems. It may be fair to attribute much of this change to the introduction of the Arduino family of microcontrollers. According to David Cuartielles of the Arduino development team "The philosophy behind Arduino is that if you want to learn electronics, you should be able to learn as you go from day one, instead of starting by learning algebra," [1]. Since its introduction in 2005 the Arduino has seen increasing popularity as an electronic prototyping platform amongst students and hobbyists. Built upon existing open source tools for artists, such as the Processing language [2] (a Java based data visualisation language) and the Wiring microcontroller [3] (an input/output board for artists and education.)

The growth of the platform could be attributed to many factors: its simplicity to setup, low cost, ease of programming (the language is a simplified version of C, yet still allows full C/C++ code to run), has cross platform capability, but perhaps most importantly of all, the inherent

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open source nature of the system. Both the hardware and software are released under open licences–the hardware through a Creative Commons licence, which permits both commercial and non-commercial derivatives to be manufactured and distributed, and the software via an LGPL open licence [4]. These permissive licences have opened the door for much community sourced innovation-the hardware and libraries have been customised for numerous diverse applications such as the compliant wearable "Lillypad" version which can be integrated into textiles, or Google Android ADK, which allows the microcontroller to be controlled remotely via or pass information to an Android smartphone. Alongside the different "flavours" of controller itself, the open nature of the system has opened the door for dozens of third party "shields" that facilitate plug and play access to things like internet access, networking (both mesh and standard), wireless sensing, data logging and motor control.

There are two major hurdles in perception that a microcontroller (μC) and its language need to overcome in order to be embraced by the non-technical student artist or designer. First is the proposition that there is a simple learning curve. Arduino addresses this by emphasising a small number of tangible programming constructs, loops and input/outputs, providing multiple interaction libraries (such as servos and LED matrices) and avoiding abstract ideas such as object orientation (though not preventing it via the aforementioned C/C++ capability). This layered approach to complexity allows the student to concentrate the majority of their effort on creativity rather than software engineering. Secondly, there needs to be the perception of 'cool'. As discussed by Hu and Alders [5] "In industrial design, students need to be motived and intrigued with things that have a physical form, especially a physical and dynamic form that is driven by embedded intelligence". The proliferation of websites such as Instructables and the Makezine blog, have opened the floodgates regarding what is possible, and invariably there is an Arduino μC sitting at the heart of the devices on display.

Engagement has to be the priority when introducing students to something they have little knowledge and/or experience of. The students emanate from different backgrounds so there has to be a common platform to build upon. Whether it is within a seminar or workshop common sense prevails, as there has to be some form of consensus concerning the aim and objectives of the project that reflects a Meta cognitive approach and its relationship to problem solving [6]. The students have pre conceptions, as do most lecturers. It is important to dilute these from the beginning. Engagement is important to teaching; we cannot assume that all of the students will be automatically interested to the same level in the topic. It is important to induce, to encourage an inquisitorial approach to the project. There is a need to ensure that the engagement is right; this is achieved by producing a glossary of terms in plain English defining all technical terms to make sure that the students are comfortable with new concepts. This is simply good teaching practise when wishing to increase a learning curve.

The main and potentially the most important difference between software created by the open source community and that licensed by commercial software companies is that open source software is published under license ensuring that the source code is available to everyone to download and modify as required. The idea of open source has always had the concept of a 'community' at its core, and it is within the Arduino community forums that beginners and experts come together to share ideas, code snippets, tips and tricks. While it could be argued that the availability of large quantities of open source code could lead to plagiarism within an academic setting, it must be realised that the student artist or designer will rarely find code that functions precisely as they want–instead they most often find a best fit, then proceed to dissect the code and customise it for their specific application. An ability for re-appropriation or "hacking" is becoming an increasingly important skill for the designer.

Consumer electronics and devices are increasingly being built on generic hardware platforms such as ARM, and communicating via platform agnostic protocols. Interaction design appears to be changing; showing a shift away from the old top down linear approach–that of expert designers who builds systems for users who interact with them in a prescribed way. Supplanting the idea is the concept of an intermediary "prosumer" or Professional-Consumer [7]. This concept hinges on the idea of a saturated marketplace, where mass production of standardised products satisfies the basic needs of the consumer. When this paradigm shift takes hold, the prosumer will take part in the process by specifying the design requirements through feedback and the re-appropriation of existing artefacts. This shift was also suggested by Gibbons et al [8] where he suggested "Mode 1" (which takes the academic/investigator initiated form of knowledge production–that which has highly defined hierarchies between disciplines) is to be superseded by "Mode 2" (a context driven, problem focused and interdisciplinary) form of knowledge production.

Initially as a project example, consider a student that developed systems for both a Peripheral Interface Controller (PIC) microcontroller as undergraduate BEng level, and then utilising Arduino hardware at MSc level. The PIC formed the central control system for an infrared (IR) Theremin like musical instrument, the function of which was to linearise the output of IR sensors, outputting to an analogue oscillator circuit and passing a Musical Instrument Digital Interface (MIDI) control signal to a commercial synthesiser. The student when dealing with programming the PIC faced many issues, even though proficient in the C language. A particular challenge that was faced was the timing of MIDI control signals. This issue was common to many MIDI based projects due to the slow and asynchronous serial I/O rate of MIDI (a 1980's technology) and the relative high speed of the microcontroller. It was felt an inordinate amount of time was spent resolving this problem, and this took away from many other design considerations. At the time Arduino as a system was in its infancy, and not widely known or available. Had this project been done a number of years later on Arduino, a simple and cheap MIDI shield could have been purchased for approximately $12, which would simplify the task of converting the data rates. This would have allowed the student to concentrate on many other (more important) aspects of the design.

Example 1: Animatronic Face

An MSc Smart design major student project at Nottingham Trent University focused on creating an animatronic face that was actuated by shape memory alloys (Figure 1). This project was linked to a *live* research project based on facial rehabilitation for stroke patients.

Development is also focusing on the Electromyography (EMG) interface for obtaining effective smile control on an animatronic head. The first stages in assessing both the strengths and limitations of Shape Memory Alloys (SMA's) towards resolving biomechanical problems and relieving disability have been undertaken. Experimental work to date confirmed an SMA system could be precisely controlled via EMG data.

Future development of this project is related to both short term and long term goals. The final goal will be the implantation of the device/smart material within the human body, to include a power supply and the control electronics to provide real-time and 'realistic' move- ment of the paralysed mouth. The expectation is that the proposed system will at least provide cosmetic improvements for the patient, in addition to providing improvements with speech and fluid swallowing.

The control system for the actuators within the animatronic face utilise Arduino µC. Whilst discreet power control circuitry had to be designed from basic principles, the use of Arduino allowed the student to rapidly iterate code ideas and versions. As a control system for the animatronic face, a computer vision system was written in the Processing language. This system used a link into Intel's OpenCV library to recognise facial expressions, and then pass said expression to the Arduino controller. The ability to communicate between PC and µC was greatly simplified by the tight integration of the Processing and Arduino environment.

Within a relatively short period of project time the student was able to achieve far more interaction from the system than had they been confined to a PIC or Basic Stamp µC system.

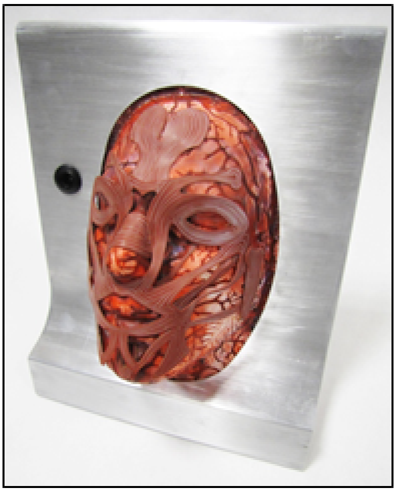

Figure 1: Animatronic Face and Computer Vision System

Example 2: Autonomous Underwater Vehicle

Background

Underwater vehicles, in an all-encompassing sense, cover manned and unmanned vehicles, with the unmanned vehicles being divided into Remotely Operated Vehicles (ROV's) and Autonomous Underwater Vehicles (AUV's).

Students were asked to design, manufacture and test an AUV for a major design technology project at undergraduate level at Nottingham Trent University. The objectives for the project were based on the SAUC-E competition and event [9]. The aims of the SAUC-E event are to advance the state-of-the-art of Autonomous Underwater Vehicles by challenging students to perform an autonomous mission in the underwater environment and to foster ties between students and the organisations involved in AUV technologies. The student AUV competition in Europe started in 2006. It was held in the UK at Pinewood Studios. The competition stayed in the UK for 2007 but was held at the QinetiQ Ocean Basin Tank. The 2010 and 2011 SAUC-E were held in La Spezia, Italy at the NATO Undersea Research Centre (NURC).

The Challenge (a Brief Overview)

Undergraduate Product Design Students were asked to design and build an AUV capable of performing a series of tasks autonomously. The AUV used an obstacle avoidance system to navigate through a water channel/tank, students also having to consider changing the submersed depth (neutral buoyancy) of the AUV for it to navigate successfully. Students were also requested to keep a video diary and a journal of the design development and testing process. The video diary focussed on significant events during your preparations of the event, and included team meetings, designing, building and testing. The design was assessed on overall design quality, software algorithms, interfacing, mechanical design and design choices. The Arduino platform provided a useful and intuitive platform for software development, interfacing and control for the AUV project. The development of a functional prototype was achieved relatively quickly reducing the number of iterations of testing sensor, mechanical and user interfaces (Figure 2).

The key attribute for the designer with little or no programming or electronic experience is that they can be provided with an electronics and interface development platform to rapidly prototype basic electronic functionality.

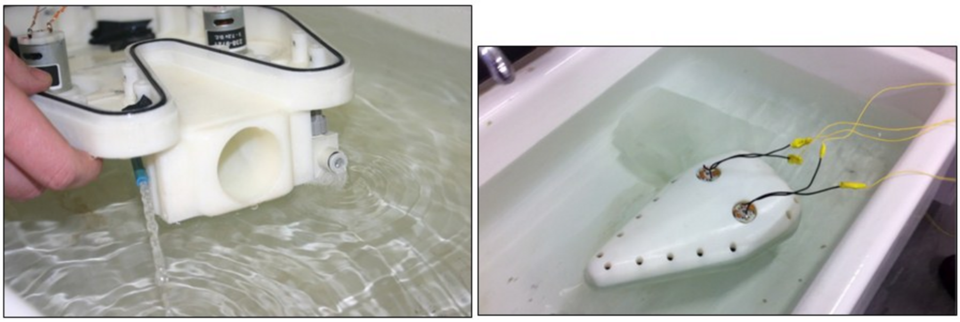

Figure 2: AUV Propulsion and Buoyancy Testing

The numerous disciplines and subject areas that range from the Sciences to the Arts all have various different working practises. The methods and rationale for research are also wide ranging. However, within some areas of Higher Education in the UK, there is a strong drive to correlate the knowledge and to some extent, the working practises across the subject area with the purpose of nurturing and facilitating innovation. Within the UK the Design Council has been the champions of this impetus and reported upon how a considerable number of Universities have designed projects and produced products that link the large number of disciplines together considering Pugh's controlled convergence [10], this is also a significant part of the Design Councils current strategy towards Design [11].

One of the ways to ensure that there is some degree of innovation is to create working groups and teams involving teaching staff and students. The purpose of these teams is to challenge how people think within their working practises by establishing a form of consensual criteria that facilitates cognitive dissonance [12]. It is important that the experience of working together is of real value to the students; as in their third and penultimate year they are employed in industry for a minimum of thirty weeks. This is similar to working in the 'real world'.

The focus of the examples within this paper provide tangible evidence of how the Cox report [13] continues to influence the culture and working practises within Higher Education.

Conclusion

This research focuses on the development of a multidisciplinary design curriculum for students who today are growing up in a visual world, where it is suggested that traditional working methods are still of great value; however, undergraduates do study and work differently than they did 20 years ago in Higher Education.

Students do adapt to the differing processes that are presented to them. The two example projects described in this paper provide clear illustrations of the student's ability to learn new processes and techniques that are not necessarily associated with design education. The research for this paper also identified that change as a concept can make people feel uncomfortable, if it is introduced in an organised way and delivered with a considered tone of voice students will adapt and actively contribute to multidisciplinary design projects.

Basic knowledge of programming constructs provides an advantage that can equip the designer with a common language with which to communicate with an electronic engineering team.

Equipped with an understanding of what can be achieved, and the limitations of electronic systems, the whole product design team can take a conceptual idea, expand and realise a final product in a much shorter timeframe, without expecting or faltering on unrealistic outcomes. Functional prototypes are much quicker to bring to fruition and a product can go through many more iterations of user experience testing when the designers themselves can prototype the basic electronic functionality from the beginning.

Potentially the Arduino's key attribute for the designer is that with little or no programming or electronic experience they can be provided with an electronics and interface development platform to rapidly prototype basic electronic control functionality. This coupled with the proliferation of rapid-prototype 3D printing, the design student can quickly realise their concepts in a tangible and functional way rather than relying on computer rendered images and animations. It is arguable that this makes for a better design education.

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ABOUT THE AUTHORS

Dr. Philip Breedon: Dr Philip Breedon is a postgraduate programme leader within College of Art and Design at the Nottingham Trent University. He started his career as an indentured engineering apprentice and has taken on a series of engineering and computing academic challenges culminating in the award of his PhD based on artificial intelligence and robotics. A number of previous cross disciplinary robotics and pneumatic technology research projects have been undertaken, including Snake Robot and Muscle Machine. These exciting and innovative projects provided numerous challenges in terms of design and control. His research interests and latest projects centre on new and emerging technologies and include technical textiles, wearable technologies, swarm robotics and investigative research related to the utilisation of 'smart materials' for medical applications and surgical implants.

Leslie Arthur: It is important that innovation is encouraged by senior managers and understood by students. Farming for knowledge is something we all need to cultivate, consistent in nurturing and supporting a cross discipline to our work.

Fergal Coulter: Fergal Coulter qualified in Electronic and Computer Engineering at University of Limerick, followed by a number of years working with internet and server technologies and user interfacing. In 2010 he completed an MSc in Smart Design at Nottingham Trent University, specialising in the design and fabrication of active facial prosthetics (or artificial muscles) to help sufferers of facial paralysis recover symmetric expression. He is currently pursuing his PhD at NTU, within the discipline of Bio-Robotics and Artificial Muscles via minimum energy structured electro-active polymers (EAPs).

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