

BUZZ-BOARDING; PRACTICAL SUPPORT FOR TEACHING COMPUTING BASED ON THE INTERNET-OF-THINGS

Prof Victor Callaghan
University of Essex
COLCHESTER, UK CO43SQ
vic@essex.ac.uk
<http://dces.essex.ac.uk/staff/vic/vic.html>

ABSTRACT

In this paper we discuss the challenges of educating students in emerging technologies such as the Internet-of-Things. In respect of this we present an innovative approach (Buzz-Boarding), to supporting laboratory based teaching of these newly emergent science and engineering skills. The approach is based on a novel modularised learning toolkit (both physical and virtual), which is described in this paper. The primary aim of this work is to arm universities, with the means to support the acquisition of these key skills by students in a motivating and effective way. A secondary aim is to support the wider effort of teaching computing in pre-university schools.

Keywords

Embedded-Computing, Internet-of-Things, Educational-Technology, School ICT

1. INTRODUCTION

The next wave of Internet technologies promises to move beyond the era of connected computers to an era of connected “things”; the so-called “*Internet-of-Things*” (IoT). In this new digitally augmented world, everything in a person’s life from bathroom scales through cookers to cars might have an Internet connection, the behaviour of which can be orchestrated by people or their agents. There are no reliable estimates for the size of this market but a report by the “Arthur D. Little management consultancy” suggests that by 2020 the IoT market could be between 22 billion and 50 billion dollars (Schlautmann et al 2011) made up of some 16 billion connected devices (Vermesan & Friess 2011). These figures seem plausible, or even pessimistic, as the current value of China’s *Internet-of-things* industry alone has, supposedly, already reached 30 billion dollars (exclusive of the application layer) (Business-Wire 2012). This rising demand for Internet ready “things” is good news for companies and graduates alike as there will be increasing opportunities for both. However, it raises the question of where the developers of these products will come from, what skills they will need and how will they be trained. As always, universities will be expected to provide graduates with the required skills, so, for example, some of the estimated 60,000 enrolled UK computing undergraduates (HESA 2011) will need to be trained in these new technologies. In respect of this, the remainder of this paper seeks to explain what the “*Internet-of-Things*” is, what special needs it places on the practical aspects of university teaching and how the *Buzz-Board* approach can support Universities in addressing this challenge. Finally, we introduce research on a new immersive teaching environment that can use mixed reality to extend current lab based teaching to the online education community?

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission.

© 2012 Higher Education Academy

2. UNDERSTANDING THE SCIENCE

Computers that are embedded into “*things*” such as washing machines or cars are different to the more familiar desktop, laptop and palm computers in that they generally don’t have display screens, keyboards or built-in development and debugging tools. They are somewhat naked machines where, in computational terms, the computing principles are laid bare and visible to students making them perfect vehicles for education. For instance, the minimalist hardware, and real-time operation, requires more efficient software, which in turn needs a good understanding of the principles of operating systems (often modularized) and software algorithms (often hand crafted). Also, the varied nature of the input/output (I/O) demands an understanding of sensory signals, communication protocols and synchronization issues that underpin computers of all sizes. Thus the lack of frills, which can make embedded-computer development seem difficult, becomes an advantage to students by exposing them to the underlying science. By and large universities make a good job of teaching these fundamental principles but to-date, the real problem has been in UK pre-university schools where the current ICT curriculum is widely viewed as being too focused on using high-level applications, such as spreadsheets, databases and the web (which mask the underlying science), rather than the core scientific fundamentals underpinning computing and how it all works. As Professor Simon Peyton-Jones eloquently put it “*Children are taught physics and biology because we live in a physical and biological world. We now live in a digital world and children should be taught how it works. This will allow them to manipulate computers for their own ends,*” (Brittain 2011). In many senses, the digital world Professor Peyton-Jones describes is the *Internet-of-Things*, or more simply put, pervasive computing. Fortunately, it seems educational policy may be about to change for the better as the UK Minister for Universities and Science (David Willetts) has declared that the UK government intends to produce a new computing curriculum, focusing on computational principles, systemic thinking, software development and logic that will be backed up by rigorously assessed GCSEs and A-levels. In addition, it seems, there will be Industry-backed challenges to encourage creativity, entrepreneurship and teamwork. In this paper we describe a modularized toolkit that allows “Internet-of-Things” products to be imaginatively created in an educationally effective and fun way that helps teachers to emphasis computing fundamentals; *buzz-boarding*.

3. BUZZ-BOARD HARDWARE

The *buzz-board* toolkit is an open-system comprising some 30 pluggable hardware boards that can be interconnected together to make a variety of “*Internet-of-Things*” applications (see www.fortito.com). To understand the *Buzz-Board* concept, it is easiest to look at some pictures; figure 1 illustrates a few of these modules.



Figure 1. *Buzz-Board* Examples - From Left to Right Audio, Midi, Keypad, Base (Processor), LED & Network

Notice how most modules have through-connectors (a daisy chain bus system) at each end, enabling the units to be assembled in mechanical stacks, in various combinations, thereby allowing different functionalities and physical forms to be built. Other connectors allow the units to be stacked into orthogonal layers. This approach takes the design options from being solely electronics and computation into the mechanical domain allowing, for example, a wheeled robot to be constructed (see figure 3a). The *Buzz-Board* strategy is to reuse as much industry standard development technology as possible, both to allow students to benefit from the experience of using standardised industry systems and reaping the financial gains from commercial economies of scale. For example

the main processor board (the heart of the *Buzz-Board* system) is designed in such a way as to accept a daughter mezzanine board containing the processor of choice. One variation of this mezzanine board is a version that is pin compatible with the industry standard mbed (see Figure 2a) whilst another is aimed at the newly emerging \$25 Raspberry Pi (see figure 2b). In addition to ARMs, other processors that the *Buzz-Board* system supports are AVR, Coldfire, 68K, and PIC processors. The flexibility afforded by this strategy enables students to be exposed to a wide set of technologies and allows industrial based developers to move between processors as financial or performance advantages change.



The mBed is based on the ARM Cortex-M3 Core running at 96MHz, with 512KB FLASH, 64KB RAM and various interfaces including Ethernet, USB Device, CAN, SPI, I2C

Figure 2a. mBed



The Raspberry Pi is based on an ARM1176JZF5, running at 700Mhz, with a Videocore 4 GPU. (BluRay quality playback) in a Broadcom BCM2835 SoC. The current best specified model has 256Mb RAM, 2 USB port and an Ethernet port.

Figure 2b. Raspberry Pi

4. BUZZ-BOARD SOFTWARE

Like the hardware, the *Buzz-Board* software uses industry standards wherever possible. For example, the mbed option makes maximum use of the existing online mbed tools and software (see <http://mbed.org/>). The development software is based around C & C++ (the most widely used languages in embedded-computing) coupled with a simple 'drag & drop' environment using web based development tools. In this, the processor board is connected to a PC via a USB which behaves like a USB memory drive. Using this, the compiled program can be "dragged and dropped" into the *Buzz-Board* and executed by pressing the reset button. A variety of software demos, and fully working assignment templates are provided (including software source code and the full text of assignments – see www.fortito.com).

5. BUZZ-BOARDS SUPPORTING THE CURRICULUM

One of the major problems facing teachers designing practical assignment work for students following '*Internet-of-Things*' related courses is, how to match the relatively open creativity that software allows with hardware. Whilst at an integrated circuit level it is possible to design almost any computer product it is, unfortunately, a very time consuming task that doesn't fit easily into the typical time available (half a day). This limitation means that a teacher is faced with various unattractive choices such as getting students to programme a pre-built product or experiment on some sub-part of the technology (eg write a programme to generate bit streams monitored on an oscilloscope) which, whilst useful, can be somewhat boring and demotivating. *Buzz-boards* overcome this problem by providing a set of "deconstructed" '*Internet-of-Things*' appliances in which the generic functionalities can be reassembled to make the original '*Internet-of-Things*' appliances or combined in novel ways to make new appliances. In terms of the pedagogical approach our work belongs to the schools of constructionalism and experientialism in that learning takes places through the construction of meaningful soft and physical artifacts, with support for open design (Papert 1991). In technical terms its based on the concept of 'virtual appliances' and 'meta applications' (Chin 2009).

The following discussion illustrates the type of systems that students can create from the current *Buzz-Board* modules. It's not exhaustive, rather illustrative. Firstly, simple applications such as making a calculator can be effected by using the *processor baseboard* with the onboard OLED display and buttons. Games are always popular with students and the same arrangement can be programmed to create games such as *Pacman*. Another popular application is music and by using the *processor baseboard* with a '16-button keypad *Buzz-Board* a simple musical instrument can be built. By adding an *A/D Buzz-Board* or the *MIDI / Audio Buzz-Boar*, a guitar tuner or full synthetic musical system can be created. Media gadgets such as cameras and mp3 players can simply be created by adding a *Buzz-Board miniature camera* or by adding the *audio / SD storage Buzz-Board*. Personal fitness and health applications can be constructed using the inertial, physiological and EMG sensors on the *medical Buzz-Board*. Internet-appliances, such as an Internet radio, can be made using the *network Buzz-Board*. For students with interests in human biology or physics the physiological or EMG sensors from the *medical Buzz-Board* enable brain wave, lie detection and emotion sensing systems to be created. Alternatively, by using a tunnel diode on the same *Buzz-Board* true random number generators or even more speculative "multi-universe splitters" can be made. Mobile robots are very visual, futuristic and great for exposing basic computing principles. By using the *robot chassis Buzz-Board* a desktop mobile robot can simply be made to perform tasks such as line following, light seeking and maze escapes. By adding the *audio Buzz-Board* it can be given a voice. By using the *Test-Point Buzz-Board* it is possible create instruments such as a multi-meter, oscilloscope, or logic analyser. Finally, to make the design possibilities as open ended as possible, the *Buzz-Board* kit includes two types of *prototyping boards* into which basic electronic and computing components can be inserted.

By way of an example of what is possible, the following describes how a *mobile desk based robot* can be constructed from *Buzz-Boards* using a *ARM-Cortex mbed mezzanine board*, *processor base board*, *robot chassis* (with IR proximity sensors and batteries), and two *three-way inter board connector Buzz Boards*. This is a simple task involving just plugging the boards physically together (see figure 3a). The finished robot has a wide range of features, including: 8 IR range finders, 5 Line following sensors, 2 Light sensors, Lithium-Ion Battery, 2 Dual mode gear-motors (with motor load monitoring & quadrature feedback), 8 Push buttons, 8 Tri-colour LED's, Ambient light level sensor, 3-axis accelerometer, temperature sensor and a full colour high resolution OLED display. To program the robot, the student either writes their own custom code or downloads the prebuilt software from the mbed site, saving and compiling it to their local computer. When the *Processor Base Board* is connected the computers USB, it appears as a usb-drive. Executable software may them be moved to the robot, using 'drag and drop'. Pressing the reset button on the 'processor base board' will initialize and run the program. More details on the *Buzz-Board* range of modules and their usage is given elsewhere [Wang 2011]

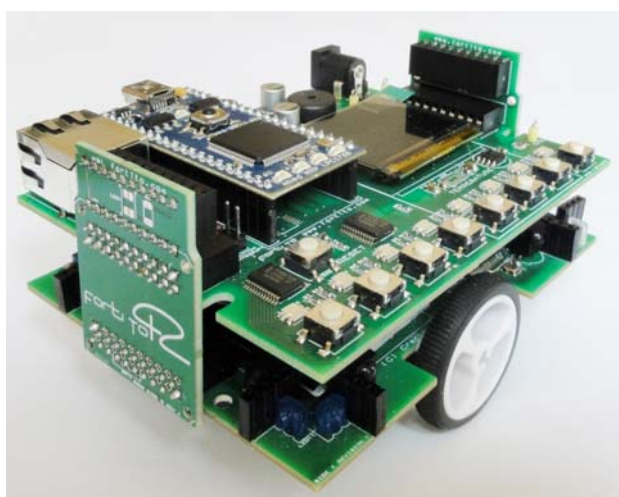


Figure 3a. The Buzz-Board Desk Top Robot

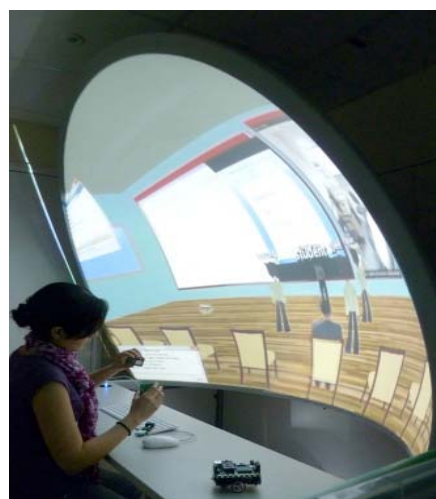


Figure 3b. The Immersive Learning Desk

6. THE FUTURE – AN IMMERSIVE EDUCATION MIXED REALITY DESK

In the science-fiction prototype “*Tales from a Pod*” (Callaghan 2010) the scenario describes the concept of immersive learning educational pods (ePods), in which students experience personalised learning from a futuristic “mega university”. A joint research project between Essex University (UK) and King Abdulaziz University (Saudi Arabia) is exploring the possibility of bringing part of this vision to reality by creating a version of the ePod that takes the form of a desk; the iDesk (Peña-Ríos 2012). A central feature of this iDesk is an *InterReality Portal*, which is a 3D virtual environment within a semi spherical sectioned screen that gives the student an illusion of being in a remote location (see figure 3b). More formally, it allows users to complete activities at any point of Milgram’s Virtuality Continuum (Milgram 1994). The idea is that geographically dispersed students using these desks can come virtually together to collaborate in mixed reality learning exercises. The collaborative work is based around the deconstructed ‘*Internet-of-Things*’ *Buzz Board* toolkit in which the modules have both real and virtual forms (and where components can be created and moved between any of the connected virtual and real worlds – ie between iDesks). The iDesk supports both students and teachers using variety of agents to mediate both the users and learning content (Zheng 2011).

7. SUMMARY

This paper has presented a constructionist based pedagogy and toolkit (Buzz-Boards) for supporting the practical aspects of teaching computing. It is based on a deconstructed embedded computer in which the constituent software and hardware modules may be reconstructed (or redesigned) by students to make an almost endless variety of computing systems. This methodology also supports creativity by giving the students more design choices and seeks to increase their motivation by enabling them to create real products within the short timescales available to most teaching laboratory classes. Apart from allowing computing to be taught in a more effective way, this approach also directly addresses a gap in current teaching concerning how to support the learning of practical skills needed in the fast growing market of the *Internet-of-Things* and pervasive computing. Finally, the paper discusses a speculative development in another growing area of education; *immersive learning*, which, like the *Internet-of-Things* is based around networking and suggests how these two synergetic areas might be combined in an educational setting.

8. ACKNOWLEDGEMENTS

I am pleased to acknowledge the valuable contributions to this work from my Essex University colleagues Malcolm Lear, Martin Colley & Anasol Pena-Rios.

9. REFERENCES

- Brittain N, (2011), “IT education remains mired in uncertainty”, Computing, 20 Sep 2011
- BUSINESS WIRE, (2012), “China’s Internet-of-Things Industry Sees a Landscape Characterized by Clustering in Four Regions”, <http://www.businesswire.com/news/home/20111004005055/en/CCID-Consulting-Chinas-Internet-of-Things-Industry-Sees-Landscape> (February 2012)
- Callaghan V, (2010) “Tales From a Pod (aka: A Lesson You Will Never Forget)”. Creative Science 2010 (CS’10), Kuala Lumpur, Malaysia, 19th of July 2010.
- Chin J, Callaghan V, Clarke G, (2009), “Soft-appliances: A vision for user created networked appliances in digital homes”, Journal of Ambient Intelligence and Smart Environments, IOS Press, Netherlands.
- HESA (Higher Education Statistics Agency), (2012) “2010/11 student and qualifier statistics” <http://www.hesa.ac.uk/> (February 2012)
- Milgram P, Kishino F, (1994), “A taxonomy of virtual reality displays,” IEICE TRANSACTIONS on Information and Systems, Vols. E77-D, no. 12, pp. 1321-1329.
- Papert, Seymour. Situating Constructionism. In I. Harrel & S. Papert (Eds.), Constructionism: Research reports and essays, 1985-1990 by the Epistemology & Learning Research Group, (1-Norwood, N.J., USA: Ablex Publishing Corporation, 1991
- Peña-Ríos A, Callaghan V, Gardner M, Alhaddad M, (2012), “Towards the Next Generation Learning Environments: A Mixed Reality Intelligent Learning model”, 8th International Conference on Intelligent Environments (IE’12), Guanajuato, México, 26-29 June 2012
- Schlautmann A, Levy D, Keeping S, Pankert G, (2011) “Wanted: Smart market-makers for the “Internet of Things”, Arthur D. Little, management consultancy, see http://www.adlittle.se/prism_se.html?&view=383 (February 2012)
- Vermesan O, Friess P, (2011), “Internet of Things - Global Technological and Societal Trends Smart Environments and Spaces to Green ICT”, River Publishers, Denmark, ISBN-10: 8792329675
- Wang M, Callaghan V, Lear M, Colley M, (2011) “Teaching Next Generation Computing Skills; The Challenge of Embedded Computing”, Intelligent Campus 2011 (iC’11), Nottingham 26th July 2011
- Zhang T, Callaghan V, Shen R, Davies M, (2011), “*Virtual Classrooms: Making the Invisible, Visible*”, Intelligent Campus 2011 (iC’11), Nottingham 26th July 2011