Nurturing the Cyber-Physical Pedagogical Approach for Outcome based Learning in Embedded Systems

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ABSTRACT

Embedded system is a rapidly emerging branch of Electronics engineering that derives the concepts and ideas from host of other branches of knowledge such as Electrical Engineering, Computer Networking, Ergonomics and Management to name a few. Moreover being a highly laboratory oriented subject, it always poses challenges for the academicians to impart state-of-art skill sets by imposing the hands-on-training. However with differing background of the learners, the pedagogical issues are always put to test and thus demands innovation in teaching-learning along with project implementation. The present paper put forth a outcome based approach for inculcating the right kind of skill set amongst the embedded system learners which is further blended by the cyber physical model. A thorough discussion regarding the prevalent pedagogical issues along with the different pedagogical models have been presented in the paper. Analysis of a credit course in Embedded System Project design has been done to validate the findings of the authors.

Keywords: *Embedded System, Cyber Physical Model, Electronics Engineering, Outcome based learning*

INTRODUCTION

There are various important but complex problems, phenomena and concepts that resist understanding or resolution when approached from single disciplines (Golding, 2009).Electronics engineering which is highly regarded as an applied discipline is full of such interdisciplinary, cross disciplinary and multidisciplinary academic programs. Electromagnetic Engineering, Computer Networking, Digital Signal Processing and Embedded Systems are few such interdisciplinary courses which make use of more than one discipline to comprehend, develop, apply and address the various issues faced by the scientific fraternity. In particular the last decade has witnessed fuelling of large number of interdisciplinary courses in the discipline of the Electronics Engineering due to the blending of Mechanical, Automobile, Telecommunication, Industrial and Software Engineering with the core concepts and ideas of Electronics mainly due to the innovative products spreading in the market and transforming the societal life in a big way. However, the above mentioned phenomenon has posed several key issues for the academicians in the higher education paradigm. Especially when it comes to project design in such interdisciplinary disciplines, the team necessitates members from different disciplines and the communication between them can be a challenge due to diversified semantics, notations and jargons. Sim (2010) has discussed host of such issues related to effectiveness of the teaching methods for Engineering courses in a large non-homogeneous class setting with regards to the specific disciplines – Computer Science and Mechatronics in learning Embedded Systems. The present paper too discusses the issues while implementing a credit course in Embedded System Project Design. However, before discussing the core issues, it would be worthwhile to present the very notion of the Embedded Systems.

Embedded System is the latest buzz word in the Electronics Engineering that implies a dedicated mostly single functional, tightly constrained in terms of footprint, speed and power and capable of giving the intended output in the stipulated response time. Today, embedded systems are found in cell phones, digital cameras, camcorders, portable video games, calculators, and personal digital assistants, microwave ovens, answering machines, home security systems, washing machines, lighting systems, fax machines, copiers, printers, and scanners, cash registers, alarm systems, automated teller machines, transmission control, cruise control, fuel injection, anti-lock brakes, active suspension and many other devices/ gadgets (Engineers Garage, 2012).Some of the typical characteristics that made these systems challenging interms of design and also interdisciplinary in nature are detailed below vis-à-vis the discipline from where the ideas are borrowed from:

- Repeated execution of tasks (Software Engineering especially the while(1) loop)
- Tightly constrained interms of code length and execution time (Software Engineering)

- Slick, less weight, small footprint (Electronics and Industrial Engineering and Ergonomics)
- Less time to market, cost effective (Design Reuse and Management Sciences)
- Sensing the environment (Sensor Technology)
- Manipulating the physical variables for control purpose (Control Engineering, Mechatronics)
- Communicating with external environment (Computer Networking, Protocols)
- Operating system fitting into small memory (Real Time Operating System)
- Efficiency of implementation in given application (Mathematical Modeling)
- Onchip testing and debugging (Simulation Engineering and Prototyping)

Due to the above discussed highly interdisciplinary nature of the subject, a typical academic programme in Embedded System has been launched by most of the institutes of higher learning as a 'Choice based Credit Course' which can be opted by other Engineering disciplines. Inspite of specifying prerequisites before opting for such as course, the academicians still find it challenging to deliberate the concepts to the heterogeneous group of learners with different academic backgrounds. This has also led to different approaches of implementing this course as presented in following section.

RELATED WORK

The discipline of Embedded Systems seems to be accelerated since 2001 as seen from the report of Committee on Networked Systems of Embedded Computers of National Research Council (National Academic Press, 2001). The above mentioned report essentially describes the growth of the Embedded System as "Advances in the miniaturization and networking of microprocessors promise a _day when networked computers are embedded throughout the everyday world. However, our current understanding of what such systems would be like is insufficient to bring the promise to reality." With the ubiquitous penetration of such systems, there was no wonder that the academic community was sensitized and launched many programmes in this niche area. This was followed by different pedagogical approached to inculcate the concepts amongst the students.

Griffiths et. al. (2005) presented the multi-disciplinary nature of embedded control system design and how a course developed at the University of Michigan which addresses the broad set of topics needed for embedded control system design to senior engineering undergraduates from a variety of backgrounds. They reported a laboratory component that uses a typical automotive power-train micro-controller and teaches topics in system dynamics through programming assignments involving dynamical systems simulations. Farias et. al. (2010) introduced a novel approach to building virtual laboratories of embedded control systems using TrueTime and Easy Java Simulations. According to the proposed approach, authors use TrueTime to develop the simulation of an embedded control system and then move to Easy Java Simulations to link the system to a sophisticated graphical user interface that provides the visualization and user interaction of the virtual lab required for pedagogical purposes. While Huang et. al. (2010) proposed a wiki-based pedagogy approach to help learners undertake their project successfully. In this pedagogy, three key elements, namely a web-based collaborative platform (WCP), collaborative learning theory (CLT) and scaffolding theory (ST), were designed and implemented to realize the objectives of the project work. Tuma et. al. (2006) came up with a special concept, which attracted sponsors from industry. They proposed to use the same platform with only different add-on boards, which further reduces the per-system price and getting-started overhead. Since the students can do much of their work at home, the after hours spend in the laboratory are less which frees the resources to other activities. Nooshabadi (2005) et. al. first time launched an international collaborative teaching project involving the design of a state-of-the-art microprocessor and embedded system between the University of New South Wales, Manchester University and the Imperial College, London University. This project, being the first of its kind anywhere in the world, provides an environment that replicates the current industrial practice in embedded system design in an easy and comprehensible setting; an environment where the processor, dedicated coprocessors and software are all integrated to create a functional system such as used in sophisticated electronic devices, including mobile phones, webphones, photocopiers, televisions, digital cameras and PDAs.

However, in order to bridge the gap between the industry and institute interms of the skill sets in Embedded Systems, a new approach of 'Hands on Training' is emerged in last five years. As discussed by Mahmoodi et. al. (2012), Modern embedded systems design relies on heavy use of Intellectual Property (IP) and involves both hardware and software design. Moreover, there is an increasing unitization of a diverse set of I/O ports in embedded systems including video, audio, Ethernet, etc. In order to reflect these trends in education in a hands-on manner, a platform is needed that allows fast integration of hardware and software, rapid prototyping capability, and rich IP library covering processor cores, I/O interface standards, arithmetic and signal processing functions, etc. Also as pointed out by Kumar et. al.(2013), the multidisciplinary nature of such systems makes it challenging to give students exposure to and experience in all their facets. This made the authors to propose a generic architecture, containing multiple processors, that allows easy integration of custom and/or predefined peripherals. The architecture allows students to explore both the hardware and software issues associated with real-time and embedded systems. Even one of the authors of the present article also tried the hands-on approach through his latest books (Parab, Shelke, Kamat & Naik, 2007; Parab, et. al., 2008; Kamat, Shinde & Shelke, 2009; Kamat, Shinde, Guikwad & Guhilot, 2012). The gist of the above said hands-on approach is achieving certain competencies by the students as presented in the following section.

METHOD

A successful Embedded System project requires a great deal of interdisciplinary competencies amongst the students. In view of this the authors have developed a questionnaire shown in table 1 to quantify the outcomes of the students.

Table 1: Questionnaire to access the Competencies of the Students

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Design aspects

1. Is the microcontroller / Microprocessor / FPGA has been judiciously selected?
2. Can the students support their decision of selection of processor based on percentage of on chip resources used in their project?
3. Whether the clock frequency for the design has rightly been chosen?
4. Whether the students have really worked on the trade-off between speed power and area in their projects?
5. Do the PCB made in house or used as a readymade?

Testability issues

1. Whether the test benches have been developed?
2. Whether the testability aspects have been taken care in the project?

Design Methodology

1. Can the students work in given constraints of components, ICs and other peripherals?
2. Whether the students are following simple to complex design approach as against the complex to simple?
3. Whether the students are aware about the design abstractions viz. behavioral, structural, dataflow?

Working after laboratory hours

1. Whether the students own their Embedded demo boards such as PIC kit or MCS51 kit?
2. Whether students work outside the laboratory hours by using their own test equipments?

Peripheral issues

1. Are the students aware about the market share of the Embedded Systems?
2. Whether the students have accessed the career avenues after completion of their projects?
3. Whether the students are aware about the free samples of ICs/KITs offered by blue chip companies which can be used in their project?
4. Whether the students are aware about the soft IP cores which can be used in their projects and the same will reduce the time to market or time to development?

Working with supervisors

1. To what extent the students have taken the help of the guiding teacher? This is to be rated right from the origin of the idea, designing aspects, hardware construction, software development, front panel design and documentation.
2. To what extent the students have taken the help of Teaching Assistants, research students in the department, laboratory assistants etc.

Ergonomic aspects

1. Whether the students have taken care of Ergonomics in their project?
2. Whether the box is made in house or made to order from outside?

Documentation and other issues

1. Whether the students have followed a standard template such as IEEE while writing their report?
2. Are the references, citations in order in their report?
3. Whether the work has been projected in the project competitions?
4. Whether the students have reported the work in conferences, journals and other scientific/technological forums?

Best practices

1. Whether the students have worked out the power budget, cost budget and other economics related to the project?
2. Whether the student has used the open source tools?
3. Whether the recycling aspects have been taken care of while selecting the components?
4. Whether the students are aware that their project should generate minimum e-waste?
5. Does the project report cover the possible future extension to help other peers as regards to the possible future work?

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The responses to the questions were sought from the Postgraduate Students undergoing the Credit Course in Embedded System Project design. The preference measures were decided based on the well known Likert scale for attitude measurement where, in place of a numerical scale for answers, answers were collected on a scale ranging from complete agreement on one side to complete disagreement on the other side, with no opinion in the middle. Along with this the students were also trained by using the 'Cyber-Physical' model shown in fig. 1.

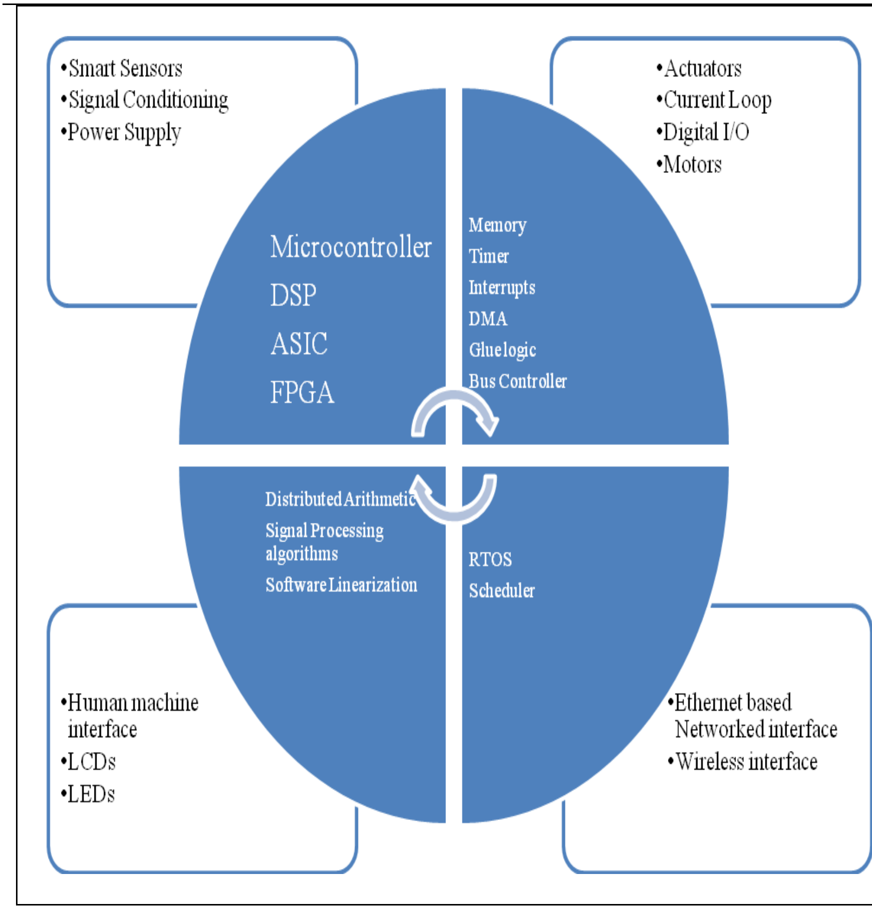

Figure 1: Cyber Physical Model for teaching Embedded System

SUMMARY AND CONCLUSION

The competency of students in terms of outcomes was assessed in a credit course on Embedded System in nine domains. Moreover the students were trained to gain the expected competencies by using the Cyber Physical Model. As perceived from the responses, the expected design competencies were well received by the students with the application of the model. Moreover the students opined that the model is taking into account good number of prevailing trends in the embedded system paradigm. On the processor domain, it harps on the coverage of diversified concepts starting from basic microprocessors to ASIC. The software concepts such as distributed arithmetic are needs to be paid more attention in view of the real time behavior of the embedded systems. As a whole the Embedded Systems are moving towards the networked monitoring and control which was presented by means of the Ethernet based interface and wireless interface. A human machine aspect that plays a vital role was implemented in the constraint of power budget by using graphical LCD interface. Thus the design aspects which are truly interdisciplinary in nature were well inculcated amongst the students using the cyber physical model.

It was also found that around 25% of the students are working on the projects after laboratory hours which deserve extra credit. However, most of the students are unaware about the peripheral issues and they need to be counseled so as to link their project with future career avenues. The documentation aspects also needs to be improved as most of the students were found to be ignorant about the citations and standard templates followed by the professional bodies. None of them have reported on the issues covered under best practices which are really a cause to worry.

Thus, whilst the embedded system paradigm is evolving in terms of the design ideas, implementation platform, and software over heads, operating system innovations, human machine interface, the traditional teaching learning has been striving hard to keep pace with the industries. In this context the present paper portrays the outcome based approach amalgamated with the cyber physical model of the Embedded System which has greater significance from the pedagogical delivery and the infusion of state of art ideas and concepts point of view.

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