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Challenges of Embedded Systems Teaching in Electronic Engineering Studies

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Introduction

Embedded systems (ES) penetrate nearly all fields of electronic equipment. The term ES was coined to name computerized electronic module dedicated to perform a well defined function as opposite to the general purpose computers. The heart of today's ES is so a called embedded microcontroller (EM). They range from ultra-low power programmable microcontrollers with very limited resources up to the digital signal processors featuring world's top computational performance. Fields of application of ES include nearly everything – starting from battery powered portable medical and personal entertainment equipment, automotive and security systems, all kinds of domestic electric appliances, and ending at powerful networking, image processing and military solutions. At the annual Embedded systems conference in Boston'2006 it was noticed that title embedded systems is loosing its meaning since we approaching the day when every technical system may be called ES.

Importance of ES teaching is well realized by the universities and colleges around the world. Traditionally ES related courses are included both in to Electronic Engineering (EE) [1, 2] and Computer Science (CS) [3, 4] curriculums. Recently, studies in mechatronics and even educational courses of technological literacy for non-engineering students are supplemented with ES material [5]. Numerous publications can be found to deal with ES education approaches in the last decade [6-8]. New tools and methodologies are reported in order to meet ES teaching needs in response to the industrial trends, appearance of multimedia technologies, and tools from vendors [9-11]. Giving ES related courses is as dynamic and challenging as is the field of ES itself.

The goal of our investigation is to carry out an analysis of challenges of teaching ES in the EE curriculum context. It could contribute to the improvement of understanding of the current status in the field, which is of strong importance for effective shaping of ES teaching.

Methodology

To reach our goal we will pursue the methodology consisting of two parts. Firstly, we give an overview of publications concerning recent trends and faced challenges in ES teaching and compare them over our experience. Secondly, we do an analysis of EE bachelor degree final year projects (FYP) presented and defended at Kaunas university of technology, Telecommunications and electronics faculty in 2007-2009. The analysis is targeted to extract the information about how widely and how professionally ES related issues are presented by the students in their final qualification proof project. We expect the results of analysis could be appended to many feedback collection methodologies (student's opinion surveys, response from industry, accreditation conclusions) that are applied to assess successfulness of teaching curriculum of ES related courses.

Related work overview

Challenges related to the ES teaching may be classified to student related, lecturer related and contents related.

Student related challenges:

1. Lack of sufficient knowledge and skills from background related disciplines [1]. It is first of all discrete and analog electronics, programming skills.
2. High competence and motivational differences [5]. This makes it difficult to select starting level of teaching during lectures and laboratory practice. As a consequence lecturer chooses to communicate to the mid-level student, which is hard to understand for the least advanced students and is not interesting for the most advanced. The first group then looses self confidence in the subject and takes a position "this is not for me", while the second group also sees little sense to attend lectures and opts to continue self education involving himself in the projects little related to the theoretical part of the course. The situation calls for personal approach to each group of students and possibly additional attributes in evaluation grades like special

certificates indicating very good results in the number of ES related courses. This attribute stated in student's CV could be of some value to the hiring companies while selecting new employees. Personal approach to each student could be an expensive solution, requiring increase of lecturer's academic hours.

3. Programming EM is an essential topic in ES design. However, very considerable amount of EE students are very opposed to programming as also mentioned in reference [2]. It is even mentioned, that software oriented courses de-motivate EE students [4]. Approaches to use gaming elements design [12], restructuring curriculum in order to start from very high level languages instead of assembly [2] are already implemented.

4. Lack of technical English language knowledge. It is virtually impossible to publish up to date teaching books in the field of ES in native language. Therefore, English is a must even if courses are officially given in native language.

5. More general learning mentality issues like planning skills [6] (leaving everything for the last moment, especially during course projects), not understanding the essence of plagiarism, inability to write technical reports, etc. Introductory courses targeting the above issues and more strict control could be suggested to facilitate the problems.

Lecturer related challenges:

1. ES covers several fields of EE and CS [3]. Therefore, a lecturer is challenged to be an expert in all of them, including several programming languages, development tools, analog and digital signal processing, control theory, etc.

2. Very dynamic progress of technologies used in ES design adds a requirement of constantly updating the knowledge [13].

3. Compatibility of many hardware and software tools and especially their versions puts a requirement to adapt laboratory supplement material constantly. Web based material hosting is therefore a must.

4. Innovative teaching requires ever more work hours from lecturers leaving less time for research projects [14].

Contents related challenges:

1. Too limited time for so many theoretical topics and practical skills is very evident in ES courses [15].

2. ES is relatively new and not yet well defined discipline. Focusing on ES technologies teaching or ES applications teaching is always a dilemma [6].

Final year project analysis

Number of full time and partial time students graduating EE was respectively 48 in 2007, 37 in 2008, and 46 in 2009. By manually searching reports of FYP of 2007-2009 we were looking for the information described in this chapter.

The number of FYP with an EM utilization given in Fig.1 very good follows the world's trends of wide spread of ES. For this plot we have assumed that EM is utilized if it was included in the final electrical schematics.

A rough indicator about how professionally students design ES could be the number of projects with given EM software. In Fig. 2 there are presented results about what programming languages were used. Evident popularity of C having assembly far behind reflects today's trends in ES design, too.

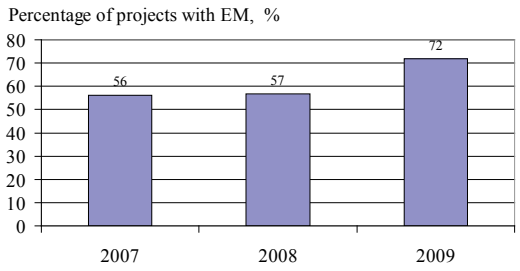

Fig. 1. Percentage of projects with embedded microcontroller

The disappointing result is that more than half of projects with EM does not contain any source code. This to our opinion can be caused by:

1. Lack of knowledge and skills to design ES software.
2. Insufficient time allocated for the project since software has to be written at the final stage.
3. The software part was done by someone else, most often by the staff of laboratory involved in designing ES.
4. EE students are heavily opposed to developing software.

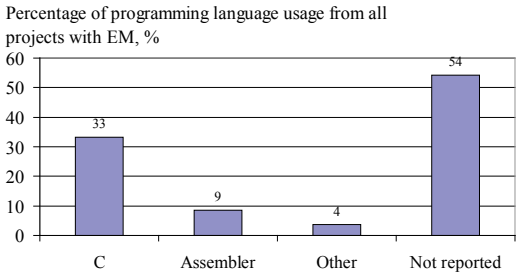

Fig. 2. Programming language usage

As seen from Table 1 the number of projects with EM nearly matches the number of projects reporting block diagram of the embedded software algorithm. Even though block diagrams in many cases were of low quality, their presence reveal deep understanding of software importance.

Table 1. Summary of ES design features

Features	**Percentage form all projects**
Projects with EM	62
Projects with EM software	28
Projects with block diagram of embedded software	58
Projects with electrical schematics	78
Projects with PCB drawings	28
Projects with prototype	37
Projects with EM and prototype	24

The remaining rows of Table 1 are also intended to show the level of professionalism in bachelor projects. In particular we see that one fifth of all projects does not contain electrical schematics, only approximately one fourth contain printed circuit board (PCB) drawings, around one third reached the stage of prototype implementation. By the prototype we have treated not only

self developed equipment or systems but also utilizing of-the-shelf hardware and equipment designed in the university laboratories that was used by the student to carry out some experimental activity.

To focus on the issue "what we teach and what students opt to use in their projects" we have produced Fig. 3-Fig.5. Fig. 3 in particular shows that around half of the projects are based on Atmel AVR family microcontrollers, despite the fact that they are not included in the contents of ES related courses in our curricula. Texas instruments MSP430 and flavors of 8051 stand as the second and the third choices. These two microcontrollers are covered in several undergraduate courses. Fig. 3 surprisingly reveals that it is not necessary that students will use tools and technologies they were taught in classes.

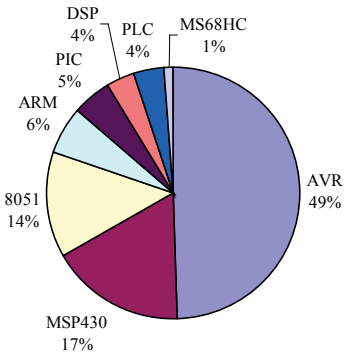

Fig. 3. Distribution of microcontrollers used in projects

Seeing AVR at the first place can lead to the following notes:

1. 8 bit EM are still good for educational needs.
2. Cheap development tools and chips, easy to assemble packages from Atmel as well as numerous resources on the web play an important role at the initial stages of electronic engineer's carrier.
3. In the very considerable number of cases students opt to use tools suggested by their supervisors and university laboratory people. It has to be mentioned that many active research groups in the faculty use AVR microcontrollers in their developments.

Looking at Fig. 4 and Fig. 5 one can find the data disclosing how projects with the three most popular EM are finalized in respect to the ES software and prototype.

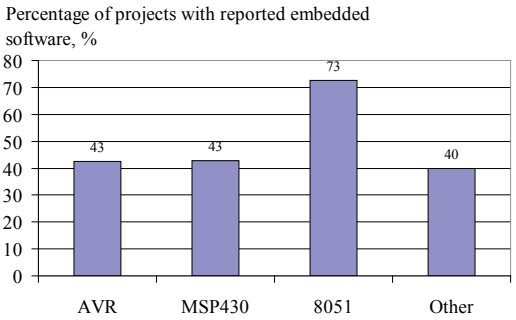

Fig. 4. Percentage of projects with reported software source

Finally, Fig. 6 presents the data concerning the final grade in respect to the EM utilization in the project. The grade is derived according to the weighted sum of grades given by supervisor, reviewer and jury of 8 members. It is interesting to note that the probability to get grades "excellent" and "very good" drops very significantly if the student does not utilize any EM in its FYP. On the opposite, the probability of high grades is obviously higher if EM was utilized as compared to the overall projects. This may indicate that both evaluators and more advanced students realize that importance of ES in today's electronic engineering.

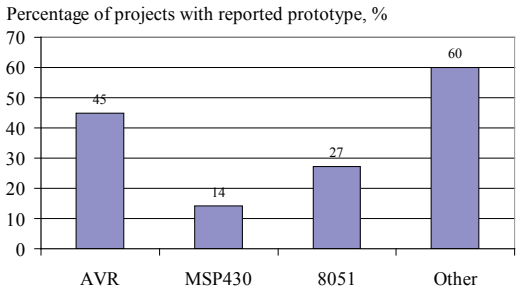

Fig. 5. Percentage of projects with prototype

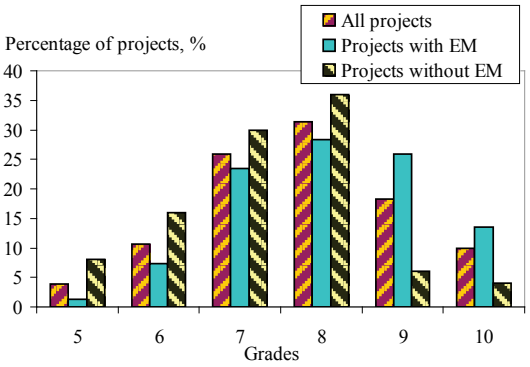

Fig. 6. Histogram of final year project evaluation grades

The FYP analysis results are obtained from one institution though the largest technical university in Lithuania. In the future it would be interesting to compare them over the similar results from other universities and colleges.

Conclusions

1. As seen from the related references review and our experience the teaching of embedded systems in the electronic engineering context is challenging both for students and lecturers, mainly because of interdisciplinary relationship, limited time, large variations of students motivation, skills and attitude towards programming.
2. Results of analysis of final year projects defended at Kaunas university of technology Telecommunications and electronics faculty supports the world wide trends of electronic systems transformation to embedded systems.
3. Majority of our students still utilize 8 bit embedded microcontrollers in their designs. Though selection of microcontroller is influenced by choices taught in our faculty courses, but even bigger stimulus is made by the supervisors advises and availability of cheap and easy to use tools.

4. Embedded software development in EE students projects is a rather weak part, perhaps because of insufficient allocated project time, lack of practical skills or attitude that embedded software is not a part of electronic engineering.

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An overview of the key challenges that are faced during teaching of embedded systems (ES) in electronic engineering context is given in the paper. The study of the last three years final bachelor projects defended in electronic engineering (EE) branch at Kaunas university of technology, Telecommunications and Electronics Faculty is conducted. The goal of the study was to summarize what ES related tools and solutions students do utilize in their projects and how professional they are in their reports. The intention of this analysis is not only to reveal the extent of ES penetration of EE field but also to estimate the correlation between tools and technologies taught and really selected by students in their final qualification proof project. The results can among other issues be used to estimate the success of the group of courses targeting ES design. Ill. 6, bibl. 15, , tabl. 1 (in English; abstracts in English, Russian and Lithuanian).

Ж. Накутис, М. Саунорис. Вызовы преподавания встроенных систем в обучении по специальности инженерия электроники // Электроника и электротехника. – Каунас: Технология, 2010. – № 6(102). – С. 83–86.

В статье описываются основные вызовы, с которыми сталкиваются в процессе преподавания встраиваемых систем в контексте обучения инженерии электроники. Исследование проводилось по данным последних трех лет окончательных проектов бакалавра специальности инженерия электроники в Каунасском технологическом университете, Факультете телекоммуникаций и электроники. Целью исследований было обобщение данных о том, какие встроенные системы и соответствующие инструменты и решения студенты используют в своих проектах и как профессионально документируют это в своих докладах. Целью такого анализа было не только выявление степени проникновения встроенных систем в области инженерии электроники, но и оценка корреляции между инструментами и технологиями, которым студенты были обучены и которые реально выбрали для своих окончательных проектов. Результаты анализа также могут быть использованы для оценки эфективности группы курсов связанных с проектированием встроенных систем. Ил. 6, библ. 15, табл. 1 (на английском языке; рефераты на английском, русском и литовском яз.).

Ž. Nakutis, M. Saunoris. Įterptinių sistemų mokymo iššūkiai elektronikos inžinerijos studijose // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 6(102). – P. 83–86.

Straipsnyje aprašyti su kokiais iššūkiais susiduriama dėstant įterptinių sistemų kursą elektronikos inžinerijos studijose. Tyrimui naudojami elektronikos inžinerijos studijų programos pastarųjų trejų metų baigiamieji bakalauro darbai, kurie buvo apginti Kauno technologijos universitete, Telekomunikacijų ir elektronikos fakultete. Tyrimo tikslas yra apibendrinti kokias su įterptinėmis sistemomis susijusias priemones ir sprendimus studentai naudoja baigiamuosiuose bakalauro darbuose ir kaip profesionaliai pateikia tai savo ataskaitose. Tyrimu siekta ne tik parodyti vis platesnį įterptinių sistemų taikymą elektronikos inžinerijoje, bet ir nustatyti koreliaciją tarp to, ko studentai buvo mokomi, ir ką panaudojo savo darbuose. Gautus rezultatus galima būtų panaudoti vertinant modulius, susijusius su įterptinių sistemų projektavimu. Il. 6, bibl. 15, lent. 1 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).