AC 2009-923: DESIGN COMPETITIONS: A PRACTICAL APPROACH TO IMPROVING STUDENTS' HARDWARE AND SOFTWARE SKILLS

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Design Competition: A Practical Approach to Improve Students Hardware and Software Skills

Abstract

As the complexity of microelectronic systems is steadily increasing, universities must update their curricula to cope with the increased demands of research and development required in industry. By integrating digital design competitions into the undergraduate experience, students are better prepared to enter the field of engineering and make more meaningful contributions to their firms at an earlier rate.

Trying to address the current and future needs of the industry in the context of a global economy, instructors at the Technical University of Cluj-Napoca, Romania and Rose Hulman Institute of Technology, USA, have integrated an annual Digital Design Competition open to engineering students from the above mentioned majors. Competitions at both schools have been sponsored by Digilent and Xilinx. These companies produce state of the art PLDs boards and CAD tools.

This paper summarizes five years of experience at the Technical University of Cluj-Napoca and two at Rose Hulman Institute of Technology , organizing such competitions. The logistics and challenges of the competitions, results of the past editions and plans regarding the future of these competitions at both schools are presented. Evaluations of the competition and students' perceptions as an alternative learning experience were investigated through student surveys.

Introduction

As the complexity of microelectronic systems is steadily increasing, universities must update their curricula to cope with the increased demands of research and development required in industry. By integrating Digital Design competitions into the undergraduate experience, students are better prepared to enter the field of engineering and make more meaningful contributions to their firms at an earlier rate.

According to a report published for The Royal Academy of Engineering, UK (2006)[1], the pace of change in industry is expected to intensify in both the technological and non-technological domains. Particular themes that have emerged include: **(a) an increased need for firms to focus on solving customer problems; (b) a growing requirement to provide system solutions to those problems; (c) and the increasing complexity of the management task.** Another important factor is globalization which will continue to affect both the demand and the supply side of industry.

Certain disciplines, including **electrical/electronic and system engineering** are seen as particular likely to be of increasing importance over the next ten years. Looking at particular skills and attributes needed for engineers, there is strong evidence that the top priorities in terms of future skills will be: **(a) practical applications, (b) theoretical understanding and (c) creativity and innovation.** Also required are closer university ties and continuing commitment

by industry to ensure that good practice is shared and to ensure that the brightest and best youngsters are attracted to engineering.

Trying to address the current and future needs of the industry in the context of global economy, and giving electrical/electronics/computer engineering graduates the right skills, instructors at both schools, have integrated an annual Digital Design Competition open to engineering students from the above mentioned majors. Competitions at both schools are sponsored by Digilent[2] and Xilinx[3]. These companies produce state of the art PLDs boards and CAD tools.

The paper is organized as it follows: The logistics and challenges of the competitions at the Technical university of Cluj-Napoca (TUCN), Romania and Rose Hulman Institute of Technology (RHIT), USA; Results of the past editions and plans regarding the future of these competitions; Competition's evaluation and students' perceptions as an alternative learning experience.

Digital Design Competition; Logistic and Challenges

Several reasons for organizing such a competition were presented above. According to reference[4], "a good design experience offers opportunities for learning to identify and remedy procedural and factual knowledge deficit and to exercise judgment". A design contest is a good vehicle to offer students, outside the class, a consistent design experience. Trying to organize a competitive design competition, the instructors focus on the following attributes of a good competition:

a) fosters creativity and the spirit of innovation;
b) incorporates significant course material from more than one discipline such as Digital Systems, Signals and Systems, Robotics, Mecatronics, Data Acquisition Systems, etc.
c) provides success commensurate with care in design[4];
d) requires increasing factual and procedural knowledge[4];
e) requires exercising engineering judgment[4];
f) does not require significant infrastructure[4];
g) improves communication skills, both written (through project's documentation) and oral (through project's presentation);
h) offers students a marketing perspective on their engineering work;
i) offer a spectacle[4].

This last item should not be overlooked. The status that students feel when talking with their friends and family about the contest is an important motivator A little "glitz" also attracts better students to the program and raises the interest of the community [4]. Several students answering the surveys said that it sounded fun or cool, and one student was proud to represent his school.

At both schools, the emphasis of the competition is on conceptual design, implementation and validation of original and projects using FPGA boards and HDL languages (VHDL at TUCN and Verilog at RHIT). The contest is mainly dedicated to undergraduate students, who enter the competition with original projects. In terms of logistics the idea is to have a *"Call for Projects"* in the fall quarter at RHIT /fall semester at TUCN, to assess and accept the projects in the

winter quarter/ fall semester, and to have the final competition in the spring quarter /spring semester.

Contest Requirements and Rules are the same at both schools, as requested by the sponsoring companies.
***"Scope of Projects**: This is an open competition. We are looking for creative designs that utilize Digilent's product line and solve problems or have real world applications. We are looking for projects that allow our hardware to be used in real-world situations – for example, acquiring data from sensors, controlling motors, performing DSP on incoming data streams, building closed-loop controllers etc. Since our boards are used by universities, corporations, and digital designers around the world, we will showcase you and your projects on our website, inspiring students and impressing employers worldwide".*
*"**Contest Requirements***
-Completed projects must be fully functional and all features need to behave in a consistent manner. Projects must be well-structured.
-It is critical to provide comprehensive comments so that users can easily understand the structure and logic of your project in order to make their own modifications.
-Projects must be open source. Qualifying projects will be posted on public web pages, so potential customers, students should have free access to them.
-Projects must be the original work of team members.
-Teams will present their completed projects to a panel of judges using Power Point and a practical demonstration. Teams must follow the presentation guidelines and format.
-Judges will evaluate projects based on relevancy, complexity, innovation, use of good design practices, clarity of documentation, and quality of presentation. Awards will be determined by the judges and prizes awarded accordingly."

One big challenge is to attract and stimulate the students who are already extremely busy. The students enrolled in the contest receive free boards donated by the sponsors of the competition, and they can keep the boards if they finalize their projects regardless of the final prize or position in the competition. This experience counts also as professional development (2 credits) at Rose Hulman Institute of Technology. Other challenges at both schools are:
a) keeping the students interested and motivated so they can finalize their projects;
b) distribution of boards and additional hardware;
c) recovering the boards from the students who are dropping the competition;
d) guiding the students in implementing their ideas;
e) traveling from Pullman, WA to the city of Cluj-Napoca, Romania in order to judge the competition projects.

Digital Design Competitions at the Technical University of Cluj-Napoca, Romania

Technical University of Cluj-Napoca is a large state university, in the academic city of Cluj-Napoca, county of Transylvania. The university has eight faculties in its structure, about 640 academic staff and an enrollment of about 13,000 students. The choice of courses in various engineering specialties ranges from mechanical and manufacturing engineering to electrical engineering, telecommunications, computer science and control engineering, from civil engineering to architecture and materials science. The electrical profile includes the Faculties of

Automation and Computer Sciences(ASC), Electronics, Telecommunications and Information Technology (ETTI), and Electrical Engineering (EE), altogether enrolling about 3,768 students and 245 academic staff.

Four editions of the competition were organized so far at TUCN, starting in 2005. The first editions were local (students enrolled at TUCN, different majors), become national and an international participation is announced for the current edition. Next table shows the number of teams enrolled initially and the number of teams who finished the projects and presented their work to the jury, contestants' major and the design platform used to develop the projects, for each edition of the contest. The number of students who enrolled initially was larger than the number of students who actually finished the project. In order to avoid having a big difference between the number of students who enrolled and the number of teams (one or two students) that successfully presented their projects, a different strategy was used in the last edition. Students were asked to provide a short specification of their projects and to give valid arguments regarding their project ideas in order to receive free hardware. This way, students were forced to analyze more deeply their ideas and the feasibility of the projects. Only after this initial screening, students received the hardware. This approach better motivated the participants and the percentage of completed projects was greater. The majority of the participants were Computer Science, Electronics and Telecommunications majors, but also Mechatronics majors found the contest challenging and interesting enough to participate. The Microcontroller or FPGA platforms were chosen by the students based on their major and their previous experience with these platforms. While the Computer Science, Electronics and Telecommunications participants preferred the FPGA platforms for the flexibility of the design, Mechatronics students chose the embedded platform with an AVR Microcontroller, this being more appropriate to implement their ideas.

TABLE 1

Edition	Teams Enrolled	Final Teams	Major for final teams			Platform	
			Computer Science	Electronics and Telecommu-nications	Mecha-tronics	Micro controller	FPGA
2005	25	11	4	7	0	3	8
2006	34	13	5	8	0	4	9
2007	42	15	5	4	6	7	8
2008	27	17	12	3	2	4	13

The following prizes were awarded in the past editions:

TABLE 2

Contest Edition		
1st	1st Prize	
	Project	Description

	Image Processing	Image Processing unit using various user-selectable convolution filters. A companion PC application downloads image files into a memory array that the FPGA access. Processed images are displayed on an attached VGA monitor. The system is implemented on a D2SB and DIO4 platforms.
	2nd Prize	
	Project	Description
	Ricochet Game	Paddle and ball video game implementation on D2SB and DIO4 platforms. The game includes extra features like moving blocks and increasing difficulty.
	3rd Prize	
	Project	Description
	Tetrix Game	Video game based on Tetris with several reusable components made available for creating other games based on the design. Implementation on D2SB and DIO4 platforms.
2nd	1st Prize	
	Project	Description
	BRAM Image Viewer	Image display and manipulation with PS2 mouse and keyboard driver implemented on a Nexys Board. The project is accompanied with a software application.
	2nd Prize	
	Project	Description
	Digital Synth	Four-note polyphonic digital synthesizer with audio effects and MIDI recording. The hardware project is implemented on a Nexys FPGA platform and also includes a software application.
	3rd Prize	
	Project	Description
	Plotting System	Monochrome image plotter with VGA image display implemented on a Nexys board.
3rd	1st Prize	
	Project	Description
	Hexapod Spy Robot with Imaging System	The Nexys FPGA based system represents a mobile image acquisition system. The movements are done using 6 servo motors and the imaging system is implemented with the VDEC video converter accessorizing board.
	2nd Prize	
	Project	Description
	A FPGA implementation of a Graphics System	A basic implementation of a graphics system on a Nexys FPGA platform that serves primarily for testing and analyzing design alternatives.
	3rd Prize	
	Project	Description
	Autonomous Movement Vehicle	The design represents a Nexys FPGA autonomous robot that can move freely in different spaces and avoid the collision with objects.
4th	1st Prize	
	Project	Description
	Point to Point Robotic	Complex design composed of a Cerebot robotic car and a Nexys FPGA GUI implementation on a VGA.
	2nd Prize	
	Project	Description
	Digital Storage Oscilloscope	The design of a digital Oscilloscope implemented on a Nexys 2 board. Several specific features can be defined by the user using a PS2 keyboard, mouse or Digilent Pmods.

3rd Prize	
Project	Description
Graphics Processor for Embedded System	Graphics Processing Unit implemented on a FPGA Nexys board capable of rasterizing vector inputs and displaying them on a VGA screen. A set of APIs are implemented on Cerebot 2 microcontroller board used for the communication management.

The projects presented covered a wide range of fields: mobile robots, graphics and sound processing, user interface games and also more specific applications, such as oscilloscopes and plotting systems.

Fig1. Projects from the second, third and fourth edition at TUCN; "Hexapod Spy Robot with Imaging System" in the upper image; "Plotting System" in the left and "Variable PWM" in the right[5].

Starting with the second edition, students from other Romanian universities were invited to participate. Students from other two Romanian universities, located in the cities of Baia-Mare and Pitesti enrolled and won prizes and honorable mentions during the last two editions.

Fig 2. Winners of the 3rd edition, together with sponsors' representatives

This year, at the fifth edition, teams from different European countries (Hungary, Finland, Czech Republic, Poland) express interest to participate, so the competition may become international.

Digital Design Competition at Rose Hulman Institute of Technology, USA

Rose Hulman Institute of Technology is one of the USA's top undergraduate engineering science, and mathematics colleges, with a total enrollment of about 1,950 students. The Electrical and Computer Engineering Department at RHIT has around 300 students.

In the first edition of the competition, over 30 students enrolled initially, but only six teams (10 students) finished the projects. In the second edition, over 20 students enrolled individually or in teams of two and four teams (6 students) competed in the final. This academic year, ten teams (14 students) enrolled. Next table shows the number of teams enrolled initially and the number of teams who finished the projects and presented their work to the jury, students' major for the final teams, for each edition of the contest. *Note:* Some students have double or triple majors.

Table 3

Editions	Teams Enrolled	Final Teams	Major for final teams		
			EE	CPE	CS
2006-2007	22	6	4	6	0
2007-2008	16	4	3	3	0
2008-2009	10	-	4	9	1

The range of their projects is wide from computer/editor/graphics, music and image processing to videogames. Selected examples of innovative projects from the first and second edition are: "Laser Harp with variable volume and tone", "Low Cost Oscilloscope", "Audio Signal Equalizer", "Spectrum Analyzer with VGA Display", "Reactive Light Machine", "Remote Control Robot", "Oregon Trail", Drum-O-Scope", etc. The following prizes were awarded in the past two editions:

First edition 2006-2007:

There were two divisions: upper division (juniors and seniors) and lower division (freshman and sophomores).

Grand Prize-"VGA Spectrum Analyzer". Captures an input signal and displays on a monitor the real-time spectrum as well as a time-varying waterfall spectrum.

First prize -Upper division- "Musical Synthesizer"

Second prize-Upper Division- "VGA Based Oscilloscope"

Third prize- Upper division; " Guitar Cord Identifier" and "Design of a Real-Time Band-Limited Spectrum Average Display"

First prize-Lower division- "Monochromatic laser projector"

Second edition 2007-2008:

First Prize: "Remote Control Robot" The project is a robot that tracks mouse movement through a remote connection.

Second prize: "Drum-o-Scope".

Second Prize: "Serial Teletype Emulator".

Third Prize: "Oregon Trail Game".

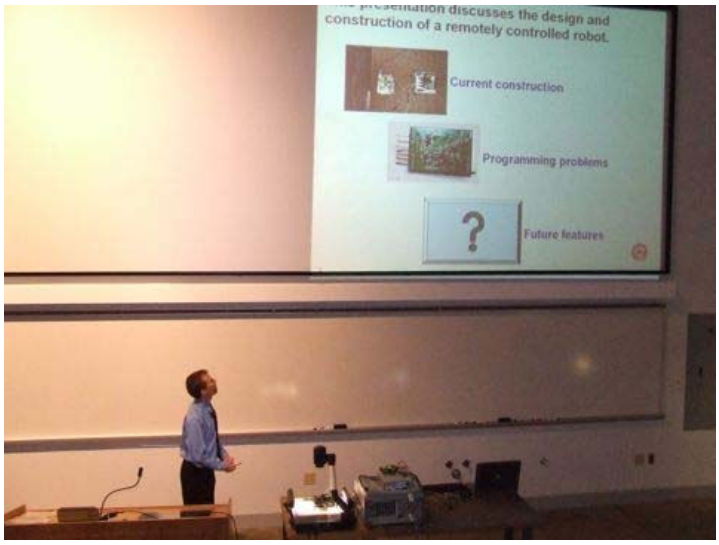

Fig. 3 Presentation of the winning project at RHIT, 2007-2008 edition

This project counts for two professional development credits for finished projects. Students who qualify on the top position receive three credit hours for this contest. Starting this academic year, projects with the junior level Principles of Design class will be entered in the competition.

An active web page of the digital design competition is maintained, showing the latest news in the development of the competition.

Fig. 4. The webpage of the Digital Design Contest at RHIT[6]

Competition's evaluation and students' perceptions as a learning experience

Starting in the academic year 2006-2007, a common survey was used at both schools, trying to evaluate the competition and students' perceptions as an alternative learning experience. The survey was also used to give useful feedback to the sponsors related to the quality of their products, support materials, website, and reference materials.
It is interesting to notice that student's answers were very similar at both schools. At TUCN, Romania, 9 students answered the survey in the first year when it was administered and 13 in the second year. At RHIT, 6 students answered the survey in the first year and 7 students in the second year. The first three questions try to evaluate students' overall perceptions as a learning experience.

The first question investigates how beneficial is the competition for students' professional development and future career as an engineer. Students' comments range from: *"a chance to develop a portfolio"* to *"take on a project without guidance from the instructor"* and learning from mistakes. Suggestive examples of students' comments:
"This project gave me a better approach on how a design should be implemented as I learned from my mistakes."
"I found out that an initial architecture can fail if you don't know the hardware capabilities."

The second question investigates in which area the students think that they improved their understanding and engineering abilities: Hardware-digital, Hardware-analog, Software-HDL or others. The majority of students mentioned Hardware Digital and Software HDL skills as the main skills developed participating in the competition. Other mentioned abilities were: mechanics skills building robots, programming languages(C++).

The third question investigates what skills do the students think that they developed during this competition. Provided examples in the survey were: problem solving skills, analytical skills, creativity, spirit of innovation, team work skills, managing the time, etc.

The vast majority mentioned that the biggest challenge was to learn how to manage their time, without having the constraints and deadlines provided by an instructor in a regular class. This was a major lesson that the students learn. A large number of students mentioned creativity, problem solving skills and team work as qualities developed during this competition.
Suggestive example of student's answer:
"I learned how to cope with problems, implement solutions and keep deadlines."

The last question related to students' motivation to enroll in this competition. Answers vary from hardware and money prizes to pride to represent school, challenge themselves.
Several students in both countries saw this competition as a chance to assess their strengths and weaknesses as students, to see where they stand, compared with their peers.
Suggestive students' comments include:
"My motivation was the challenge to design and implement something from scratch".
"I gained confidence that someday I'll be able to manage and implement a great project."
"I wanted to test my abilities as a hardware designer".

The last two questions provided useful feedback to the sponsors. Students' comments range from being very general (like content with the information they found on-line) to very specific comments related to the hardware that they used, software problems, more documentation.

Conclusions

The authors of this paper have reasons to believe that Design Competitions give students the opportunity to demonstrate their creativity, problem solving skills, competitive skills and motivation to work for a project outside class requirements. Students also benefit as they are better prepared for industry's needs. After reviewing the results of several Design Competition that took place at the Technical University of Cluj-Napoca and Rose Hulman Institute of Technology, and from student surveys who participated in the contests, it appears that the exercises were a successful tool for better preparing students to enter the market place.

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