Some Aspects Of Student Teamwork On Practical Assignments For Complex Control And Measurement Systems

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Abstract - Students of the first year of master program „Electronic and Computer Engineering" of the Faculty of Electrical Engineering and Computing of Zagreb University are challenged to leverage their theoretical knowledge with real-life assignments they are likely to be involved with after the graduation.

"Smart home" was chosen as the complex joint project for a group of 20 students. Every student had his/her own individual subproject for which he/she defined project requirements and acceptance protocol herself. The challenge was to master practical aspects of the teamwork and to adjust individual project requirements as well as acceptance protocols in order to achieve interoperability of subsystems and final functionality of the system as a whole.

Especially challenging for teachers was segmentation of the target system and student's assignments in order to avoid that subsystems and their authors who performed well be penalized or blocked by those who did not perform their best or at all.

On the technical level the challenge was to choose microcontroller platform suitable for various subsystems with wide range of tasks and to choose protocols to interconnect subsystems.

I. INTRODUCTION

In the course of their undergraduate and graduate education students acquire substantial theoretical knowledge which they test through laboratory exercises and through implementation in their assignments and projects. However, most of the time this practical experience is focused on the narrow subject they are studying. Similarly, they are most of the time instructed to do the work individually, alone.

However, after their graduation they will be faced with different environment, expectations, conditions and assignments. They will be mostly solving complex, multidisciplinary assignments, in teams. Most often project requirements they will receive will be very basic, coarse so they will have to draft the fine details on their own. They will be expected to survey existing products and solutions on the market as well as technologies and solutions and then decide which to use. Most importantly, their product will have to smoothly and seamlessly interact with other components and products of a much bigger system, most of the time.

Within the framework of "Measurement and Control Systems" students are given the opportunity to experience their future assignments in as similar conditions as possible.

II. CHALLENGE

In order to provide students the experience of working in a team, the assignments given to them need to be of a size which cannot be mastered by a single student in the given time, effectively encouraging students to form groups.

On the other side, assignments should be small enough so that groups can be small enough so that within the framework of one enrolment (about 20 students) at least several groups are formed requiring students of one group to intensively cooperate with several other groups.

Further, all these assignments need to be interconnected forming a bigger whole. It is the goals of this "big project" towards which goals of smaller projects should be defined and aligned.

However, the whole setup should be robust enough so that failure or underperforming of one team would not hamper another team from full success.

Looking at one student team (typically two to four students) similar requirements arise. First, there should be a diversity of work within one team so that each student gets her own set of tasks and responsibilities.

Secondly, it is a true challenge to prevent that one student's failure doesn't compromise the success of the whole group. This one is very hard to achieve. The only solution is the peer pressure, timely management of the group and taking over the job of the failing student by other group members, on time.

Another set of challenges is in self organization and self guidance. Students are used to be given well defined assignments, to be controlled and guided. However, this real-life simulation requires the team to define their own assignment, to put specific requirements towards other teams and to respond appropriately to theirs. The whole experience is new to them and intensified by the fact that there is no one specific to call and lead a meeting, to make decision when teams disagree nor to take responsibility or blame. [1][2]

There are also technical challenges. The technical severity of the problem to solve shouldn't be too high, because students have limited time, and other aspects of project work to master. On the other hand it should not be trivial nor the one which can be mastered by copy-pasting a solution from Internet.

The aim is for students to integrate their gained knowledge of analog and digital electronics, signals and processing, communications and programming. This means that their projects should concentrate either around a PC with some signal and communication interface or around a microcontroller. The microcontroller should be programmable in a comfortable way in a well known language. It should be cheap, easily obtainable with significant user community and ample of other people's projects speeding up student's learning curve by the mean of learning by examples. There should be a significant offer of third party interfaces for the microcontroller platform enabling it to hook-up with a number of other devices and subsystems, as well as with the rest of the subsystems in the project to create a whole. Students should be able to tinker with their project at home. Thus selection of a microcontroller platform is important for the success of the whole activity.

III. Similar projects at other universities

Similar courses and projects also exist on many other universities around the world. For instance, George Mason University, Northern Virginia, USA has a course called "User Interface Design and Development". It focuses on man – machine interfaces, human cognitive limitations and various computer interface designs (command interface, menu, desktop views, GUI interface and web based interface). In 1999 one of the projects was a GUI-based interface for a "Smart house". This interface allows the user to input commands by clicking on buttons, or using a command based interface. Temperatures from every room are shown, and also, it is possible to control ventilation, music, computers and doors. [3]

Second example comes from Boğaziçi Üniversitesi, Istanbul, Turkey from Senior Design Project Classes. Students have to choose a project from a given list, write a project proposal according to a template (with help from the mentor), midterm reports in the middle of the fall semester, final report at the end of the semester, and also do a presentation of the project. Remaining of the grade comes from the work on the project. In the academic year of 2008/2009 one of the topics was "Smart House". There were two students working on the project, and their task was to build electrical and software infrastructure for a smart house, i.e. centrally controllable lighting system, microphone array design for voice recognition and speech synthesis... [4]

Third example is an MSc project at the Technical University of Denmark, Denmark from 2006. The goal was to develop a Java tool for design and simulation of a simple smart house model. The tool had to be able to design physical limitations of the house, position the inside sensors and observe the scenarios inside the house, in which the tenants could find themselves in. They've divided smart houses in two categories: Programmable houses (actions are programmed in relation to sensory inputs) and Intelligent houses (contain some level of intelligence that controls various operations). [5]

Fourth example comes from Virginia Tech, Virginia, USA, course Computer Control (2002) where work was organized in small groups, and the assignment was to design and build an automated system using Quick Basic. Every input and output was handled through the serial or parallel port. Students actually built a real wooden model of the house, that had the lights turn on when it got dark outside and/or a car parked in the driveway. Windows would automatically close if it started raining, and also, if it got too warm inside (thermostat), air conditioning would be switch on. This smart house model connected to a computer through the interface that has also been developed by the students (easier access to the parallel port contact pins). [6]

The last example is a course at Duke University, North Carolina, USA, called “Smart Home Technology Design”, and is open for students on any year of the college. Their assignment is to find the best technological answer to a given household problem. Some of the developed projects are installed in the student dorm – laboratory (The Home Depot Smart Home). This gives students the chance to live with all the advantages, as well as the shortcomings of their own technology design and decisions. Some of the projects that the students work on are: solar platforms used to power up electrical cars and electrical bikes, design of renewable power sources that could be used during a power shortage from the city electrical grid, smart billiard table which uses cameras and projectors to draw predicted path of the balls on the table, RFID e-locator, smart entrance door... To improve the group work, students are advised to use wikis and forums. Also, they are encouraged to communicate and work together with the industry, and to think about the possibilities of the house promotion. [7]

IV. The selected concept

After much research, thinking and evaluation a “Smart Home” has been selected as the “big project”. The reason is that a smart home consists of a number of rather autonomous subsystems, that many components are loosely coupled and that there is a lot of inherent redundancy. Thus many of the challenges are met, in particular: the need for all subsystems to interconnect while simultaneously not critically depending on each other; and many parts of subsystems can be defined as individual projects.

At the beginning of the semester there was first a brainstorming meeting, where various ideas about the smart house were proposed. Amongst other things, students thought the house should have:

- energy subsystem: energetic efficiency, power consumption control, windmill generator, a photovoltaic cell, controllable floor heating, ...
- health care subsystem: medicine-taking time reminder, disease diagnostics, healthy nutrition, …
- user subsystem: studying assistance, menu recommendation from available ingredients, automatic control (blinds, lights, air conditioning, windows), gesture control (hand waving, clapping), fast shoe drying, animal repelling (pigeons, mosquitoes, ants,...), shopping assistant, awakening during REM phase, …
- communication subsystem: speech recognition, intuitive user interface, touch screen in every room, remote control (cell phone, Internet), …
- security subsystem: video surveillance control, locating owners in- and outside of the house, smart key (fingerprint, retina), …
- household chores: self-tidying bed, smart lawnmower, waste recycling, household animal and plant care, house cleaning, …
- sensors: speech, heat, gas, movement, damp, fire, presence, smell, earthquake, …

Some of the ideas aren't feasible yet while others are too complex for student work, but they all successfully inspired creativity in students.

Defining their own project requirements, suggesting others and accepting other student’s suggestions for their own was a novel and unusual concept to students. It took them more time for them to accommodate than expected and to yield appropriate specifications and documentation.

Another problem proved to be essential: joint work without appointed leader and external control. Reaching decisions when opposed opinions prevailed or getting efficient when leadership was necessary was especially difficult. Students sought solution from teachers to the extent that they demanded it as a prerequisite for successful competition of their assignments. When such intervention was denied, students were confused, surprised and it took them quite some time to finally find the way out.

V. The Microcontroller Platform

Some of the subsystems were designed to be based on a PC (like Smart shopping or Graphical display of the house, state and processes or SMS user interface). Others were based on a microcontroller platform. A number of candidates were identified (Table 1). [8][9][10][11][12]

Finally Arduino *Duemilanove* development board was chosen as the uniform solution for the whole project.

This board is a low-budget development system with very good characteristics. What especially raises it above the competition is its easy hardware expansion with other modules available from Arduino, large user community and lots of examples of applications where these devices have successfully been used. Also, Arduino offers their own set of free development tools. From additional modules available for the functional expansion of the Duemilanove board, it is important to mention the *XBee* (Arduino's implementation of ZigBee) and *Ethernet* modules, which are used in the realization of a large number of Smart house subsystems.

There are a number of projects at other universities which use the same platform.

One example comes from *The Royal Melbourne Institute of Technology*, Australia, from the elective course called *Physical Programming*. Group projects, developed using Arduino environment, score 60% of the grade. Also, if necessary, students can use other additional electronic components. Some parts of classes even cover basics of working with Arduino. Some of the student projects were: connecting Arduino with temperature sensors, sound to light converter, interactive display... [13]

On the *New York University's Tisch School of the Arts*, USA, exists a course with similar name, called *Physical Computing*. Here, project development, the presentation and documentation also bring 60% of the total grade. Some of the projects were: enlarged model of broccoli that talks (as a commercial for supermarkets), a box that changes shape depending on the pushed button, reaction measurement performed on visitors of the museum while they were watching some of the exhibits, small robot that can travel through the city in a smart manner, room lighting controlled by a candle on the table... [14]

At ETH Zurich, Swiss Federal Institute of Technology, amongst other things, students work on projects like: wireless communication with XBee, experiments with various sensors (step motor, compass, piezoelectric sensors, infrared, ambient light...). [15]

TABLE I
CHARACTERISTICS OF MICROCONTROLLER PLATFORM

	Characteristics	**Price**
Futurlec ATMEGA8535 Educational Board	• microcontroller ATMega8535L with 8kB embedded Flash program memory, In-circuit programming, installed 8MHz crystal oscillator, buttons, buzzer, large protoboard surface, RS232 connector (including MAX232 driver chip) • documented, but third party software development tools necessary	$44.90
SK Pang Electronics LPC-2119 ET ARM Start Kit	• microcontroller ARM7TDMI-S 16/32-bit, crystal oscillator frequency 19.6608MHz with a 58.9824MHz PLL, 128kB Flash program memory and 16kB static RAM, 46 input/output pins, RS232 communication, character LCD, 20-pin ARM JTAG port • usage examples on the following CD, good quality of the device documentation, but limited version of the development tools that come with the device (evaluation)	£37.50
Arduino Duemilanove	• microcontroller ATMega168 (or ATMega328), 16kB embedded Flash memory (32kB, respectively), clock frequency 16MHz, 14 digital input output pins, 6 analog input pins, PC connection over USB • easy extension with additional devices available from Arduino, excellent documentation, lots of examples, large user community	€22.00
Extreme Electronics xBoard	• microcontroller ATMega32, IR receiver, connectors for LCD unit and external LCD, buttons and light emitting diodes, RS232 communication (over installed MAX232 driver chip), unit for motor control • lots of instructions in video format	€22.88
Protostack ATMEGA8 Development Kit	• microcontroller ATMega8 with 8kB Flash program memory, 6 channel 10-bit A/D converter, clock frequency 16MHz • manual assembly necessary, insufficiently documented	$15.90

Arduino is also used for a group project in the course called *Physical Computing* at *University of Dundee*, Scotland, UK [16]. Similar projects that use Arduino can be found on *Universitat Pompeu Faabra*, Barcelona, Spain in the course *Advanced Interpace Desig* [17]; *Massachusetts Institute of Technology,* USA in the course *Principles of Electronic Music Controllers* (where the projects are connected to music, like piano, Glass Controller, The Granular Patchbay, Wetspace,...) [18], and so on.

Our course uses Arduino as a central element of every subsystem. Dependant on the project that a particular student had, additional external elements had to be used: Xbee Shield, Ethernet Shield, resistors, light emitting diodes, various sensors... Arduino can be programmed using Arduino Software, which is based on C/C++.

VI. THE STUDENT PROJECT

While building these systems, students had to use the knowledge ascertained in the class and expand it with their own research. So there had to be some sort of communication within a system, or amongst systems themselves, like: modem (1 student), RS-232 (1 student), Ethernet network (2 students), digital inputs and outputs (1 student), ZigBee (1 student), SMS messages (1 student), 433MHz (1 student), IR signal (2 students).

Finally, the “Smart Home” project consisted of the following subprojects:

- smart shopping (automatic online grocery ordering, if it's current quantity in the home storage is lower than minimal) – 1 student
- air conditioning (read from temperature sensors, associate with subprojects: IR control and graphical status display) – 1 student
- lighting (light and movement sensors, associate with subprojects: receiving and sending IR commands, graphical status display) – 1 student
- windows and blinds control (sensors for temperature, lighting, window and blinds position, associate with subprojects: receiving and sending IR commands, control through digital inputs/outputs over DC motors and graphical status display) – 1 student
- pet care in the absence of owners (tracking cat's whereabouts with RFID (radiofrequency identification), food and water dispensing, small door that keeps track whether the pet is in- or outside of the house, informing the owners with SMS messages (associate subproject)) – 2 students
- alarm system (smart alarm type selection, wireless communication with the rest of the house over a ZigBee node (associate subproject)) – 1 student
- protection in the case of a fire (sensors for smoke, flame and temperature, elements for fire extinction, associate with subprojects: audio and visual alarms) – 1 student
- graphical display of the house, state and processes (temperature, lighting, fire and burglar alarm status, position of window blinds) – 1 student
- web server – 1 student

Figure 1. show the graphical representation of this "Smart house".

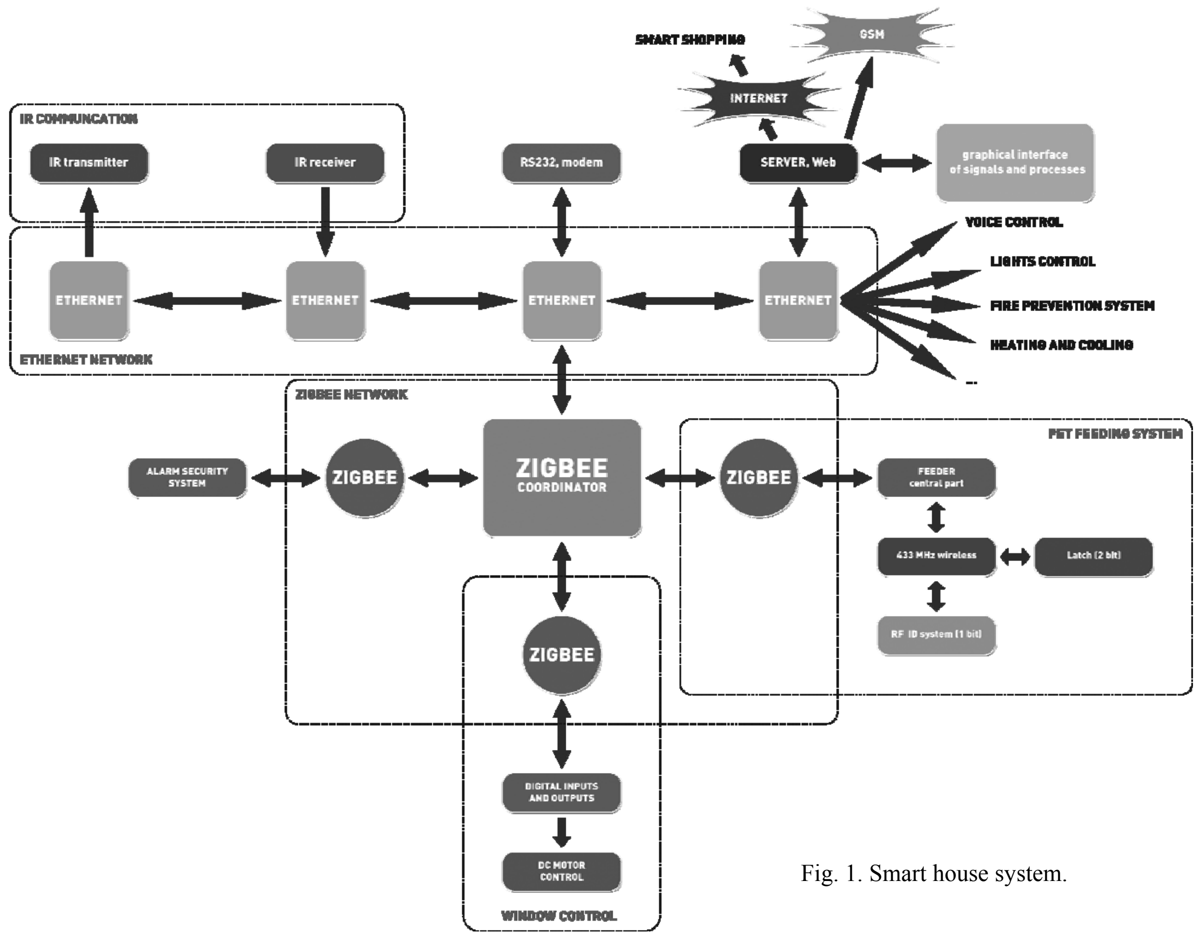

Fig. 1. Smart house system.

VII. The Results

After months-long work and numerous meetings, a modem connection over a leased line was established. There is still a possibility of establishing a connection over the public telephone network. Ethernet network connection has also been introduced, but unfortunately, sometimes there was a great time delay or package loss. There were additional difficulties with connecting the Ethernet network to the ZigBee subsystem. No discernible time delay or package loss was noticed while sending or receiving messages over the ZigBee network. One-way 433MHz RF communication has also been established and used for sending simple information like whenever a pet has entered or left the house. Although this type of communication is wireless, and the signal is not blocked with physical obstacles, there are still some problems when trying to mutually connect devices from different manufacturers. In some of these cases, it's better to use infrared connection, although the devices have to be visible to one another. Sending and receiving IR commands has also been realized as a part of this project. Communication between the house and its absent owner has been accomplished through SMS messages and a GSM cellular phone, connected to a PC. Since every cellular phone connects to a PC in a different way, only one phone was used for testing purposes in this project.

Smart shopping can successfully be used to buy groceries over the Internet, but it lacks useful sensors and a way to maintain the database of items, without any human interaction.

Automatic air conditioning is controlled by inputting the desired temperature. The developed subsystem measures and displays temperature and heating/cooling status. Automatic light regulation has been achieved by using an IR movement sensor and a light detection sensor. Automatic blinds and windows control was conducted with a DC motor over digital inputs and outputs. Economical and intelligent regulation of these subsystems depends on many parameters. Some of them will be taken into account in future projects.

Main elements of the pet care system were successfully realized (i.e. RFID pet identification). Every future upgrade is also possible by developing other subsystems of the house (for example, two-way RF communication), or by establishing a connection with the GSM node.

Protection in the case of a fire and the alarm system were also successfully implemented (at least at the testing level). These subsystems were designed for easy future expansion.

User interface over a web server is used for a graphical display of the house, state and processes. The user interface was created so that the owner could monitor the status of the house remotely. With increase of the number of subsystems and their possibilities, this user interface will also have to be expanded and improved in the future.

VIII. Conclusion

This approach has proven to be successful in achieving its goal of integrating students knowledge and giving them experience of real-life assignments.

Average score of 52.3 out of 60 possible, clearly demonstrates how much students liked this kind of work. This is further supported by student's comments:

Matija Draganović: "I would also like to comment the seminar work because it enabled us to improve existing and gain new knowledge. This is exactly what is missing from most of other subjects: the practical work. Components and equipment we needed was acquired timely and easily."

Jure Šimundić: "This is the only subject so far enabling me to visit certain important and for my future profession relevant institutions and which required me to practically implement my newly acquired knowledge. To put it simply: if it were not for this subject, I would graduate without ever going to an electronic store, purchasing few components and putting them together into a functioning device."

The project theme (Smart Home) has been proven to be well chosen meeting most of the organizational, technical and professional challenges. It will be used for the next generation of students, as well. It allows next generation to both, build on the experience of the previous generation while offering a plentitude of new subproject ideas.

Those students who dropped out (one student) or did not perform their best did not obstruct others in successfully completing their assignments.

Arduino was easy and simple to use, build interfaces for, and integrate with other interfaces.

Experience gathered by teachers will be used to make better planning of time and better organizational guidance of students.

Throughout this meta project (designing project assignment for students) it became quite apparent that teachers of many other subjects in various disciplines are acutely lacking methodical guidance, cases, suggestions, examples and advices which they could use in designing similar project assignments for their students.

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