

A systems engineering laboratory in the context of the “Bologna Process”

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ABSTRACT

A project oriented laboratory for education in the area of embedded system design is presented. The structure of the laboratory has been strongly influenced by a workshop about measures of the “Bologna Process”. Furthermore, the project is based on a “real world” example from industry. The students are divided into teams and become acquainted with commercial CASE (computer-aided software engineering) tools. Process oriented development is emphasised by using the V-Model methodology in combination with engineering phases from automotive SPICE throughout the project.

The development itself is based on a state-of-the-art FPGA platform for rapid prototyping as well as a linux operating system extended for real time operation. The pursued training goal is twofold: On the one hand students gain competences with practical aspects of object oriented programming for embedded systems. On the other hand, it is focused on the achievement of a global understanding of hardware and software interaction and the potential of reconfigurable platforms. Both goals are to be considered in the context of a process based industrial-like project introducing a high amount of student activity. A technical description of the system and instructions for the students is briefly outlined. Main emphasis is put on the teaching strategy acquainted during the laboratory.

1. ENVIRONMENT

Understanding customer requirements, finally resulting in system specifications is one of the main tasks in early phases of a system design process. Thereby, the essential engineering skills include understanding requirements, reaching a common understanding inside the team and possible problems lying ahead, system specification, system modeling, hardware-software partitioning, architectural design, system integration, verification and test. The demand for these competences implicitly modifies the tasks of electrical engineers. The corresponding design space is inherently huge and is still growing. As a result, expertise in hardware and software development and more important their interaction, the classification of each abstract component (tool flow, SW-parts, HW modules, development strategies) within the whole system is absolutely essential and must be covered in education. This comes along with a burdening amount of complexity, so that a flexible mindset only emerges if the student can classify the given problems and really understands the problem and its implications on the subject.

The presented project supports the technical needs by coupling state-of-the-art software design [1] with reconfigurable hardware and tries to envelope these topics in a didactical environment featuring new concepts in teaching. A laboratory for embedded system and software design for 3rd or 4th year students is described. Its adaptation due to the fact that projects in the engineering business are developed by interdisciplinary teams, which have to handle tasks of growing complexity, is taken into account. As a result, teamwork and communication as well as the support of standardized process assessment and process improvement models are in the centre of interest.

Summarizing, the competences gained in this laboratory are:

Skills in tool usage to provide more efficient embedded system development; Skills in object oriented software analysis and design; Getting the complete picture of an embedded system, existing of software, hardware and mechanical components; A realistic design flow scenario, based on a standardized process assessment model mainly used in the automotive industry; Development with project character; Teamwork and communication; Self-learning; student-to-student communication (Stud²COMM) and presentation.

2. THE LABORATORY – TECHNICAL VIEW

The students will implement firmware on a reconfigurable rapid prototyping platform, which finally controls a sensor-actuator-unit [2]. Thereby, the students don't start from scratch. Instead, hardware, device drivers and software services will be provided as illustrated in figure1. The target application is a chemical analysis scenario executed by this robot stage, which is provided by a cooperating industrial partner [2]. The robot is capable to move its arm in three degrees of freedom to inject chemical samples. The rapid prototyping system is remotely controlled through LAN. We introduce a standard FPGA based state-of-the-art RP system [3], so that students have the chance to reuse their knowledge. This choice has also supported an integrated perception of embedded systems including hardware knowledge.

Since the assignment ought to be industrial project oriented, which include accurate process characteristics, the students will be given the system requirements by the tutor. Information is given such as the available API, IO specifications as well as functional requirements of the application. Also timing and precision constraints are formulated. The software design pictures the software requirements in a UML model [1]. C++ code will be generated from this graphical representation. During the implementation phase of the project, the generated code needs to be extended, adopted and refined due to simulation

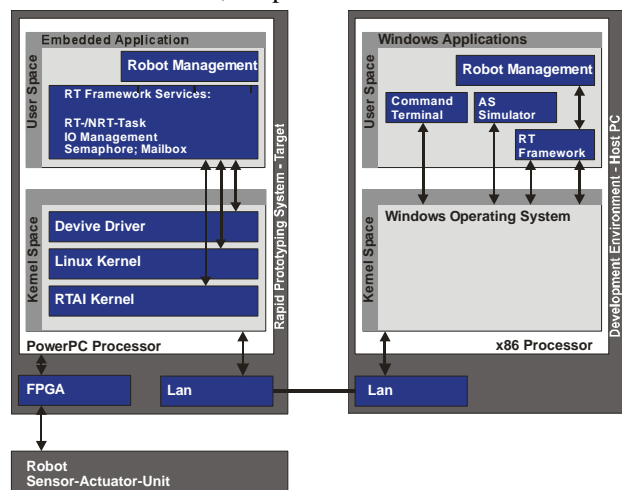


Figure 1 SW/HW architecture

and test. Of great importance are well written tests such as unit test cases in the phase of software development. Tests have to be continuously expanded in the same manner as the C++ code evolves. When succeeding with these steps, the sources will be compiled for the target system and uploaded on the PPC hard macro that is located on the Virtex2pro FPGA of the RP system.

3. THE LABORATORY – TEACHING CONCEPTS BASED ON THE „BOLOGNA PROCESS”

The followed development process in the laboratory, which, like most development processes can be visualized by using the V-cycle [4], was adjusted to a standardized process assessment model. Automotive SPICE [5] was taken as assessment model. Figure 2 shows these development guidelines as given to the students.

To allow a good knowledge distribution, about 30 students participate in the laboratory, which are randomly grouped to teams from 5 to 6 persons. Since development is supported by a standardized process, the outcome of the development task is highly influenced by innovative ideas of the respective team, so that finally each team will present different realisations.

The tutor fulfils the role of a project manager. He is the interface between an imaginary customer and the developers and creates by process specification the framework for a structured project and clearly defined development stages.

While the project proceeds, the tutor is watching quality and progress, prioritizes the implementation of student activities and accepts the disposition of recourses in each team. He doesn't take the traditional role as an institution of competence on the treated area, he rather provides an environment for students to teach themselves (student-to-student communication). The end of each development step comes along with a review, inspecting and approving the results of each team's approach.

To increase initiative readiness, students are required to gain detailed knowledge by themselves or in the team and respond to emerging problems through communication with other participants of the laboratory. Therefore, students are given computer-, development environment- and internet-access also outside the laboratory times.

To learn processes, tools and techniques more intensively, and to practice the presentation of complex content and relationships, each laboratory date is introduced with a 10 to 15 minute lecture held by 3 students. The subjects are distributed by the tutor at the beginning of the term and cover areas and topics directly related to the development activities of the laboratory and the corresponding techniques and methodologies. Through the presentations and the subsequent discussion session, the lab

participants get the opportunity to gain knowledge about techniques and tools in the area of embedded design. Thereby also didactical presentation techniques and the subject's essentials in terms of research and development are trained.

In this context, quality management and knowledge transfer contain acknowledging cycles. Quality management and knowledge transfer in several loops lead to the fact that for each generation of students, higher teaching and learning complexity can be settled so that better training results can be achieved. So, for presentation preparation, the teams receive the presentation of their predecessors. They are told to improve and extend the material for their own understanding. After having presented, feedback from the auditorium directly flows back into the documentation and will be integrated. As an outcome both students and tutors benefit from this synergic effect. This procedure also suggests the communication among the students: know-how is spread all over the attendants of the laboratory. This means that teaching, documentation, given tasks, teaching strategy, student activity and the test achievements become each year visibly better. This technique enables students to achieve competences on a higher level with less expenditure. Methodical and orientation knowledge increases as does their ability to understand and solve more complex tasks in less time. So, student activity is exploited, in a positive sense both for the teaching staff as well as for following student generations. They are implicitly forced for interaction.

In the preliminary discussion to the laboratory, the goals, the skills to be achieved as much as the assessment attributes together with their quality criteria are established together with the students. Course of instruction for students: not only the teacher knows which competences he wants to distribute but also the students' suggestions for improvement can be assessed in the same or next laboratory run.

4. CONCLUSION

As a consequence, the quality of the laboratory and the quality of the skills acquired by the students is closely connected to a consistent organization. This requires the tutor to manage the necessary activities like identification, establishment, planning, coordination and monitoring of tasks and recourses in the system development process as well as adjusting them to the specific demands of a laboratory for students in electrical engineering. With these measures this laboratory is in the spirit of the European Tuning model [6], which puts the strategic Bologna structure reforms into operation

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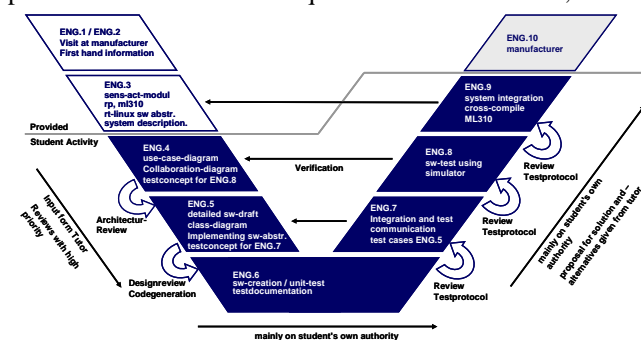


Figure 2 Spice processes trimmed for the laboratory