Interdisciplinary Approach to Software Engineering Education

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ABSTRACT

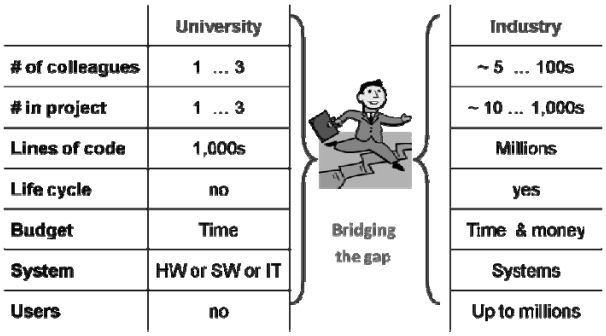
One of the most serious problems in software engineering projects is the communication between users and developers. It is widely recognized that communication problems are a major factor in the delay and failure of software projects. During university education, students are usually well-skilled in programming languages, hard- and software engineering tools and project management. This paper provides theoretical background and some successful examples how we train our students under 'real world' conditions within software projects at the university e.g. to work in teams or to communicate with different stakeholders? Both method and employability result in excellent ratings.

1. INTRODUCTION

Depending on the different requirements of technical systems and business IT, software engineering training is different in both disciplines: Specialists for embedded systems concentrate on the technical environment of the software (incl. hardware and networking tasks) while business software developers focus on business processes and data modeling. However, central problems in IT projects are integration and scaling problems as well as the communication between users and developers [1]. It is widely recognized that communication problems can cause a major impact in the delay and failure of software projects. Software specialists from different backgrounds have to work closely together in order to integrate as well as to launch a system.

Furthermore there are big differences between working on IT projects during a university education and in industry projects as shown in Fig. 1. At university students often act as single programmers on short-term projects dealing with only a snapshot of a software system without any communication with the software users. In the 'real world' IT projects are integrated projects with groups of different developers, years of development and a large number of different users. This paper shows how we instruct and train our students in IT-Topics with 'real-world' examples.

Fig. 1. Main differences between IT projects during a university education and in industry projects



The basis of our multidisciplinary approach at Pforzheim University is to implement as much as possible 'real world' conditions within software projects e.g. to work in larger teams or to communicate with different stakeholders. This new learning methods have successfully 'bridged the gap' as described in §2 Methods and §3 Results.

2. METHOD

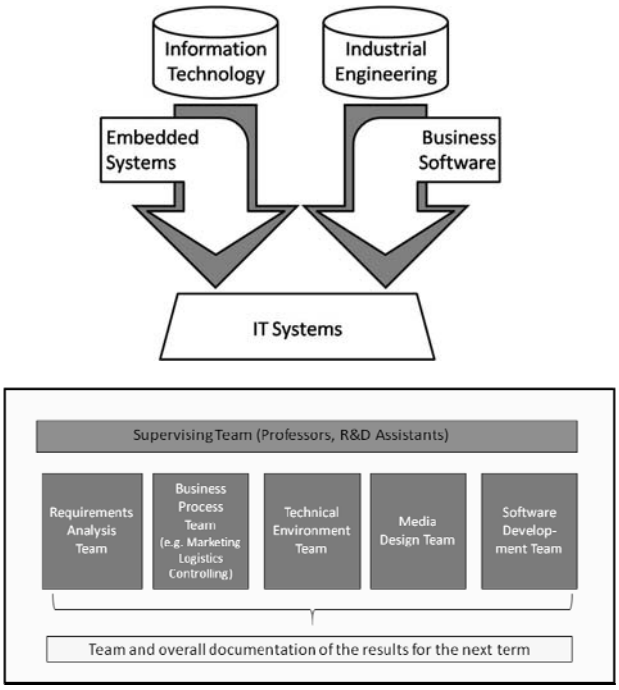
Structure of Software and IT Education

To overcome the issues described before, a multidisciplinary approach was introduced at the School of Engineering at Pforzheim University. The students start with low scale projects in the first years of their studies to learn project work and to apply specific knowledge. In their third or fourth year every student of the faculty has to work on at least one large scale interdisciplinary project which is integrated into the curriculum of our study programs (Industrial Engineering, Information Technology).

Within these interdisciplinary projects each term a group of about twenty students works together on a complex software development project. Teams of three or four students take part in different tasks within the overall project: e.g. one team analyses the current situation, another team provides the requirements analysis, two teams design the IT architecture and the hardware and the other teams write the software. Finally one team is responsible for the training of users and implementation of new processes based on the software developed. Using the procedure of lean incremental software development the students pass their term results on to the next term's students. The project is managed and supervised by professors of different departments and the participating students are involved in different study programs.

Students and instructors work closely together using this interdisciplinary approach. The students can experience different roles and learn to communicate within the project as a specific stakeholder. International exchange students can easily be integrated as well. The general structure of the interdisciplinary approach is shown in Fig. 2.for 'both worlds (top) and breakdown into dedicated teams (bottom).

Fig. 2. General structure of the interdisciplinary approach



Teaching methods

The keyword "bridging the gap" demonstrates the preferred teaching approach practiced at Pforzheim University in which students are given practical training in order to meet the requirements of today's companies. This so-called 'Pforzheim model' characterizes the teaching and learning methods which aim not only to impart knowledge but also to demonstrate how to apply it successfully. This method - as has been our experience for many years – works most successfully when the participants of the class are able to apply their knowledge to solve the given problem themselves.

Knowledge and Self-involvement (K & S – method):

Before the applied theoretical and didactic concepts can be broached, it is essential to briefly characterize the learning situation. The students, who work on the projects mentioned below, are in their sixth or seventh semester and have already had a broad theoretical education in their first five semesters. Engineering topics (e.g. construction, IT, production…), economic topics (e.g. financial controlling, finance, logistics, marketing…) and also supporting competencies (eg IT, quality management, foreign languages, presentation techniques, negotiating…) are part of the curriculum.

The newly development learning method (K & S method) incorporates up to date brain research. Here it has been postulated that effective learning processes in humans are in principle inductive[2]. For the students this type of learning method is generally much more successful than the deductive teaching method. This form of knowledge transfer involves a much greater degree of preparation and supervision for the instructor. The K & S method, with its dual components of "knowledge" and "self-involvement", represents a didactic-methodic concept which is based on integrated active learning. The students have the opportunity to acquire the same content through totally diverse methods. The K & S method enables cognitive, affective and psycho-motorical learning to be brought together in balanced measure[3].

Such concepts are mainly found in constructive didactics [4]. Constructivism implies that everyone has their own perception of reality, so that there is not just "one reality". Thus each person builds up their own form of reality even when learning and adapts the knowledge they have acquired in their own way in their own world [4].

This method does not concentrate on the principle of teaching of the content of a subject area but rather on the use of examples. The fundamental objective is not to learn terms but how to apply them and how to combine the data in a different way. To sum up the holistic approach is applied as a constructivist process.

Activity oriented teaching methods generally use a concrete situation as practice in the first phase, in order to learn from a concrete example. Then in the second phase a general legality or a general principle is deduced in order to explain the inductive approach [2]. By contrast instruction learning first explains the principle and correlation of a subject area –the deductive approach (classical lecture format).

Our many years of experience have proved that personal experiences and interests of the students should be taken into consideration more fully when dealing with issues through

activity-based learning, in order to challenge them on emotional and cognitive conflicts. Furthermore students who have reached this phase of their studies wish to focus more on fields of activity which they must address in their professional lives after the successful completion of their studies The K & S method lays the foundation for success in "bridging the gap".

Planning, Decision making, IT development and documentation:

The essential idea is to implement a term oriented lean incremental software development process adapted from the spiral model defined by Barry Boehm [5] (Fig. 3). The spiral model is the basis model for incremental software development combining the advantages of top-down – and bottom-up concepts and integrating prototypes in the design process. It's an ideal model and several software development methodologies like agile software development or Extreme Programming (XP) are derived from the spiral approach. For the purpose of applying the idea of the spiral model in educational software projects it is necessary to put the development steps into term slots and work on them as concurrent operations.

Fig. 4 shows how the spiral model has been adapted under university education conditions. Within an initialization step a term is planned based on the results of the last term. Different groups work on two basic loops of the overall project, the development loop and the deployment loop. Incremental development slices the system functionality into iterations. In each iteration of the development loop a slice of functionality is delivered through cross-discipline work, starting from the requirements analysis through to the integration of the new software. The deployment loop consists of the implementation of training material (e.g. screen recordings, videos), training the users, implementing new business processes and a user feedback for the next development loop. Close communication between groups involved in both loops is essential because the development loop is also responsible for the rapid correction of errors. In order to continue the project in the next term the results of the current term have to be well documented.

Fig.3. Spiral Model defined by Boehm [5]

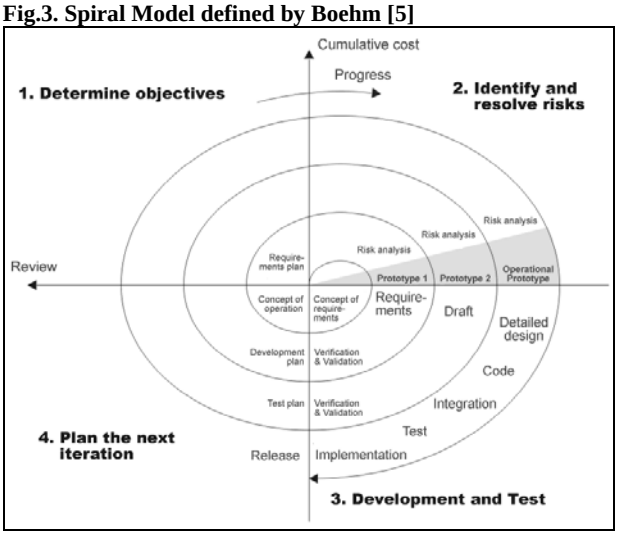
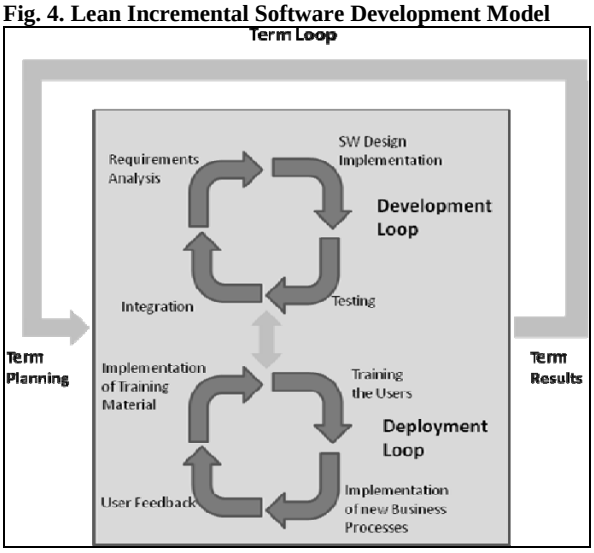


Fig. 4. Lean Incremental Software Development Model



During project work milestones are achieved for the different groups to present intermediate data to other groups and supervisors. Problems can be discussed, discrepancies can be clarified and all students can bring up suggestions during the discussion. Decisions for the next steps are prepared by the student teams and made together with the supervisory team.

With this approach the students are, on the one hand, well instructed in the subject-specific tasks which they have to deal with in their groups and, on the other hand, they learn to work interdisciplinarily and to communicate with different stakeholders and are also able to make decisions.

Incremental Process:

All stakeholders of the project act in accordance with the philosophy or practices focusing on continuous improvement. The supervising team teaches the students how to perform experiments on their work using scientific methods. Good teamwork and efficient intergroup communication establish a basis for a learning organization. The students are responsible for documenting and presenting term results to the next term students in order to introduce these students to the new tasks.

3. RESULTS

This educational procedure has led to quite remarkable results. A great variety of interdisciplinary projects have been carried out during the last few years focusing on different topics like business software, factory automation, embedded systems or quality management. Two software products were developed and successfully deployed to university administration and external partners. One is a Business-to-Business marketplace called BEMA [6] used now for all purchasing activities of our university and includes about 1000 external suppliers. The other system is a web portal for quality management activities – tqm forum - [7] where amongst other things term papers and e-learning units are stored and can be downloaded. This platform for education in total quality management is used by hundreds of students of the Industrial Engineering study program and by many companies to train their employees.

The TQM forum project and the BEMA project are described in detail including the project organisation and the teaching methodology. Additionally two more interdisciplinary projects in the field of Embedded Systems (KANBAN project and Securitas project) are presented here.

TQM forum project

A commitment to quality has to extend through the whole company and must originate from the management. Active management is not only to delegate successfully to the relevant department but also to provide the best quality. Tasks are not just carried out with a starting and finishing date but the focus has to be on continuous improvement. As described through the PDCA cycle, all company activities must be defined and managed as processes. The customer is at the core. One of the most important goals of a company is to improve its customer orientation. In order to develop quality management into Total Quality Management (TQM) it is essential to follow some principles, mentioned below:

- Principle of strategic prioritization
- Principle of internal customers
- Principle of decentralization and independence
- Principle of process orientation

In order to inform the students more closely and clearly about these topics the internet platform **www.tqmforum.de** has been set up by the authors. This platform represents the above-mentioned principles and focuses on the specific needs of employees who work in the field of quality management.

Students focus on quality issues with practical relevance on this platform. There are some specific tasks relating to different branches, for example the food industry, the automobile industry and suppliers. The jewellery and electrical industry have also been working alongside the university in the field of quality management.

TQM Forum status quo

The internet platform www.tqmforum.de is of great benefit for our students' education, as ever more quality issues and approaches have been integrated. Each semester a wide variety of topics are dealt with where the students are able to familiarize themselves with some challenging subject matter within a very short time period (a few days). A more complex selection of topics can be worked on without any difficulty following the principle of "learning organization". With regard to the organization and structure of the TQM forum the authors have ensured that every type of learner has been catered for in the subject matter, for example:

- TQM – specialist subject areas
  The specialist subject areas offer a diverse collection of currents topics in the field of Total Quality Management. Information on methods is provided along with the basic knowledge required in working practice. All contributors are requested to integrate one practical example in their papers.

- TQM – e-learning
  E-learning is used to complement the units on specialist subject areas. The visitor to the platform is able to access the subject matter which has been illustrated in words and pictures. The reader is also able to check the knowledge they have acquired through a quiz. An answer key is provided at the end of each unit.

- TQM - training concepts
  Company representatives, from small and medium-sized companies in particular, frequently have the problem of how to provide appropriate training for their employees. The tqm forum offers ideas for training concepts through its guidelines on the organization and implementation of training programs in the field of TQM.

- TQM – Keyword dictionary
  The TQM keyword dictionary provides speedy help on central concepts. The user is able to research technical terms quickly and easily through the integrated search function. The terms are explained briefly and succinctly and are easy to understand.

- External and internal TQM – Software
  Software support has also become very important in quality management. The platform offers download information on commercial software as well as other tools, some of which have been developed by us. For example. an excel tool has been developed which is a type of cockpit and which reproduces defined functions of the six sigma process for tools. Firstly data acquisition forms are developed. In addition modules (box plots and histograms) are compiled so that empirical distribution functions can be checked. The provisions required of location and dispersion parameters in six sigma, amongst others, can be checked as well as the calculation of the process capability. With the help of the control card (quality control card, account card) it is then possible to check if the process is running smoothly within the specified tolerance limits.

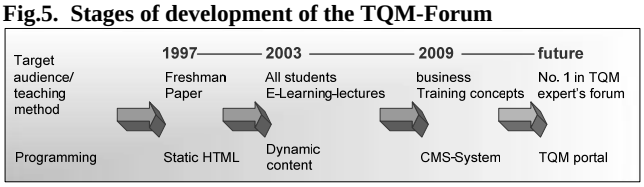
- TQM – Recommended reading
  The recommended reading helps the user to locate suitable sources on specific topics on quality management. As well as a bibliography there are also short reviews and appraisals. The content of the TQM forum is added to continually to include current topics, e-learning units and training concepts. Furthermore there are additional features including a discussion forum, as well as knowledge network on the subject of quality management.

IT development

When the TQM forum was founded 12 years ago there were not so many opportunities available in the field of web technology. Since then the TQM forum has developed at a great pace. Firstly there was a collection of self-compiled HTML pages and some directories from which a variety of documents could be downloaded. A short time later it was possible to program dynamic content like for example a search function and dictionary and to develop a CI.

Today we use a (free) CMS system which is common almost everywhere. The editorial support of the TQM forum no longer requires any knowledge of programming. This allows the developer the opportunity to focus totally on further development and implementation of new ideas. New impetuses for marketing and advertising have arisen through the regular appraisal of google analytics.

Fig.5. Stages of development of the TQM-Forum



BEMA project

Pforzheim University offers a study program for students who are looking to work in the field of procurement. For this reason one of the aims of the authors, together with the university administration department, has been to revise the procurement processes and to develop an ideal type of procurement system. The field of procurement has recently become increasingly more important in companies. The procurement costs, depending on the branch, are between 30 and 60 percent of the turnover of a company.

Processes of procurement:

BEMA stands for Beschaffungsmarkt (procurement market) and provides all the procurement activities at Pforzheim University. An online platform was developed by students of Business Administration and Engineering as part of their BEMA project. All the digital communication between suppliers and the university is located within BEMA.

Before commencing digital implementation into the BEMA system students identified the theoretical processes of procurement at the university. This was then compared to the actual processes which then provided the implementation parameters. One of the elements of the process was the management of the materials and supplier master data, which was part of the system development. A range of new functions has recently been added to purchase requisitions, enquiries and offers from suppliers such as digital signatures and automatic email notification to the customer once the goods have arrived. In addition it is now possible to process urgent and special orders through BEMA. Development has continued with the implementation of an online shop for office stationery which demonstrates the greater efficiency of the procurement structures.

The advantages of the BEMA system, alongside the educational opportunities for our students, are in the cost savings made through:

- better market transparency and
- use of quantity discounts

Furthermore in-house improvements have been achieved through:

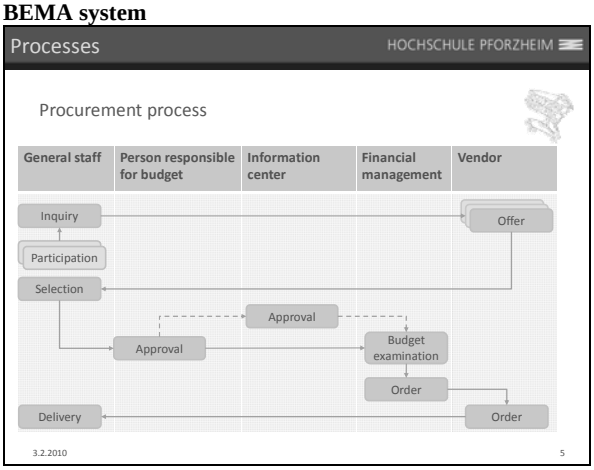
- fair invoicing to cost centres
- centralized enquiries
- complete electronic handling

The basic principle of the BEMA system is:
Leaner – faster- better
This is the guiding principle of our CIP approach. The BEMA system is being continually expanded and optimized in cooperation with the university administration department.

BEMA structure:

The structure of the BEMA system demonstrates to students how the central procurement cycle works and illustrates the role played by all parties involved in our "University Company". Fig. 6. shows the process sequence of a standard order through the BEMA system. The enquiry is the most important element within the procurement process and determines the success of the purchase. Firstly an internal enquiry is sent through the system in order to ensure the cooperation of all departments within the university. The university maintains a single policy when negotiating with suppliers. Furthermore the release of the order through the cost centre staff (in the case of group orders) is important in the development of the procurement process at the university. The final phase of the operation is deadline monitoring, receipt of goods and exact calculation of the total costs for the respective cost centre as well as payment of suppliers.

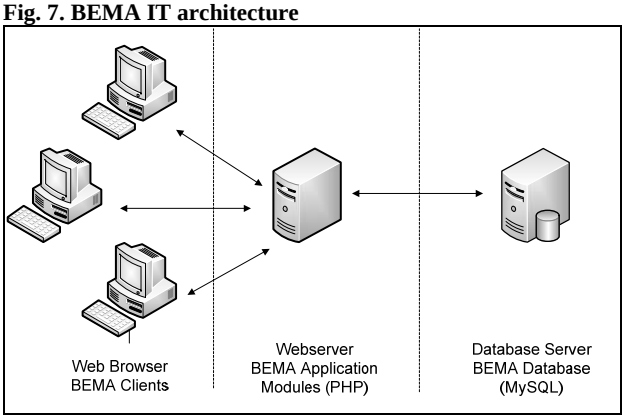
Fig. 6. Process sequence of a standard order through the BEMA system



BEMA IT development:

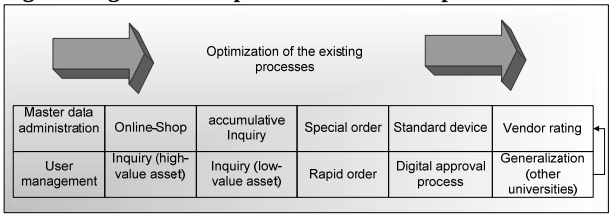
As shown in Fig. 7 the BEMA software system was developed as a classical dynamic web application on the basis of the scripting language PHP and a MySQL database in 2005.

Fig. 7. BEMA IT architecture



The stages of the BEMA development are shown in Fig.8.

Fig. 8. Stages of development of the BEMA platform



Against this background master file data and user administration were introduced at first. In the first basic version fundamental processes like the online shop and inquires for high value assets were implemented. In further iterative stages of development the inquiry process was refined, an order process was implemented and gradually different order variants were integrated into the system. Next the workflow for procurement authorization was introduced into the system and organizational improvements were made. Parallel to the development of each prototype the next stage of iteration was introduced in accordance with the incremental development process (see Fig. 4) – the launch of the previous stage. The new requirements for the user which resulted from this process were then taken into consideration in the next stage of iteration. Thereby the essential feature was to provide a fully functioning version of the software at the end of each stage of iteration. At present the introduction of a supplier rating and expandability of the processes for other universities are being planned.

As the incremental development of the software is still over several years away the BEMA system in the meantime consists of hundreds of PHP scripts which, despite the existing programming specifications from the different programming styles, has been developed by various student groups. Also the MySQL database has been extended several times in the meantime, as the data model had to be modified to include new functions during each stage of iteration.

That is the reason why at present a completely new IT redesign of the BEMA system is being carried out on the basis of XML technologies. During the first stage the data model is to be consolidated and a new MySQL database introduced. We have ensured that through a new BEMA framework with templates for the graphic user surface the pages of web application are constructed modularly and created dynamically through PHP core functions over XML documents. This approach has enabled the compilation of new pages with much less programming input. Furthermore the new IT concept has meant that the BEMA system can be customized and can also be used at other universities. The relaunch of the BEMA system has been planned for 2010.

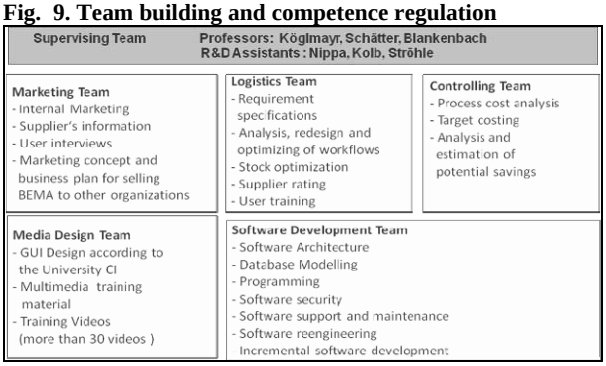
Organization and communication:

Student projects have demonstrated that there is room for improvement of the established purchasing organization at Pforzheim University. Due to a lack of resources, the idea of "virtual purchasing" for the university has been discussed in a workshop. The students will work on this in 2010 and present their results to the university committee. Thereby the structure of the university must be taken into consideration as well as the fact that there is a very limited amount of funding for such projects available.

The fundamental idea is that one expert per faculty acts as a "professional buyer" and thus is the contact partner and decision maker internally and externally for the supplier. The relevant purchasing formalities and basic agreements with the suppliers will be undertaken by the purchasing department.

In order to manage such an assignment, there is a need for a variety of talents. Fig. 9 demonstrates the project teams in each department. In order to customize the processes within the area of IT there are 2 qualified teams available (software development and media design). The logistic experts will deal with the material and information flow, the marketing students will talk to users and will eliminate any acceptance constraints through selective communication and the financial controllers will check the costs and the procurement processes. A well-established communication process between developers, operators and users is guaranteed through this structure and furthermore any deficiencies within the training will be dealt with.

Fig. 9. Team building and competence regulation



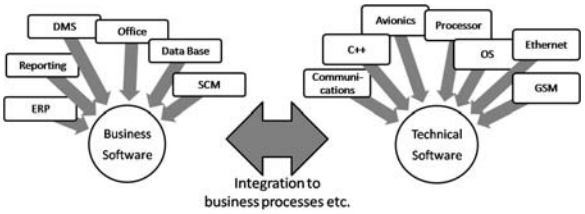
Embedded Systems with Business Software Integration

A further field of interdisciplinary projects is the development of hardware and software for embedded systems and their integration to business IT software. Compared to pure business software, embedded systems focus on system integration and always require hardware and software development. Embedded systems are nowadays very common and can be found in a number of applications like:

- Medicine: diagnostics, monitoring, etc.
- Automotive: ABS, ESP, telematics, infotainment, etc.
- Mobile and wireless: devices like phones, remote sensing
- Network computing infrastructure
- Consumer electronics: audio, video, white goods etc.
- Industry: automation, field busses, image processing etc.

A demanding challenge for many the above listed systems is to combine business software with embedded systems (see Fig. 9) for an optimized logistics value and control functions like quality assurance.

Fig. 9 Integration of business software with technical software / embedded systems

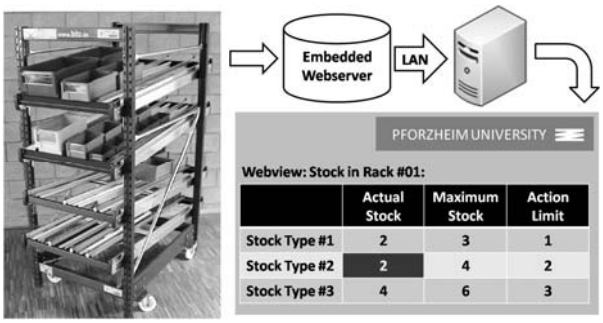


At Pforzheim University these projects have been launched in order to experience the difficulties of projects of the "real world" within a lab-scale environment. Various engineering disciplines are combined – often in co-operation with industry and/or end users. The benefit is a lab experience without the cost and complexity of "real world" systems. Our aim is to bring together hardware development such as board design and electronics with software development, e.g. web based applications including business IT. The target is to train students to get a "system view" of complex projects involving electronics, network connectivity and internet applications in one embedded system. This will be pointed out by two examples: a KANBAN system and a telefon security system.

KANBAN project

Students had to structure and to solve various tasks (see Fig 10) in terms of hard- and software: First a reliable mechanical design for the KANBAN rack is necessary for stable operation has to be designed. The mechanical and electrical engineering departments worked together to define the mechanics, electronics and sensors to detect the KANBAN boxes in the rack. The sensor values had to be captured and stored on an embedded web server with sensor inputs. The web application visualises the stock and provides an interface for logistics applications. Finally, the system was integrated into SAP software as a link to the business world.

Fig. 10. Embedded Systems: KANBAN project



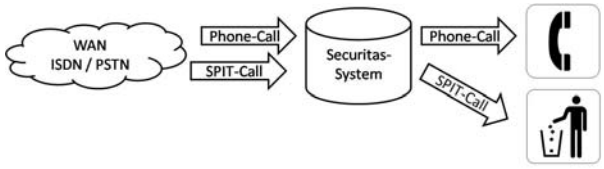
In the course of the project the electrical engineers learn to understand the challenges of today's logistics and business IT software and the IT students got an impression of the complexity and requirements of embedded systems design and optimization strategies. During the project the tasks of an enterprise resource planning (ERP) system become clear, even if this is not part of the lectures that students of electrical engineering usually attend.

Securitas system

Since the first email was sent more than 25 years ago the use of this easy and cheap way to communicate has become more and more common. Nowadays more than 84% of global email traffic is unfortunately SPAM mails [8]. So in the mid-nineties SPAM filters and engines were developed to get rid of this annoying and time consuming form of unsolicited advertising which had become a significant cost factor. The same problem today seems to affect the relatively new form of telephony, Voice over Internet Protocol (VoIP). Due to the fact that VoIP, just as with email, is available at zero cost it has become the subject of more and more abuse and is now used for advertising purposes in a similar way as email is used. This so called spam via internet telephony (SPIT) is turning into a major problem. In 2008 the "Securitas" project, designed as an anti-SPIT application, was launched at Pforzheim University involving beside R&D staff many of engineering and IT students (some of them on a part time contract during their graduate studies).

The Securitas system (Fig 11) is based on hard- and software and located between the WAN and VoIP phone. It has a function which is similar to a firewall or SPAM filter in order to sort out incoming calls and reduce SPIT calls to a minimum.

Fig.11 Embedded systems: Securitas SPIT filter system



These functions lead to a nearly SPIT-free situation. The current version is running stably on a server with an open source ASTERISK environment. This project, sponsored by the state government, has already been running since the summer of 2008 and has now involved more than 20 students. Due to the co-operation with a local IT company, the students can acquire experience close to reality in a single term project.

4. CONCLUSIONS

An interdisciplinary approach and new learning methods are presented in this paper in order to train students in software projects under 'real world' conditions at the University. We invented and implemented a 'real world' software project education in our curricula to "bridge the gap" between industry and University. Students can experience specific topics e.g. Programming, Logistics, Marketing, Embedded Systems as well as work interdisciplinary within the same project. The students are well-trained to write their bachelor thesis within the IT sector either on business software or embedded systems integration. The multidisciplinary approach leads to a significantly better understanding of the tasks of large software projects. All these activities have significantly enhanced the employability of our students as we got this feedback from our industrial partners. Moreover the interdisciplinary collaboration within the Technical Faculty of Pforzheim University fosters R&D activities and projects with the industry.

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