Integrating Medical Robotics in the Robinson Program

Sabina Jeschke, Lars Knipping, Marcus Liebhardt, Fabian Müller, Ursula Vollmer, Marc Wilke, Xin Yan

IITS – Institute of Information Technology Services & RUS – Center of Information Technologies & MuLF – Multimediacenter for eLearning & eResearch
University of Stuttgart & TU Berlin

Abstract
The Robinson curriculum contains a novel approach to improve the engineering education, to enhance technological literacy of students from non-engineering fields and to increase in the number of students, especially young women, in the fields of engineering and natural sciences. Since robotics holds a special fascination among all the technological fields – due to its cross-disciplinary approach as well as its popularity through movies and literature –, this field allows hands-on teaching of scientific and engineering methodologies at an early stage of the academic education, not limited to engineering students but encompassing students from all academic – and even pre-academic – areas.

1. Introduction
One reason for developing the “Robinson” curricula is based in the modified demands concerning a modern engineering education: The job description of engineers is increasingly defined by requirements difficult to teach in the basic courses of the bachelor studies. Especially interdisciplinary skills are rarely conveyed before the advanced courses taught to engineering students, including the teams’ skills necessary to design and implement solutions to complex, interdisciplinary problems. As a result, the students are often lacking in a deeper understanding of the correlations between the different courses and subjects they have been taking and their relevance to the requirements of their future jobs.

Additionally, for years experts have been warning that the number of graduates in engineering and natural sciences fail to meet the growing demands of the economy. If this situation is not dealt with, it will have a strong negative impact on the future economical development. Despite a growing presence of high-tech devices in everyday life, the proportion of high-school graduates choosing to study engineering or natural sciences is declining. The negative image of technical studies has been identified as a major reason behind this trend. They are perceived as focusing too much on theoretical issues, while ignoring experimental, hands-on aspects of the technical disciplines. At the same time, potential students are alienated by the perceived lack of social relevance and the failure to teach important soft skills. In particular, the lack of young women in these fields has been the topic of an intense debate for some time [1, 2].

Another central motivation for the creation of curricula on robotics for students from the non-technological areas is given by the increasing indifference to technology in large sections of society. The division between natural and technical sciences on one side, and humanities and social sciences on the other hand, has been strongly enforced not only in Germany. This has led many humanists and social scientists to become indifferent or even hostile to technology. Despite recent attempts to improve this situation, many students of the humanities and social sciences are still lacking a deeper understanding of modern technology, with disastrous consequences for the economical and social development.

Robotics, in particular mobile robotics, holds a special fascination among all the technological fields: Starting with the first “automatons” of ancient times (Archytas of Tarent, Heron of Alexandria) and da Vinci’s studies of androids to the modern heroes of movies and literature, robots (and in particular, humanoid robots) have always captivated the fantasy of human beings. Unsurprisingly, robotics is attracting even the interest of people who are normally more reserved and cautious towards technological fields of study. As a result, robotics is well suited to strengthen the interdisciplinary components of the academic education of all students, in particular also of students from non-technological areas, in order to strengthen their technological interest and literacy. Furthermore, the fun of creating, building and programming their own robots will make students look at the other technological oriented areas with more interest.
2. Modules of the Robinson-Program

The Institute of IT-Services (IITS) at the – mostly technologically oriented – university of Stuttgart is currently introducing a new, project-oriented course for robotics:

![Robinson Program Modules Image](image_url)

- **A – “Robinson Med”: Improving the medical engineering education**
  
  Robotics is an important area in the field of medical engineering and its popularity is unabated. This makes it suitable for giving medical engineering students a possibility to make early acquaintances with the working structures of a medical engineer. The aims of the course include social skills as well as specialist content. The course aims at training team skills and conveying methodologies for solving complex interdisciplinary challenges. Furthermore, students acquire knowledge in the field of medical robotics and concepts of soft and hardware engineering. The course consists of three basic components: a series of lectures providing the necessary theoretical foundation and an overview on robotics in medical engineering, practical application of this knowledge in a hard and software project and presentation and discussion of the results in front of the whole course. The topics for the lectures as well as for the practical part will bear reference to the field of medical engineering. This integrated course allows not only addressing the aims outlined above, but trains additional skills useful for time constraints and presenting solutions and results to colleagues. The course is aimed at bachelor students of medical engineering and is part of their core elective courses.

- **B – “Robinson Ing”: Improving the engineering education**
  
  The field of robotics combines a wide range of technological disciplines with popularity while addressing socially relevant challenges. As a result, it is well-suited to providing engineering students with an insight into the working life of a modern engineer. As in “Robinson Med” the aim of the course lies in forming social skills and conveying methodologies for solving complex interdisciplinary challenges, as well as teaching concepts of soft- and hardware engineering at an early stage of the studies. The course consists of the same three components as “Robinson Med”, but the lecture topics will provide a general overview on robotics, without any special focus. And the students will have even more freedom in the choice of their projects, as they are not limited to a specific topic. The course is primarily aimed at bachelor students of electrical engineering and the computer sciences and is part of their core elective courses.

- **C – “Robinson Mixed”: Providing technological, interdisciplinary courses for students of non-technological fields**
  
  This course will emphasize supervising and mentoring students from non-technological fields and early semesters. Project and team work are an integral part of the concept as they are in “Robinson Med” and “Robinson Ing”. The course enables the students not only to design, construct and program autonomous robots, but also qualifies them to teach basic robotics to high school level students. The students have the option to participate in instructor courses licensed by the Fraunhofer Institute as part of the Roberta program (see below) receiving an official certificate granting the right of instructing a Roberta course upon completion of the course. Aim of the course is improving the interdisciplinarity of students in non-technological fields, particularly their interest in the technological fields. The course will be offered as a regular, elective module credited with ECTS points.

- **D – “Roberta”: Increasing the number of female students in the natural sciences and engineering**
  
  Robotics has the potential of attracting girls to the natural sciences and engineering early in the course of their education by showing them their own potential in a playful, experimenting environment. The independent design and construction of robots demonstrates the importance of creativity and the social relevance of the field to students, two factors important in young women's choice of studies later on. Additionally, it gives girls more confidence in their skills concerning technical and scientific issues. We are offering courses for high school students of grades 10 through 12. This part of the program is based on the “Roberta” project and is offered in cooperation with the IAIS Fraunhofer Institute.
3. Academic Education – Didactic Approach

All academic Robinson modules have a similar didactic approach. The lectures of “Robinson Ing” and “Robinson Mixed” cover basic robotics fields, as can be seen in table 1. The lecture topics of “Robinson Med” differ from these by always bearing reference on medical engineering.

### Table 1. Lecture topics and tasks

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Teamwork</th>
</tr>
</thead>
</table>
| 1       | Introduction & History of Robotics  
| 2       | Principles of Hard- & Software Design  
| 3       | Introduction to Hardware & Development Environment Specifications (Hard-/Software)  
| 4       | Sensors Presentation of Chosen Topics  
| 5       | Kinematics and Bionics Implementation  
| 6       | Cybernetics Implementation  
| 7       | Energy Concepts for Autonomous Robots Implementation  
| 8/9     | Algorithms Implementation  
| 10/11   | Specialized Lectures Implementation  
| 12/13   | Result Presentation  

However, it is important to mention that despite of the similar lecture plan the curricula of the academic classes are not identical: Due to the differences in pre-knowledge and interest, the lectures for the non-engineering students vary significantly from those for students from technological areas. For engineering students, it is important to explicitly address their technological pre-knowledge gained within other classes in order to demonstrate how the different fields and disciplines interconnect each other. Contrarily, for non-engineering students the challenge for the instructor is to teach a highly technological field to an audience without comprehensive theoretical foundations in engineering, mathematics, physics, computer sciences – but at the same time enable students to run their robot projects autonomously and successfully. In particular, since not even basic knowledge of programming languages and structures can be expected, it is important to support the students with tools and programming environments which focus on the general ideas and the logical aspects of a program – instead of details of their particular syntax structures.

The “Robinson Med” and the “Robinson Ing” modules are designed and lectured as an integrated “interdisciplinary robotics laboratory: soft and hardware engineering” for medical engineering students and electrical engineering and computer science students respectively. For the “Robinson Mixed” module, the focus is on “interdisciplinary robotics laboratory: application, construction, behavior”. All are held each semester during regular term or as a compact course in semester break and consist of three basic components:

- the introductory and accompanying lectures, giving an overview to selected principal topics (2 hours per week, 11 weeks),
- a team oriented practical training with small groups of 3-4 students designing, building and programming whole robots or components (4 hours per week, 11 weeks), and
- a seminar and presentation part, giving the teams the possibility to demonstrate their project results on a project web page and to introduce it to their lecturer and fellow students during an oral presentation in class (6 hours per week, 2 weeks).

Thus, the combination of all characteristic components of an “integrated course”, i.e. the integration of the lectures given by the instructor, students’ presentations, and the hands-on part – all of them influencing the final grades – allow for a complex yet highly sophisticated course in which the students benefit in many ways. They do not only acquire the necessary theoretical foundations and knowledge about their application; during all organizational tasks within the teams, beginning with the formation of groups and later in the design-, specification- and presentation-phase students are also trained in the soft skills, which they will need for the rest of their professional life.

4. Academic Education -- Details and Realization

The focus of the practical team work is chosen from a list of possible topics or defined in cooperation with the instructor by the single teams. The suggested projects involve all fields of applications for mobile robots (household and service robots, exploration robots, robots for nursing duties [3]), specific technical concepts and components of robots (sensors, actuators,
special motive systems, autonomous energy supply, human-machine-interfaces [4]) or specific algorithms (cooperative learning, simulating a swarm, autonomous learning). For “Robinson Med” the choice of projects is restricted to topics that bear reference to medical engineering. The list of topics is not meant as a restriction on the students’ creativity. Rather it is meant to guide their choices to avoid a common problem, overly complex projects unmanageable in the given amount of time. Again, this aspect is of particular importance when working with students from non-engineering fields.

The projects can involve challenges from the fields of electrical engineering, computer sciences, mechanical engineering, energy technologies, materials science, biology and other natural sciences and fields of engineering. The practical, project-oriented component is specifically aimed at supporting the teams and team members to work independently of closer guidance by the instructors. During the presentation of their project specification, the teams receive feedback, constructive criticism and suggestions from both their colleagues and the instructors, providing additional input before the actual design and implementation is started. Additional support is given by the instructors at the robotics lab during the implementation phase.

The choice of the tools “best suited” is a central challenge in any design process and is dependent on the team, its members and the task at hand. As a result, the students are free in most of their choices from hardware to development environment and operating system. We provide a default, well-suited to students with less experience, based on the Lego Mindstorms NXT [5, 6], the graphical programming language NXT-G [7] under Windows or alternatively NXC under Linux. The students are free to deviate from these default configurations but cannot expect full support of their chosen configuration by the instructors, especially the further they move away from it. The freedom in defining both topic and environment allows the adaptation of the difficulty to the skills and previous knowledge of the teams.

Another important task within the course and one of the central learning goals is securing the findings of the single projects. The students are faced with the challenge of presenting and securing their experience, ideas and results in a way that allows others to reproduce their project. To facilitate this goal the teams will create a documentation of their projects in a Wiki provided on the course home page. The documentation should include the original hard and software specifications, a documentation of the developed code, documentation of the design and construction of the robot, and the slides of their final presentation of the results before the course. The Wiki will grow with every semester as each team adds their projects. While risking plagiarism based on older results this concept offers additional options and opportunities for more complex, future projects, based and expanding on the results of previous teams. The danger of cheating and copying will be addressed by only allowing projects similar to already existing ones, if the new projects has a significantly changed focus or methodology.

Students participating in the course will be credited with ECTS points. The final grade for the course is composed of the results of three separate examinations. The hard- and software specification of the robot is weighted with 20%. The final presentation of the robot is weighted with 30%. The result of an oral examination of the whole team is weighted with 50%. In addition to continuously monitoring the students' performance, this will improve student motivation and give teachers the opportunity to intervene and help at any time. Experience from a similar integrated project [8] has shown that it is necessary to rate each team member individually. Otherwise, “backbench riders” might be pulled through by the other team members without any effort of their own.

5. “Roberta” - Didactic Approach

The module “Roberta” is based on the well-established pedagogical concept “Roberta - girls discover robots” developed by the IAIS Fraunhofer Institute 2000/2001 [9]. The project uses the fascination of robots and their development to convey knowledge about engineering and computer science in an exciting way to pupils, in particular to female pupils. Within small classes, the participants build their own robots and start to control their behavior, using a simple graphical programming interface.

Classes of different length aiming at different project goals are offered. The students usually start with a half-day class (3–4 hours) which contains the building of a Roberta prototype and its programming. As for the programming, certain tasks are suggested, including a simple change maneuver and the tracking of a given path. After completing this beginners' class, different classes for advanced learners are offered depending on the program of the local Roberta center. A common continuation is given by courses which lead to the participation of “RoboDance” or “RoboCup”, two well-known competitions in the robotic scene offering special tracks for pupils.

Before holding Roberta robot courses all tutors are trained. Teaching materials were developed to support tutors. To assure attractiveness and quality of courses
and materials both are evaluated by the University of Bremen (Schelhowe, Schecker). A national network of regional Roberta centers is being established to support tutors locally, to ensure nation-wide exchange of experience, and to disseminate the results of the project.

First practical experiences have shown that robotics have a huge potential to motivate students. The “Roberta” courses for girls have been met with considerable interest and enthusiasm by the participants. Furthermore, the number of student applicants for instructor positions and the requests for future courses on the topic indicate that a curriculum such as it has been proposed in this paper will be a major success.

6. State of the Art

A similar project [10] has been launched at the beginning of 2007 at the Institute for Personal Robots in Education (IPRE), a joint effort between Georgia Tech and Bryn Mawr. Their main goal is to use robots in computer science education. They developed a robot that should be cheap enough for every student to buy one. This robot is supposed to be used by the students for learning programming throughout their studies.

In contrast to our approach, the project focuses on computer science education and does not capitalize on the interdisciplinarity provided by robotics. Students are supposed to learn programming basics in one specified programming language. They do not have a choice of tools. The main intention of the project is to teach students the basics of programming and not to introduce an engineering process to them and bring forward their team and social skills. Creativity is shortened, as the students are restricted to the given robot. The construction of an individual robot is not intended.

7. State of Preparations, Summary and Outlook

In the summer of 2007, the multimedia center of the TU Berlin (MuLF) and the Institute of IT Services of the University of Stuttgart established “Robinson” together, a joint facility focusing on the use of robotics in academic education2. This center incorporates the existing “RobertaRegioZentrum” in Berlin as well as the new one established at the University of Stuttgart in autumn 2007. We successfully participated in the training courses necessary to use the “Roberta®” brand [11]. Beginning in the summer term of 2007, Roberta courses for elementary and high-school students have been held at the TU Berlin. “Module B – Robinson Ing” will be the first of the courses to be taught at the University of Stuttgart in the summer term of 2008. It will be followed by “Module C – Robinson Mixed” in the winter term of 2008/2009. “Roberta” courses will also start to be taught in spring 2008. At the TU Berlin, Modules B and C will be launched in the winter term of 2008/2009. “Module A – Robinson Med” will be included in a new degree program B.sc. Medical Engineering. This bachelor program will be carried out as a cooperation of the Universities of Stuttgart and Tübingen and is still in the planning phase. The program will presumably start in the winter term of 2009/2010.

The project will receive a formative evaluation by the instructors during the course, as well as a summative evaluation by the participating students at the end of the course. There will be an additional summative evaluation by the members of the faculty after two terms.

8. References


2 http://www.mulf.tu-berlin.de/Roberta