

# Autonomous Systems at Gelsenkirchen

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**Abstract.** This paper describes the didactic concept of how robots and mobile robots are used in Bachelor and Master Courses held in the computer science department of the Applied University of Gelsenkirchen. It reflects the general concept as well as the equipment e.g. sensors and robots used or built for the robotic lab.

**Keywords:** Robots, mobile robots, autonomous robots, education with robots

## 1 Introduction

It is well known that practical work motivates pupils and students while learning difficult material e.g. mathematics. At schools Lego robots are very popular and e.g. in Germany it already exist a large network [1]. Roberta supports teachers and pupils not only with robotic kits but also with high level teaching material which is very important. In the RoboCup competitions Lego robots are supported up to the age of 18 whereas students especially at an Applied University have to be trained on more industrial oriented sensors and robots, so Lego robots are not suitable.

The author has adopted a reputation as a Tenure Professor for Autonomous Systems at the Applied University of Gelsenkirchen and has design two Bachelor lectures and two Master lectures including the practical work with the robots i.e. building a robotic lab and unfortunately with only a limited budget.

## 2 Didactic Concept

In order to promote study according to the objectives of the project, technology - especially robot technology - should get a higher significance at all different level of education from the Bachelor to the Master at the Computer Science Department of the Applied University of Gelsenkirchen. Furthermore, the interest of students and in particular female students in technical questions should be encouraged and increase in future. Like physics and chemistry technology also has some acceptance problems that should be addressed in a creative way. The following approaches are selected according to the current status of research in robotics and didactics. They are appropriate to achieve the project objectives and fundamental to the development of

the lecture series. Three components are considered: a) selection of themes, b) general learning aspects and c) methods of learning. For the development of the lectures and materials, the model of didactic reconstruction was used since it takes into account the above-mentioned points. The basic idea of didactic reconstruction is, to equally consider the background and perspectives of the students both according to their cognitive and affective skills as well as their interests, for the planning of the lectures. Especially the following questions and terms play a central role in the development of the lessons:

- the theme
- goals to achieve (both technical and interdisciplinary goals)
- fundamental principals
- expectations of the students

The lectures will be set up according to an iterated procedure based on the above criteria.

## 2.1 Selection of themes

First of all lectures have to deal with state of the art robotic technology in both terms hardware and software. Both, hardware and software have to be understood as technologies that have to be useful and helpful for humans. Architecture aspects of the hardware and software have to be general and not only limited to robotics. Comprehension of technology includes “knowing”, “understanding” and the “critical evaluation” of the basic concepts and phenomena of robotic technology. Also ethical aspects have to be discussed since e.g. 30% of the robotic market deals with military and combat robots.

The specific themes especially the practical lessons again have to consider the interests and knowledge of the students. In general, i.e. independent from the gender, new studies show that robotic teaching is interesting if its content directly leads to everyday situations, the human body, amazing phenomena or social importance. All of the four points have to be considered. The lectures empower the students to be responsible participants in discussions and experts of technical developments and innovations.

## 2.2 General learning aspects

“Everything changes and improves continuously” is one important aspect not only in the computer science area e.g. hardware and software. Within the lessons the students will get the opportunity to experience that their recent concept is not tenable in all situations and may be discarded or expanded. This is the first step towards the construction of new concepts. Both, discarding old architectures and concepts and finding new more expanded architectures and concepts (preferably done through self-directed action) is one of the central aspects. The continuous change is studied by the consideration of older robotic generations and by giving a leading vision e.g. “play soccer against humans in 2050”. Summarized the students have to develop five basic competences:

- “Understanding”; Goal orientation and knowledge regarding functions, concepts, structures, principles and ability to apply technique.

- “Design and construction”; Plan, design, manufacture, optimize, evaluate and test Robotic solutions.
- “Using”; Select and apply technical solutions, consider professional and safety requirements including the removal (substantiality).
- “Estimation”; Appraise robots based on historical, ecological, economic, social and human perspectives.
- “Talking”; Communicate and share robot technology, or appropriate technology-related information and subjects.

### 2.3 Methods

The methods used in the lectures are:

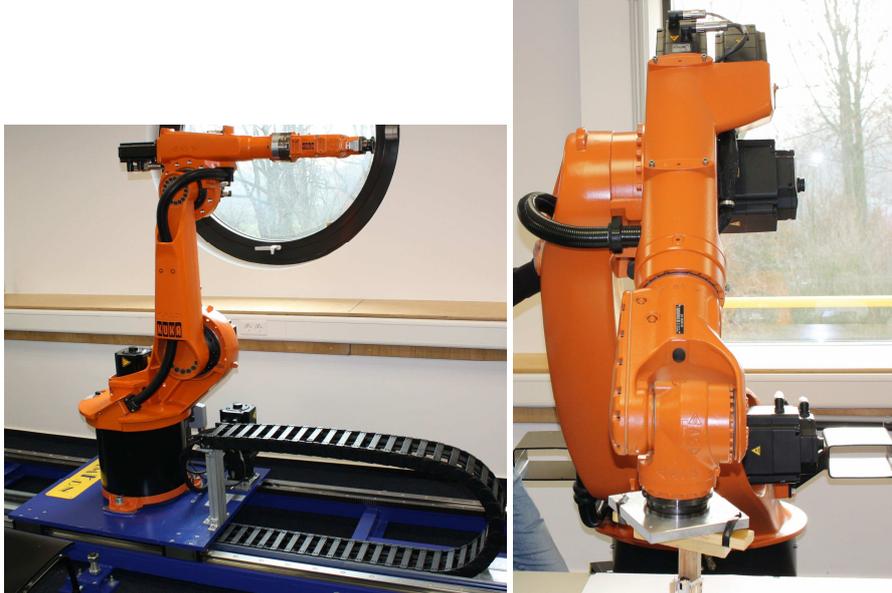
- Example based learning,
- task learning,
- workshops, talks,
- group work and
- discovery learning.

All lectures will be provided online. The relevant information will be organized in wikis and FAQs. The focus is on enabling the students to learn the scientific approach i.e. identifying the relevant problem, reflecting the state of the art, developing and documenting an appropriate solution based on the state of the art and compare it with other solutions.

## 3 Robots

The two Bachelor lectures are subdivided in bases of standard robots e.g. manipulators and bases of mobile robots. In addition to the two hours lectures per week, the same time for practical work is reserved. For the manipulator two Kuka robots a KR16 and KR60 had to be bought (Fig. 1) [2]. Both robots are 6 degree of freedom manipulators with a triple-roll wrist. The triple-roll wrist ensures a closed solution of the backward transformation which is therefore one of four main topics of the lectures. The other three are a) the robot programming b) robot design and standards (e.g. Denavit-Hartenberg Parameters) and c) robot control.

The practical part starts with a safety briefing and the calibration of the robot together with the manual programming of the robots with the control panel. After that small programming exercise e.g. playing a chess game, writing the content of a pdf-File (e.g. Hello world ;-)) or 3D printing has to be done by the student's. Furthermore, predefined trajectories have to be programmed to calibrate other sensor like gyros or IMUs.



**Fig. 1.** The two manipulator robots Kr16 (left) and Kr60 (right). The Kr16 has a horizontal slide.

The second Bachelor course deals with mobile robotics. As a driving base we use a modified version of Roomba robots since they are available for a reasonable price (Fig. 2). Furthermore we have a VolksBot RT3 [3] belonging to Fraunhofer IAIS and a Handycart (Fig. 3). The VolksBot RT3 is controlled by a Maxon motorcontroller (EPOS) via OpenCan. The RT3 is very powerful and can carry a payload of 40 kg (<http://www.youtube.com/watch?v=kz0AJy6sZBU>). The Handycart is an industrial AGV usually guided by a wire. It has a weight of 250 kg and can carry a payload of 200 kg. With our modified version we can perform autonomous as well as wired or combined experiments. The main sensors for the mobile robots are cameras e.g. from 2 up to 10 million Pixels, and 2D or 3D laser range finders (most Sick LMS 200 and LMS 100 variants). Each robot has a docking station for the automatic charging of the batteries (Fig. 4) and therefore is able to operate fully autonomous over a long period of time without human interventions.

The lecture starts with the basic terms. The core areas of the Bachelor lecture covers:

- Sensors with a focus upon cameras and laser range finders
- Actuators and gears
- Localization
- Mapping techniques and SLAM approaches
- Navigation strategies

Elaborated vision algorithms and machine learning are not part of the Bachelor lessons and are covered by the Master courses. Each lesson is followed by a practical tutorial and hands-on seminars in the robotic laboratory where according to the

lecture the practical work with the robots and sensors has to be done. The Robot Operating System (ROS) [5] is the robot control architecture and middleware used, and has to be installed by the students in the first lessons. Exercises with the laser range finder and cameras have to be passed and example nodes i.e. publishers and subscribers have to be implemented. During the last third of the lecture small individual student projects have to be worked out in small groups.



**Fig. 2.** A modified version of a Roomba. Left: With a 3D laser range finder. Right: With a 2D laser range finder, a pan and tilt camera and a notebook with touch display. A video of an example student project can be found at:

[http://www.youtube.com/watch?v=SFZtYKA\\_hcU](http://www.youtube.com/watch?v=SFZtYKA_hcU)

The first Master course in Autonomous Systems extends the two Bachelor courses with advanced techniques for localization and mapping as well as with elaborated robot navigation, planning and robot control architectures. Furthermore, chosen chapters of machine learning are presented. As well as in the Bachelor courses each theme is accompanied with practical exercises in the robotic laboratory based on ROS. The second Master course is designed as a seminar where the students get a paper or a collection of papers that have to be worked out by the students. Each student has to be present his results in a 45 minutes (35 + 10 for discussion) presentation. Afterwards follows a practical training of some examples with the sensors and robots or data sets from the cameras, laser range finders etc.

## Evaluation

The concept could not be really evaluated since the course just started or given only once. Nevertheless the first evaluations from the students are very promising.



**Fig. 3.** Left: Handycart with a Sick PLS laser range finder. Right: A Volksbot RT3 controlled by a MacMini.



**Fig. 4.** Docking stations for the automatic battery charging. Left: VolksBot, Middle: Handycart. The arm is moving out if the robot it detected via infrared light, Right: The Roomba has an additional battery pack for the laser scanner and a digital relay card to switch power to the notebook if necessary.

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Fig. 5. Components and interfaces of the Roomba robot.