Name Module	Robotics and Vision
Language	English
Contact person	Ferdi van der Heijden
Specific prerequisites (regarding incoming exchange)	
Participating study	EE
Starting block	1B

Theme

A robotic device is a goal oriented machine that can sense, plan and act; often, in an unknown or dynamic environment. Robotics binds elements from physics and mechanics, sensor and actuator technology, pattern analysis and computer vision, estimation and control, and computer science.

One of the more versatile and information-rich class of sensors are the one that are based on vision. Our own, human experience is that eyes are very effective for understating our own position e.g. in a room, for navigating safely in a crowded environment, for obstacle detection/avoidance, and manipulations. However, the 2D image data of a camera provides only 3D information in a very indirect way. The cognitive process of deriving 3D information from the image data is referred to as "computer vision". It entails tasks like: detection, recognition (classification), localization of objects, motion detection and estimation. Nowadays, different types of active optical sensor systems are available. Examples are stereo vision cameras (Kinect), structured light systems, laser range finder, and time-of-flight cameras. These systems provide the 3D depth information more directly, but even with that, computer vision is far from trivial.

Robotics and vision share the same elements in the sense that both disciplines have to deal with the dynamics of objects in a 3D world. The active manipulation of the camera by the robot creates potentials, such as:

- SLAM: navigating in and charting an unexplored environment
- Visual servoing: using the camera in the feedback loop to control the robot

The objective of this minor is to introduce the undergraduate students to the main principles in robotics and vision by offering them hands-on experience toward independent decision making of the tools (both hardware and software) necessary to complete a task by means of an autonomous robot.

Content (including project)

The course will offer a panoramic, introductory view on the field of robotics and vision, exhibiting the many aspects of it. The overview includes the mathematical tools necessary to analyse robotics and vision problems in a more rigorous way. The topics that will be addressed are:

- Types of robots (mobile robot vehicles: car-like, flying, sailing, and arm-type robots) and configuration of robots.
- Elements from 3D geometry and 3D kinematics: coordinate systems, coordinate transformations, homogeneous coordinates, representation of orientation, linear velocity and angular velocity, state space representations.
- Introduction inverse kinematics and planning.
- Introduction navigation: state estimation, dead reckoning, updating, localization, SLAM
- Introduction control and feedback
- Image formation, perspective projection

- Introduction image processing and geometrical image transforms
- Introduction segmentation and feature extraction
- Stereopsis: camera calibration, rectification, stereo matching, triangulation
- Active optical sensors
- Image motion: optical flow and focus of expansion
- Vision-based control and visual feedback

Many of these topics will be addressed in a simplified setting. For instance, some of the aspects can be treated in 2D without sacrificing too much on the insight in the principles that are applied.

Multiple interdisciplinary groups will be formed working on a project that will provide hands-on experience. The project will teach the students to use the basic software tools for robotics and vision. Students will be able to integrate multiple domains into a unique device. The groups will have the possibility to challenge each other in a robotic competition aimed at achieving course-driven goals defined as tasks to be achieved by the autonomous robot with certain performances.

Learning goals

The students will work in groups composed of complementary skills. By the end of the course the groups will be able to:

- understand the basic system aspects related to mechanics, electronics and optics by analysing and describing these physical systems with mathematical models
- understand and use the basic principles of image processing and computer vision, and develop the ability to manipulate data using mathematical principles and software tools
- develop and use basic versions of a fully functional mobile robot with manipulation capabilities by integrating different electro-mechanical systems
- put into practice these mathematical tools and give the robot the capability to localise itself, reconstruct the environment and perform manipulation tasks using its actuators and sensors
- design, work with and understand real robotic systems

Although an individual student is allowed to specialize him/herself in specific subarea of robotics and vision, he/she should still understand the principles of operations in the other subareas.

Educational forms

- 5%: Introductory lectures
- 20%: Self study based on Peter Corke's textbook: "Robotics, Vision, and Control"
- 35%: Problem based, individual exercises using Matlab
- 45%: Integrating project

Assessments

The evaluation of the integration project is performed in a final demonstration with a scoring system based on performance metrics. At the beginning of the module, the teams will be given a set of tasks and a scoring table. The metrics will be based on ground truth errors (e.g. the state estimation error) and time performance (e.g. total time to achieve an autonomous task). The final score will define the 50% of the grade.
The other 50% of the grade will be defined by assessing the quality of the final report describing the overall work (25% of the total grade) and a final group presentation (25% of the total grade).