Part 1

Introduction
Your instructors

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Lectures

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Informatik 11 - Embedded Software (i11)
Control and Perception in Networked and Autonomous Vehicles

Part 1: Introduction | Dr.-Ing. Bassam Alrifaee

Informatik 11 - Embedded Software (i11)

www.embedded.rwth-aachen.de
Informatik 11 - Embedded Software (i11)

► Head: Prof. Stefan Kowalewski (since 2003)
► Ca. 20 researchers, 4 non-academic employees, 5 apprentices
► > 1.600 students per year in our courses
► Ca. 40 graduates per year (15 Bachelor and 25 Master)
► 3 spin-off companies in the last five years
Control and Perception in Networked and Autonomous Vehicles

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- **Biomedical Systems** (5 researchers)
  - Head: Dr. André Stollenwerk
  - Supervision of medical devices
  - Data analysis

- **Cyber-Physical Mobility** (7 researchers)
  - Head: Dr. Bassam Alrifaee
  - Networked control systems
  - Service-oriented architectures

- **Formal Methods** (4 researchers)
  - Head: Marcus Völker, M. Sc.
  - Verification of CPS
  - Application: industry automation
# Control and Perception in Networked and Autonomous Vehicles

## Part 1: Introduction

### Dr.-Ing. Bassam Alrifaee

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### Informatik 11 - Embedded Software (i11)

#### Practical Work
- HiWi-Job
- Cyber-Physical Mobility Lab
- Carolo-Cup
- Automated distillation

#### Scientific Work
- Proseminars/Seminars
- Bachelor thesis
- Seminars

#### Specialized Courses
- Embedded Systems
- Functional Safety and System Dependability
- Formal methods for logic control software
- Control and Perception in Networked and Automated Vehicles

#### Mandatory Courses
- Einführung in die Technische Informatik
- Praktikum Systemprogrammierung

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Part 1: Introduction | Dr.-Ing. Bassam Alrifaee

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Cyber-Physical Mobility Group at i11
Students
Students

Shortly introduce yourself, e.g., with your ...

► Name
► Study program
► Semester in master program
► Motivation/Expectation
Lab Visit
Movie of 150 years of RWTH

► https://youtu.be/RBuqHPCQPMo?t=428
Course Logistics
Course contents (CPM group course)

- Vehicle models
- Control and optimization
- Network and distribution
- Machine perception
- Software architectures and testing concepts
- Case study

- Course materials are posted on moodle
- Lab will allow you to apply techniques on real model-scale vehicles
Literature


► Available in UB, some in Adobe Digital Editions
Participants and prerequisites

► Participants
  ▪ Computer Science M. Sc.
  ▪ Automation Engineering M. Sc.
  ▪ Computational Engineering Science M. Sc.

► Prerequisites
  ▪ B. Sc.
  ▪ Interest in networked and autonomous vehicles
  ▪ Interest in experimental work
Lecture style

► Presentation

► Flipped classroom
  ▪ Short introduction
  ▪ A week to prepare by reading and watching videos
  ▪ Discussion

► Group discussions

► Practical exercises in MATLAB
  ▪ Campus license
  ▪ More information: [www.matlab.rwth-aachen.de](http://www.matlab.rwth-aachen.de)
    • New to MATLAB? Work through the “Skript zum Treffpunkt MATLAB“
Groups and teams

Lecture Group

1

A

B

C

D

E

2

Lab Group

3
Logistics

► Participation
  ▪ Your choice: on-campus or online
  ▪ Attendance list
  ▪ Waiting list

Lab

► Your choice: in the lab room or in simulation
► Teams of 2 students, lab groups of 10 students
► 8 mornings during the semester
► Plagiarism check
Grading

Oral exam: 20 minutes per student
► 5 minutes presentation about lab work
► 15 minutes questions on lecture content
Diagnostic test

https://forms.office.com/r/MkMpxNkgjf
Lab
Literature


Lab-Vision: See your ideas develop into reality!

Simulation
Test your ideas in a simulation environment

CPM Lab
See your ideas work in a model-scale testing platform

Real World
Apply your ideas to real world scenarios

https://cpm.embedded.rwth-aachen.de
Cyber-Physical Mobility Lab – main features

Open source, remotely accessible platform
- Open code, plans, and documentation
- Remote access via web

Rapid algorithm prototyping
- 20 networked model-scale vehicles (µCars)
- Centralized and distributed computations

Hierarchical service-oriented architecture
- High- for complex computations, mid- and low-level
- Middleware for data exchange and synchronization
Setup/Infrastructure

Sense
Plan
Act

Mission planning

Simulation of passive traffic participants

Scenario server

Static map
Dynamic map
Preview map

Scenario, static map, mission plan

Object data

Map

Environment model

Error, noise

Environment model

Coordination

Coupling graph

Decision-Making

States, plan
Control inputs

Verification

Routing
Behavior
Trajectory
Control

Sensors

Sensor data

Perception

Decision-Making

Coordination

Sensors

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Lab – apply techniques from lectures

Software architectures and testing concepts

Network and distribution

Control and optimization

Perception

Sensor fusion

Trajectory planning

Sensor fusion

Trajectory control

Sensors

Actuators

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Some Terms
Driving tasks (group discussion)

► Which tasks do you perform during driving?
► Suggest a definition of automated vehicles
Driving tasks

Navigation

► Route planning
► Routing (Routenführung)

Guidance

► Interaction with environment
► Trajectory planning

Stabilization

► Longitudinal control
► Lateral control

Winner, Handbuch Fahrerassistenzsysteme, 2012
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CPM Lab architecture

Setup/Infrastructure

Sense

Plan

Act

Scenario, static map, mission plan

Error, noise

Environment model

Mission planning

Scenario server

Simulation of passive traffic participants

Preview map

Dynamic map

Static map

Object data

Map

Sensor data

Perception

Environment model

Coordination

Coupling graph

States, plan

Environment model

Decision-Making

States, plan

Control inputs

Actuators

Routing

Behavior

Trajectory

Control

Environment model

Scenario, static map, mission plan

Sensors

Sensor data

Environment model

States, plan

Verification

States, plan

Informatik 11
Embedded Software

RWTH Aachen University

Control and Perception in Networked and Autonomous Vehicles
Part 1: Introduction | Dr.-Ing. Bassam Alrifaee
Definition of automated vehicles

► When the car was invented, the formulation of “automobile,” combining the Greek autòs (“self, personal, independent”) and the Latin mobilis (“mobile”) stressed the “self-mobile”

► Greek nómos: “human order, laws made by people”

► Kant’s concept of autonomy, as formulated by Feil
  - “Self-determination within a superordinate (moral) law”

► Similarity to robotics

► Automated vs. autonomous
  - Mission planning
  - Communications and cooperation
Levels of automation

► SAE J3016 from Society of Automotive Engineers (SAE)
  - Level 0
  - Level 1 ("hands on")
  - Level 2 ("hands off")
  - Level 3 ("eyes off")
  - Level 4 ("mind off")
  - Level 5 ("steering wheel optional")

► US National Highway Traffic Safety Administration (NHTSA)

► German Federal Highway Research Institute (BASt)
Levels of automation (SAE)

Figure from [Link]
## Levels of automation

<table>
<thead>
<tr>
<th>Level</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SAE</strong></td>
<td>No Automation</td>
<td>Driver Assistance</td>
<td>Partial Automation</td>
<td>Conditional Automation</td>
<td>High Automation</td>
<td>Full Automation</td>
</tr>
<tr>
<td><strong>NHTSA</strong></td>
<td>No Automation</td>
<td>Function-specific Automation</td>
<td>Combined Function Automation</td>
<td>Limited Self-Driving Automation</td>
<td>Full Self-Driving Automation</td>
<td></td>
</tr>
<tr>
<td><strong>BASt</strong></td>
<td>Driver only</td>
<td>Driver Assistance</td>
<td>Partial Automation</td>
<td>High Automation</td>
<td>Full Automation</td>
<td></td>
</tr>
</tbody>
</table>

Figure from [Link](#)
Definition of networked vehicles

► Also called connected
► Vehicle-to-X communications
► Consists of interacting vehicles
► Contribution to better
  ▪ Perception
  ▪ Decision-making
► Many challenges arising from computation time and communications
  ▪ Feasibility
  ▪ Quality
Examples of contribution to better perception and decision-making
Vehicle models

► Longitudinal models

► Lateral models