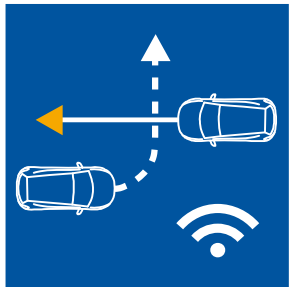

Lecture

Control and Perception in Networked and Autonomous Vehicles

Dr. Bassam Alrifaee | Patrick Scheffe, M. Sc. | Simon Schäfer, M. Sc.

Winter Semester 2023/2024

Part 1

Introduction

Your instructors

Lecture

Bassam Alrifaee

alrifaee@embedded.rwth-aachen.de

cpm-lecture@embedded.rwth-aachen.de

Exercise

Simon Schäfer

schaefer@embedded.rwth-aachen.de

Informatik 11 - Embedded Software (i11)

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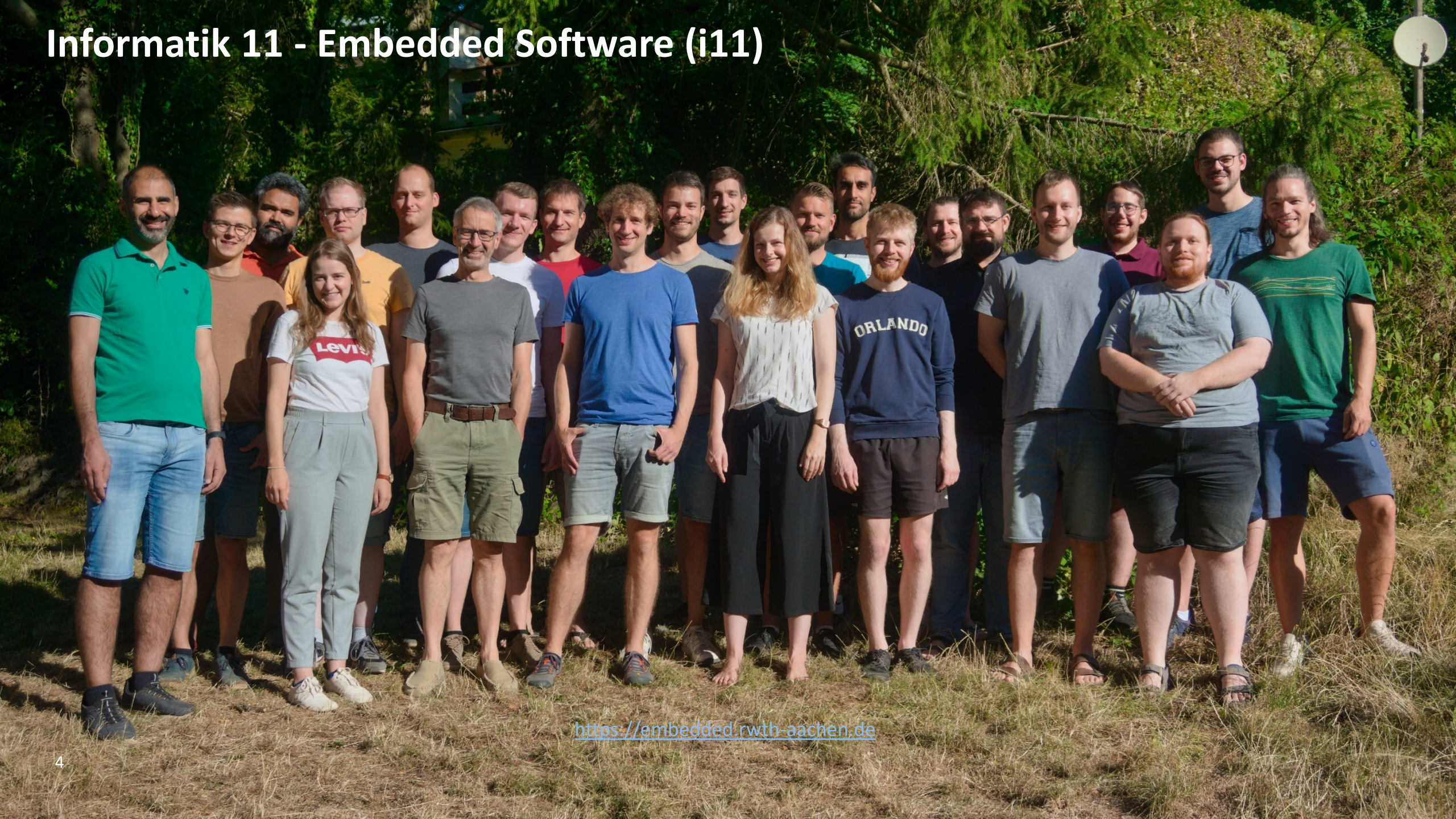


https://embedded.rwth-aachen.de

Informatik 11 - Embedded Software (i11), Oct. 2022

- Head: Prof. Stefan Kowalewski (since 2003)
- Ca. 20 researchers, 4 non-academic employees, 6 apprentices
- > 1.600 students per year in our courses
- Ca. 50 graduates per year (Bachelor and Master)
- €900,000 third-party funds spent in 2021
- 3 spin-off companies in the last ten years

  Embility, Mindmotiv, Emteria

Informatik 11 - Embedded Software (i11)

Biomedical Systems (9 researchers)

- Head: Dr. André Stollenwerk
- Supervision of medical devices
- Data analysis

Cyber-Physical Mobility (9 researchers)

- Head: Dr. Bassam Alrifaee
- Networked control systems
- Service-oriented architectures

Formal Methods (3 researchers)

- Head: Marcus Völker, M. Sc.
- Verification of CPS
- Application: industry automation

Practical Work

HiWi-Job

Cyber-Physical Mobility Lab

Carolo-Cup

Automated destillation

Scientific Work

Proseminars/ Seminars

Bachelor thesis

Seminars

Master thesis

Specialized Courses

Embedded Systems

Functional Safety and System Dependability

μC programming and debugging

Formal methods for logic control software

Control and Perception in Networked and Autonomous Vehicles

Mandatory Courses

Einführung in die Technische Informatik

Praktikum Systemprogrammierung

Cyber-Physical Mobility Group at i11

Cyber-Physical Mobility Group at i11

www.embedded.rwth-aachen.de/doku.php?id=forschung:mobility

Students

Students

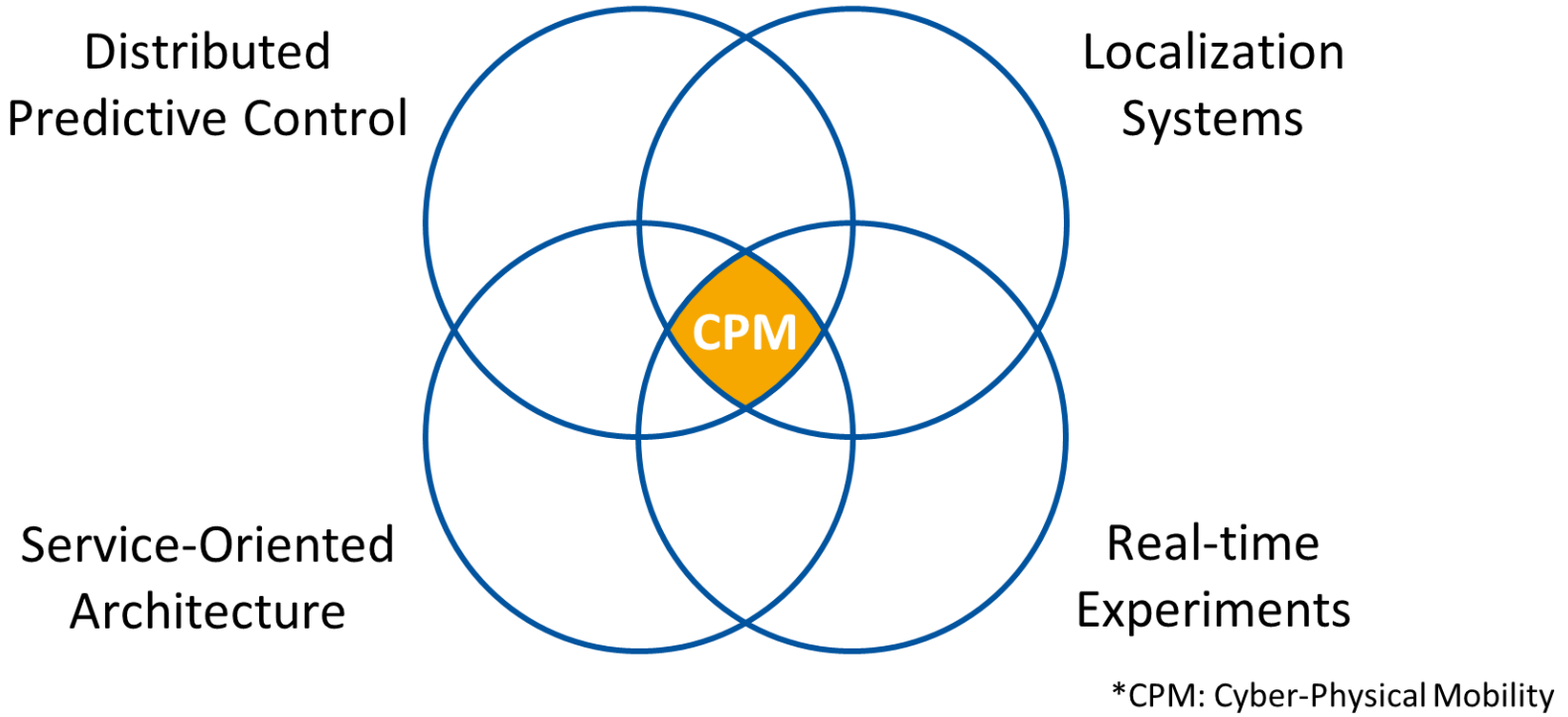
Shortly introduce yourself, e. g., with your …

- Name
- Study program
- Semester in master program
- Motivation/Expectation

Course Logistics

Course contents (CPM group course)

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



*CPM: Cyber-Physical Mobility

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

Literature

- R. Rajamani. Vehicle Dynamics and Control. Springer, 2005.
- R.C. Dorf and R.H. Bishop. Modern Control Systems. Prentice-Hall, 2008.
- S. Boyd and L. Vandenberghe. Convex Optimization. Cambridge University Press, 2004.
- F. Borrelli, A. Bemporad, and M. Morari. Predictive Control for Linear and Hybrid Systems, Cambridge University Press, 2017.
- J. Maciejowski. Predictive Control with Constraints. Prentice Hall, 2002.
- D. Simon. Optimal State Estimation: Kalman, H Infinity, and Nonlinear Approaches. John Wiley & Sons, 2006.
- J. Lunze. Control Theory of Digitally Networked Dynamic Systems. Springer, 2014.
- D. Abel, A. Bollig. Rapid Control Prototyping. Springer, 2006.

- 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

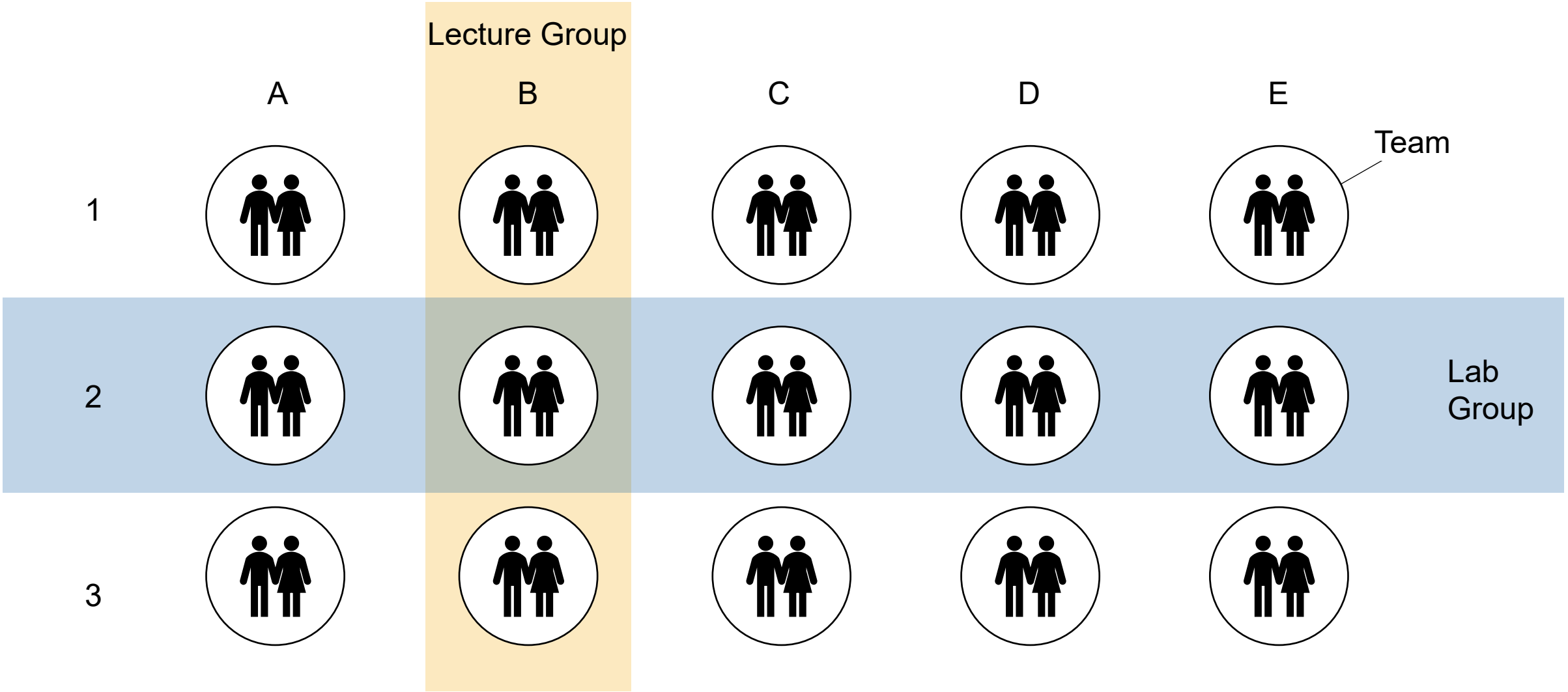
Lecture style – participation strongly recommended

- Presentation
- Flipped classroom
  - Short introduction
  - Two weeks to prepare by reading and watching videos
  - Groups of students present in class
  - Discussion
  - Dates in Moodle
- Group discussions
- Practical exercises in MATLAB
  - Campus license, more information: www.matlab.rwth-aachen.de
  - New to MATLAB? Work through the “Skript zum Treffpunkt MATLAB“, or the MATLAB onramp courses

Groups and teams

- Assignment in moodle
- Team: two students
  - 1 CS
  - 1 CES or AT
- 3 lab groups (1-3), 5 teams each
- 5 lecture groups (A-E), 3 teams each

Groups and teams



Logistics

- Participation
  - Attendance list
  - Waiting list

Lab

- Teams of 2 students, lab groups of 10 students
- 8 mornings during the semester
- Plagiarism check

Exam

Prerequisite

- Successful lab participation (checkpoints)
- Flipped classroom presentation from lecture group

Written exam

Ranking of best three solutions and invitation for networking and pizza

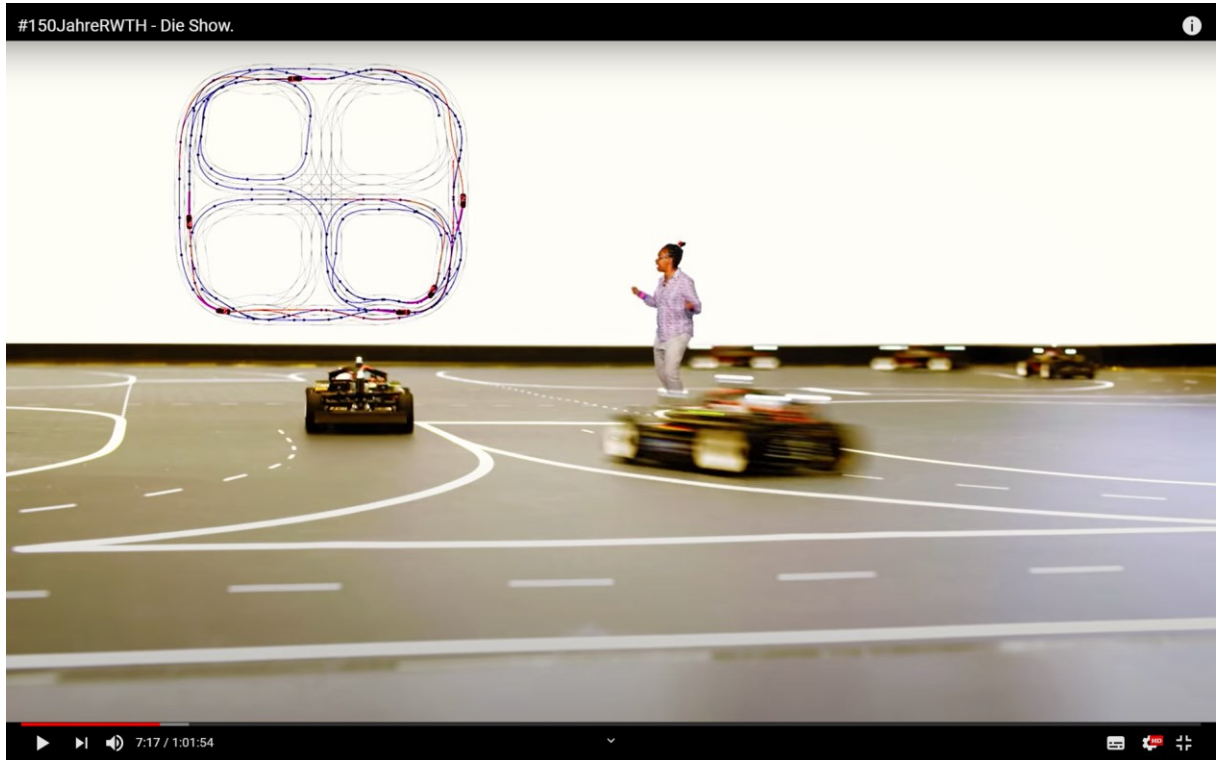
Diagnostic test

forms.office.com/r/XMYc3Viyfr

Lab Visit

Movie of 150 years of RWTH

- https://youtu.be/RBuqHPCQPGo?t=428

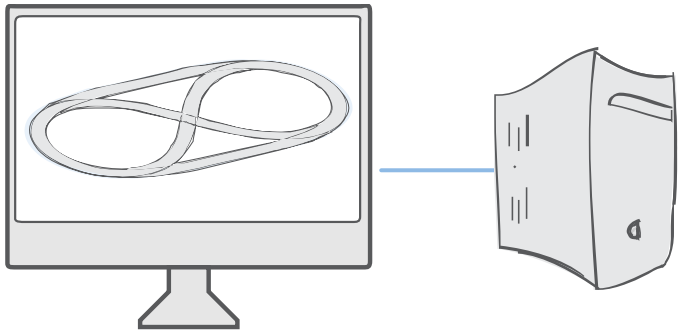


Lab

Literature

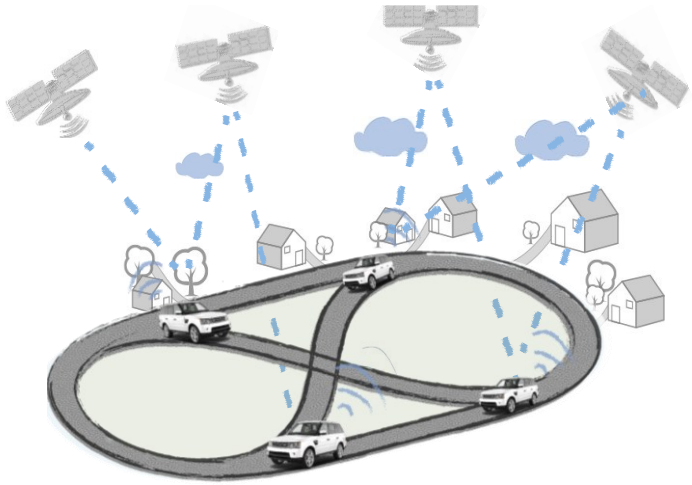
- Check out the CPM Lab website

Sim-to-real gap



Simulation

Test your ideas in a simulation environment



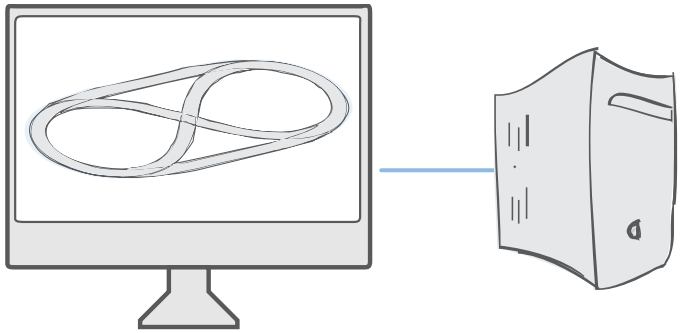
Real World

Apply your ideas to real-world scenarios

https://cpm.embedded.rwth-aachen.de

Cyber-Physical Mobility Lab

Lab-Vision: See your ideas turning into reality!



Simulation
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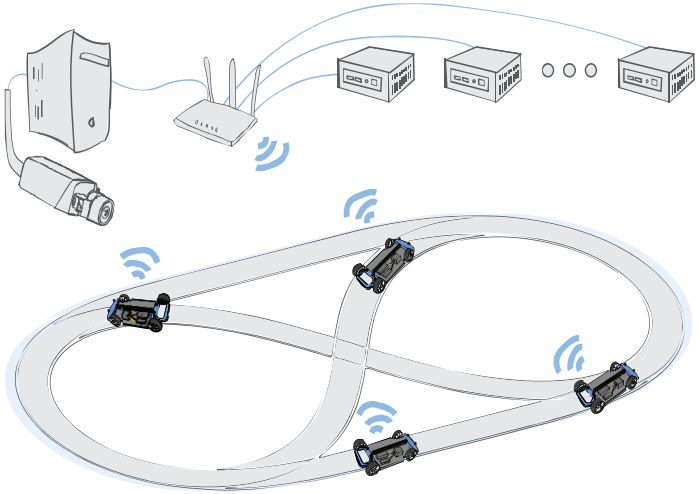
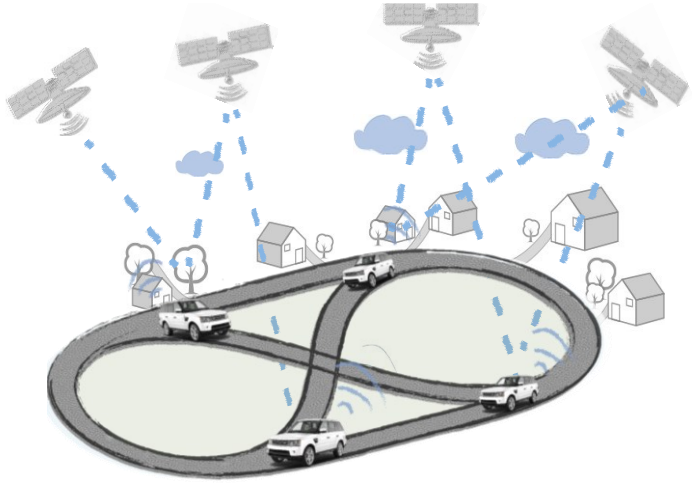


CPM Lab
See your ideas work in a small-scale testing platform

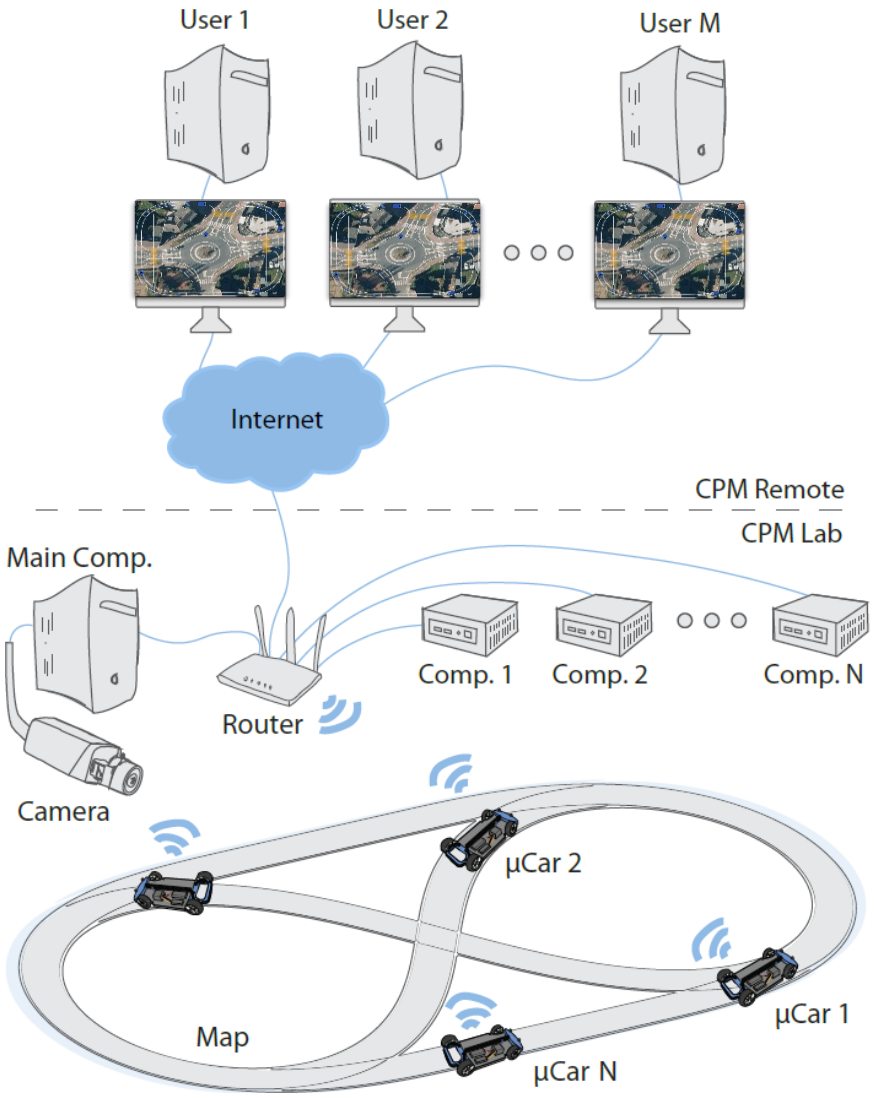


Real World
Apply your ideas to real-world scenarios

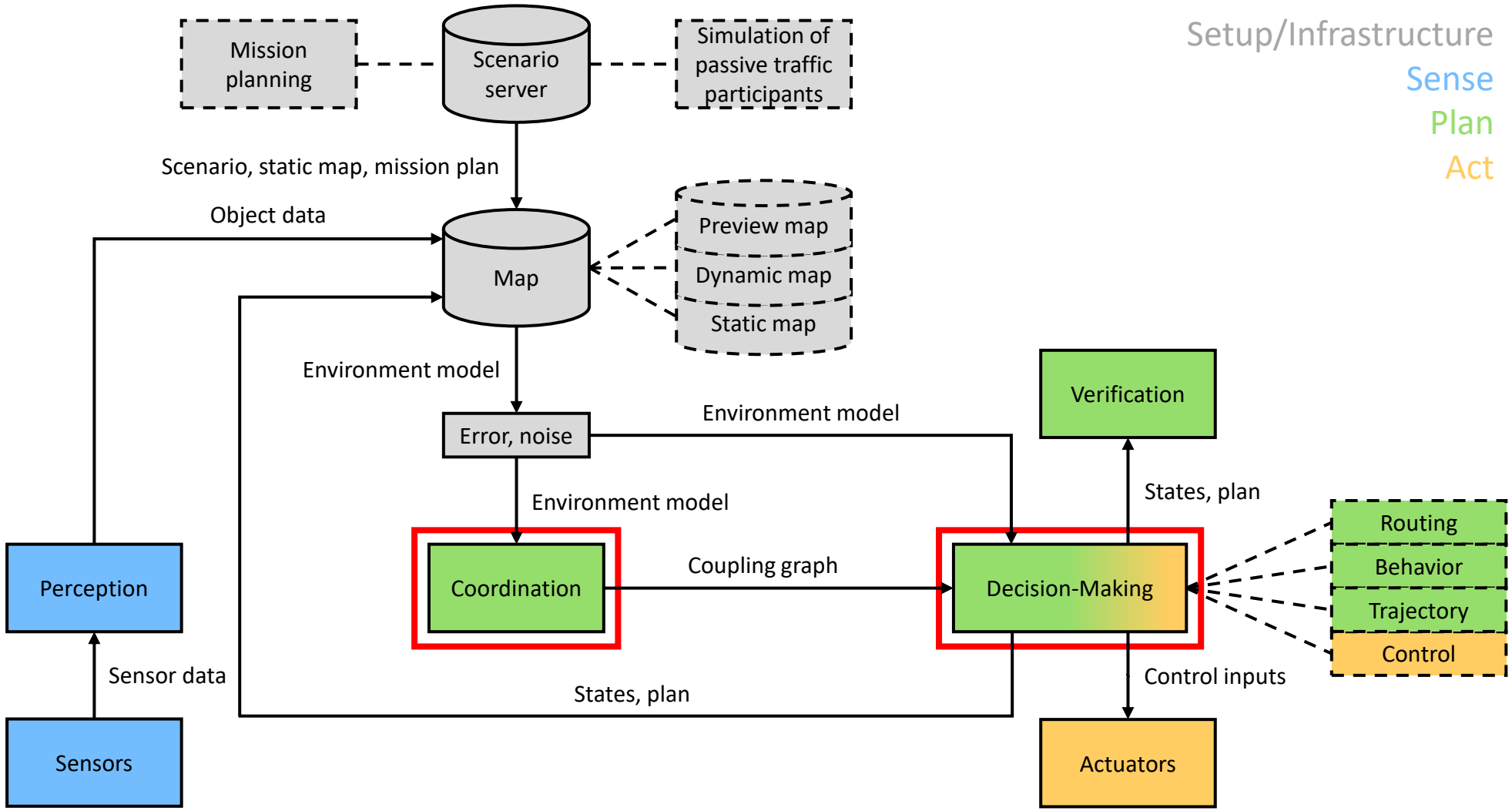
https://cpm.embedded.rwth-aachen.de

Cyber-Physical Mobility Lab – main features

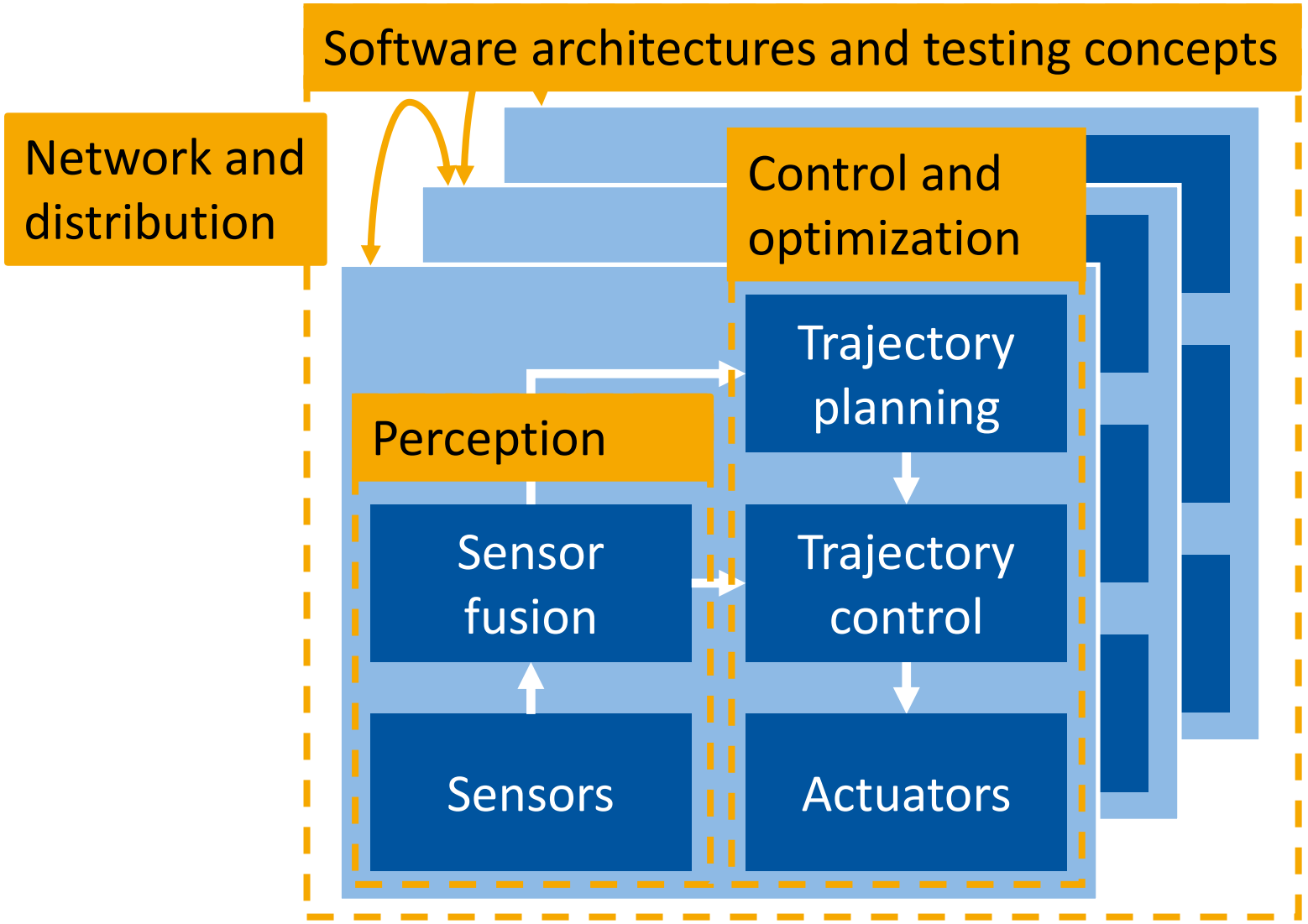
- Open source, remotely accessible
- Central and distributed computations
- Deterministic computation model; therefore, reproducible experiments
- Digital twin, seamless extension of vehicles

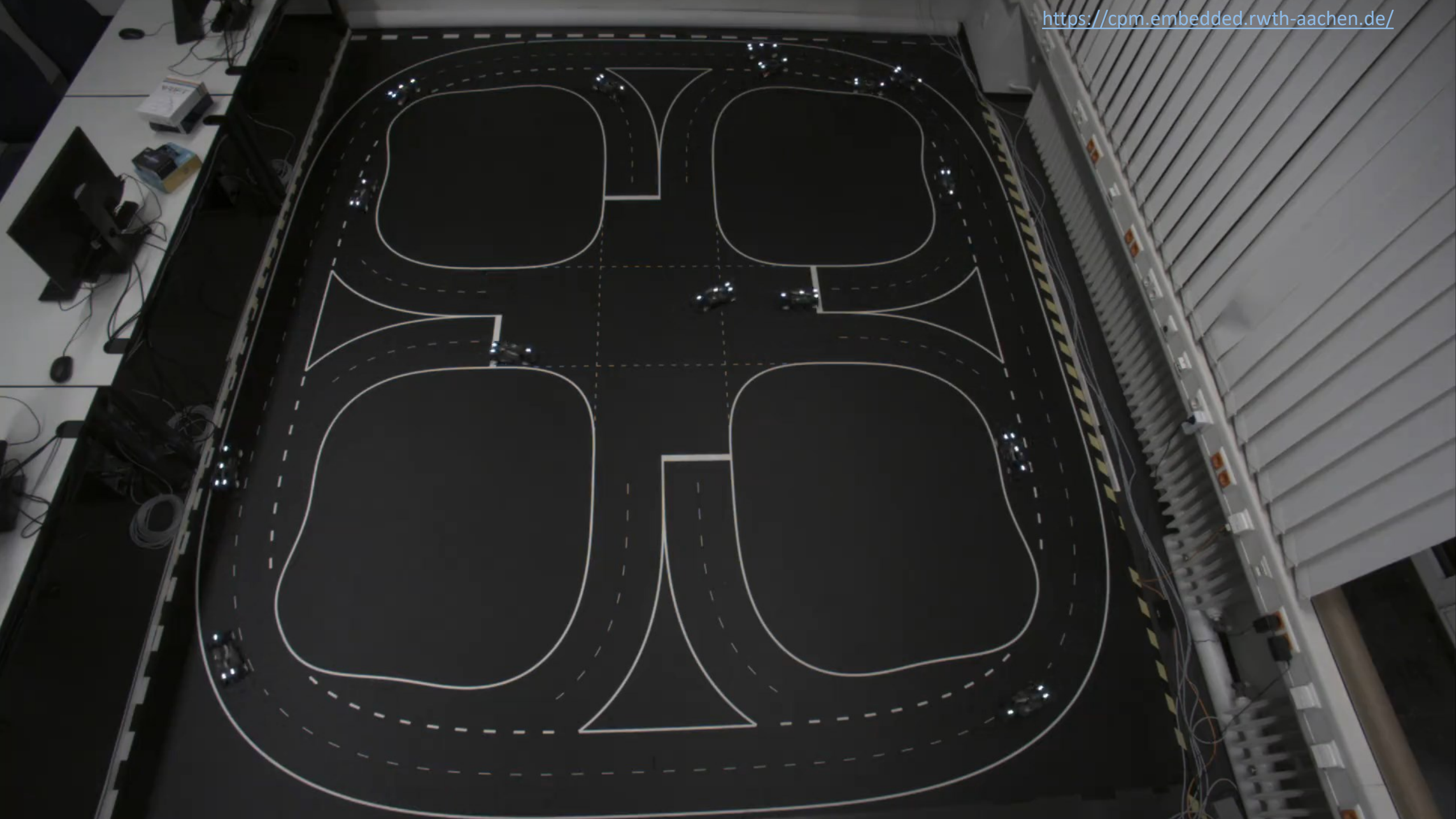


Cyber-Physical Mobility Lab – architecture



Lab – apply techniques from lectures




https://cpm.embedded.rwth-aachen.de/

Some Terms

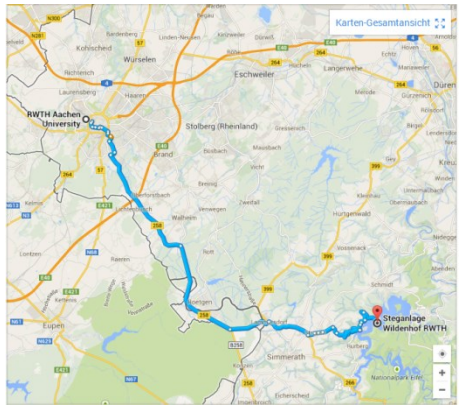
Driving tasks (group discussion)

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

Driving tasks

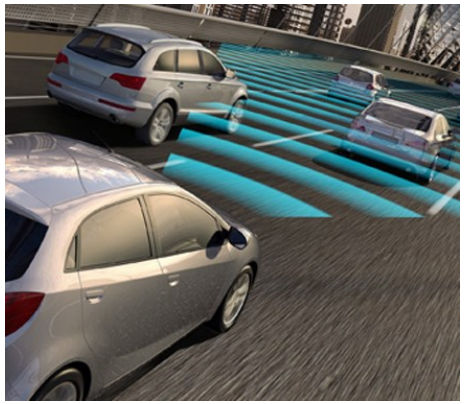
Navigation

- Route planning
- Routing (Routenführung)



Guidance

- Interaction with environment
- Trajectory planning

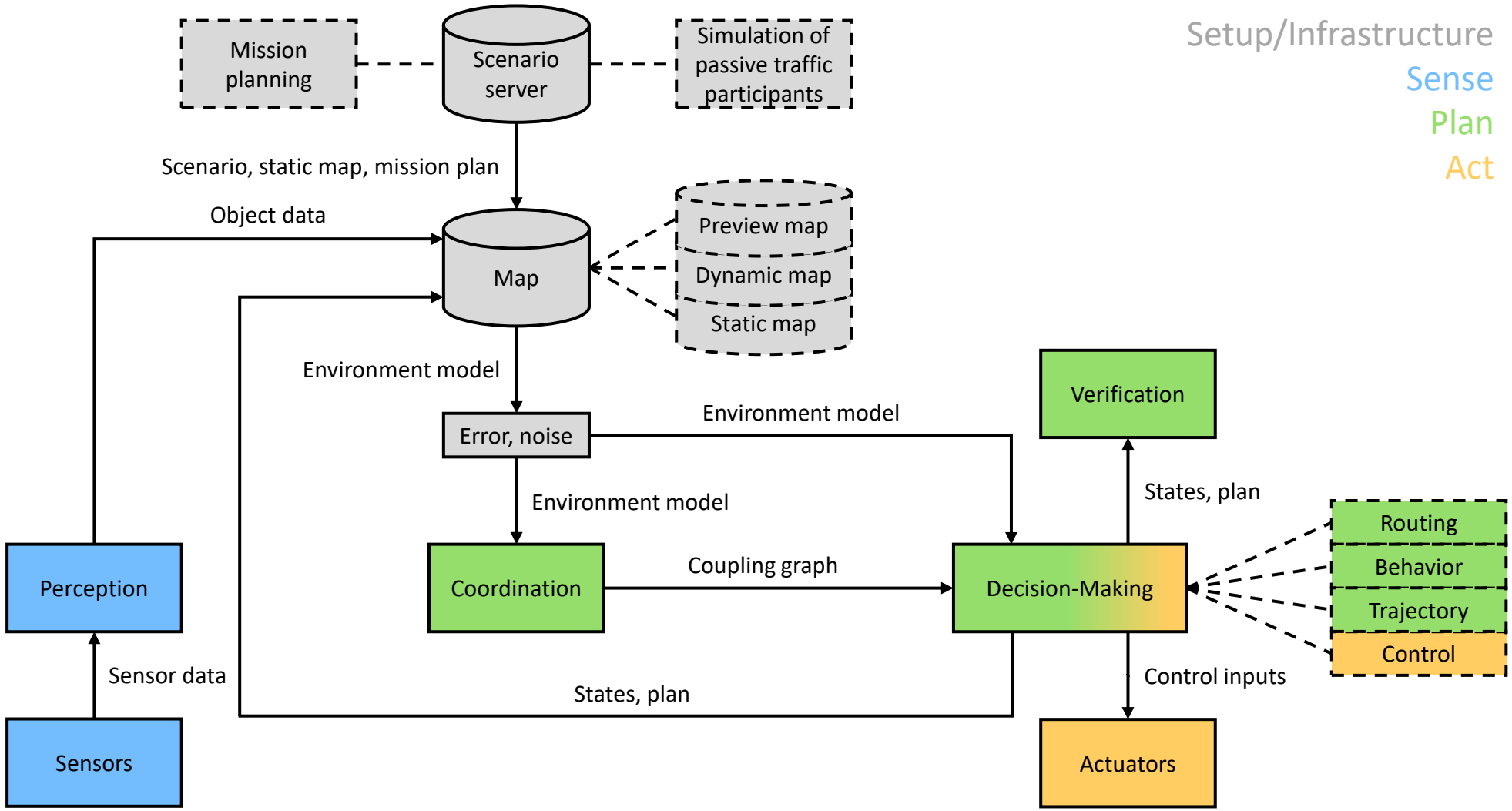


Stabilization

- Longitudinal control
- Lateral control

Winner, Handbuch Fahrerassistenzsysteme, 2012

CPM Lab architecture



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
  - Communication and cooperation

Maurer, Autonomous Driving, 2015

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)

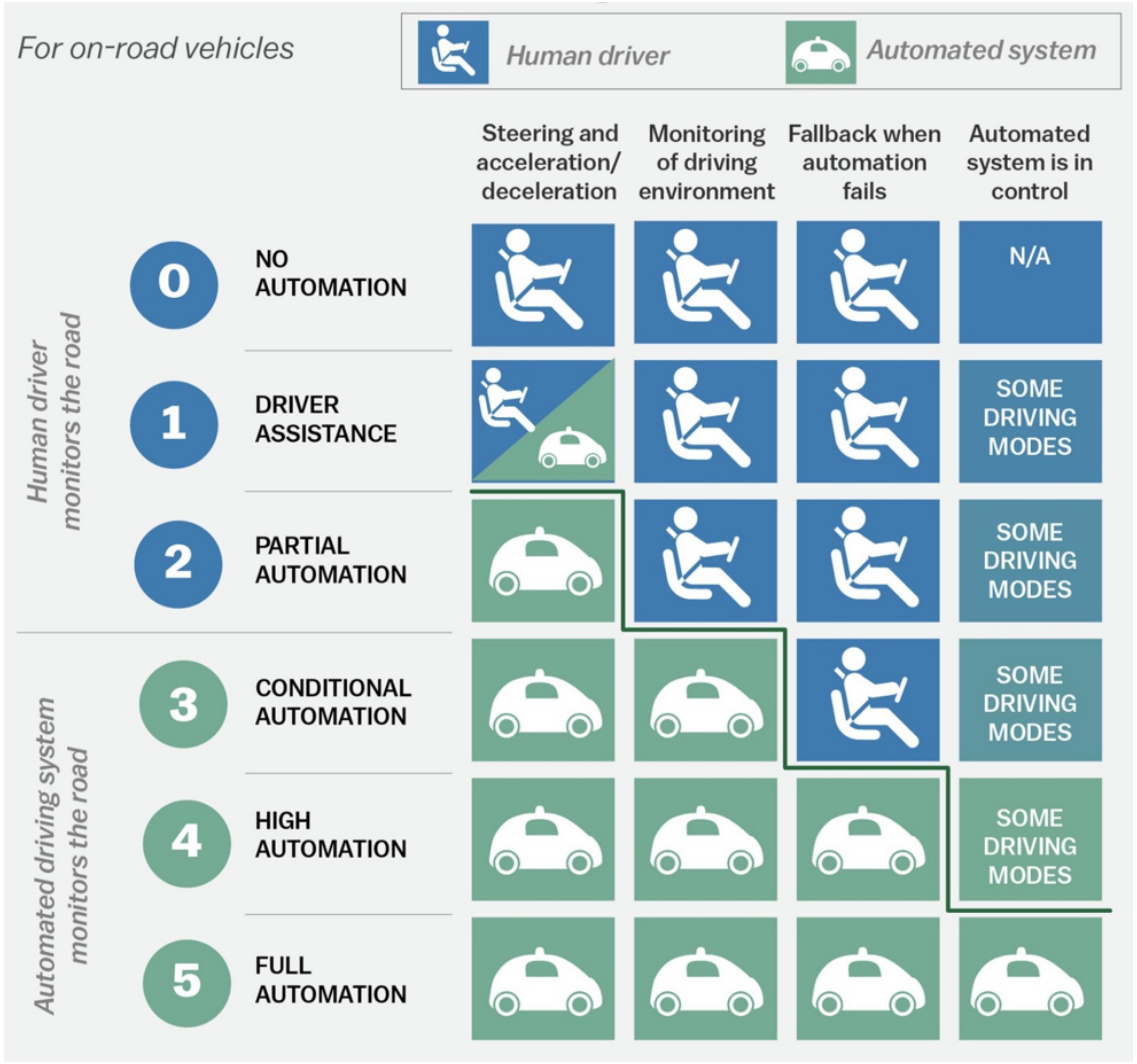


Figure from Link

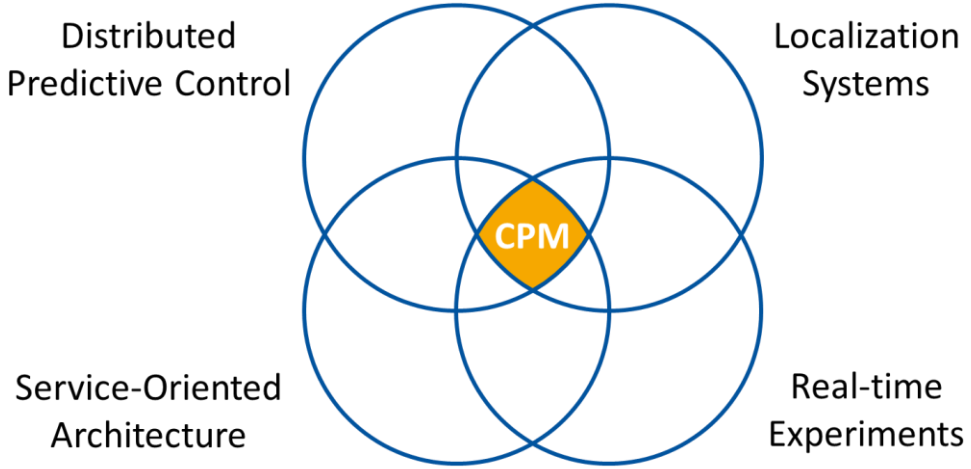
Levels of automation

Level	0	1	2	3	4	5
SAE	No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
NHTSA	No Automation	Function-specific Automation	Combined Function Automation	Limited Self-Driving Automation	Full Self-Driving Automation	
BASt	Driver only	Driver Assistance	Partial Automation	Highl Automation	Full Automation	

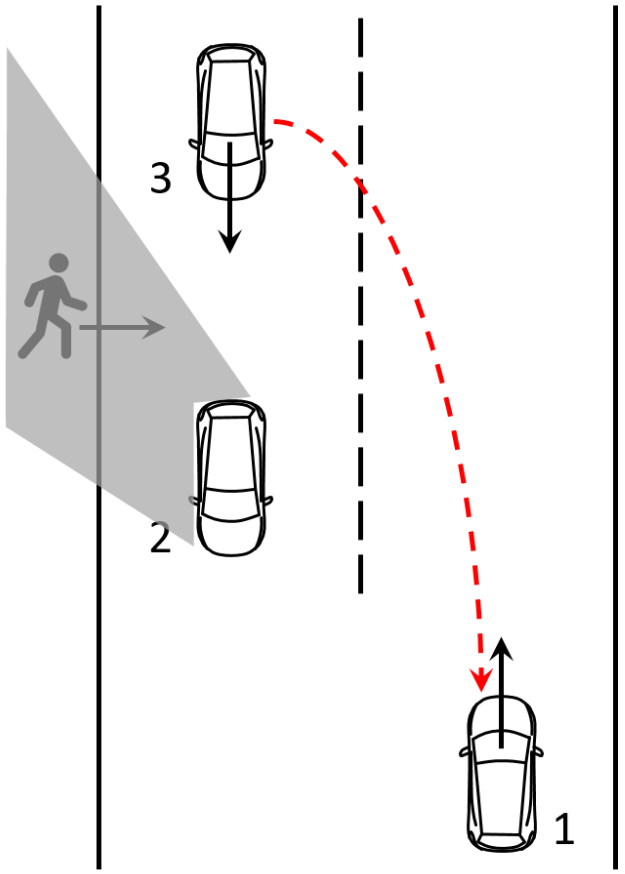
Figure from Link

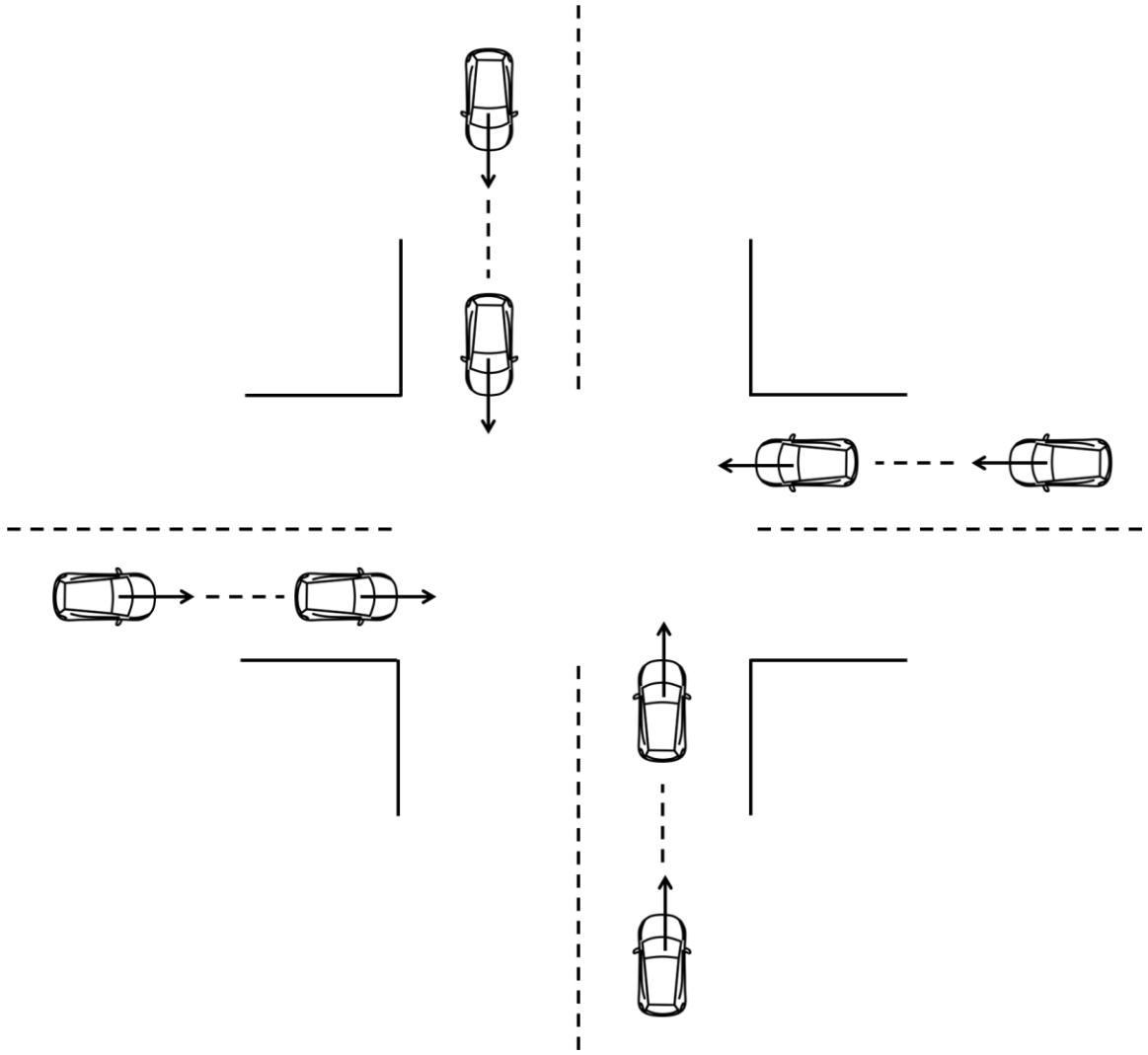
Definition of networked vehicles

- A.k.a. connected vehicles
- Communicate (Vehicle-to-X communication) and interact
- Improve
  - Perception
  - Decision-making
- Impose challenges



Examples of contribution to better perception and decision-making





Next Part

Vehicle models

- Longitudinal models
- Lateral models