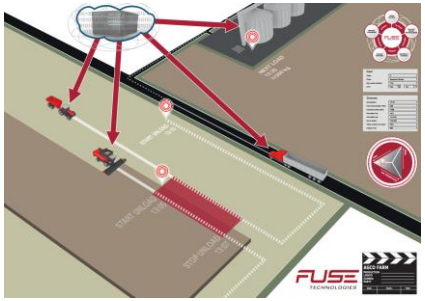
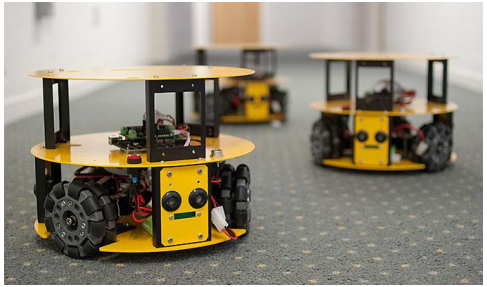
Introduction to Modelling of Cyber-Physical Systems (CPSs)

Slides partially taken from the INTO-CPS Association: https://into-cps.org/

What is a Cyber-Physical System?

- Systems of interacting systems
  - Computing elements
  - Physical elements
  - Human interactions
- Complex, networked character
- Distributed control
- Error detection and recovery



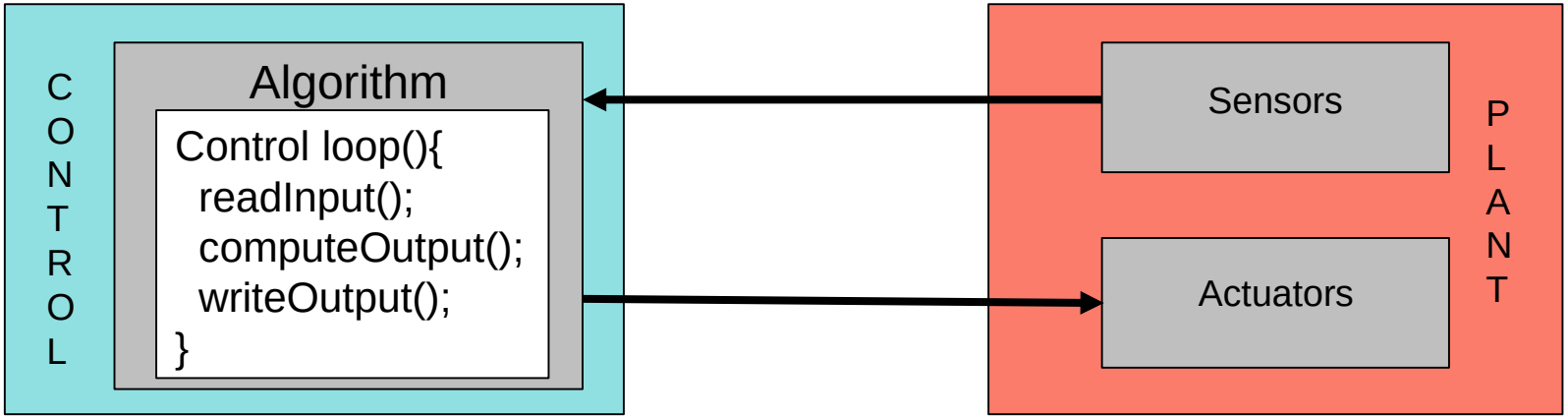


High level representation: Control + Plant

Cyber Physical Systems: discrete control component with continuous-time plant.

Distinct model formalisms

- discrete systems: discrete math
- continuous systems: differential equations



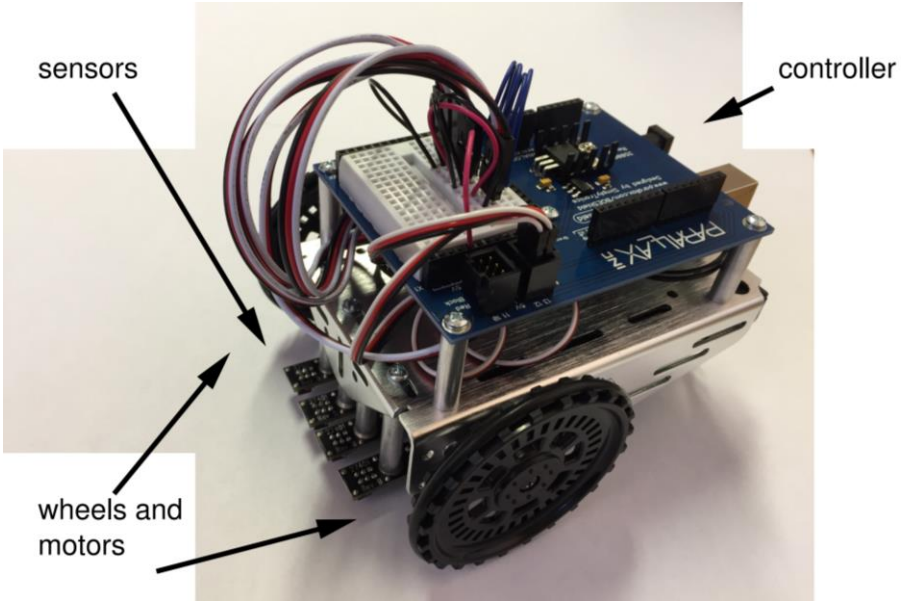
Example of CPS

Line follower robot (LFR)

The line contrasts from the background and the robot uses a number of sensors to detect light and dark areas on the ground

Equipment:

- Up to 4 light sensors
- 2 wheels (with motors)
- 1 Arduino board
- 6 Batteries

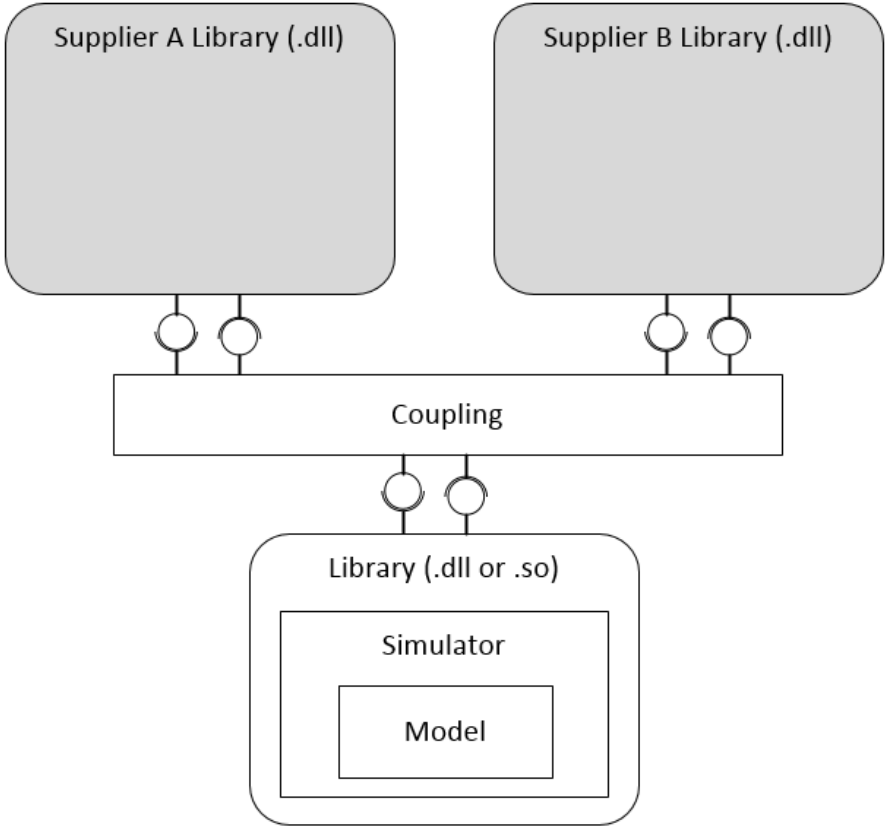


What is Co-simulation?

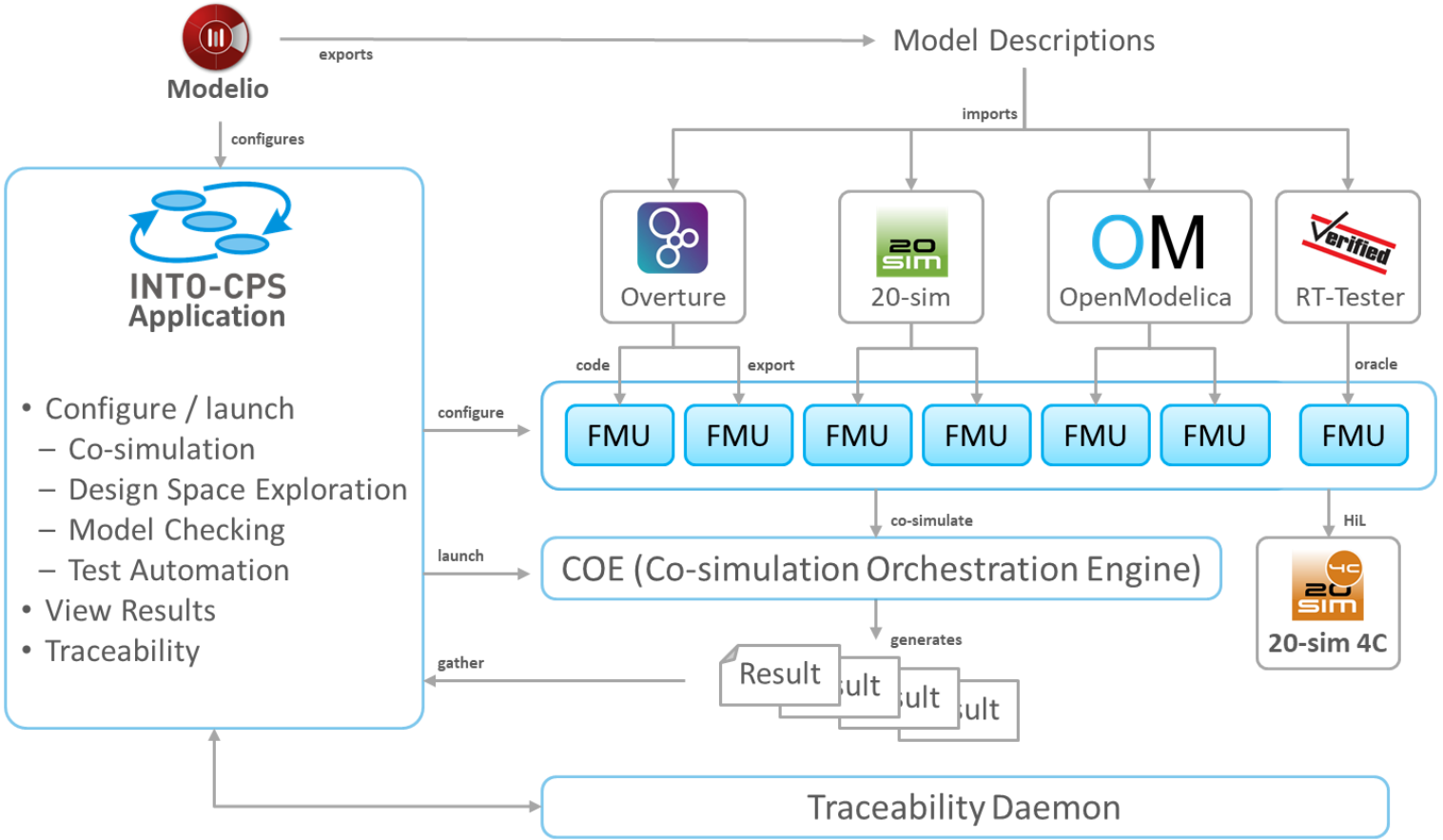
- Coupling of multiple simulators
  - Optionally as black-boxes
  - Each simulating one or more models
  - Built with different formalisms/tools.
- Co-simulation scenario
  - Description of the system
  - The simulators and their dependencies
  - Data about the capabilities of each simulator.

Standard Co-simulation

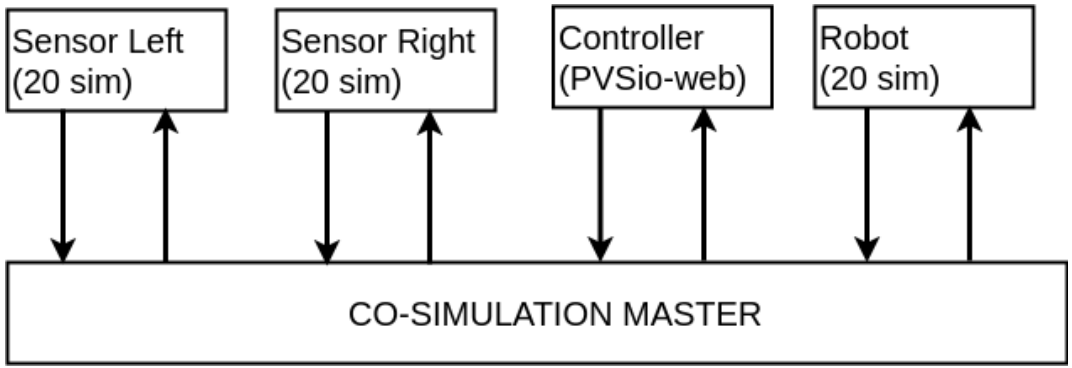
- **Functional Mock-up Interface**
- Simulator and model exported as a standardized C library
- Standard interaction with any simulator
- Every simulator is a black box.
- Executed locally but can communicate with a remote server

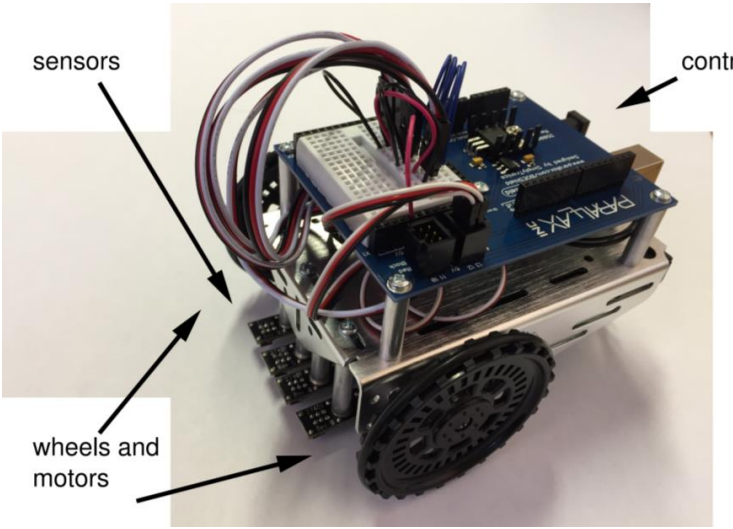


The INTO-CPS tool-chain

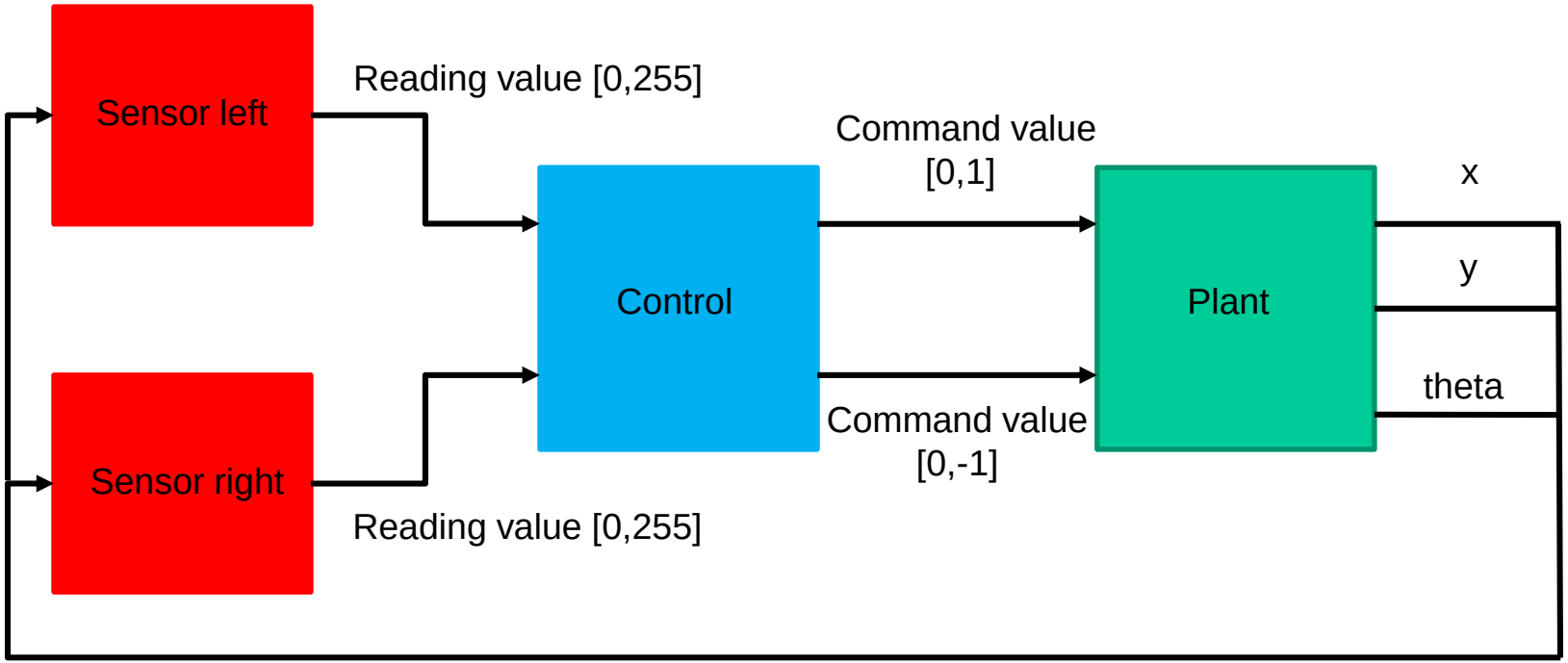


LFR co-simulation



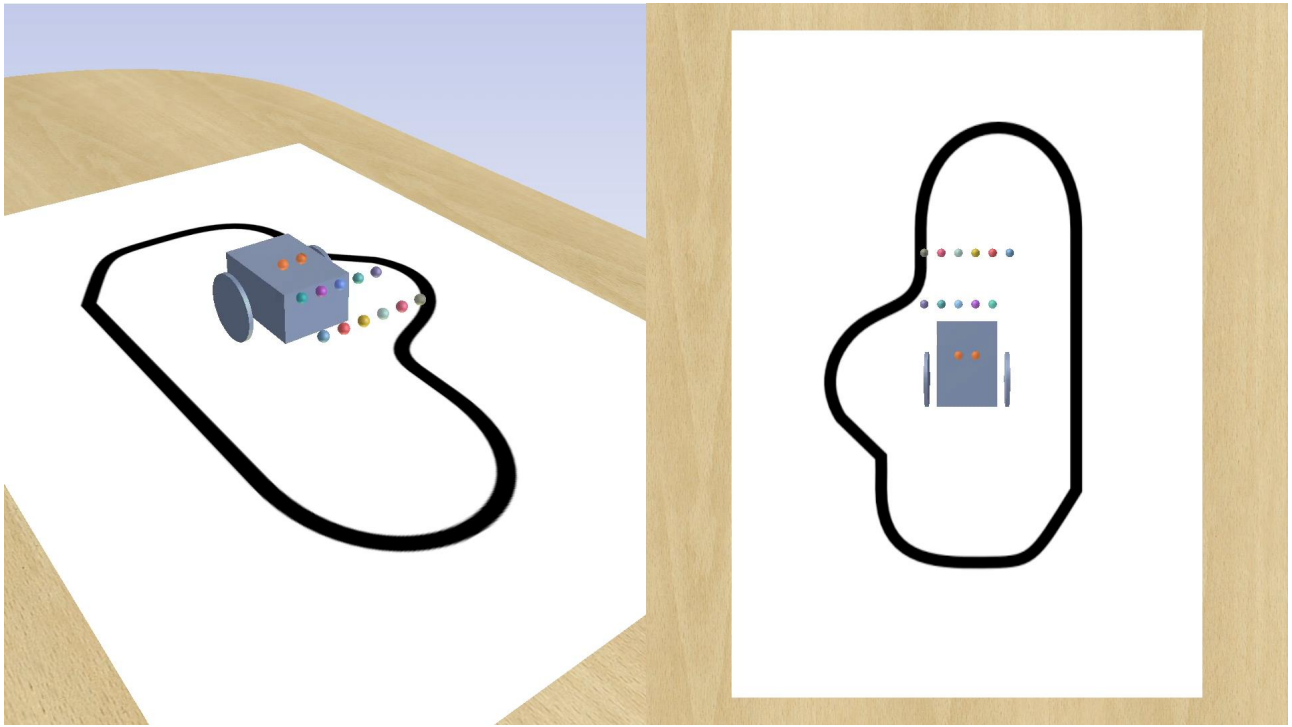


LFR Co-simulation architecture



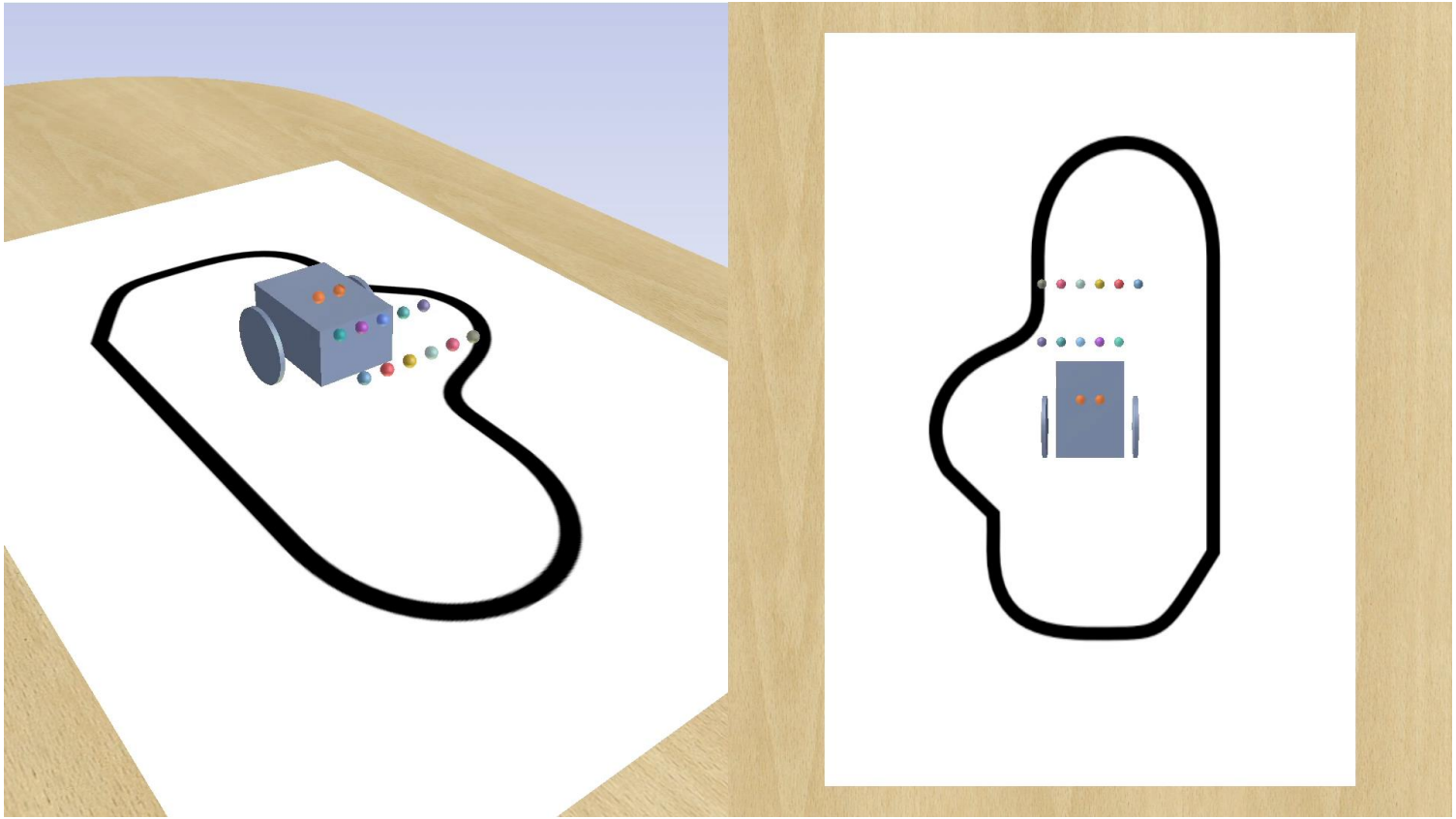
Design Space Exploration

Explore the behavior of the system with different parameters



Let’s see what happens when we change the position of the light sensors of the line following robot

Video of DSE



Solutions for CPS Engineering Needs

- Enable collaboration across disciplines
  - Collaborative well-founded tool chain
- Keep development costs low
  - Lower need for physical tests by virtual co-simulation examination
- Keep time-to-market short
  - Enable concurrent engineering and gradual integration
- Explore the complex design space efficiently
  - Using Design Space Exploration
- Ensure tolerance against “nasty” faults
  - Experiment with what-if scenarios in a virtual setting
- Build up documentation for the working solution
  - Traceability between all project artefacts
- Provide confidence to external stakeholders
  - Using combination of ad-hoc and automated tests