An Industrial Perspective on Multi-Agent Decision Making for Interoperable Robot Navigation following the VDA5050 Standard

Niels van Duijkeren, Luigi Palmieri, Ralph Lange, Alexander Kleiner
Robert Bosch GmbH, Corporate Research, Stuttgart, Germany

Motivation

Automated transportation systems in factories are usually composed of several fleets of AGVs and AMRs operated by independent fleet management systems. In e.g., the automotive industry these AMRs move in mixed environments with humans and human-driven vehicles. The new VDA5050 standard enables fleet management systems and AMRs to be combined more flexibly, resulting in larger heterogeneous fleets and posing new challenges.

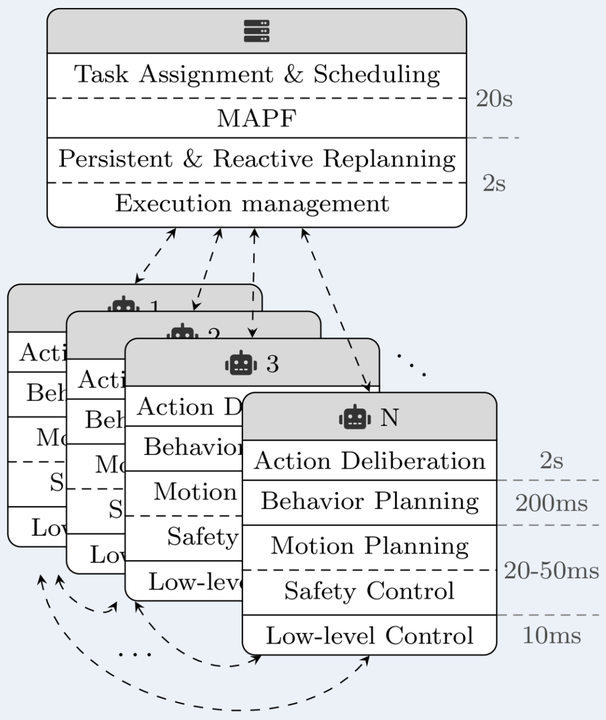
Current Problem Dimensions

Number of robots, tasks, and speed are all increasing.

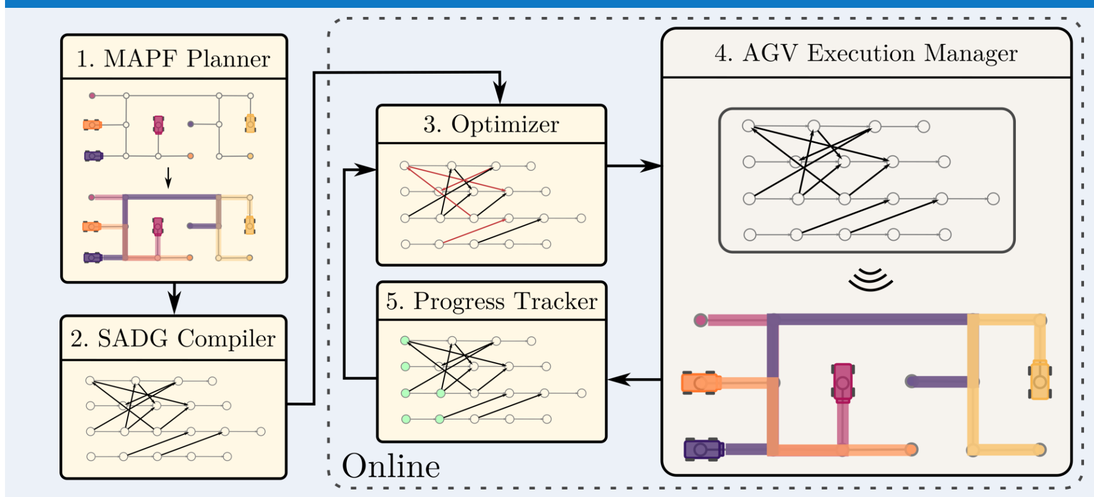
Number of AMRs in plant	50-200
Number of AMR types	4-8
AMR speed (m/s)	0.7-1.5
Duration of tasks (min)	3-20
Typical delay per task (min)	0-5
Time between tasks (min)	1+

Industrial Planning Stack

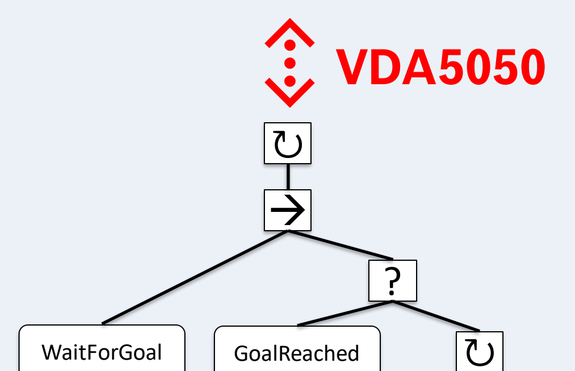
A typical decision-making stack for industrial AMRs is illustrated. A fleet of robots is coordinated by a fleet management system that plans routes and handles foreseeable conflicts between agents. Interaction with humans and uncontrolled vehicles and the collision-free motion planning is handled by the AMRs.

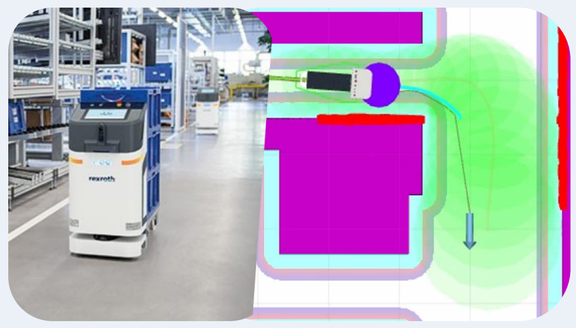


Currently Typical Implementation



An example implementation of the decision-making stack that we find in industrial AMRs. After tasks are assigned to the robotic fleet, a MAPF planner will plan the routes. Any additional tasks planned later typically do not modify the plans of robot already in motion. An execution manager continuously assigns resources to individual AMRs, ensuring deadlock-free execution and reactively optimizing based on detected delays. A collision-free motion planner guides the robot in the lane while considering the safety subsystem. Possible improvements are pursued on each layer of the stack.

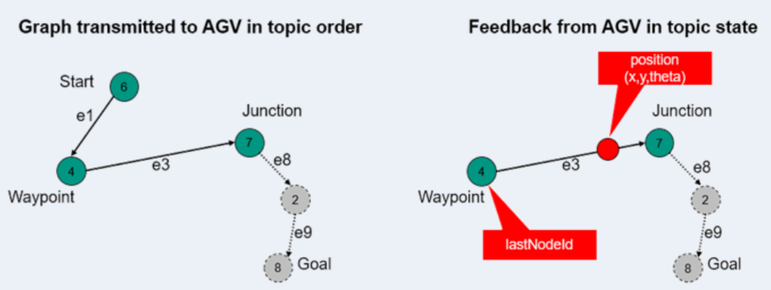




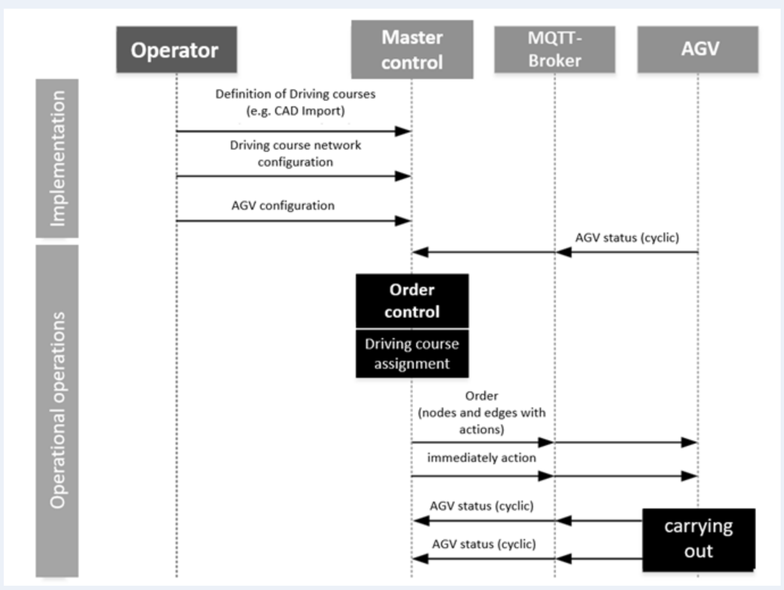
VDA5050 Standard

VDA5050 defines a communication interface between wheeled AMRs/AGVs and a central coordinator. It is developed by two major German industry associations representing members with a yearly turn-over of >€600bn.

Fact sheet:
- Physical properties
- Physical limits
- Load capabilities
- ...



Job order:
- Nodes
- Path
- Action
- Allowed deviation
- ...



Status update:
- Position
- Last node
- Velocity
- Battery level
- Load
- Error state
- ...

VDA5050 figures from documentation

Research Challenges

- Optimizing traffic flow in mixed environments.
- Persistently updating MAPF and task allocation.
- Modeling temporary free-space motions in MAPF.
- Learning heuristics from previous task execution results.
- Benchmarking combinations of fleet mgmts. and AMRs.