ECHORD call1 experiment

TRAFCON

Traffic Control of AGVs in Automatic Warehouses

European Clearing House
for Open Robotics Development
www.echord.info

TRAFCON

~20 Km

- Very close interaction
- Frequent access to the company's facilities
  - Understand the system on the field
  - Validate intermediate results on real systems
  - Help (even unasked!) of technical personnel

Geographic closeness helps **a lot** the academia-industry collaboration

The Scenario

- Humans and AGVs share the same environment
- Safety ensured by laser scanners that stop the AGV when an obstacle is detected
- The delivery rate has to be as high as possible

The Scenario

- **Congestions and traffic jams are the main issues in AGVS for automatic warehouses:**
  - The delivery rate of the goods is slowed down
  - Time consuming and costly restarts of the system can be necessary

- **Industrial practice: A set of traffic rules**
  - The path of each AGV is assigned independently of the other AGVs
  - A lot of manual tuning on site is necessary
  - Specific rules for plant dependent exception handling
  - Not robust wrt unexpected events (e.g. manual forklifts)

Traffic Rules ⟺ **Open Loop control**

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Scenario: hyper-flexible cell

Research Focus: mobile manipulators and cooperation

GOAL: Develop a traffic control strategy that closes the loop and:

- Allows to obtain a high delivery rate (good performance)
- Doesn't require manual tuning on site (low installation costs)
- Can automatically handle unexpected events (robustness)
- Allows rerouting the AGVs when convenient (flexibility)

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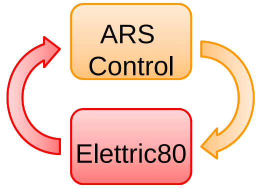
- **TASK1: Coordination(Oct10-Mar11)**

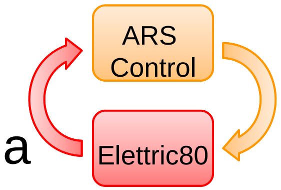


  - Architecture analysis, constraint definition, performance index
  - Development of a coordination strategy that does'n require manual tuning

- **TASK2: Routing (Apr11-Sep11)** ARS Control
  - Build a measure of the congestion
  - Deveop an efficiency optimizing routing strategy

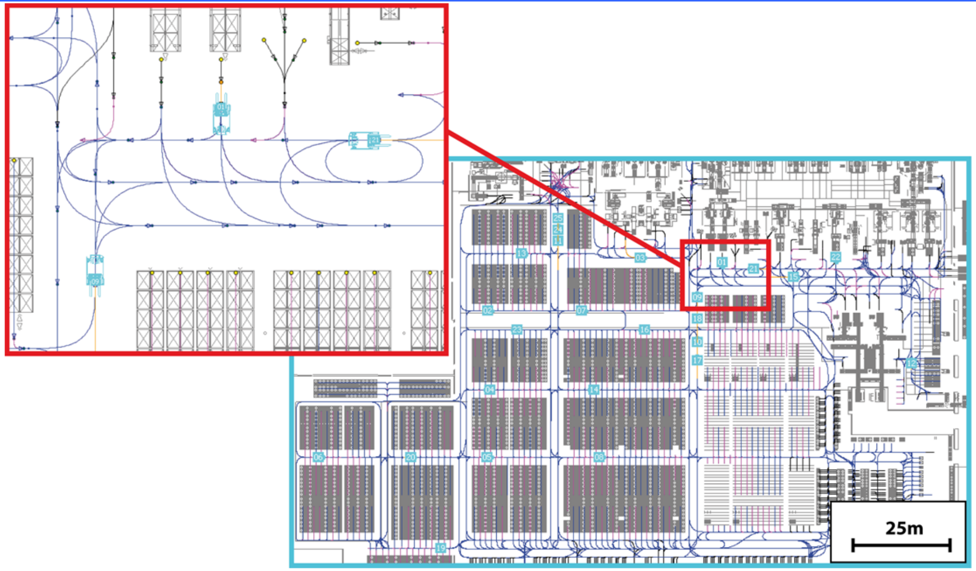
- **TASK3: Arena Setup (Apr11-Sep11)** Elettric80
  - Build an arena replicating a small scale automatic warehouse

- **TASK4: Experiments (Oct11-Mar12)**



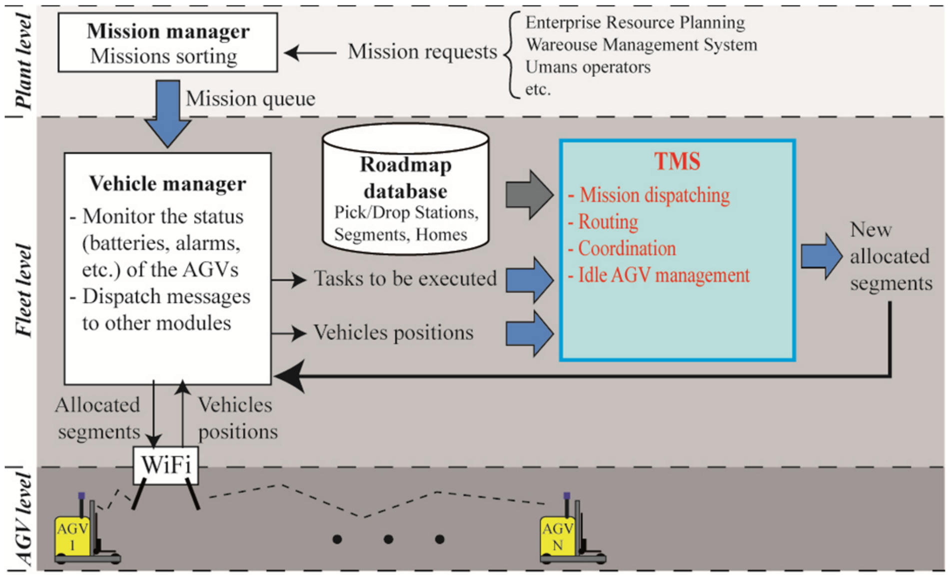
  - Comparative experimental validation on the arena

Task 1: Learning

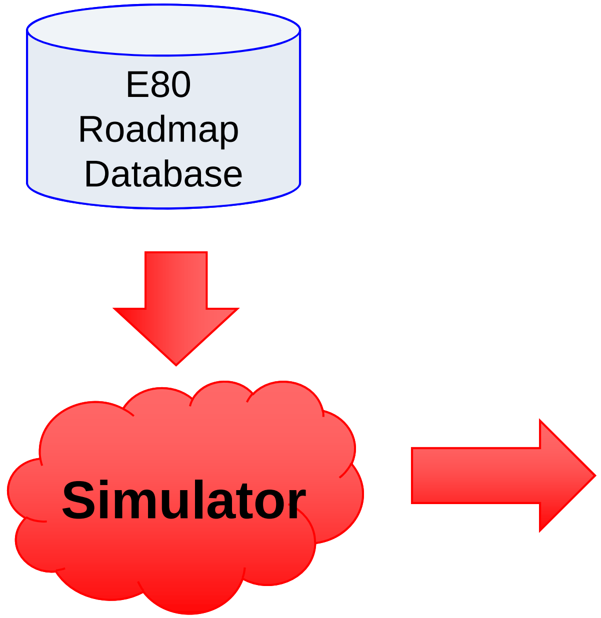


Segmented Roadmap. A path is given as a set of segments to be tracked

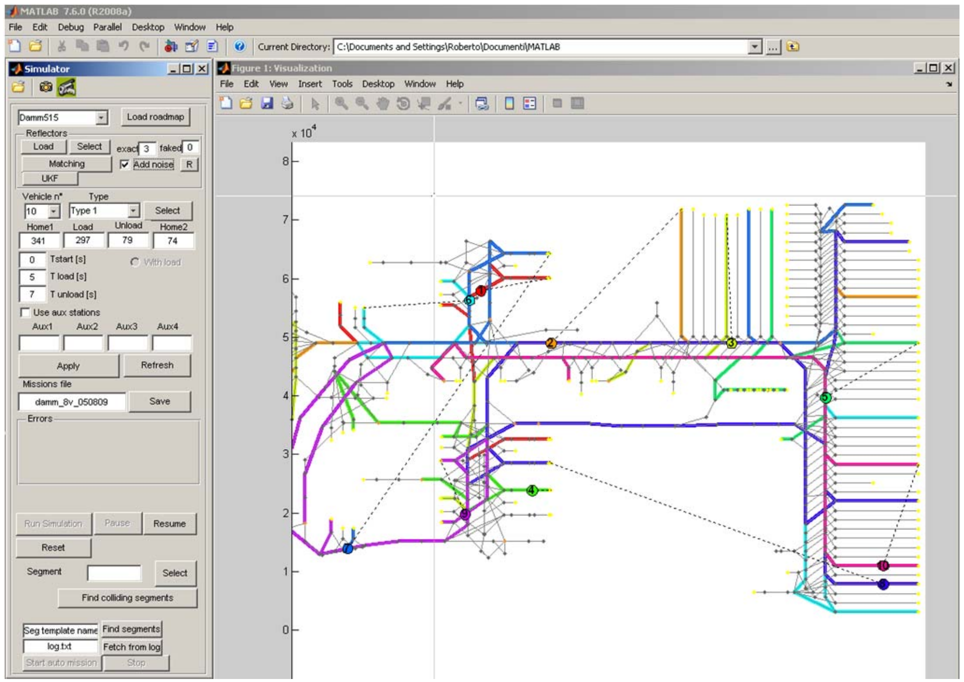
Architecture. The traffic manager receives the positions of the vehicles and allocates segments that can be tracked by each AGV



Task 1: Learning



- Simulator in Matlab Environment
- Roadmaps of real plants can be imported
- Visualization using Matlab GUI
- It is possible to interface the simulator with vehicles via UDP



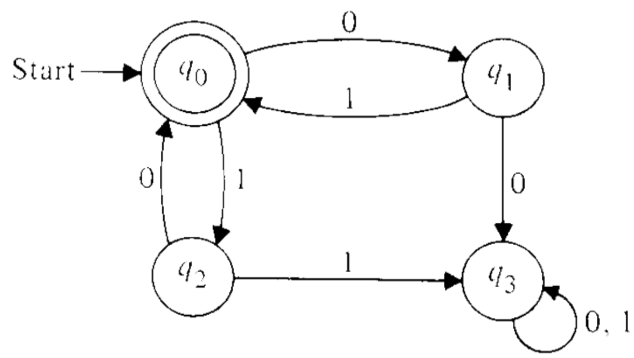
Task1: Learning

The industrial setting has to be considered since the beginning:

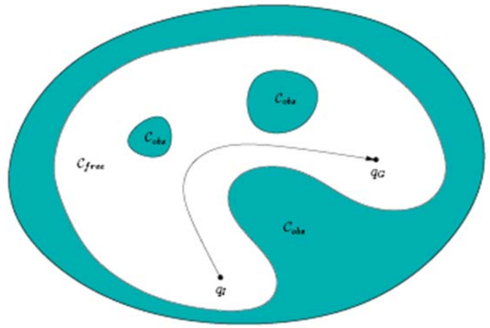
- To avoid “academic drift”
- For keeping the always actve the role of the industrial partnerl

Task1: Coordination

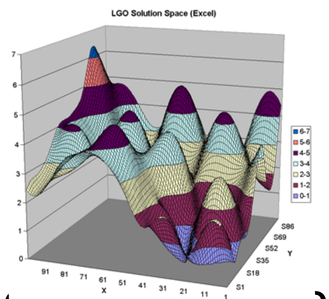
- **Discrete event systems**
  - great for deadlock free coordination
  - Unclear how to maximize performance and to deal with unexpected events



- **“Standard” Multi-Robot Motion Planning techniques**
  - Unclear how to deal with segmented roadmaps



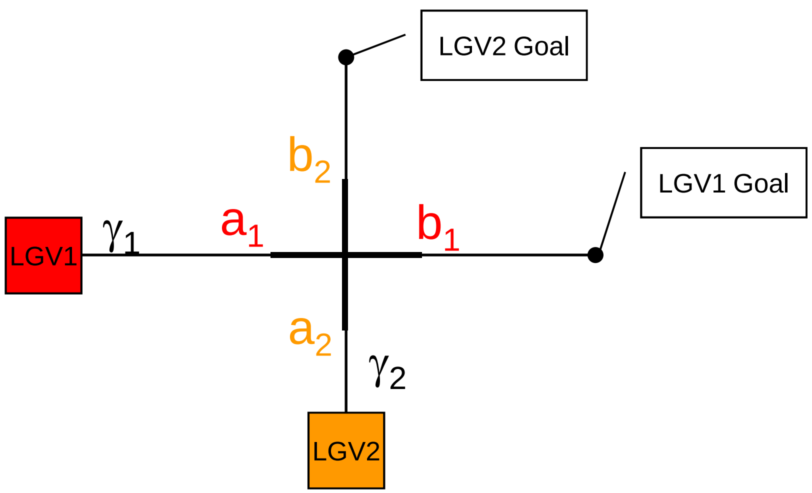
- **Nonlinear optimization strategies**
  - big computational burden

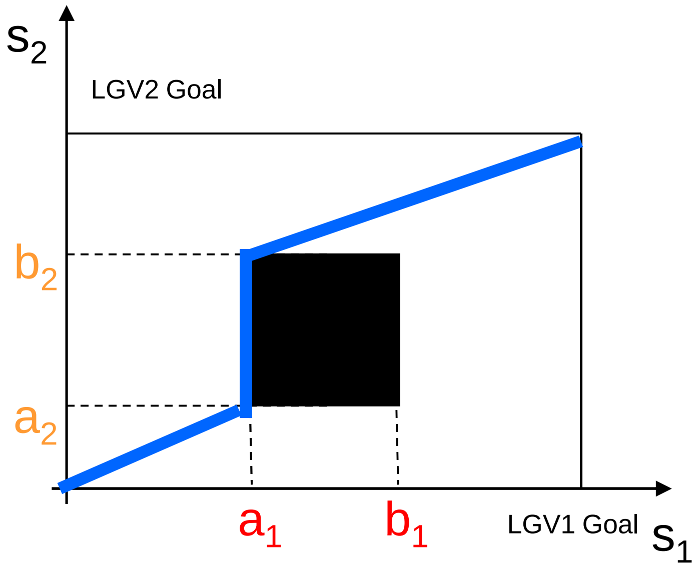


- **Distributed strategies**
  - unclear how unexpected events affect performance

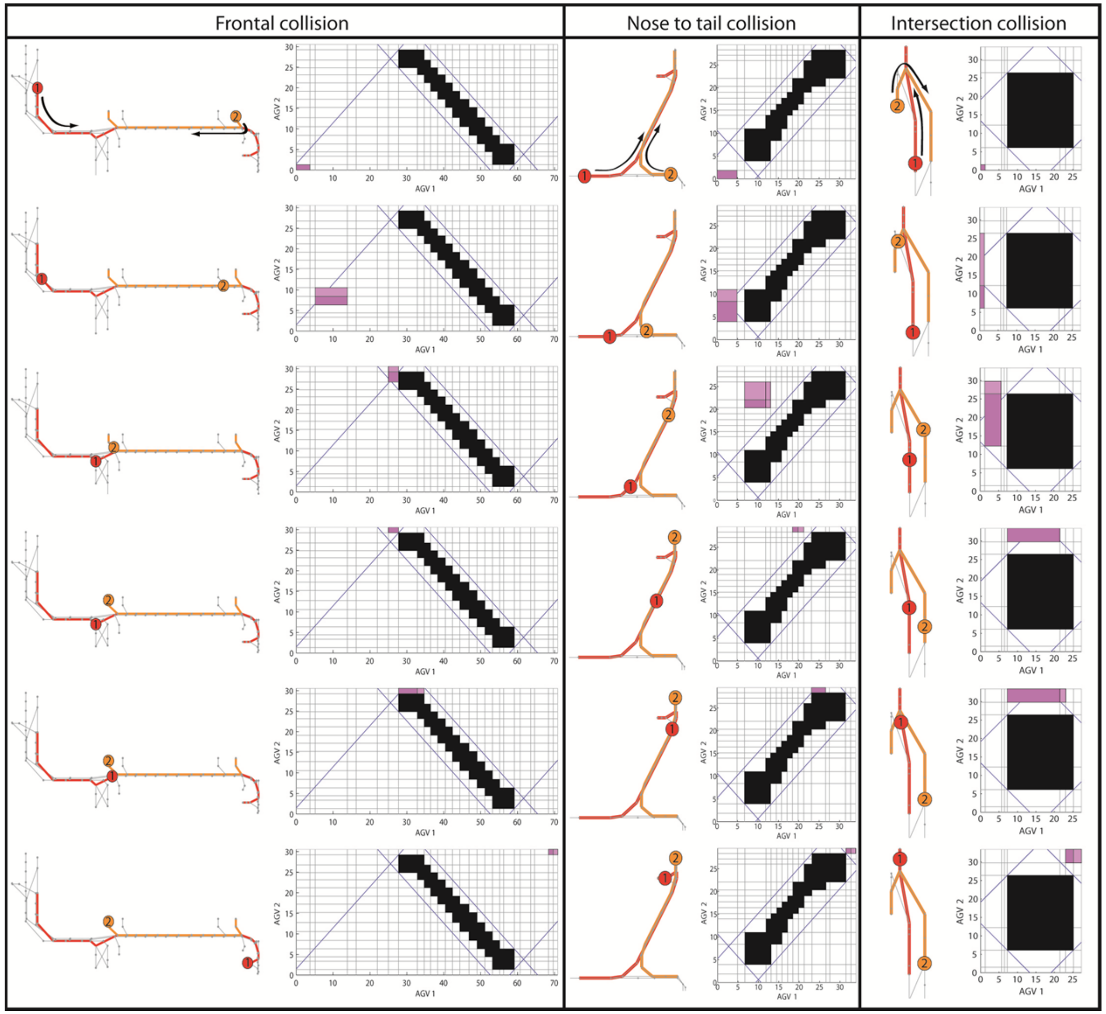
Coordination Diagrams

- Once paths are assigned to the robots, it shows very clearly where congestion can take place
- The traffic problem becomes a path planning problem
- It has been extended to segmented roadmaps





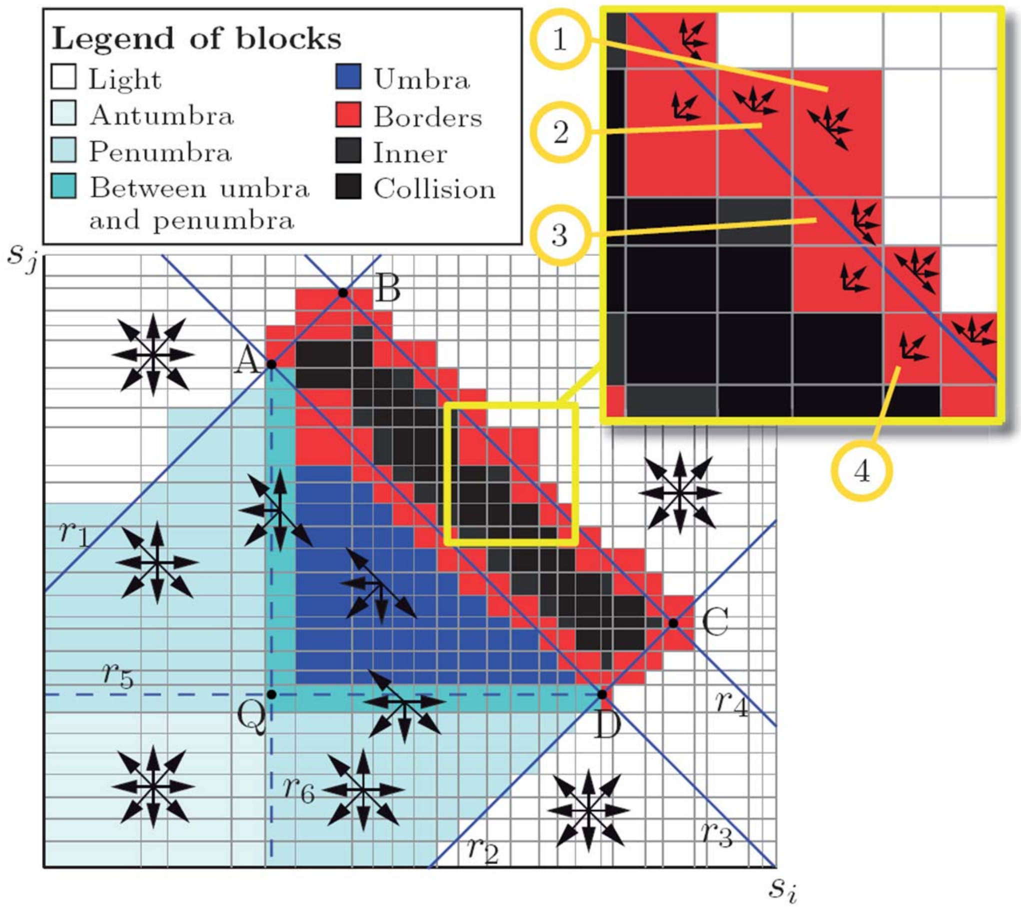
Coordination Diagrams



- An algorithm for quickly building a coordination diagram
- Possible Collision regions analysis
- Handling of unexpected events

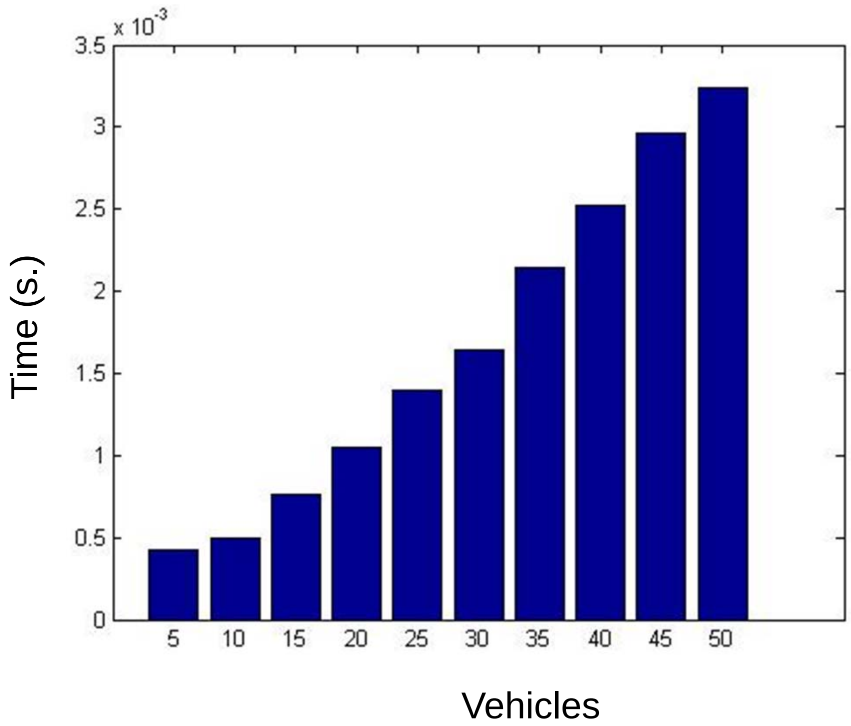
Coordination Strategy

- Takes into account the segment allocation policy
- Regions corresponding to actions constraints are identified
- Unexpected events introduce further constraints
- It acts to minimize the overall completion time



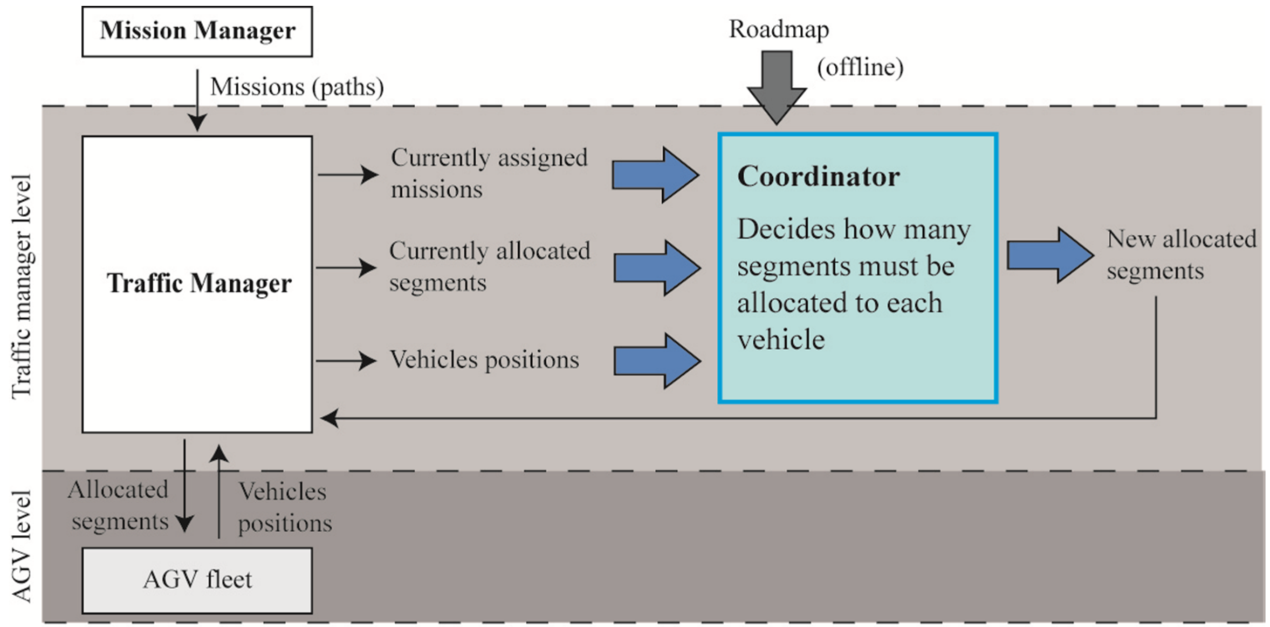
Computational Complexity

- The action choice problem is modeled as a Binary Integer Problem
- Using the optimization strategy proposed in Balaj et al. 2010, the segment allocation problem is solved with a polynomial complexity

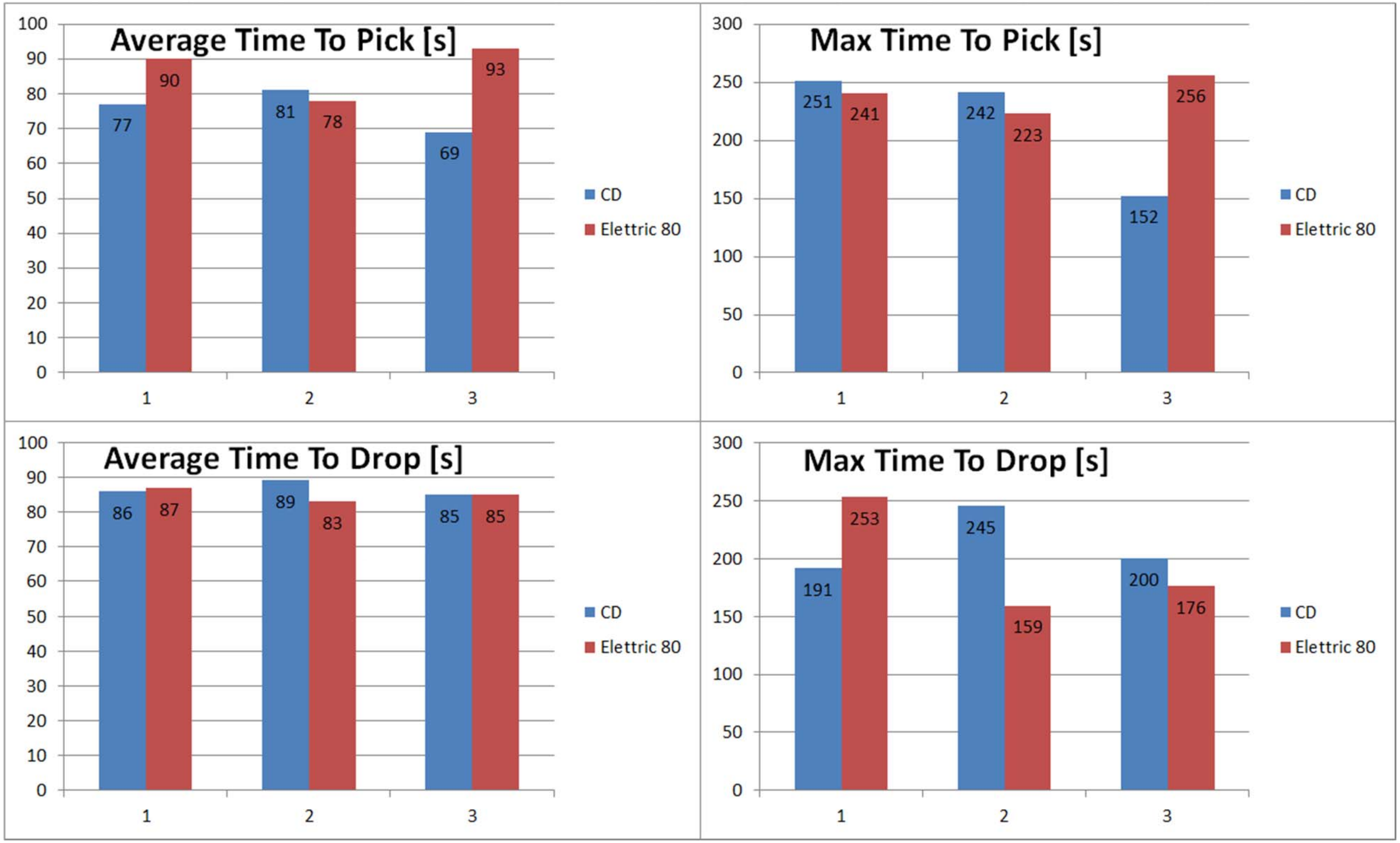


Task1: Simulations

- Plant with 25 AGVs
- 3 70mins Simulations
- 140 missions/hour generated (real case)



Task1: Results



Task 2: Routing

- A measure of the congestion of the fleet based on the coordination diagram has been developed
- A performance measure based on congestion and time to destination will be developed
- A routing strategy for maximizing efficiency has been designed

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Task 3: The arena









Industry-Academia cooperation

- Abstraction of the problem from the industrial setting
  - No! Keep the company as involved as possible for keeping academia aware of all the aspects of the problem.

- Keep the company involved in every step of the Experiment
  - They want to be part of the process and this is necessary for a good cooperation

- Safety
  - It is one of the main constraints of the applications. Industry is well aware of it while academia often is not

Frequent communication!!

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ARS CONTROL

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Conclusions

- Coordination algorithm with polynomial complexity
- Unexpected events are modeled as constraints and handled by the coordination strategy
- Performance comparable to the ones obtained by E80 but **without** requiring manual tuning
- We are working for embedding dynamic routing in the AGVS
- A small scale automatic warehouse is being set up for experimental validation