International Conference on Dynamics in Logistics,
August 28th - 30th, 2007, Bremen, Germany

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Dynamic Decision Making on Embedded Platforms in Transport Logistics – A case study

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Outline

- Introduction
- Decentralized route planning
- Agent-based shelf life supervision
- Extension for multi package problem
- Experimental evaluation
- Summary and future work

Introduction

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Shifting intelligence from central control to transport containers

- Complexity and cost pressure in supply chains forces new approaches
- Individual planning for each palette / freight item
  - Transportation of perishable goods
  - Setting with high amount of data per cargo for monitoring
  - Unexpected changes in product quality may force re-planning (change of vehicle and/or destination)
  - Vision: intelligent cargo
  - Current hardware solution on vehicle/container level
- Two points of view
  - Planning for full truckloads (existing demonstrator)
  - Combined planning for part loads (simulation of new concept)

Vision: Intelligent Cargo

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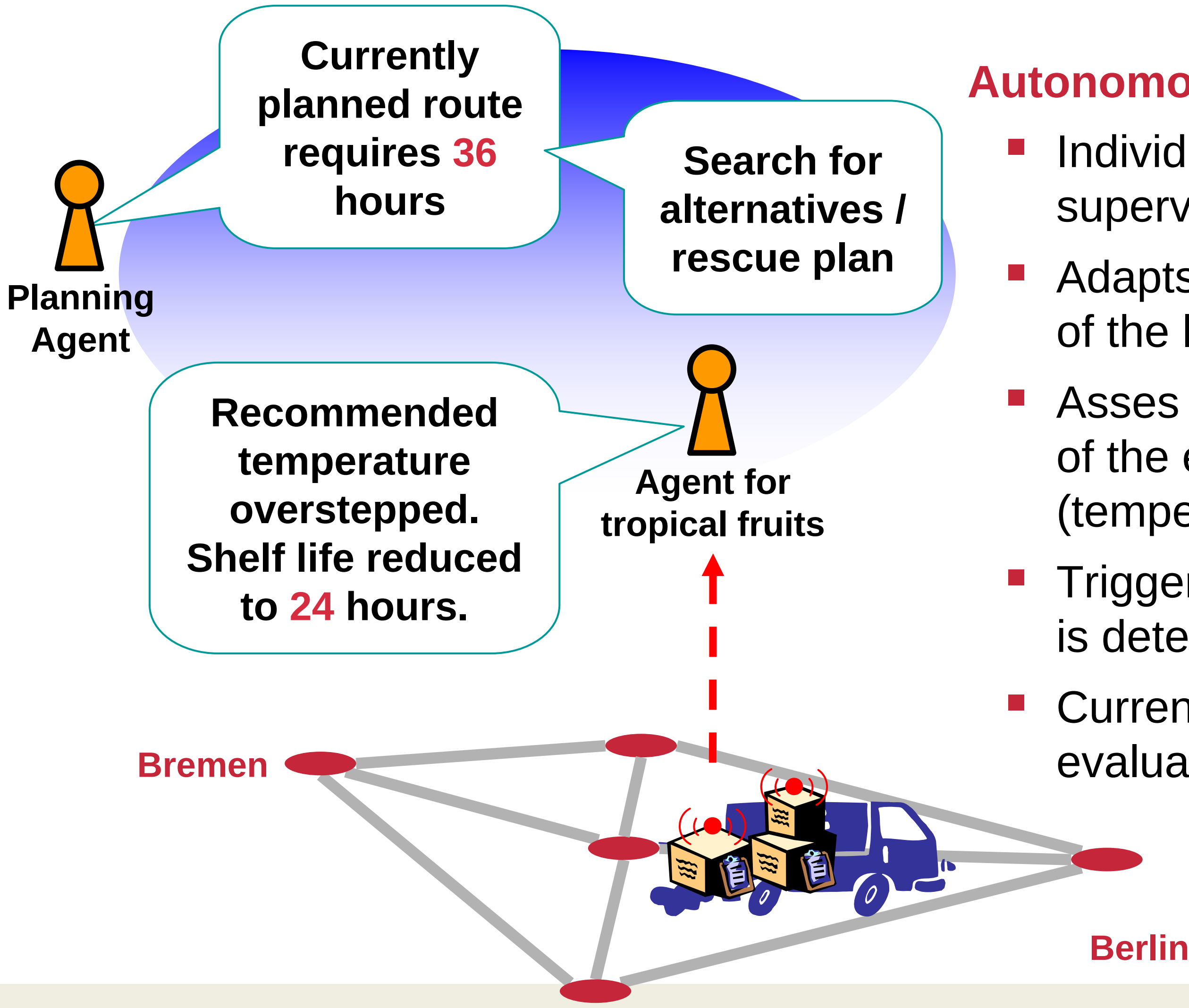

Autonomous transport supervision

- Individual software agents to supervise each freight item
- Adapts to individual requirements of the loaded goods
- Asses the influence of deviations of the environmental parameters (temperature) to the freight quality
- Triggers re-planning if some risk is detected
- Current solution: freight quality evaluation within vehicle/container

Autonomous Transport Scenario

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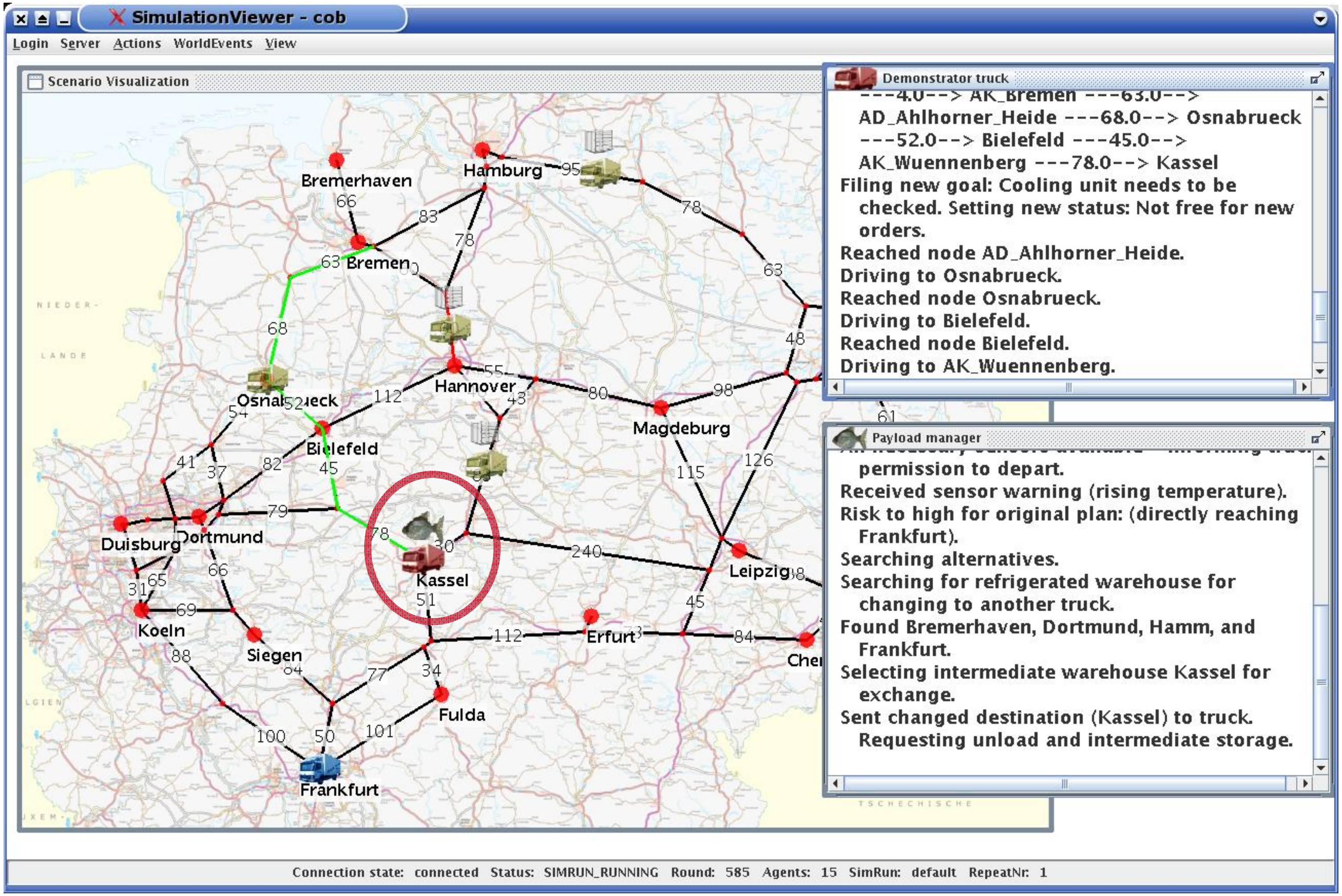

Route Planning

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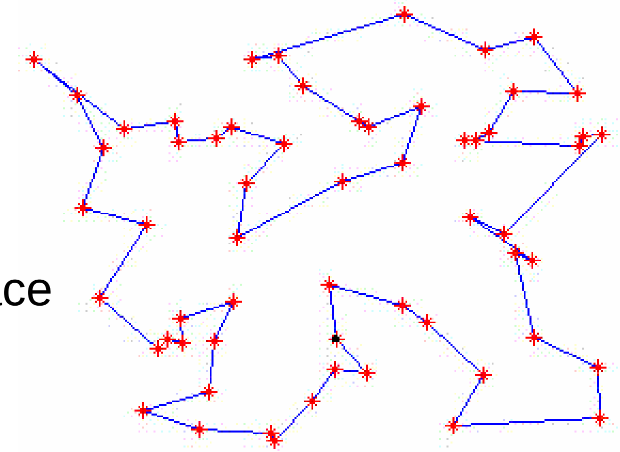
- Autonomous routing for perishable goods has to consider shelf life criteria and dynamic environments, e.g., (unexpected) quality changes
- Routing problems: TSP, VRP, VRPPD, VRPTW
- (Optimal) routing solutions are NP-hard in general
  - Constrains dimensions of maximum problem space
  - Limits practicability for embedded systems



- Cost function with shelf life is subject to information privacy concerns when using external routing services

➔ Heuristic (sub-optimal), cooperative (distributed) approaches needed

Software Agents

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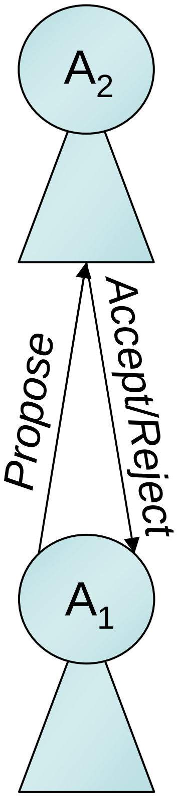
What are agents?

- "An agent is a computer system situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives" (Jennings & Wooldridge 1998)
- *Autonomous* agents act without direct intervention of others
- Multiagent systems: agents communicate and cooperate to solve complex problems that are *beyond the capability of a single agent*



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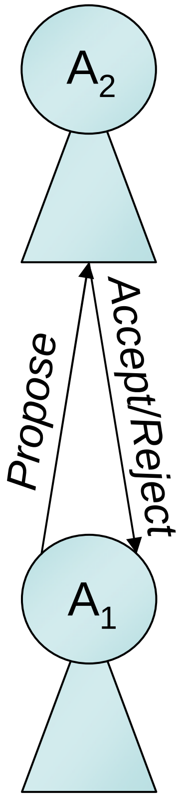
- Multiagent system architecture and communication is standardized by the IEEE *Foundation for Intelligent Physical Agents* (FIPA)
- FIPA multiagent runtime environments: JADE and LEAP
- Agent architectures: e.g. BDI, goal-oriented architecture, with autonomous goal selection (deliberation), and means-end reasoning



Autonomy in Software Agents

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Levels of Autonomy (Timm 2006)

- ***Strong regulation***: No autonomous capabilities; every decision is determined by external entities (reflex agent architectures).
- ***Operational autonomy***: Competence to choose course of action in predefined strategic boundaries
(goal-oriented architectures, *means-end reasoning*).
- ***Tactical autonomy***: Enables the system to deliberate on different alternatives for operational behavior (BDI architectures, *deliberation*).
- ***Strategic autonomy***: Conventionally determined by the system designer (desires and algorithms). Beyond classic BDI architecture.

Autonomy in Case Study

- Local vehicle agent has operational autonomy: *route selection*
- Possibly tactical autonomy: *customer/cargo preference adaptation*

Example shelf life (Lettuce)

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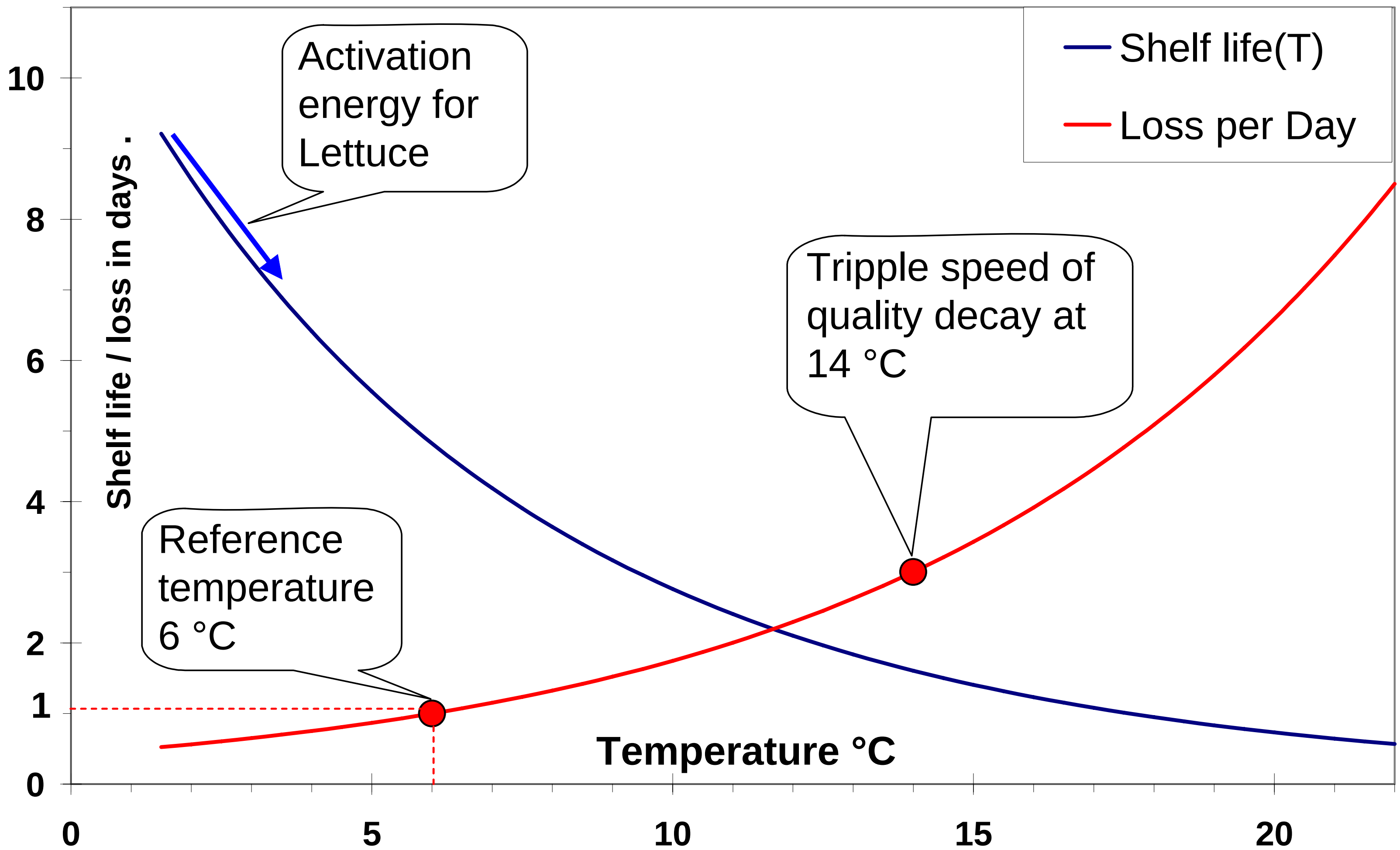

Local processing

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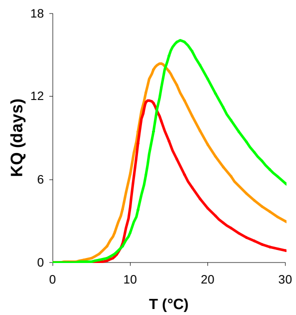
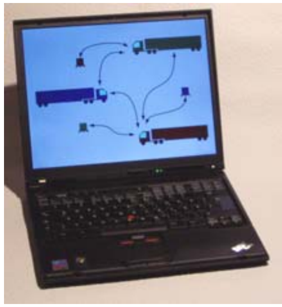
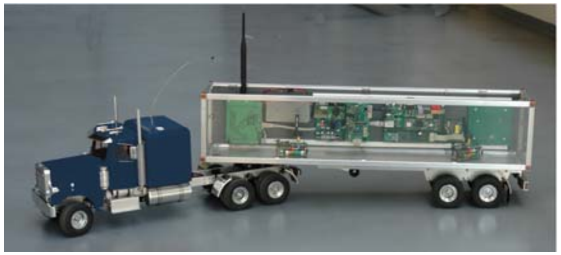




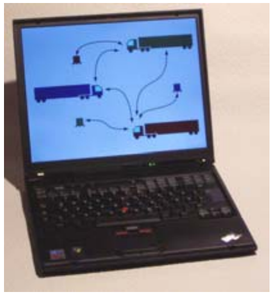
Sensor raw data



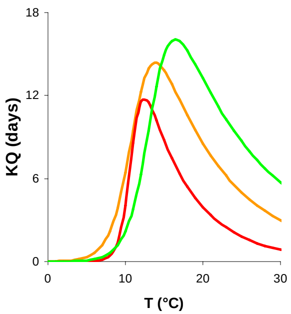
Quality Modelling

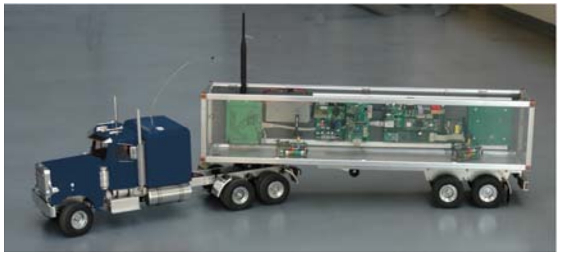
Transport Operator

Standard T&T



Quality Information





Transport Operator

Quality Modelling

Standard T&T + Processor

Implementation of agents on embedded systems

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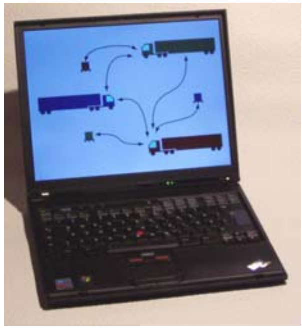


100%

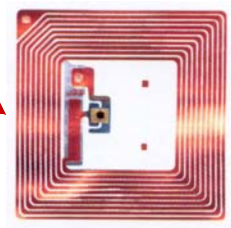
Software agents on embedded systems

- ARM Processor 1 Watt @ 400 MHz
- Embedded real time JAVA runtime environment
- Implementation of a reduced agent platform (JADE – LEAP)

< 5%

~0.1%

<< WSN



➯ **Adapt agent systems to the restrictions of embedded systems: Power, memory and computation resources**

Hardware

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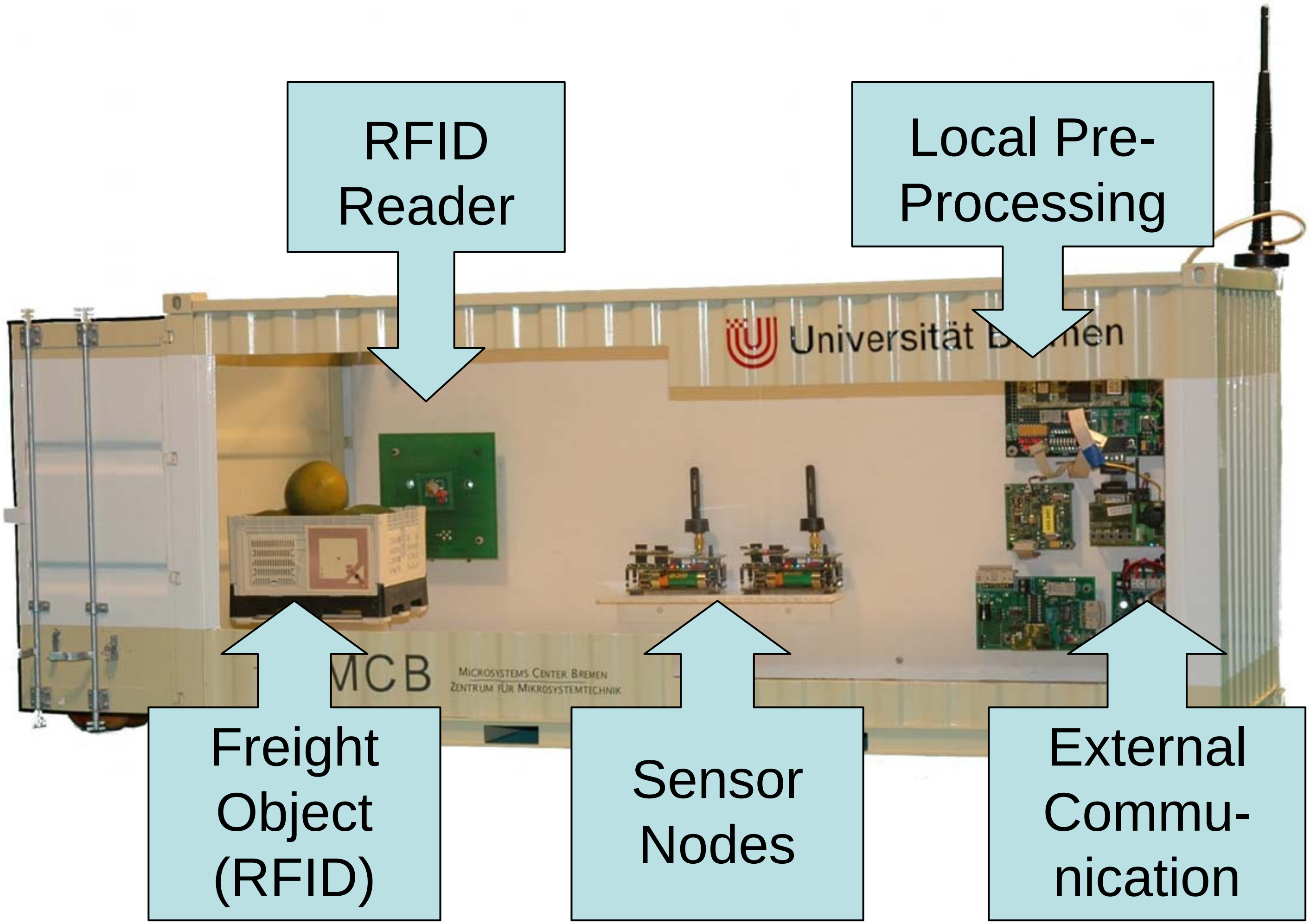

Agent Transmission process

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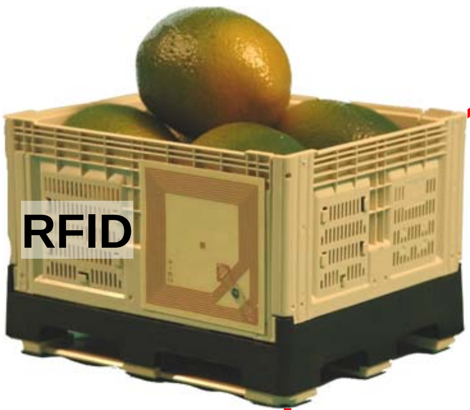
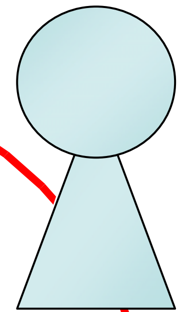
Logistical object
➔ Passive RFID-Label



Dynamic link



Intelligent Agent
➔ Transport- and handling-instruction
➔ Supervision in behalf of the owner

Reading RFID at loading

Truck requests agent at loading

Intelligent truck or container
➔ CPU platform
➔ Sensors
➔ RFID-Reader

Evaluation of sensor data

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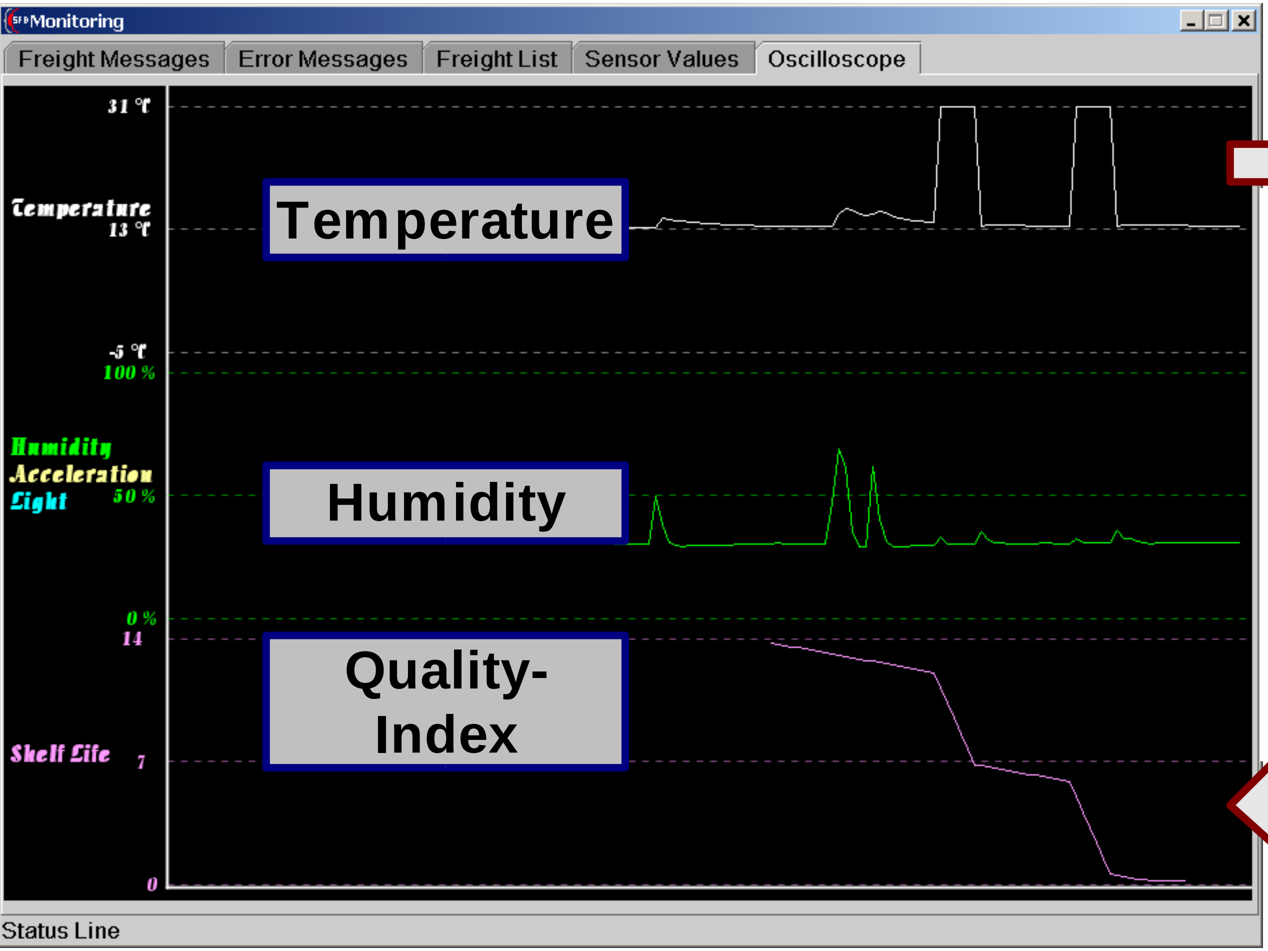

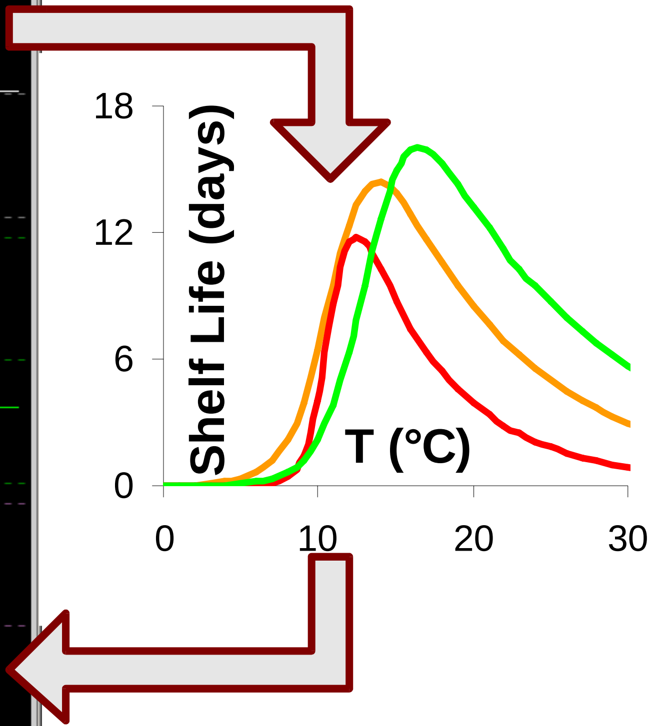

Multiple package problem

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Setting:

- Truck contains several pallets of perishable goods for different destinations.
- In which order should the destinations be served to deliver the goods before expiration?

Additional requirements

- High local temperature deviations force individual supervision
- Simply multiplying the number of agents also multiplies the amount of communication
- Truck / Container has to find a route that serves the individual needs of the majority of all loaded packages

Planned improved solution

- Extension towards the current demonstrator software of intelligent container
- Idea: Reducing communication by shifting part of the route planning into the means of transport
- Simulation
- Further improvement by increasing the level of autonomy

Temperature along the xyz-axis

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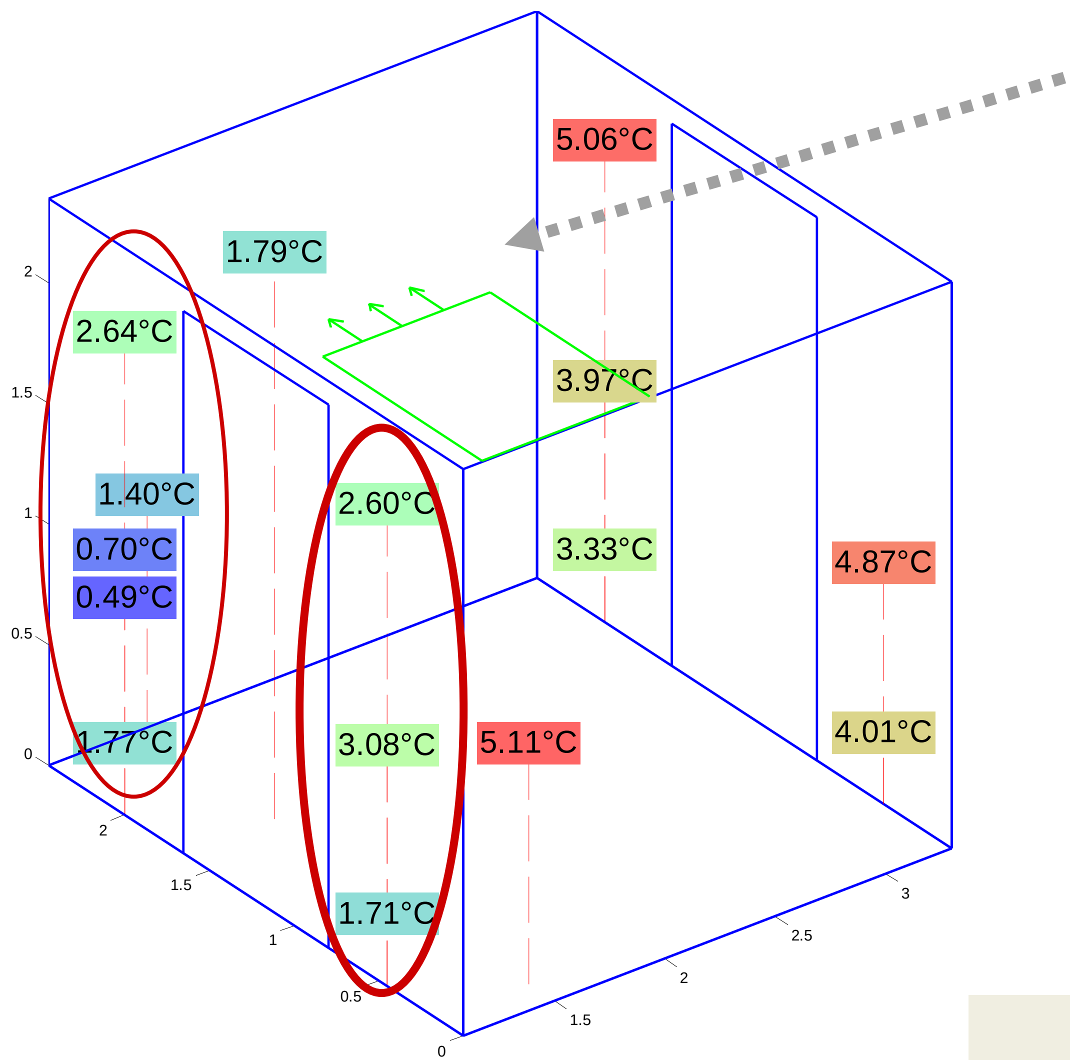

- Average of reefer side ~2 °C colder than other side
- Single loggers behave 'chaotic'

The test case

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Extension of the Traveling Salesman Problem

- Not shortest way, but minimize shelf life losses by route planning
- Dynamic form: unexpected changes of shelf life and traffic jams

Item Nr	Desti-nation	Initial Shelf life
1	Town 7	12 hours
2	Town 3	50 hours
3	Town 1	36 hours
…	…	…
…	…	…

Distance	Town 1	Town 2	Town 3	…
Town 1	-	5 hours	7 hours	…
Town 2	5 hours	-	3 hours	…
Town 3	7 hours	3 hours	-	…
…	…	…	…	…

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Distributed Planning by truck agents

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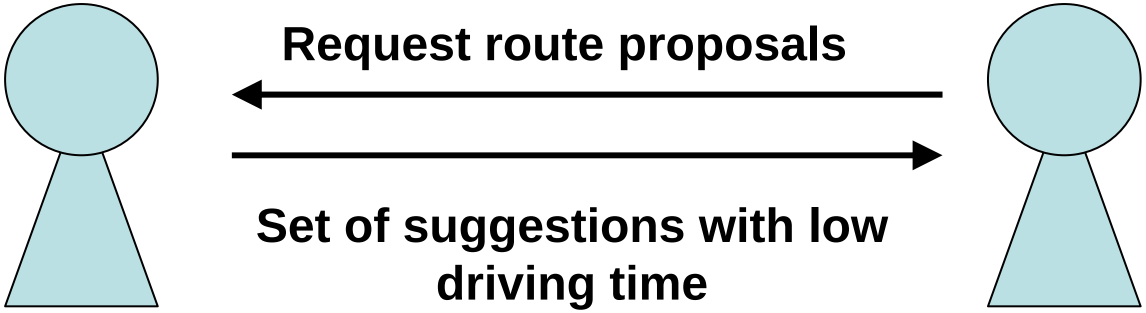

Route Planning Agent (RPA)

- Remote Server
- Access to road maps and traffic information
- Public information

Local Vehicle Agent (LVA)

- Embedded System (Truck)
- Evaluates Shelf life
- Private information

Goal fulfillment

- Maximize sum of remaining shelf life at delivery
- Strongly avoid zero shelf life / expired products

Experimental evaluation

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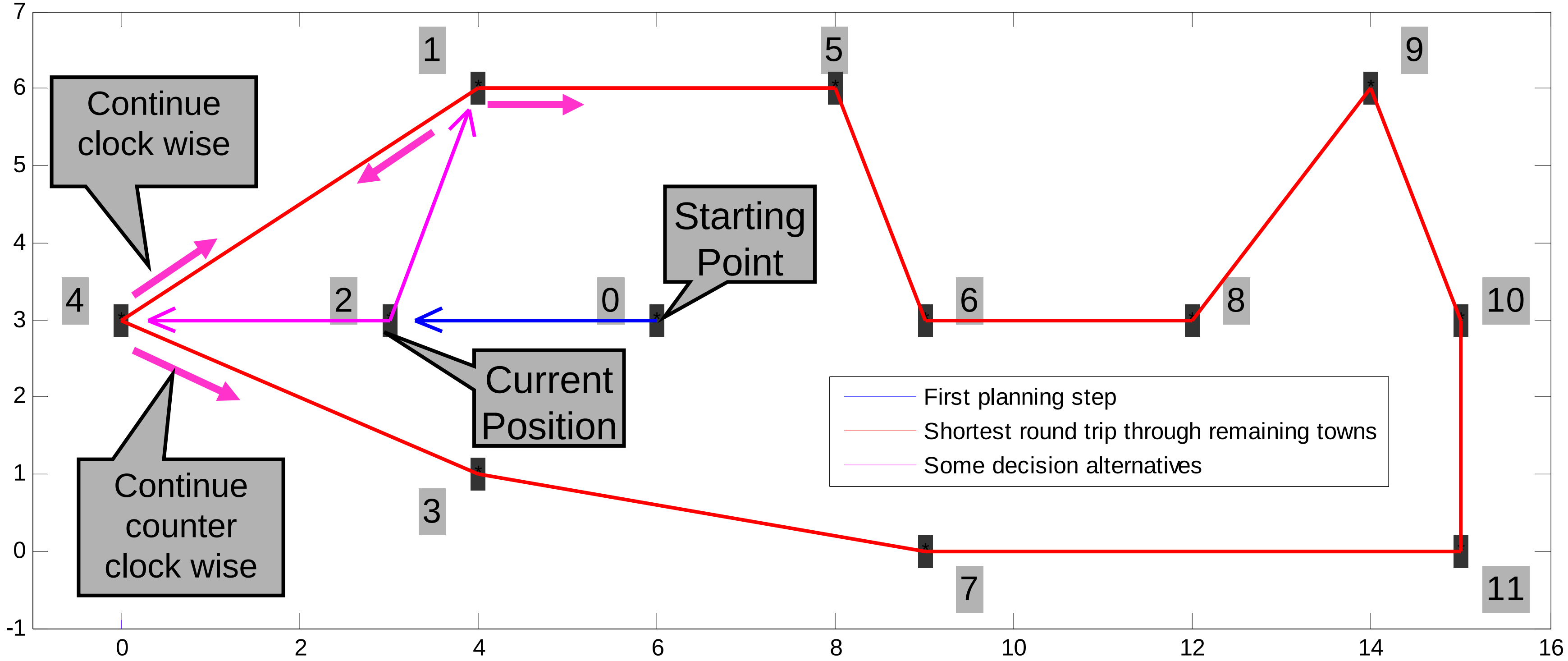
Distributed heuristic solution

- Software simulation
- Comparison with optimal solution

- Process repeated in each town
- Unit: Travel distance in hours



Experimental evaluation 2

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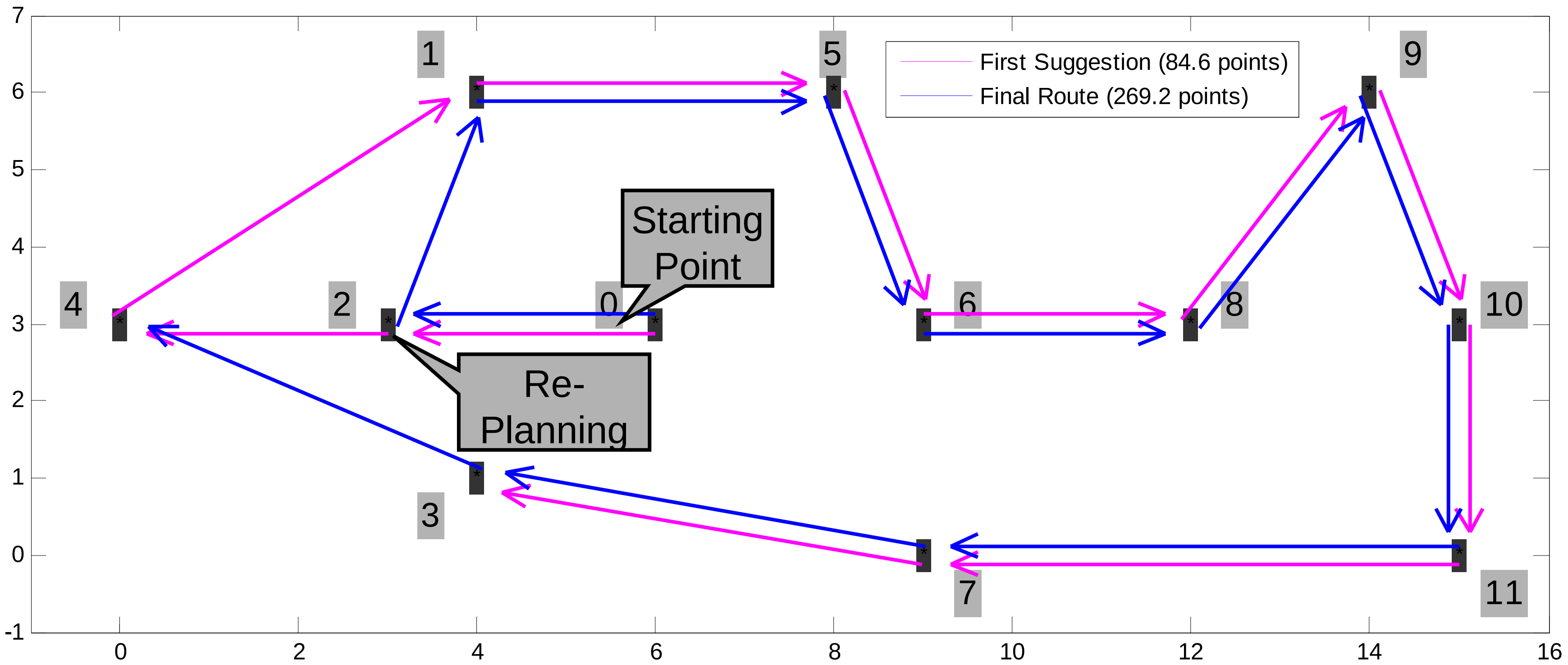
Replanning

- Change of planned route in step 2 caused by new information
- Caused by new route suggestions **or** Changed shelf life / traffic situation



Experimental evaluation 3

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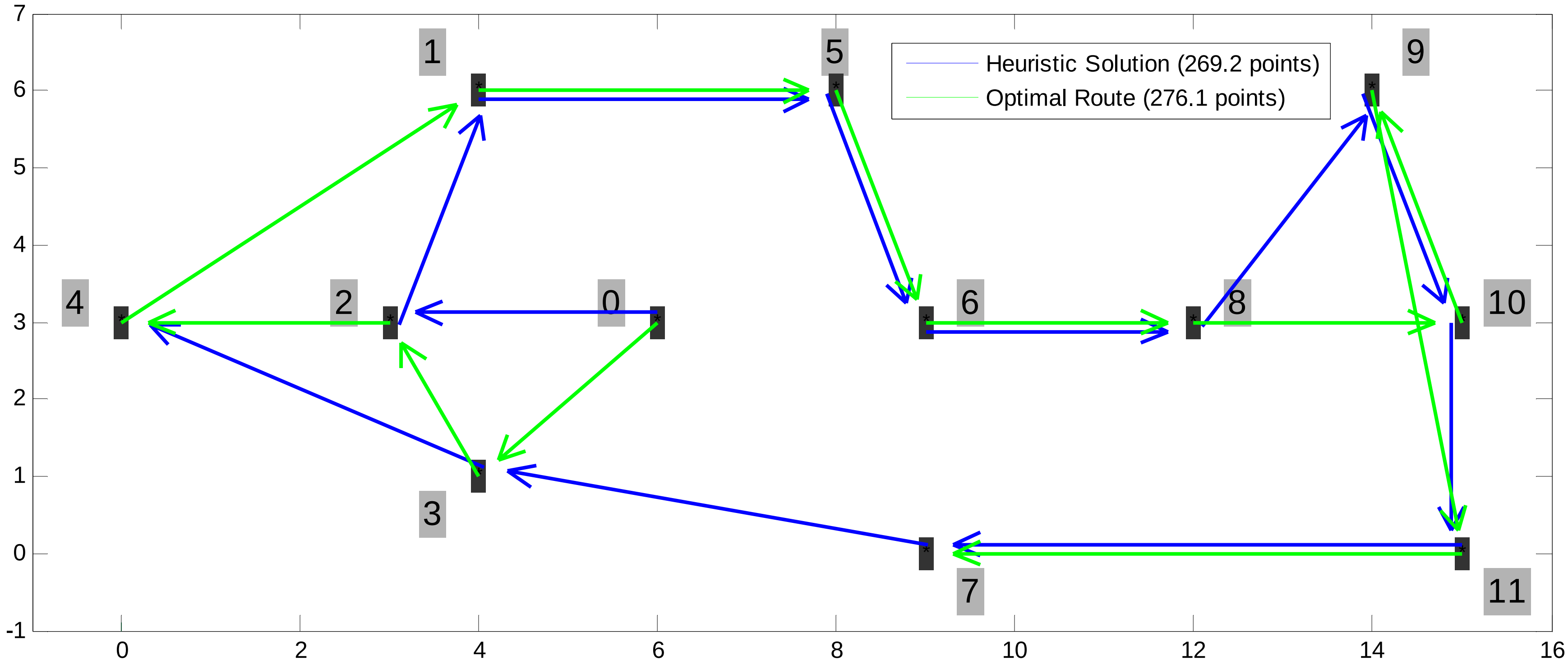
Comparison to optimal solution

- In most cases solution close to optimum
- But hard to find if big difference between short route and optimal solution



Results

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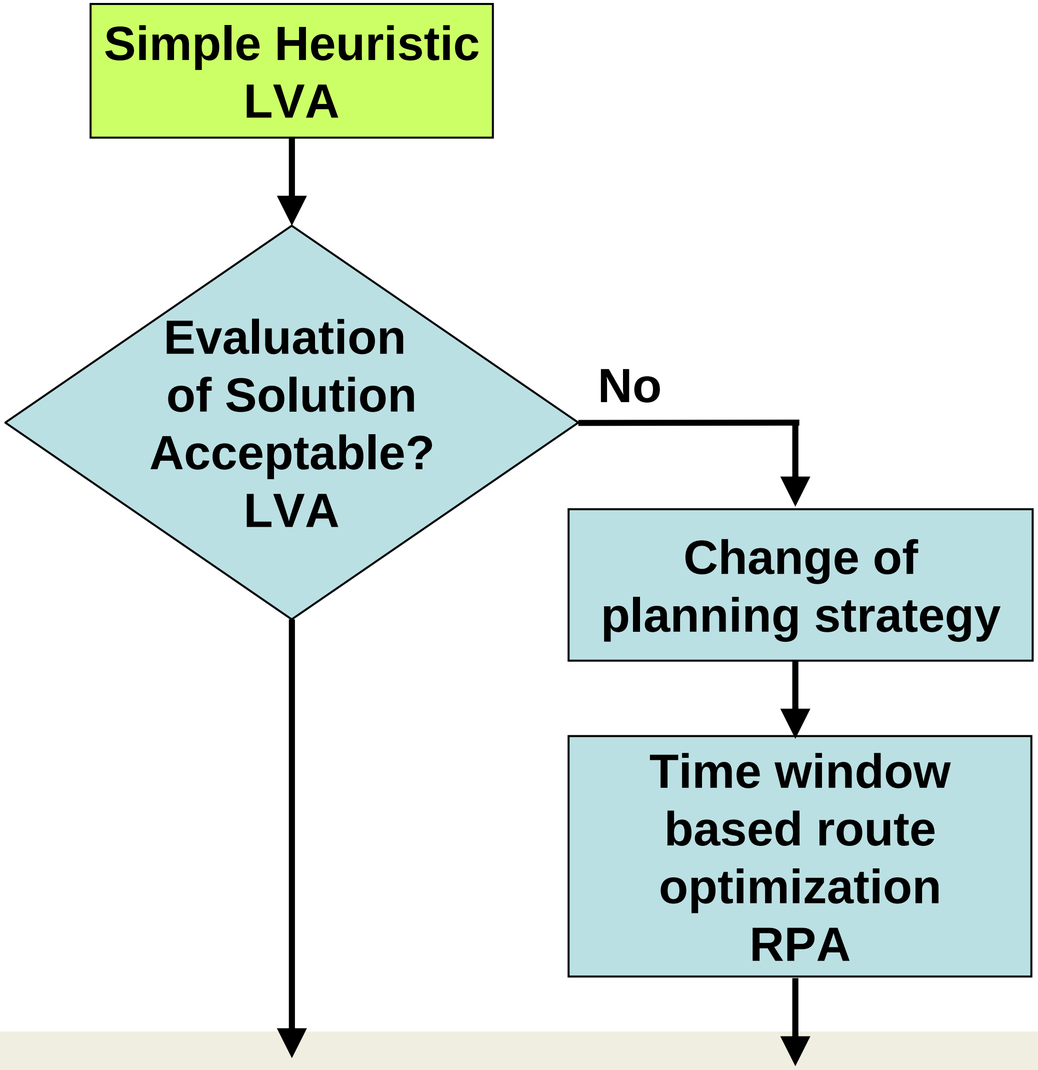
Summary of experimental results

- 600 “runs” with identical town-map and random initial shelf life values
- The points give a measure for the remaining shelf life at delivery.
- In 2/3 of all experiments the same number of packages had sufficient remaining shelf life at delivery as in optimal solution (Row A)
- In average the remaining shelf life was 92% of the optimal possible value
- In the remaining 1/3 of experiments more packages as in the optimal solution had zero shelf life (“lost packages”) at delivery (row B)

	Runs	Local planning	Optimal	Ratio
A (no losses)	402	252,73 points	272,02 points	92,62% ± 7,37
B (with losses)	198	More package losses as optimal solution		

Summary and Future work



Case study for an autonomous logistic process

- Reduced communication costs
- Lower computation resources needed
- Continue locally if communication fails
- Privacy
- Higher degree of autonomy by enhanced architecture to change strategy if required (replacing software components on request)

The End

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Thanks for your attention

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Contact

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