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Intelligent parcel or intelligent vehicle? System layers to implement embedded intelligence

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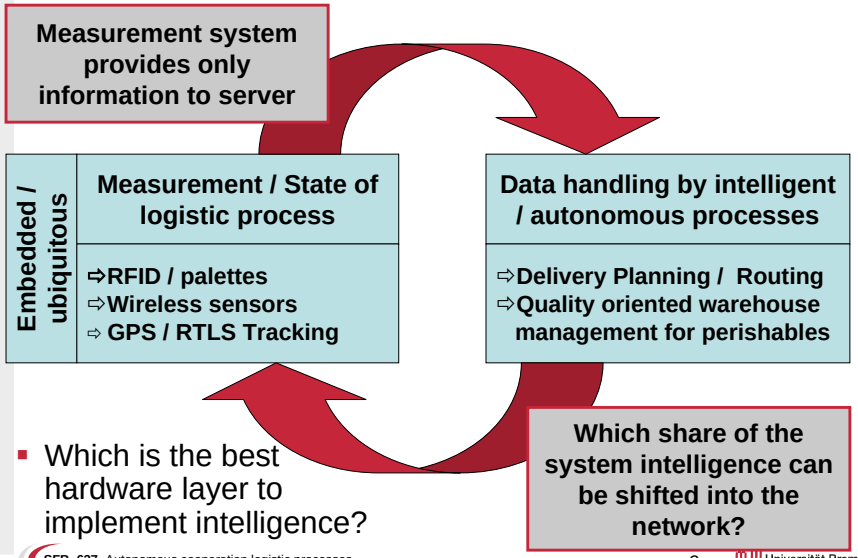
Introduction



- Which is the best hardware layer to implement intelligence?

Outline

- Background of embedded intelligence
  - Autonomous cooperation
  - Hardware layers
  - Communication as limiting factor
- Case studies and examples
  - The intelligent container
  - Local route planning
  - Intelligent RFID

The aim of embedded intelligence

Autonomous control

- Decentralized decision making
- Split (logistical) planning tasks into parallel processes
- Ideal case: each object represented by its own software entity / Software agent
- Object = parcel, vehicle or a single order
- Advantages: Robustness, Flexibility for system dynamics

- Agent **physically** linked to object
  - Object / parcel has own computation unit
- Agent **represents** object
  - Agents runs remote on server platform to act ‘in behalf’ of the object

Degree of decision freedom

Decision scope	Description
None	▪ Executes decisions of central planning instance
Evaluation of local sensor information	▪ Observes its environment ▪ Decides whether measured deviations form a risk for the good quality
Adaptive route planning	▪ Change transport route ▪ swap vehicle by own decision
Maximum decision freedom	▪ Changes its destination, according to new orders or changed quality state

Implementation levels

Location	Current application	Future applications	Computa-tion power	Basic costs	Extra costs
Server networks	Objects re-presentation by Global database	Multi agent system based vehicle routing	100%	> 1000 €	-
Means of transport	Telemetric supervision, GPS	Intelligent Container	~2 %	< 1000 €	~ 100 €
Active com-munication devices	Active tags attached to containers	Spatial supervision by wireless sensors networks	~0.1 %	> 10 €	~ 1 €
(semi-) passive RFID tags	Identification Temperature logging	Intelligent RFID	<< 0.1 %	> 1 €	~ 1 €

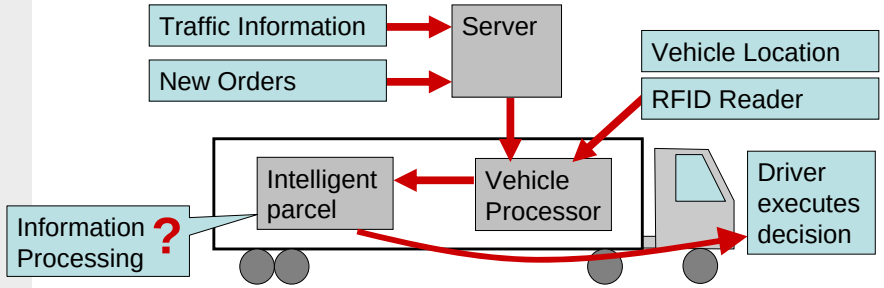
Limiting factors of Communication

- Passive RFID:
  - Access only **offline** during gate passage
  - Limited range (~3 m)
- Active wireless sensor:
  - Permanent **online** access and higher range
  - But volume limited by energy budget

Where to place the data processing?

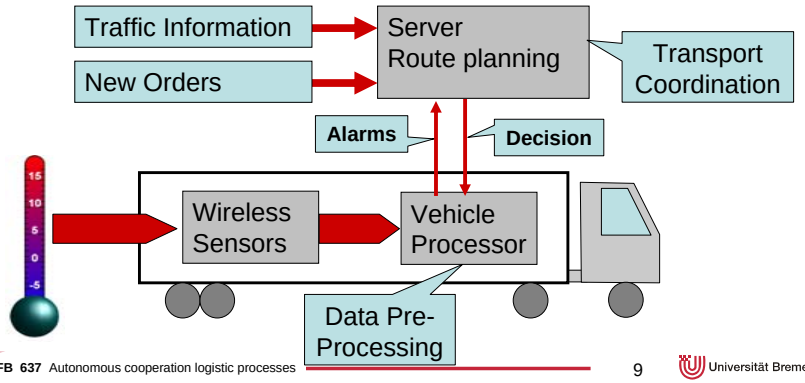
- How is information transferred?
  - Source → Processing → Sink

Length of the information path



Intelligent Container

- Supervision of perishable goods

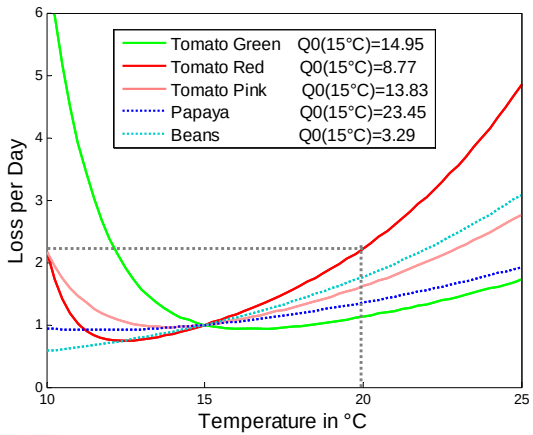


Length of the information path

- Keep it as short as possible
  - Does the shift of intelligence to another system layer shortens or extends the communication path?
- Processing close to origin of information
  - Sensor supervision ~ 10 kByte
  - Route decision ~ 100 Byte
- Thinking is cheaper than communication
  - (1 mJ < 16.5 mJ for wireless sensors)
  - If intelligence reduces communication it enables networked objects

Shelf life modelling

- Calculation of loss per day as function of temperature
  - Arrhenius equation for reaction kinetics
  - Look up table



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Local Route planning

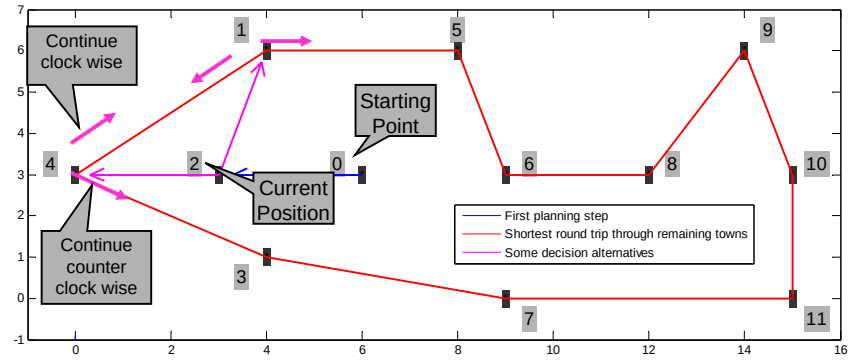
- Alternative to the intelligent parcel
- Example: Truck autonomously adapts a round trip to deliver sensitive parcels to multiple costumers
- Truck does not check all possible round trips (Travelling salesman) only local view
- **Embedded objects have only limited access to information, no bird view**
- How good is planning under this restriction?

Approach for intelligent truck

- Privacy: Vehicle does not send quality data to the outside world
- Reduced information: Vehicle receives only a limited number of route suggestions
  - Provided by external traffic information server
- Truck evaluates the suggestions on the bases of the internal quality information
  - Change the route to deliver packages with low remaining shelf life first
  - Maximize the number of packages in proper quality state at point of time of delivery

Experimental evaluation

- Distributed heuristic solution
  - Software simulation
  - Comparison with optimal solution
- Process repeated in each town
- Unit: Travel distance in hours



Performance of different planning strategies

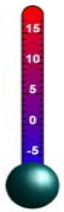
- Vehicles start with optimal route, but disturbance and re-planning after 2 packages
- N_0 = 20 packages to deliver
- 500 software experiments

Method	Delivered Packages	Driving time	Improvement
Full re-planning	16.41	76.81 hours	100 %
Local vehicle planning	15.66	76.82 hours	64.5 %
Repeated vehicle planning	15.75	75.80 hours	68.6 %
Unchanged route	14.30	74.68 hours	0 %

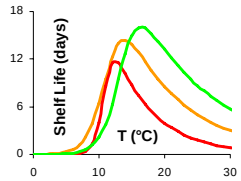
The idea of intelligent RFID

- Sensor data pre-processing by semi-passive RFID tags

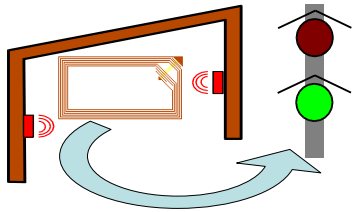
Temperature measurement



Function to access effects of temperature onto quality



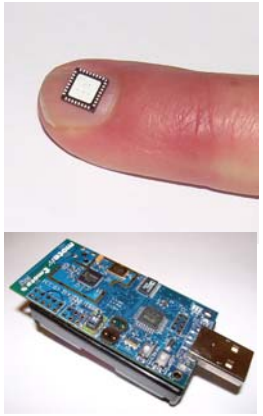
Only state flag transmitted at read out



Required hardware resources

- Is it feasible to squeeze a shelf life model into a micro-chip?

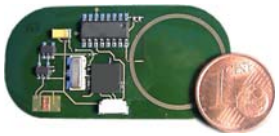
Type of Resource	Calculation of Arrhenius equations
Processing time	1.02 ms
Program memory	868 bytes
RAM memory	58 bytes
Energy	6 µJoule



Available energy

- Very small additional recourses compared to circuit of data logger
- Shelf life model can run by paper thin batteries
- Finished project: HF-Tag for Measurement of pressure

Power consumption per month	
Update every 15 minutes	0.020 J / month
Stand by current of MSP430 (1µA at 2.2V)	5.7 J / month
Turbo Tag (Zink oxide battery	80 J



Summary

- Benefits
  - Robustness
  - Flexibility
  - Privacy
  - Less communication costs
  - Only few extra hardware costs for additional processing power
  - Not all hardware levels are useful
  - Length of the communication path

Thank you for your attention

For more information and publications please visit
www.intelligentcontainer.com

- Full paper will be presented at the Internet of Things March 2008, Zurich:
  - The Benefits of Embedded Intelligence - Tasks and Applications for Ubiquitous Computing in Logistics. In: C. Floerkemeier et al. (Eds.): IOT 2008, LNCS 4952, Springer Berlin Heidelberg 2008, pp. 105–122,
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