The intelligent container: Combining RFID with sensor networks, dynamic quality models and software agents.

University of Bremen

- Founded in 1971
- First principles are interdisciplinary as well as practice-oriented project studies known as the „Bremen Model“
- 80 courses of studies, many of them are bachelor- or master degrees
- Scientific research centre in the northwest of germany
- Laboratories for 1,400 scientists
- A place to study for nearly 22,000 students, thereof nearly 3,000 foreign students
- A workplace for more than 1,160 employees
- 12 faculties representing various sciences

Autonomous Control

Long:
“Autonomous Control describes processes of decentralized decision-making in heterarchical structures. It presumes interacting elements in non-deterministic systems, which possess the capability and possibility to render decisions independently. The objective of Autonomous Control is the achievement of increased robustness and positive emergence of the total system due to distributed and flexible coping with dynamics and complexity.”

Short:
“Autonomous control in logistics systems is characterised by the ability of logistic objects to process information, to render and to execute decisions on their own.”
Autonomous Control – Opportunities and Risks

- Autonomous control is a paradigm to manage complexity, dynamics and uncertainty within logistic processes
- It is based on autonomy & decentralization for decision making
- Autonomous control designs emergent synergies & infrastructures in complex systems (chances):
  - Increase of decision capacities
  - Reduction of decision complexity
  - Transition to flexible strategies, structures, processes and resources
  - By adopting dynamic requirements the system robustness increases
- Autonomous controlled systems contain redundancies (risks)
  - Redundant tasks, structures and resources
  - Overall performance is endangered by egotism of subsystems
  - Missing central control might lead to instability

Technological Basis

- RFID and Sensor Technology
- Wireless Communication Networks
- Ubiquitous Computing
- Telematics
- Positioning Systems
- Autonomous cooperating logistic objects

Roadmap from RFID to Autonomous Control

- Data Volume
  - Autonomous Acting
  - Simple Calculations
  - Sensors, Dynamic Data
  - Identification, Static Data

Time

Today
Tomorrow
Vision

Sensors Extending Tracking & Tracing

- "We do not only want to know at any point of time where the fright item is but also in which state it is"
- Supply Chain Control by Radio Frequency Identification

Application in Fruit Logistics
- Agricultural products are still "alive" after harvest
- Maritime reefer transports total 57 million tons
  - Bananas: 29%
  - Citrus: 10%
  - Other Fruits: 17%
Dynamic Data have an Impact!

Mobile Sensors

Three generations of sensor systems

1. Standard data loggers:
   Reading of measurement protocol at end of transport
   Might be to late for appropriate reactions

2. Radio data loggers:
   Allow permanent access
   Extensive configuration work and information overhead

3. Third generation sensor system:
   a) Autonomous configuration
   b) On-the-road sensor access
   c) Autonomous data interpretation and decision-making

The Sensor System

Ultra low power design
Power consumption per month
- Temperature, humidity: 1 mAh
- Acceleration: 72 mAh
- μController MSP430: 1 mAh
- Wireless IEEE 802.15.4: 2.5 mAh
- One Message per minute

Miniaturized Ethylene Chromatography
- Development based on existing device for volatile aromatic components

The Importance of Ethylene

The gaseous hormone ethylene
- Indicator: Typical peak in ethylene exhalation at start of ripening
- Catalyst: Ripening of Bananas is forced by exposure to high concentrations
  One overripe Banana can spoil a whole transport

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The Ethylene Scale

Typical concentrations and measurement instruments

- Exhalation of Pears
- Exhalation of Lettuce
- Climacteric Rise of Bananas
- Exhalation of Apples

Laboratory Instruments
Measurement of Preclimacteric States
Portable Measurement Devices
Miniaturised Gas Chromatography

Exhalation of Apples
Climacteric Rise of Bananas
Exhalation of Lettuce
Exhalation of Pears

Mobile Agents

Linking sensor data into an electronic consignment note
- Extended Software concept (Mobile Agents)
- Each freight item is represented by an agent
- Accompanies the freight along the transport chain
- Performs actively supervision task per item

Agent knows how to handle their corresponding freight item:
- Which parameters need supervision
- Whom to inform at dysfunction
- Which actions to trigger

Protocol Level

Agents on RFID Tags

- Code size
  - Base Agent 20 k Byte
  - Dynamic extensions 4 k Byte
- Transfer rate of 13 MHz RFID-Tags
  - Overhead by Anti collision and protocols
  - Effective rate ~ 1 k Bit / sec
  - Memory typically 1 k Bit
- UHF Tags
  - limited by bandwidth of 200 kHz
  - A few hundreds identification numbers per second
- Our approach
  - Identification number
  - Quality state information
  - Address of the agent (IP of last vehicle)
Interacting Agents

- Mobile Waybill
- Shortest Route
- Fastest Route
- Cheapest Route
- Static Restrictions
- Real-Time Traffic
- Dynamic Restrictions
- Route Planning Agent (RPA)
- Means of Transport Agent (MTA)
- Load Attendant Agent (LAA)
- Negotiate
- Sensor Data
- Capacity
- Transport Costs
- Technical Requirements
- Time of Delivery
- Warehouse Capacity
- Working Hours
- Technical Equipment
- Inbound / Outbound Agent (IOA)
- Order Placement Agent (OPA)
- External Interfaces
- Traffic Information Agent (TIA)
- Load Attendant Agent (LAA)
- Order Placement Agent (OPA)
- Mobile Waybill
- Inform

Inside and Outside Dynamic Data

- Environment perception and information processing are basic requirements to autonomous controlled systems.
- Individual interpretation of sensor data in relation to monitored goods is necessary.
- Dynamic data related to smart container should be divided into inside and outside data.

Inside Data
- (temperature, humidity, ...)

Outside Data
- (traffic, market situation)

Intelligent Container
- Decision (dynamic routing)
- Mobile Waybill (based on RFID)

Communication Infrastructure

Second Prototype (Model 1:8)
On the Road again...

Composing the Consignment Note

User Interface

Warnings at quality changes
- Time: 15:15:04
- Location: Vehicle IP-99
- Message: Quality loss, take immediate action!
- UID: e0040100000586cf6
- Product: Tomatoes
- Priority: yellow
- Astress: 50%

Registering at Traffic Information Service
Rerouting due to Traffic Jam

Traffic Jam

Rerouting to Kassel

Reaching Bielefeld
Conclusion

Costs
- One time investment for embedded computer and sensor equipment

Advantages
- Use 15 cent RFID-Tags for data logging with full sensor utilization
- Online accessibility
- Option for intelligent decentralized decisions
Thank you for your attention

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