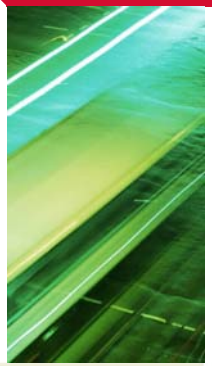
SFB 637 Autonomous Logistics



Supervision of Banana Transports by the Intelligent Container

Coldchain Manangement. 4th International Workshop, 27./28. September 2010, Bonn

Reiner Jedermann, University Bremen, IMSAS / MCB
Axel Moehrke, Dole Europe Import BVBA, Belgium

Universität Bremen

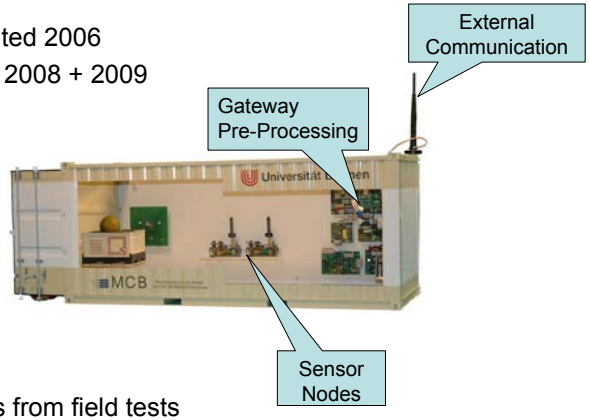
The banana challenge

- Introduction
  - Bananas can produce up to 800 Watt of heat per ton during ripening
    - Hard to control after a certain point
  - Improve processes along the transport and supply chain by permanent monitoring of quality changes
  - Untimely ripening is the greatest risk
    - Can be triggered in the field, in the packing plant or during transport
    - Or by insufficient cooling / temperature changes

↳ Full and accurate temperature supervision and control is a precondition for improvements in the banana chain.

Online monitoring by the intelligent container

- Real-Time remote monitoring of local temperature deviations
  - Idea first presented 2006
  - Transfer project 2008 + 2009

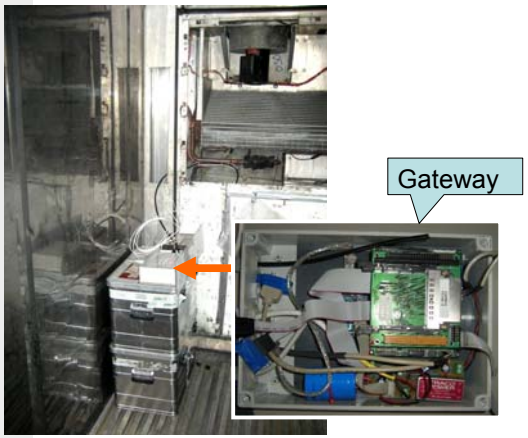


  - Online Access
  - Focus on results from field tests
  - Outlook to future research

Outline

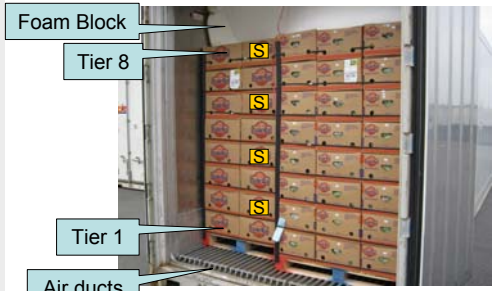
- Set up for field test
- Observed temperature deviations
  - Over length of container
  - Between different containers
  - Inside one box
  - Required sensor density
- Intelligent data processing
- The future of the intelligent container

Installation in Costa Rica



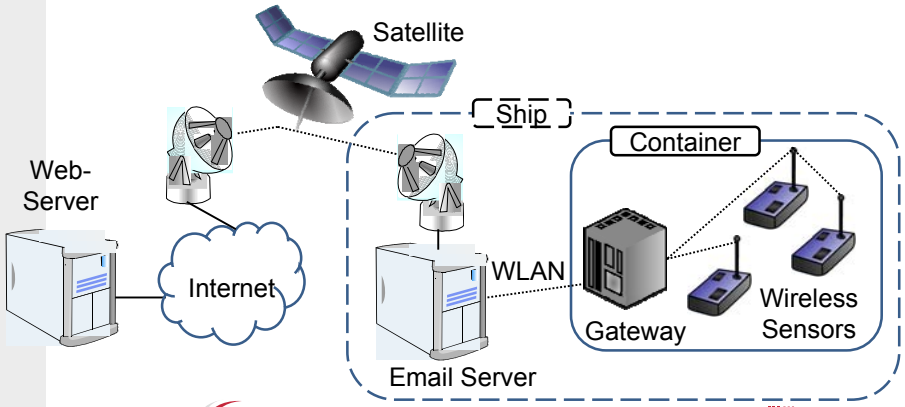
Installation in Costa Rica

- 4 pallets equipped with 4 sensors each [S]



External Communication

- Forwarding data from sensors to web-server
  - Using the vessel's email system



Webinterface

Mote-ID	Last message:	Temp.	Humidity	Voltage
1	2009-09-23 14:00:02	14.79 °C	93.0 %	2.8 V
2	2009-09-23 14:00:02	13.96 °C	94.0 %	2.81 V
3	2009-09-23 14:00:02	14.34 °C	95.0 %	2.84 V
4	2009-09-23 14:00:02	13.69 °C	81.0 %	2.8 V
5	2009-09-23 14:00:02	14.36 °C	102.0%	2.86 V
6	2009-09-23 14:00:02	15.2 °C	82.0 %	2.86 V
7	2009-09-23 14:00:02	15.57 °C	100.0%	2.75 V
8	2009-09-22 02:00:02	15.3 °C	97.0 %	2.82 V

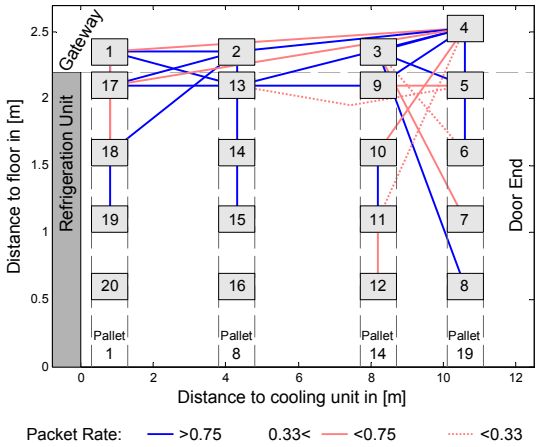
Signal attenuation by the fruits

- Water-containing goods hinder the radio communication of wireless sensors @ 2.4 GHz

Distance 0.5 meter

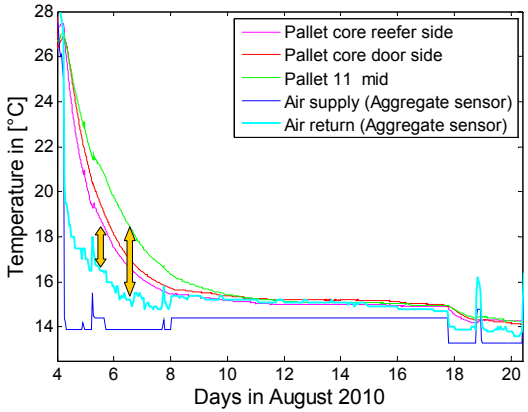
- ⅓ of all links completely failed
- ⅓ of all links was not available part of the time
- ⅓ of all links worked well most of the time

- Partly compensated by network
- New hardware?



The necessity for core temperature measurement

- The internal sensors of the aggregate help only little to estimate the banana temperature

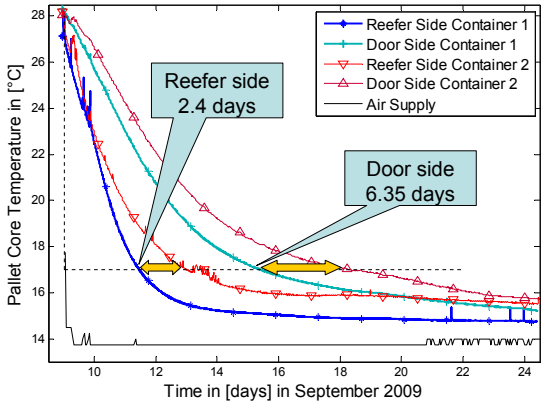


Temperature difference over length of container

- Bananas are cooled down by the container
  - Large differences in time required to achieve 17 °C

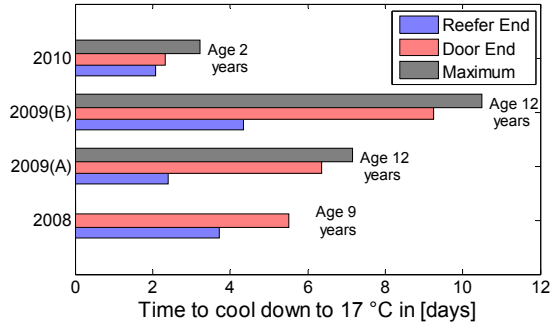
- Door-end ⇔ Reefer end

- Two containers of same type and year of manufacture ⇔



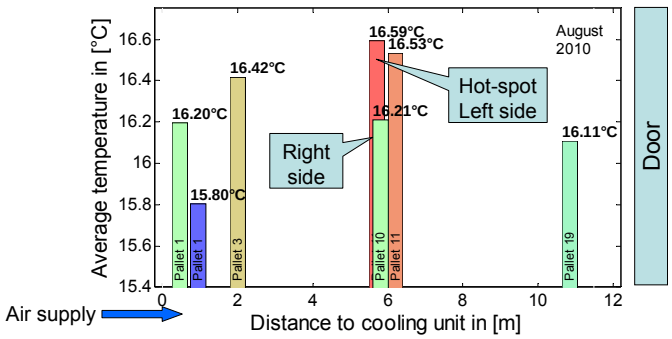
Comparison of 4 Experiments

- Large variations in age of containers
- Newer equipment cools faster, but local variations cannot be avoided
- The hot-spot can be at the door end or somewhere in the middle of the container



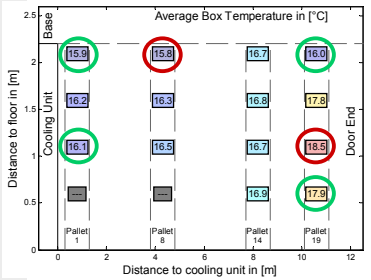
Location of hot-spots

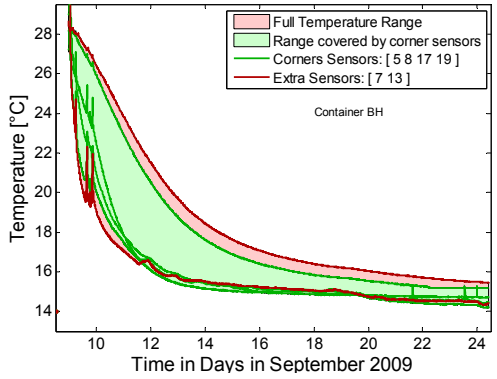
- Horizontal cut through the container
  - Average pallet core temperature in tier 5 (1.25 meter above floor)
  - Pallet 11 in the middle / left side is the hottest, but neighbor pallet on the right side almost normal.



Required sensor density

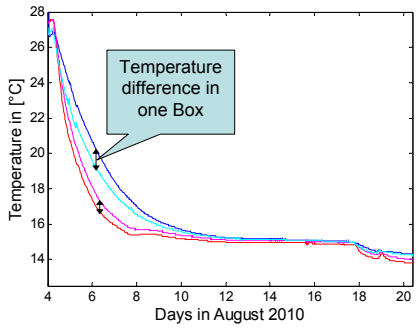
- 4 Sensors are not sufficient
  - Pallet at aggregate and door side / lowest and highest tier
- But where to place the extra sensors?





Accuracy of temperature measurements

- How accurate can we measure temperature inside a banana box?
  - Cooling air flows through the boxes → variations
  - Even loggers in similar positions (distance ~ 5 cm)
    ≈ 0.1 °C at end of transport
    Up to 1 °C during cool down



Accuracy of temperature measurements

- Pulp temperature measurement
  - Hurts the banana
  - Comparison: Logger temperature before opening of pallets ⇔ Pulp temperature → Logger in average 0.05 °C too high (σ = 0.085 °C)
  - Pulp temperature in centre of box 0.2 °C … 0.4 °C higher than side of box

Innovation Alliance

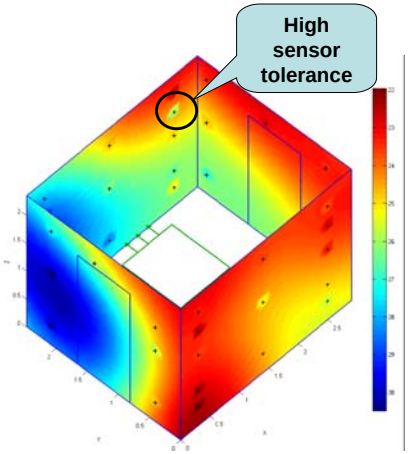
- New project starts in September 2010
  - 13 partner companies and 6 research institutes

Sea-Containers (Bananas)	Truck-Transports (Meat)	Software	RFID and Electronics	Ethylene Sensor
IMSAS	universitätbonn	aicas	ELBAU	IMSAS
ComNets	CARGOBULL TELEMATICS	BIBA	Texas Instruments	
cfs	IRUNGIS	ProSyst	ITEM	
ATB	KÜHN	Microsoft Innovation Center Europe		
Dole	WETRALOG	SEEBURGER BUSINESS INTEGRATION		
DHB TELEDATA				

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung
Federal Ministry of Education and Research

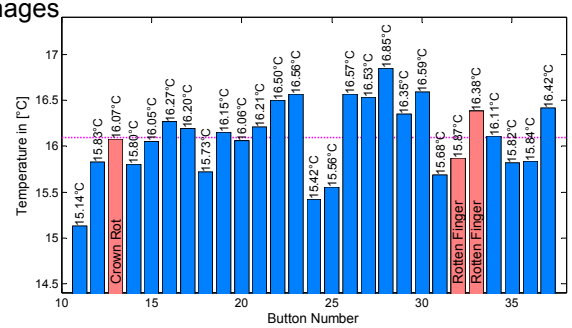
Intelligent data processing

- Not only forward data, but pre-process
  - Different algorithms (OSGi Software-Bundles) on demand, similar to App-Store for mobile phones
- Elements of the decision support tool
  - Spatial interpolation of temperature by Kriging
  - Prediction of future temperature curve
  - Shelf life models



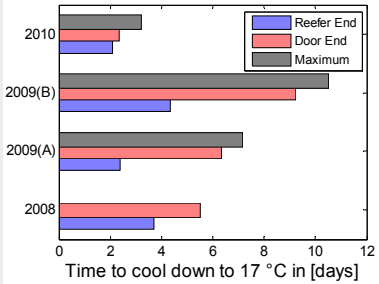
Relation temperature and quality

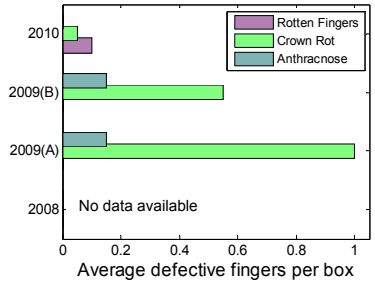
- No relation between box temperature and defects per box
- Further influence factors have to be checked
  - O_2, CO_2, Ethylene
  - Age at harvest
  - Micro biological load
  - Mechanical damages



Relation temperature and quality

- Relation to average quality per container
  - But no statistical evidence
  - Only on container level
  - No relation inside one container





Summary

- The pallet core temperature can show large variations
  - Differences in cool-down time
- Temperature is tricky to measure
  - The hot-spot can be anywhere, will be missed if only 4 sensors
  - Even inside one banana box $\Delta T \approx 0.5$ °C
- Relation of quality and temperature needs further evaluation
  - Other factors likes gases and biological variance
- The system will help to reduce losses by unwanted ripening
  - Accurate temperature monitoring is the basis for the further steps
  - Compensate different quality levels by FEFO planning

The End

Thanks for your attention

www.intelligentcontainer.com

Dr. Ing. Reiner Jedermann
University Bremen, FB1
Institute for Microsensors, -actors and –systems (IMSAS)
Otto-Hahn-Allee, NW1
D-28359 Bremen, GERMANY
Phone +49 421 218 62603, Fax +49 421 218 98 62603
Email rjedermann@imsas.uni-bremen.de

Jedermann, R: Autonome Sensorsysteme in der Transport- und Lebensmittellogistik, Dissertation Universität Bremen, Verlag Dr. Hut, 2009.