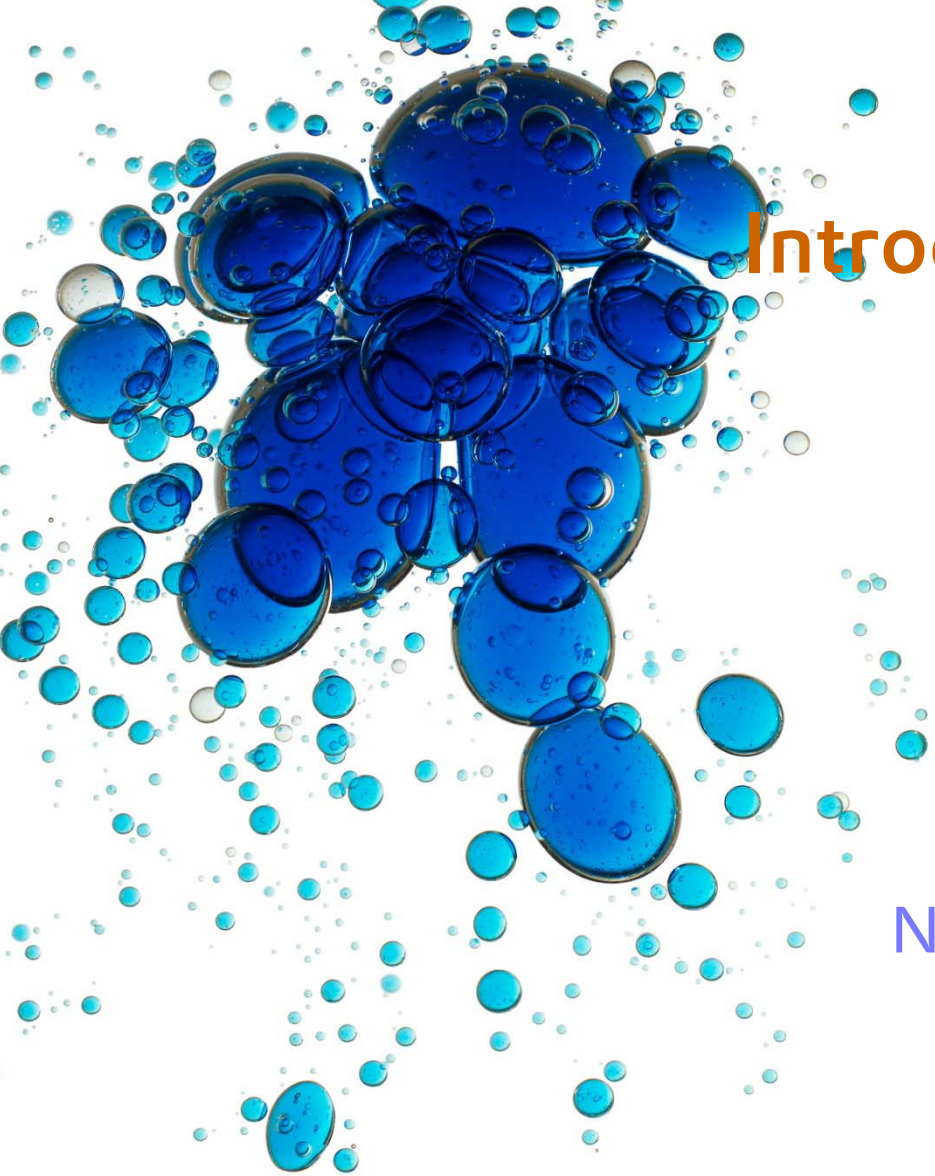


Introduction to Networked Embedded Systems

Christian Bettstetter

Professor and Institute Head

IEEE/ICE Summer School

Networked Embedded Systems

Klagenfurt, September 3, 2011

ALPEN-ADRIA UNIVERSITÄT KLAGENFURT | WIEN GRAZ

ICE

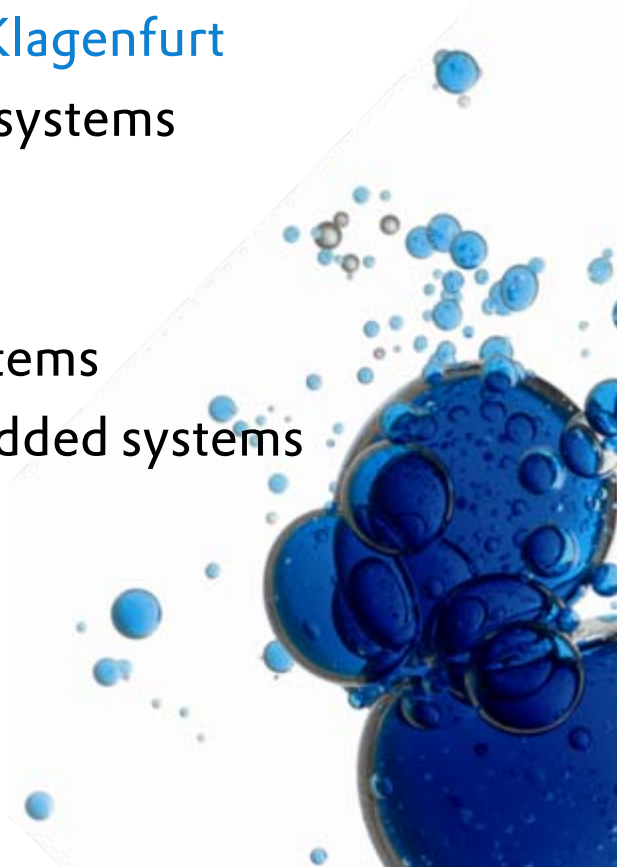
Welcome and Overview

What is this talk about?

- Warm-up for this summer school
- Introduction to applications and overview of research areas
- Umbrella talk for this school, giving links to all tutorials
- Advertisement: Examples of research done in Klagenfurt
- Personal perspective of networked embedded systems

What is this talk <u>not</u> about?

- Precise definition of networked embedded systems
- Comprehensive overview on networked embedded systems
- Technical content



Visions from the past …

The Wireless Century

People in 2010 will be equipped with wireless transceivers attached to hats or something else.

The transceiver will react to myriads of vibrations trying to find connections.

Robert Sloß: Das drahtlose Jahrhundert.
In: *Die Welt in hundert Jahren*, Berlin, 1910.

The automatic city Elektropolis

Figure copyright protected.

Erich Kästner: *Der 35. Mai oder Konrad reitet in die Südsee,* Atrium, Zürich, 1931.

Evolution of Wireless Networking

Mobile Telephony → Mobile Internet → Mobile Multimedia → Higher data rates More functionality

GSM

GPRS, WLAN

UMTS, WLAN, LTE

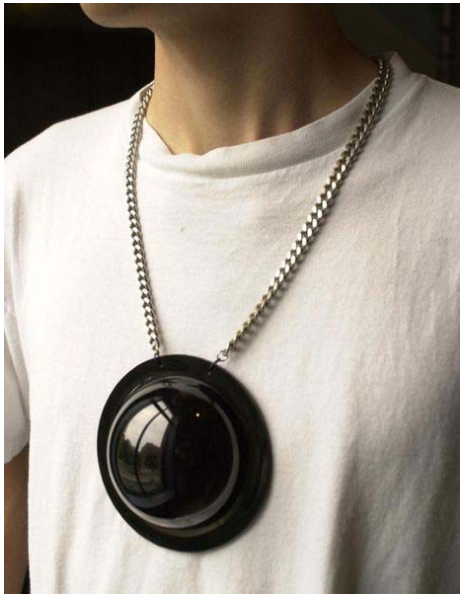
GSM	Global System for Mobile Communication
GPRS	General Packet Radio Service
WLAN	Wireless Local Area Network
UMTS	Universal Mobile Telecommunication Network
LTE	Long Term Evolution

Trend: Networked Embedded Systems

- Computer processors are increasingly embedded into everyday objects and become invisible.
- More and more objects are networked. An "Internet of things" is evolving.
- Sensors serve as an important interface: they link the real world to the virtual one.
- Completely new applications arise.

Application Domain: Wearable Computing

Researchers of a European project on wearable computing for fire fighters, doctors, and plane and car manufacturers.



Wireless Webcam

Source of right figure: wikipedia.com (2007)

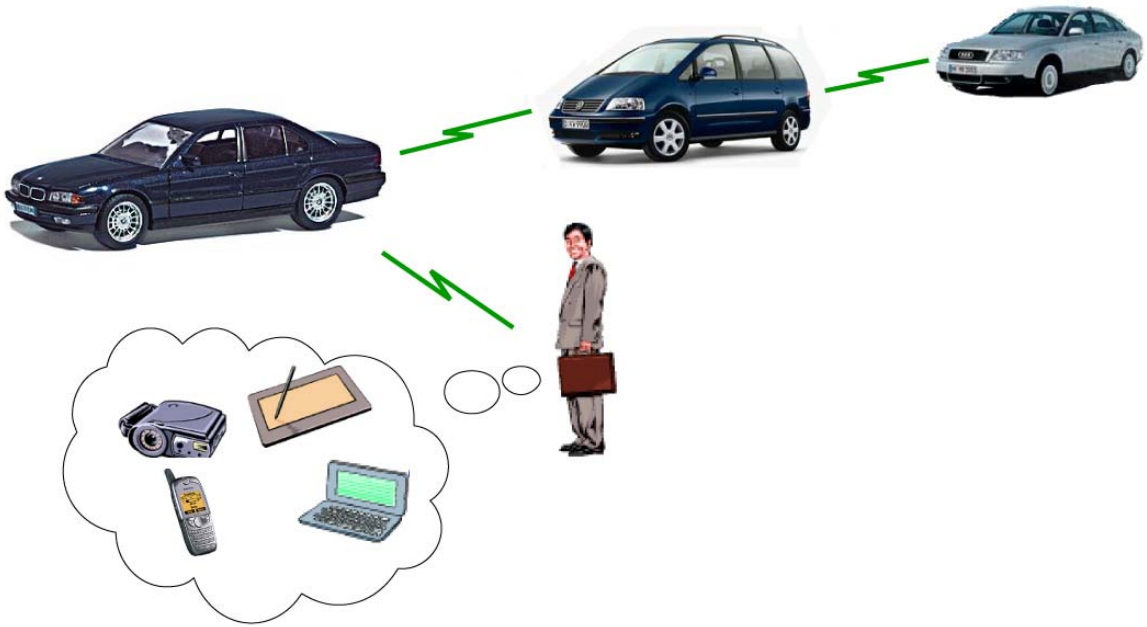
Application Domain: Vehicular Communications

Between cars

- Accident warnings
- Cognitive, self-driving cars

Within the car

- Between personal devices
- Between sensors



Application Domain: Sensor Networks

Sensors measure, transmit, and process data.

MICAz (xbow)

BTnode (ETHZ)

Monitoring of humans

- Assisted living and medical engineering

Monitoring of fauna and flora

- Warning systems for environmental disasters
- Animal observation

Monitoring of machines, vehicles, buildings

- Predict failures in industrial equipment
- Military applications

→ Talk of Wei Chen

What data do sensors measure?

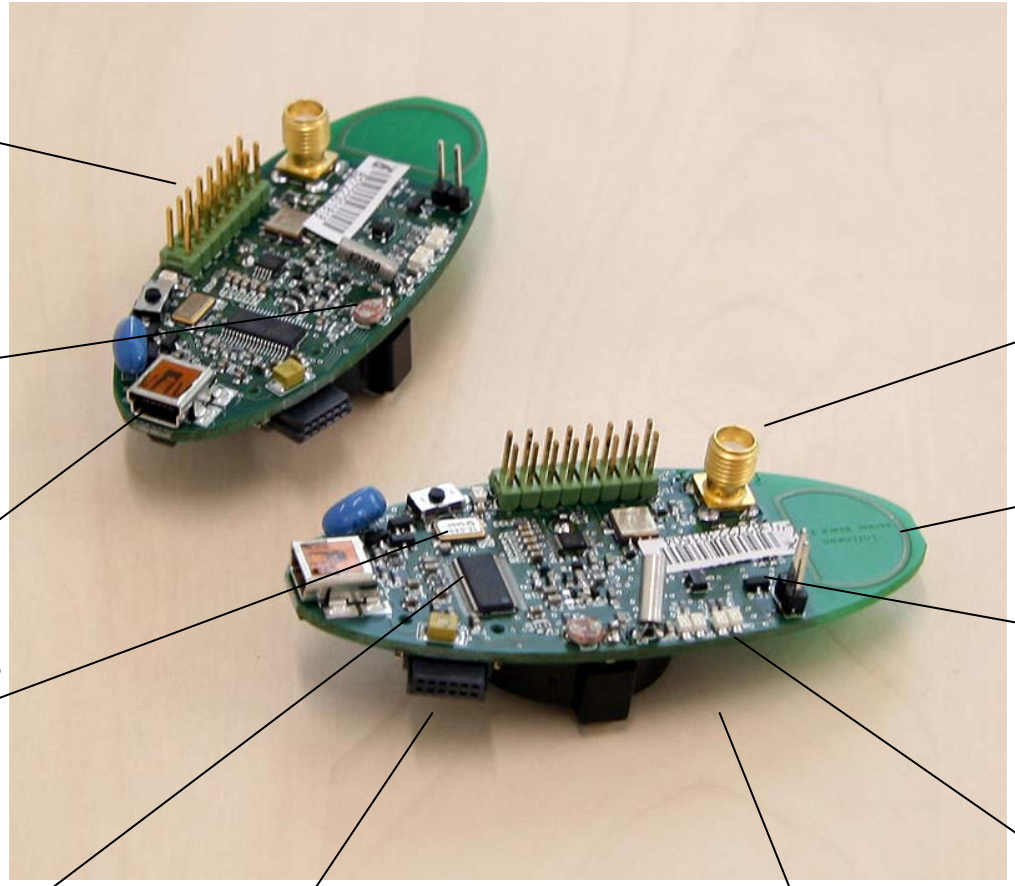
- Temperature
- Light
- Pressure
- Position
- Acceleration
- Electric and magnetic field
- Sound level
- Humidity
- Viscosity (liquids)
- Density (liquids)
- Conductivity
- …

Pressure sensor

Humidity sensor

Sources of figures: www.gesensing.com

EYES Wireless Sensor Node



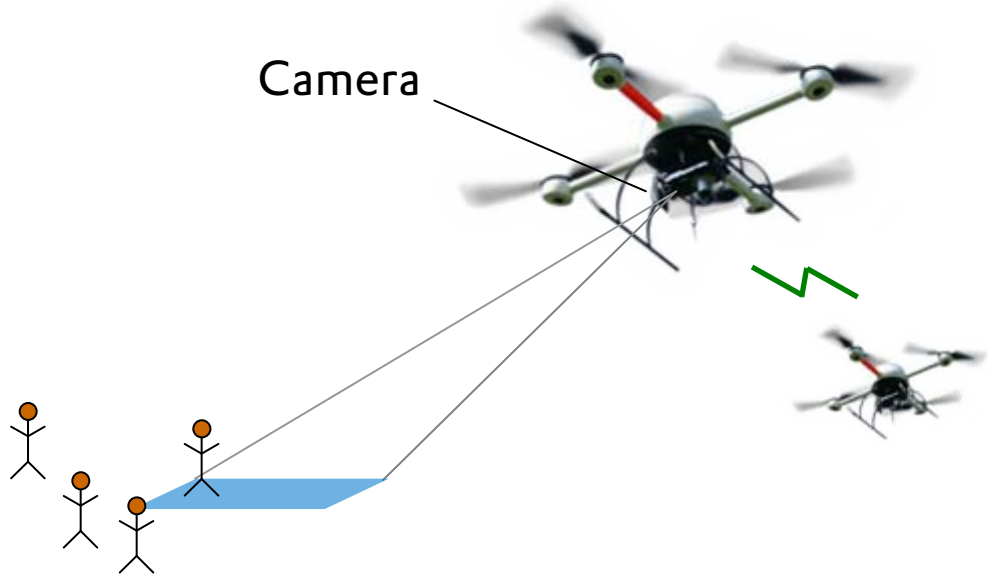
Health Applications

PillCam for capsule endoscopy

- Physiological monitoring (ECG, heart rate, respiratory rate, temperature, posture)
- Biochemical monitoring
- Imaging inside the body

→ Talk of Ian F. Akyildiz

Application Domain: Autonomous Aerial Robots



Applications

- Surveillance and military applications
- Disaster response (fire, earthquakes, tsunamis)
- Monitoring of industrial sites

→ Lab visit

→ Talk of Andrea Cavallaro

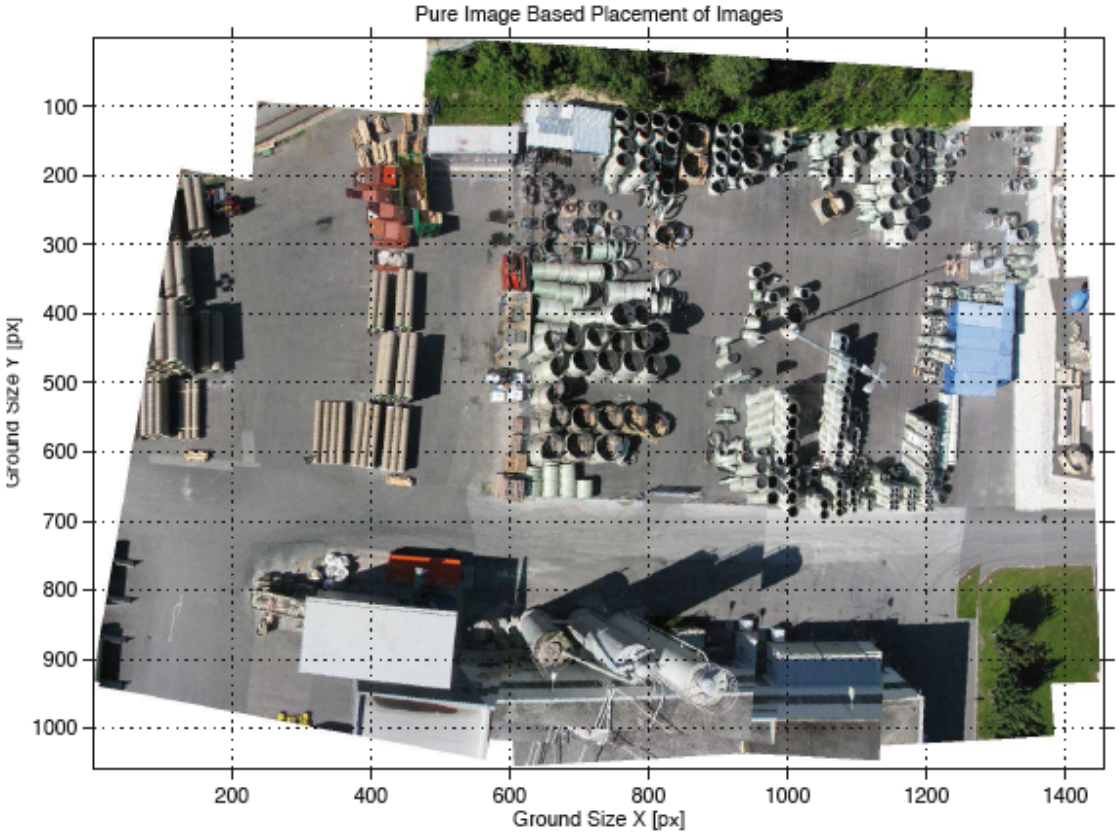
Example of Klagenfurt work: Collaborative Microdrones

Mission planning

Wireless communications

Example of Klagenfurt work: Collaborative Microdrones

Image stitching

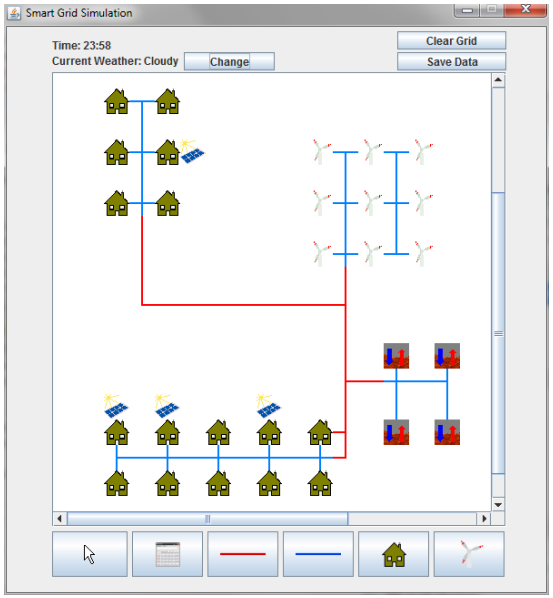


Example of Klagenfurt work: Collaborative Microdrones

A video is shown here.

Application Domain: Smart Energy Grids

- Integrate local intelligence to electrical devices, generators, storages
- Dynamically adapt depending on demand, supply, and network load
- Consumers can play a part in optimizing the operation
- Predict future energy and network requirements



Networked Embedded Systems

Sensing and perception

Signal processing

Communications and networking

Hardware architecture

Programming, platforms, and OSs

Realtime systems

Control engineering

Energy management and harvesting

Environment modeling and data management

Resource management

Security and privacy

User interface

Ethical, legal and social implications

Applications

→ Talk of Oliver Vitouch

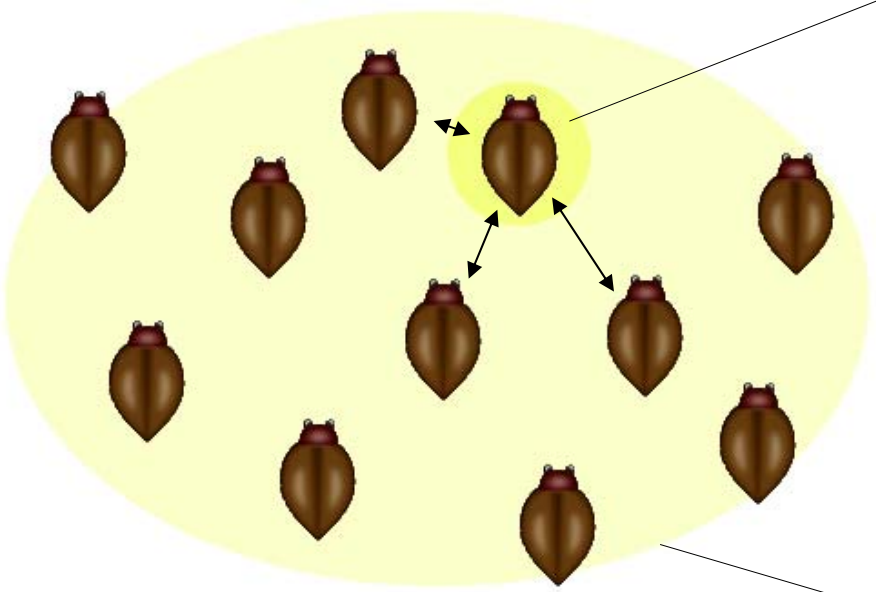
Some desired system properties

- Be energy efficient and achieve long network lifetime
- Operate in a distributed manner
- Be scalable to numerous network entities if needed
- Be dependable to provide security, safety, availability
- Be able to produce cheap devices
- Provide means of self-organization (e.g., autoconfig)

Synchronous flashing of fireflies in south-east Asia

A video is shown here.

Why is this algorithm appealing?



Individual Entity („Firefly“)

- Simple behavior rules
- Local view

Emergence

Entire System (“Swarm”)

- Solves complex task
- Is adaptive to changes
- Is very scalable

C. Prehofer, C. Bettstetter: Self-Organization in Communication Networks: Principles and Design Paradigms. *IEEE Communications Magazine*, Feature on Advances in Self-Organizing Networks, July 2005.

Example of Klagenfurt work: Self-organizing synchronization

- Transferred and adapted algorithm from biology to wireless systems
- Studied performance in terms of time-to-synchrony and precision
- Proven convergence to synchrony
- Implemented algorithm on programmable hardware platforms
- Cooperation with Max Planck Institute Göttingen and DOCOMO




A. Tyrrell, G. Auer, C. Bettstetter: Emergent Slot Synchronization in Wireless Networks. *IEEE Transactions on Mobile Computing*, 9(5):719-732, May 2010.

J. Klinglmayr, C. Bettstetter: Self-Organizing Synchronization with Inhibitory-Coupled Oscillators: Convergence and Robustness. *ACM Transactions on Autonomous and Adaptive Systems*. Accepted for publication.

Why is self-organization an important ICT research topic?

Trend toward a higher level of self-organization in ICT

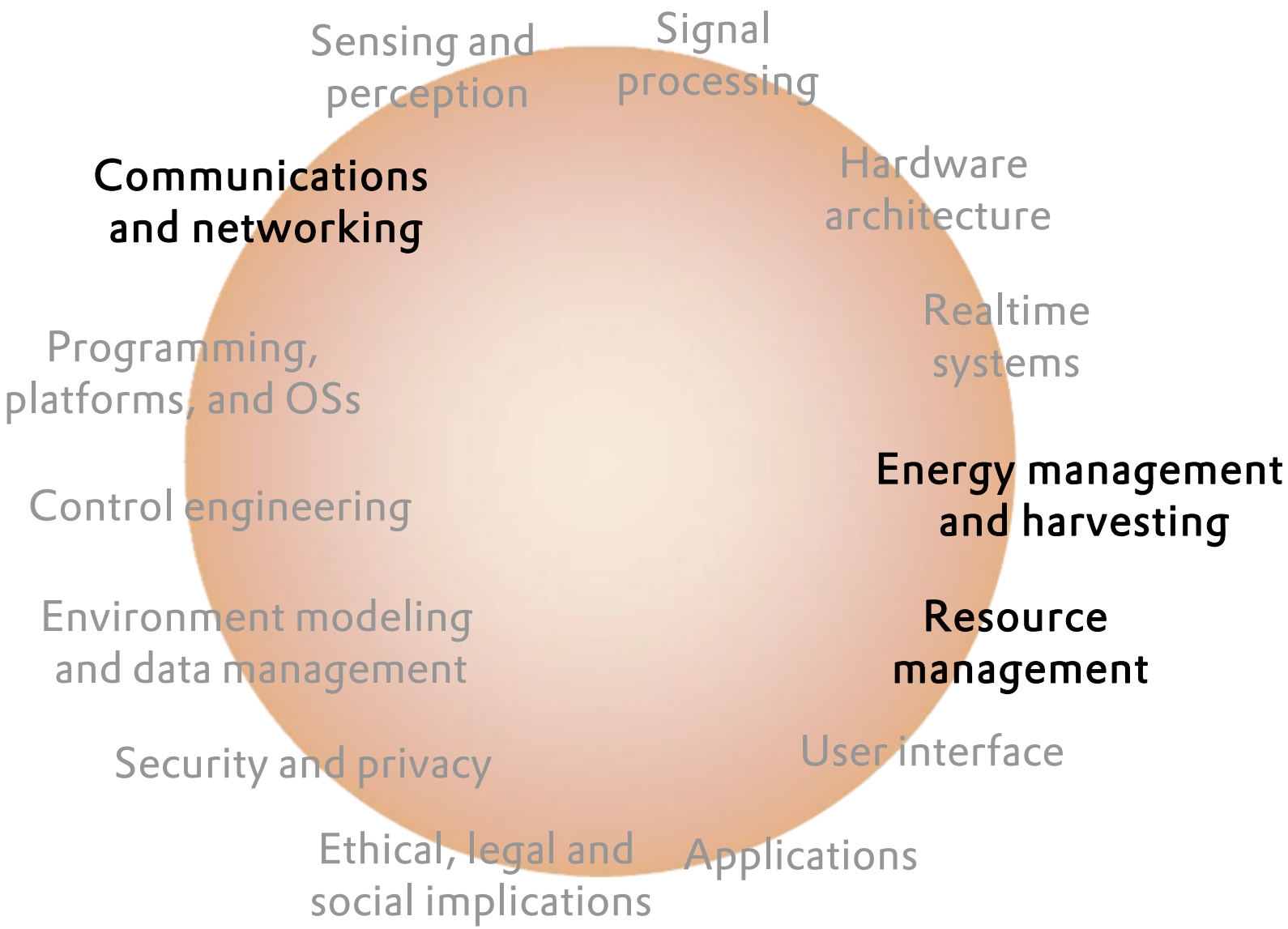
- Autoconfiguration in the Internet
- Infrastructureless ad hoc networks
- Peer-to-Peer networking
- Web 2.0, Wikis, social platforms

Increasing complexity
and dynamics

Requirements

- Adaptability
- Distributed operation
- Autoconfiguration

Networked Embedded Systems



Example Research Topics

Communications and Networking

- Localization and synchronization → Talk of Kay Römer
- Medium access
- Routing and clustering
- Data fusion → Talk of Carlo Regazzoni
- Consensus reaching and task allocation
- Service discovery

Energy and Resource Management

- Which energy reservoirs to exploit?
  Constraints: availability, max. power, size
- How to distribute energy in the network?
  Energy provider and consumer might be dislocated.
- How to control the distribution?
  "Proper amount of energy in the right place at the right time"

Summary: Main messages to take home

- Networked embedded systems is a multidisciplinary area
- Various applications, many more to come
- Applications will have impact on society
- Conducting research in this area is a nontrivial task
- Summer school will give introduction to some specific areas