VDI-Arbeitskreis LANDTECHNIK in Köln

Autonome Systeme in Haus und Hof / auf Feld und Straße

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Overview

- Motivation
- Applications for robotic systems
- Findings from BoniRob Development
- Summary

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Motivation aus Zukunftsfaktoren (ZF) / Megatrends

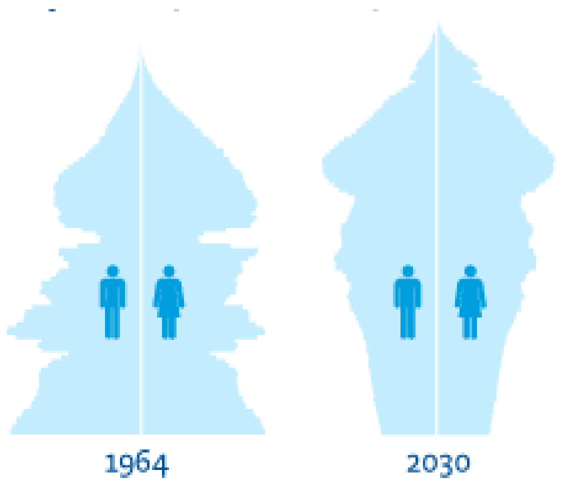
Grundlegende ZF
(Mensch / Biosphäre)
Trends

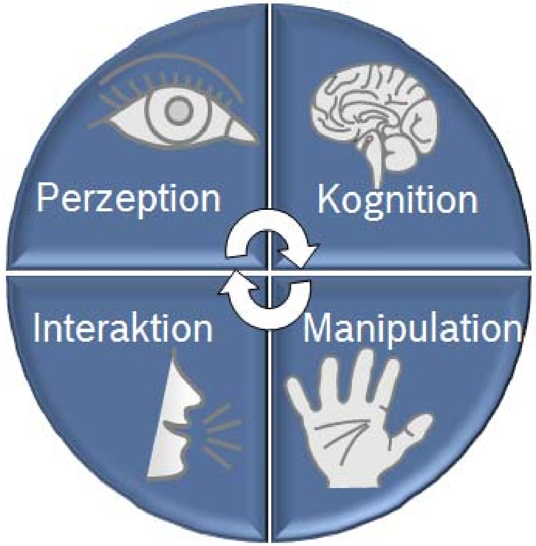
↔

Verstärkende ZF
(Technologie / Politik)
Technologien

↔

Resultierende ZF
(Wirtschaft / Gesellschaft)
Erfolgsfaktoren





Autonome Systeme
Assistenzsysteme

→

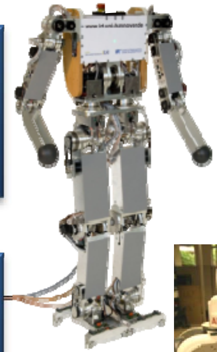
- Lebensqualität, Komfortgewinn
- Wirtschaftlichkeit (Kostenersparnis, Produktivität)
- Performanz-, Qualitätsverbesserung

Markt noch in frühen Phase und stark fragmentiert

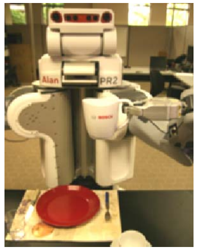
1. Private services
- Vacuum
- Lawn mower

2. Professional services
- Cleaning machines
- Production assistant

3. Edutainment & leisure
- Toy, entertainment
- Education



4. Care & attendance
- Attendance, supervision
- Assistance



5. Security & surveillance
- Private
- Professional

6. Logistics
- Courier systems
- Person transportation

7. Public Relation
- Fair, museum guide
- Store guide

8. Field robots
- Agriculture
- Forestry

9. Medical / Assistance rob.
- Surgery
- Exo, Rehabilitation

10. Military & Defence
- Intelligence
- Bomb Disposal

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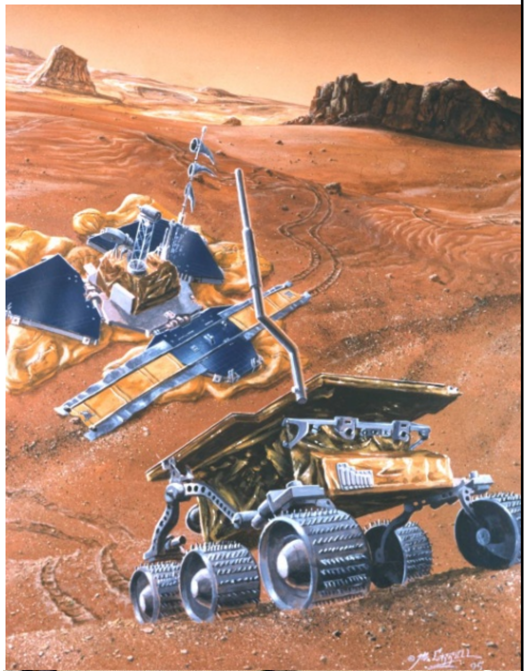
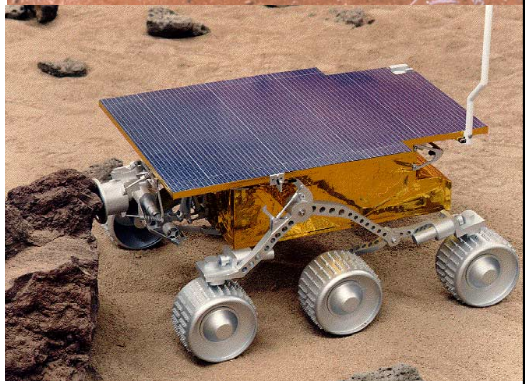
Typical attributes of mobile autonomous systems

- **Autonomous**: Robot decides

  …. However, autonomy level is not only a matter of human independence, but also of mission complexity and environmental complexity …
- **Mobile**: Non stationary, typically wheel-based
- **Unstructured**: Environment not customized for robot operation
- **Dynamic**: Environment is changing
- **Unsafe**: Hazards exist in environment
- **Uncertain**: Not all relevant environmental states are completely observable and detectable

  ➔ Key to success: Statistical instead of deterministic methods





Mars pathfinder, NASA

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Beispiel Autonomer Rasenmäher (Bosch Indego)

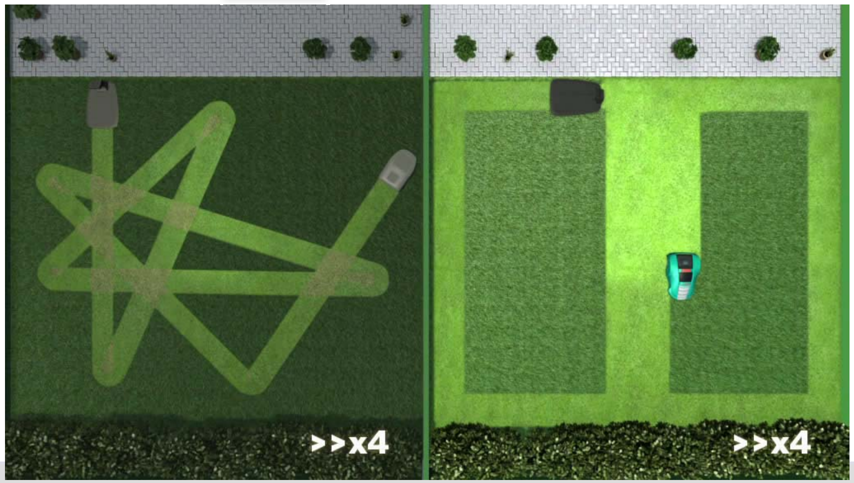
Kundennutzen

- Lebensqualität, Arbeitserleichterung
- Garantierte Abdeckung, Effizientes Mähen

Zufallsnavigation

Effiziente Mähstrategie

siehe Youtube: „Bosch Indego“



Hauptbarriere

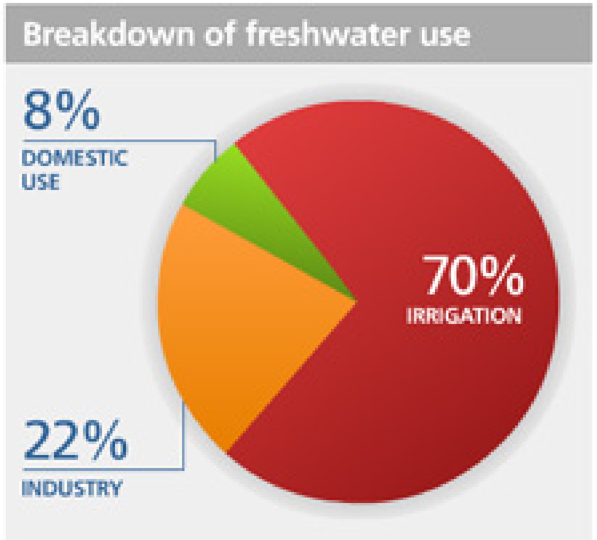
- Massenmarkt-taugliches kognitives System
- Probabilistische Inferenz (z.B. Multihypothesen-Tracking) robust implementiert auf µCs

Megatrends lead to dramatic changes in agriculture

- **Shortage** of **resources**
  - **Arable land**: 1950: **0.52** ha/person; (2000: **0.26**)
  - **Fertilizers**, e.g. phosphor availability: 50 – 380 years
  - **Water**: 70% of freshwater consumed in agriculture
  - Skilled **labor** and seasonal workers

- **Growing population**: 9.1 bn. people until 2050 (UN models: 7.8 - 11.9 bn.)
- Eating habits are changing, e.g. **organic farming** (2015: USD 104.5 bn.)

- Agriculture most vulnerable to the impacts of **climate change** but also one of its reasons



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Automation in Agriculture

Adding autonomous capabilities to existing machines – e.g. GPS-based guidance and diagnostic tools

Trimble Guidance Systems

Master-Slave systems
„One user controls multiple machines“

John Deere / Navcom / CMU

Hemisphere GPSteer + Outback S3

Green-house / nursery robots

Harvest Automation Inc.

Multi-purpose agriculture robots, adaptable to specific tasks

Bosch / Amazonen-Werke / HS Osnabrück

Mature market — *Recently introduced systems* — *Future market*

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The BoniRob[1)]: A Multi-Purpose Agricultural Robot

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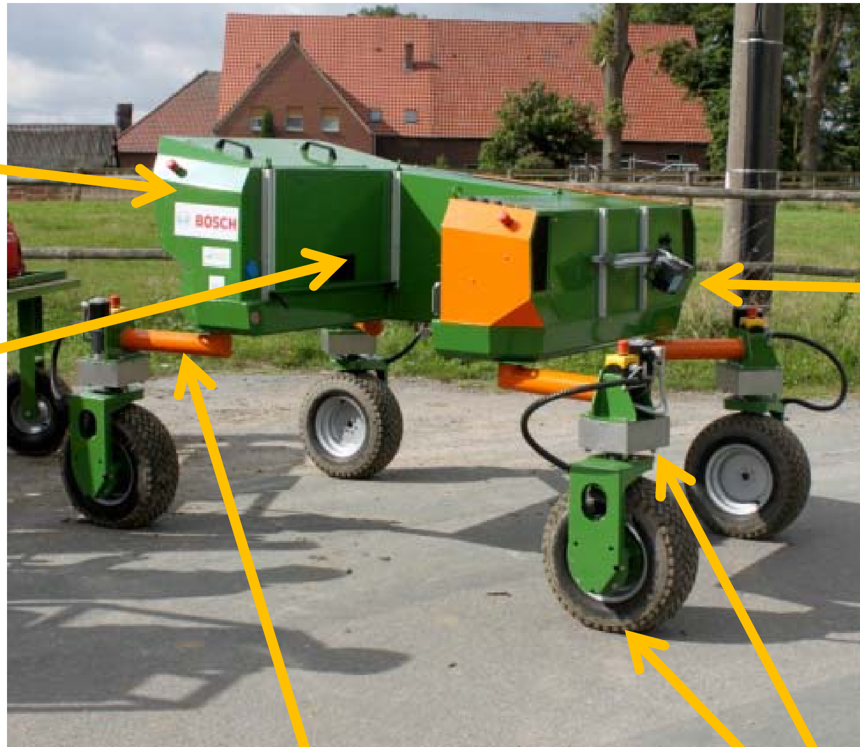
Invented for life



Powered by batteries and a fuel generator (range extender)

Slot for application module

3D sensing for autonomous navigation (optionally navigation based on GPS)

Reconfigurable joints (adaptive track width)

Total of 12 DoF

Easy exchange of application modules

1) Developed by Amazone, Bosch, HS Osnabrück in diverse publically funded projects (BMELV, BLE, Interreg) since 2008 (projects BoniRob, RemoteFarming.1)

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History of Research Activities

Partners:
Amazone,
HS Osnabrück

i.o tec electronic solutions

Partners:
InMach,
FhG

InMach Intelligence makes the difference

Fraunhofer

2008-2011:
publically funded project (**BMELV**)
„BoniRob“

- Autonomous phenotyping (scouting) in row cultivation

2011-2014:
publically funded project (**BMELV, BLE**)
„RemoteFarming.v1“

- Shared autonomy for mechanical weed control in organic farming

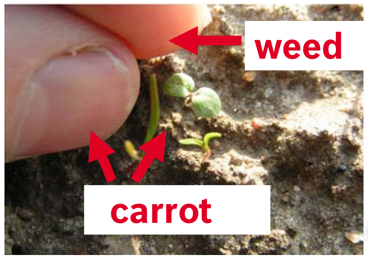
2013-2016:
publically funded project (**BMBF**)
„AgriApps“

- Application modules for special cultures

Agritechnica 2009

DLG Feldtage 2010

„RemoteFarmer“



Weed control in nurseries (box trees)

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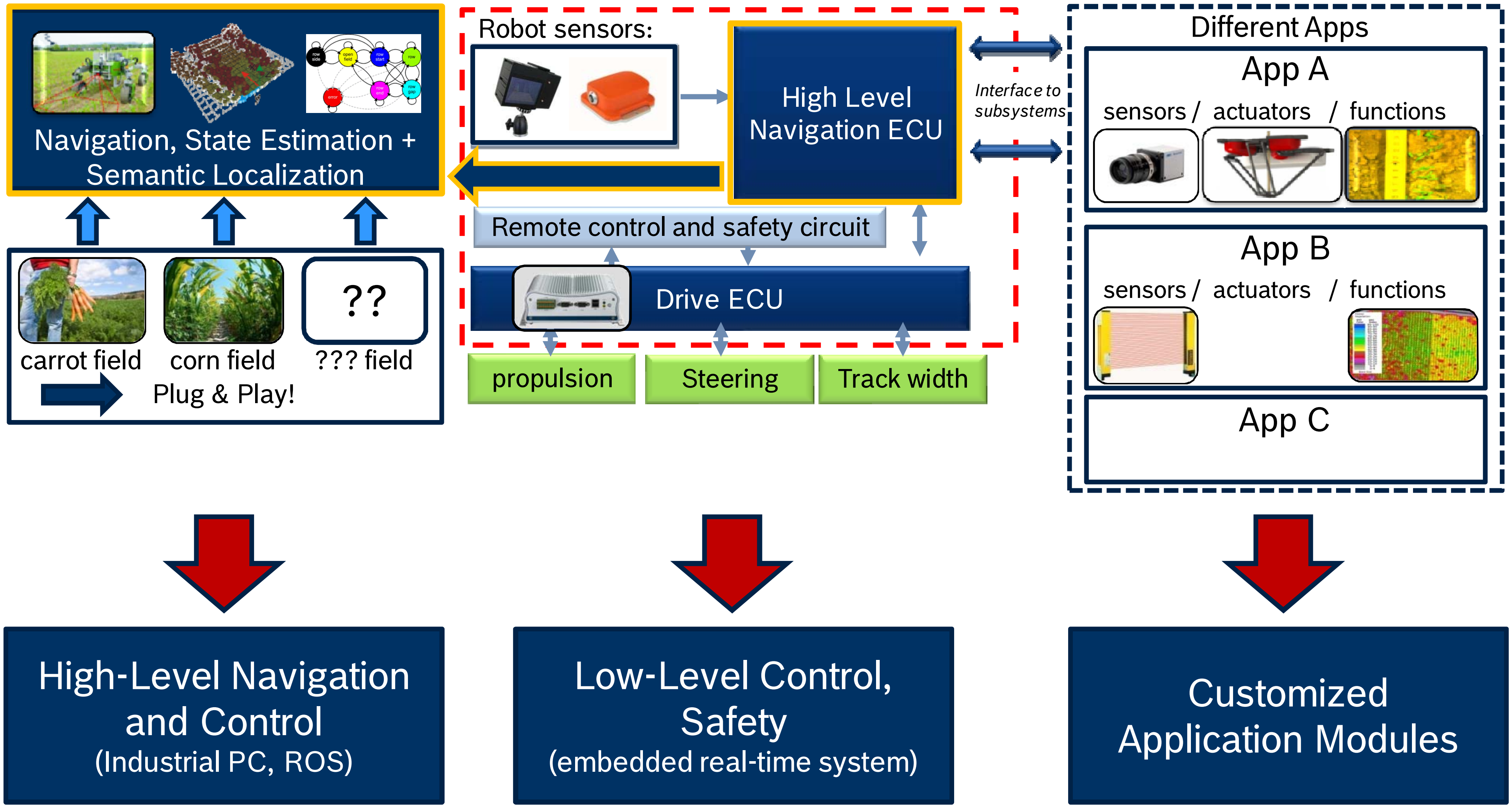
The BoniRob: Basic Modules



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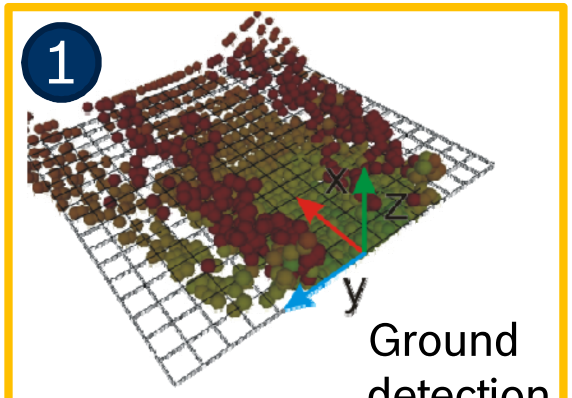
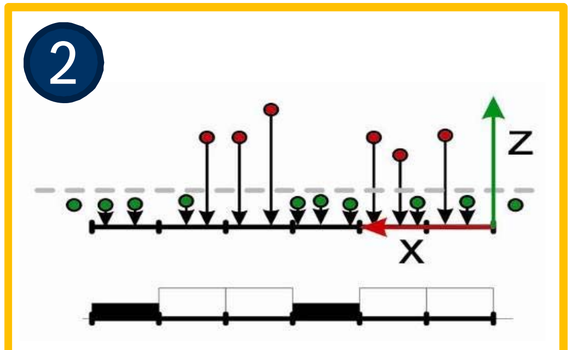
Navigation on row by means of semantic localization and mapping



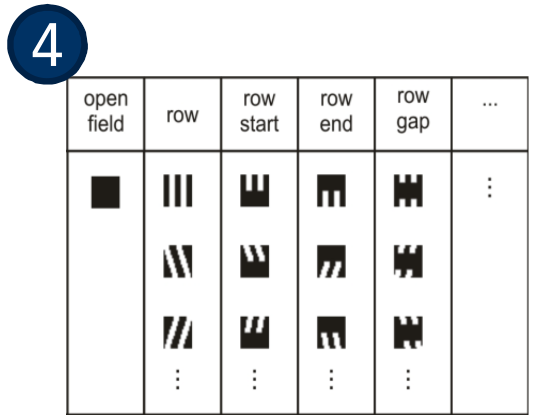
Ground detection



Thresholding

Pattern extraction

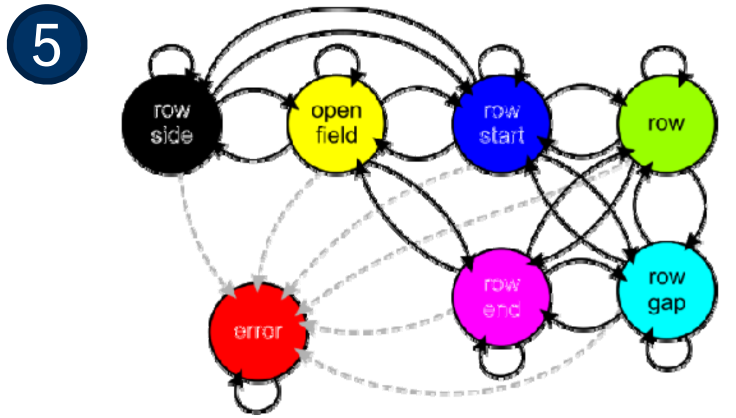
Correlation



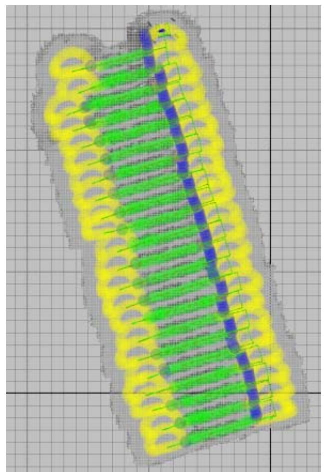
Database

Internal robot states

probabi-lities



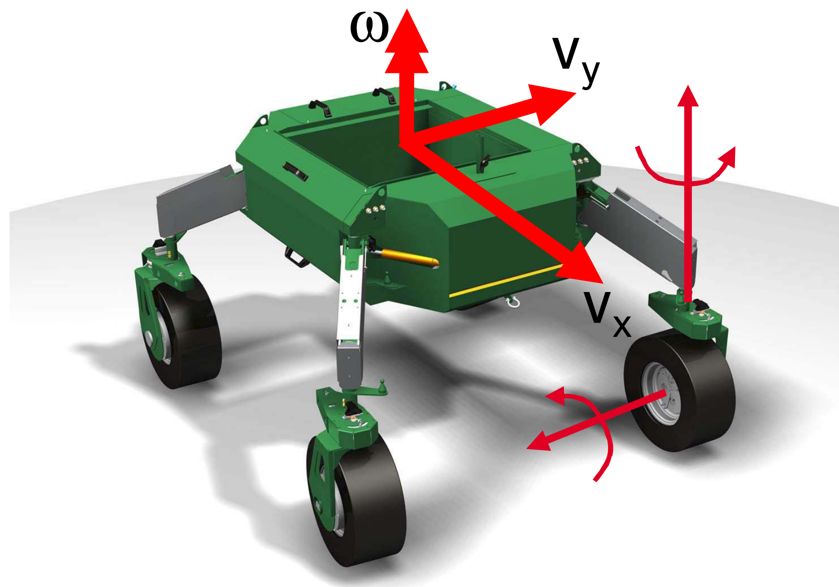
probabilistic state automaton

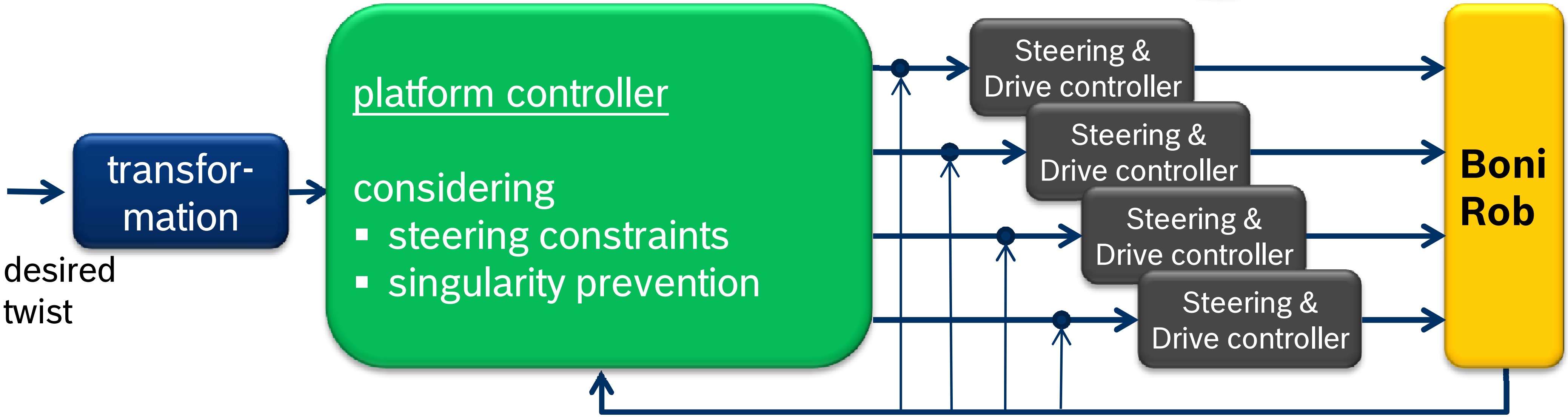


U. WEISS et.al.,
“Semantic Place Classification and Mapping for Autonomous Agricultural Robots”, IROS 2010

Kinematics and low-level control of BoniRob

- 4 steered drive wheels:
  - (quasi-)omnidirectional
  - over actuated system
- Abstraction:
  twist vector (global speed & angular velocity) → wheel steering & velocity





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Examples for BoniRob application modules

Scouting

- **Quality** / data: Health state, bio mass, morphology

Soil analysis

- **Quality** / data: Soil compaction, moisture, nutrition

Precision spraying

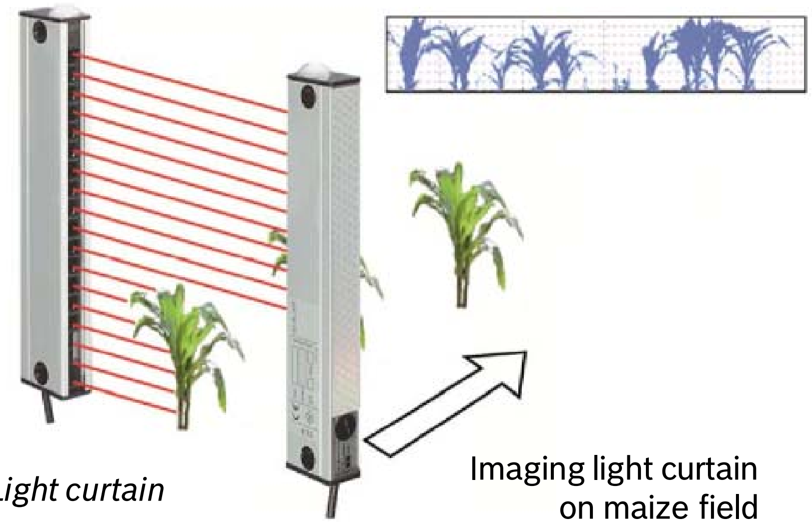
- **Ecology**: Less pesticides, less soil pollution

Mech. weed control

- **Productivity**: Organic farming, nurseries

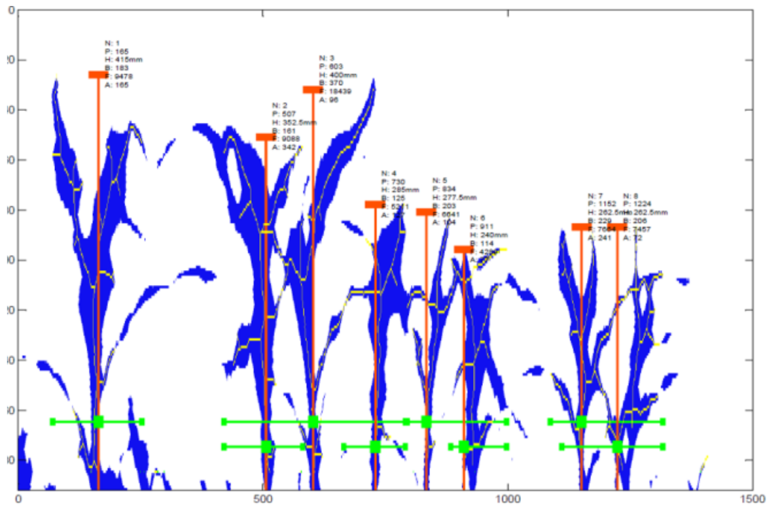
Selective harvesting

- **Productivity**: Asparagus; Lettuce Strawberries



Light curtain

Imaging light curtain on maize field



A. RUCKELSHAUSEN et.al., "**Sensor and system technology for individual plant crop scouting**", ICPA 2011

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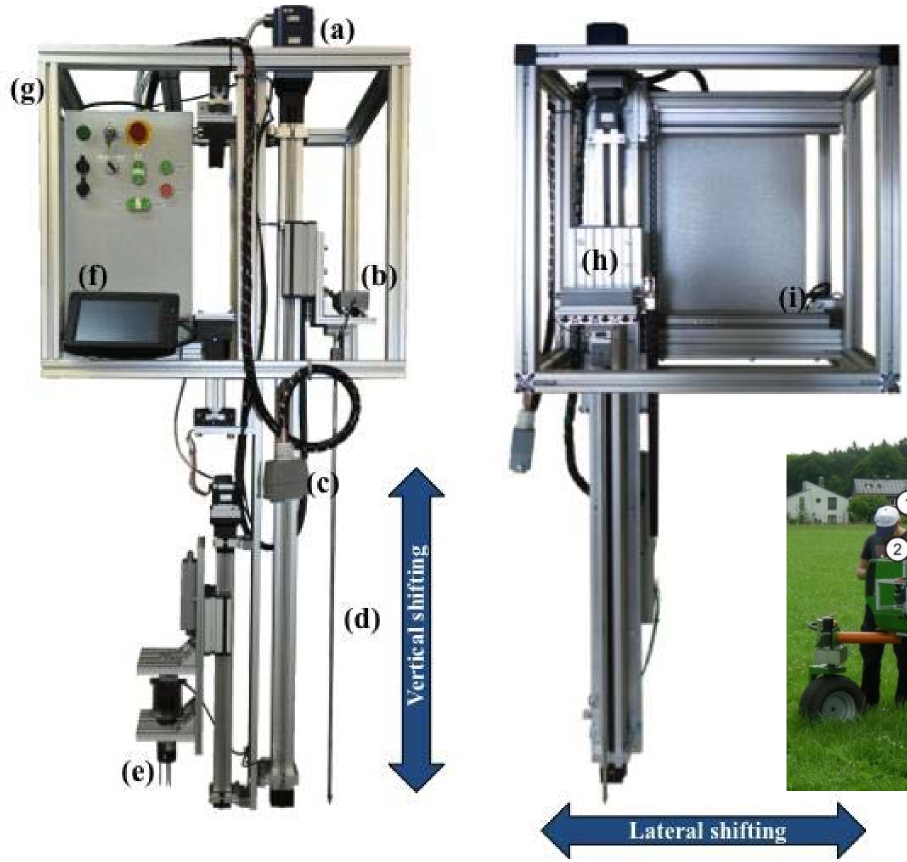
Example Soil Penetrometer: Delivers Compaction Map

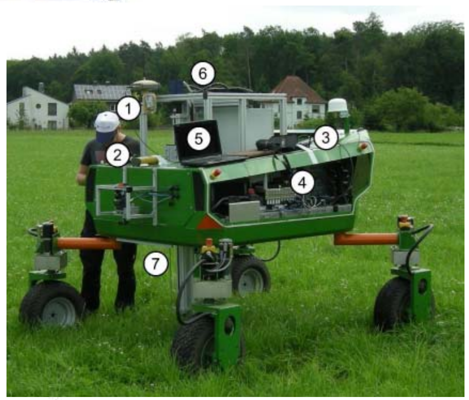
Soil Pentrometer App applied with BoniRob in SmartBot project (funding by Interreg)

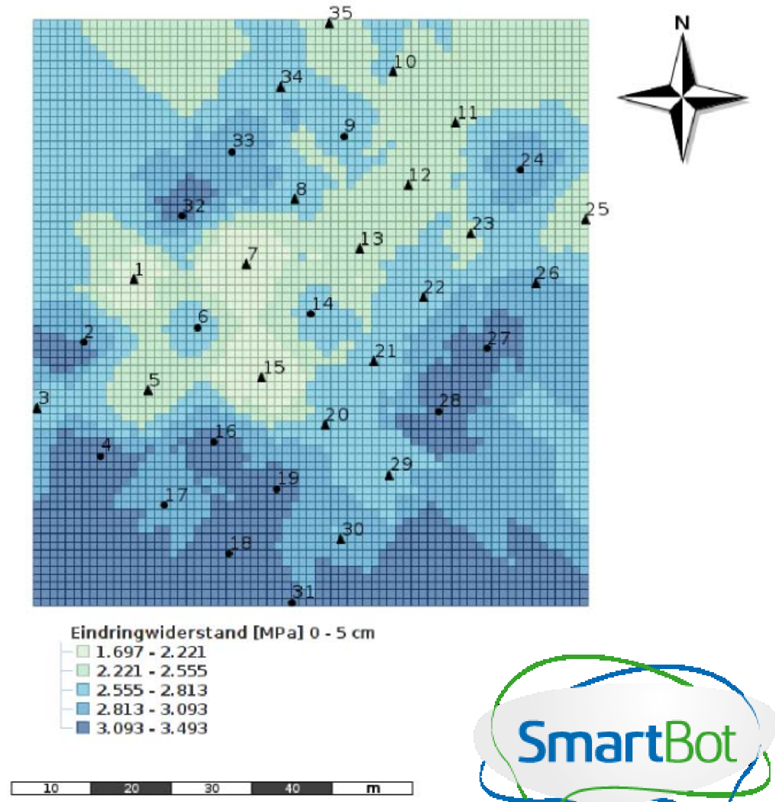
courtesy of

Hochschule Osnabrück
University of Applied Sciences

COALA® nature · technology · food







SmartBot

M. GÖTTINGER et.al.,
"**GNSS-based navigation for the multipurpose field robot platform BoniRob to measure soil properties**", VDI-Tagung, 2014

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State of the Art – Mechanical Weed Control

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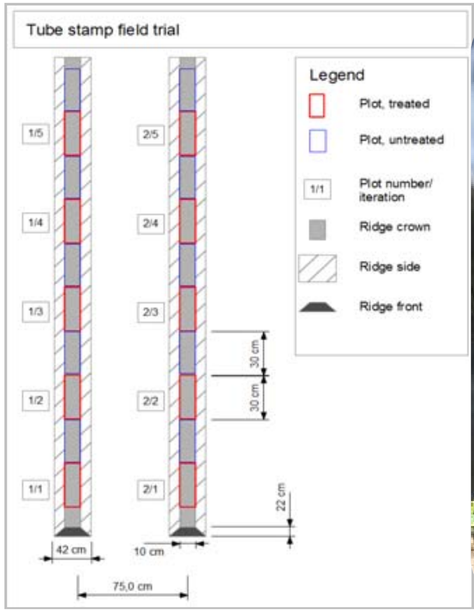
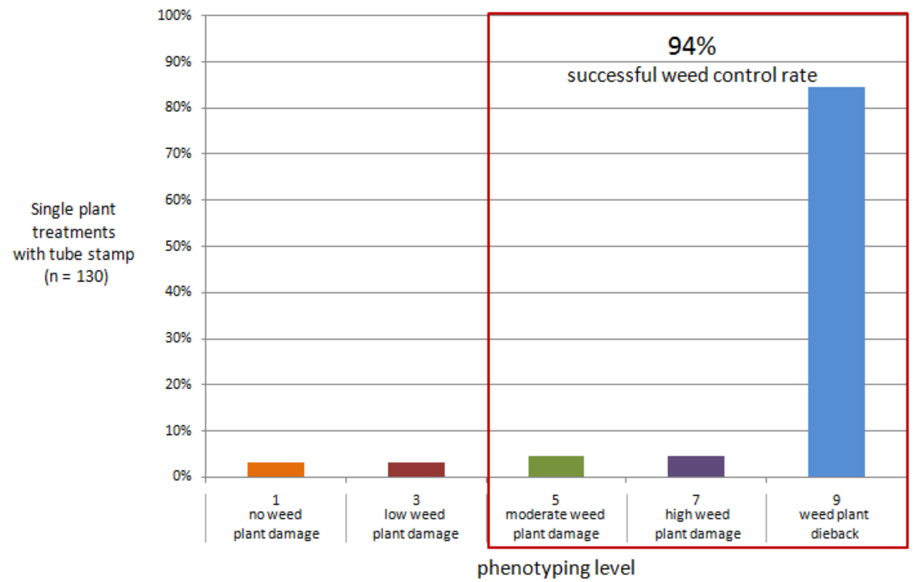
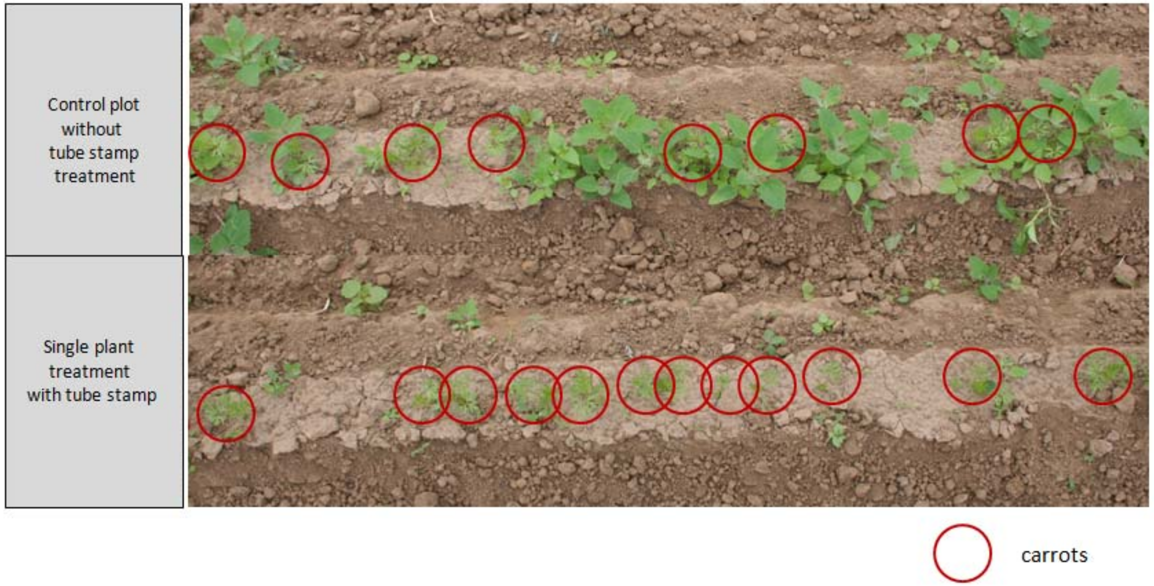


Level	Description
1	no weed plant damage
3	low weed plant damage
5	moderate weed plant damage
7	high weed plant damage
9	weed plant dieback





Source: Langsenkamp et al., „Tube stamp for mechanical intra-row individual plant weed control, 18th World Congress CIGR (2014)

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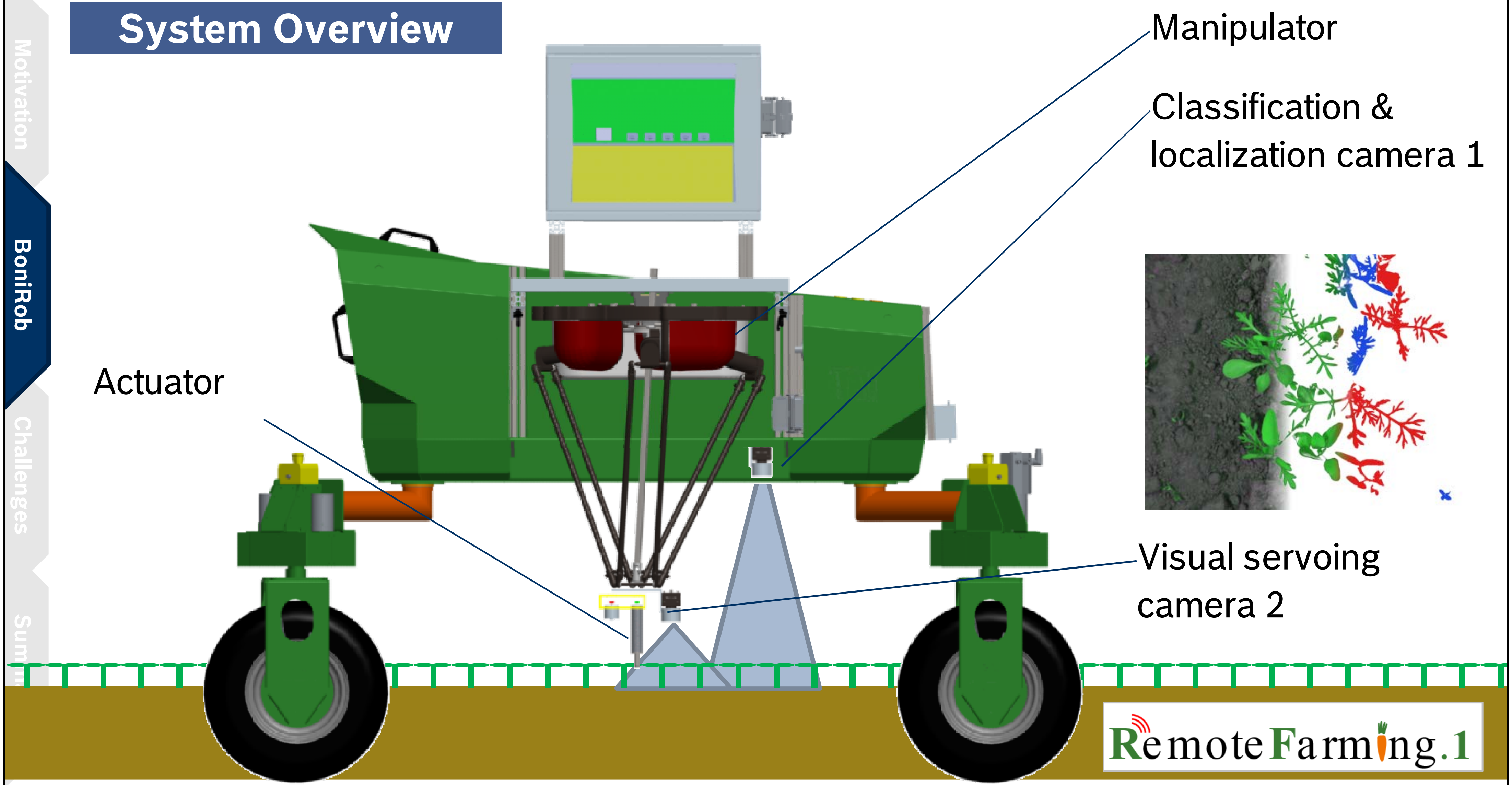
Example Application Module – Mechanical Weed Control

System Overview



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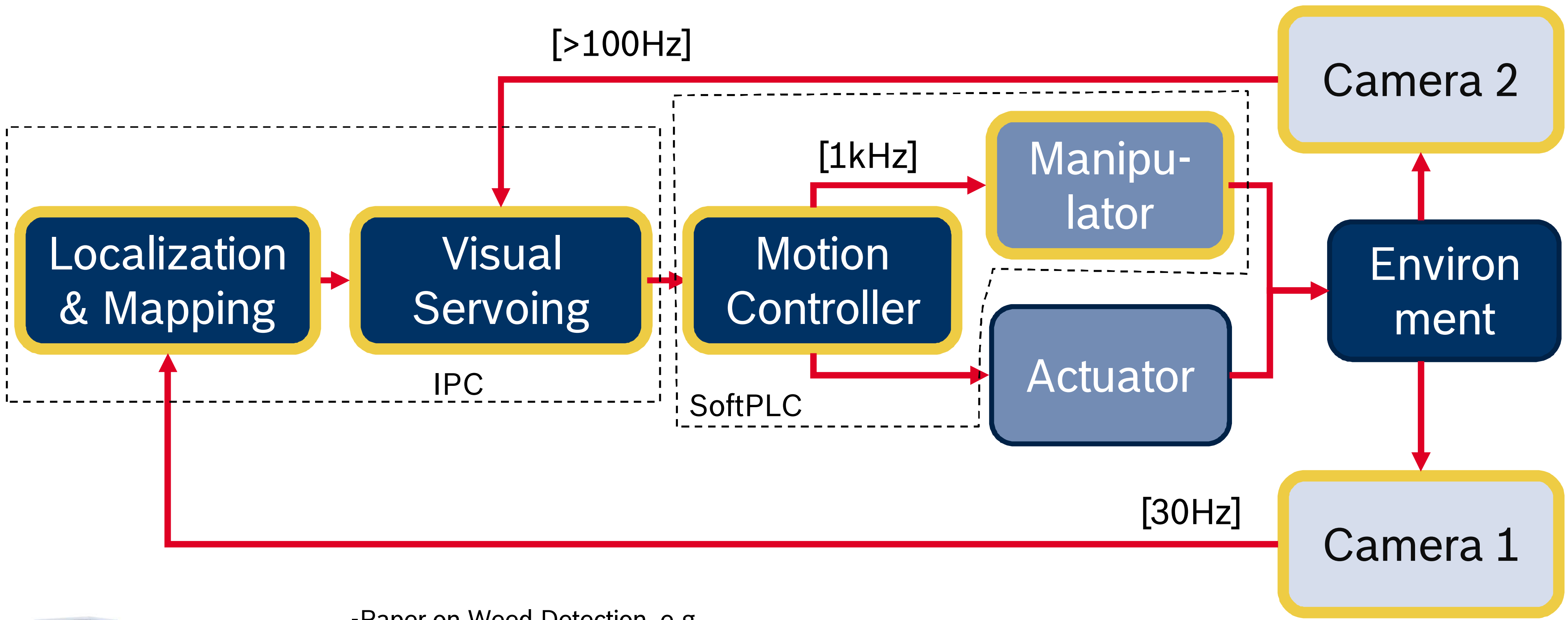
Example Application Module – Mechanical Weed Control



-Paper on Weed Detection, e.g.
S. HAUG et.al.,
“Plant classification system for crop/weed discrimination without segmentation”
IEEE Conf. Applications of Computer Vision (WACV), 2014

-Paper on Weed Manipulation, e.g.
A. MICHAELS et.al.,
“Vision-Based Manipulation for Weed Control with an Autonomous Field Robot”
VDI Landtechnik AgEng2013

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Example Outdoor Phenotyping: Picture of the future

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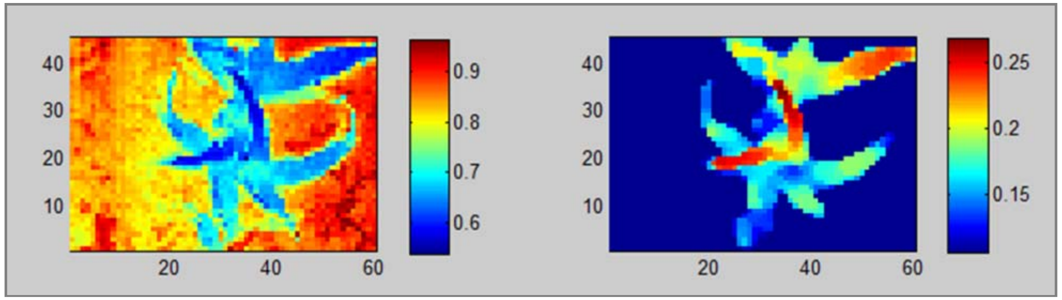
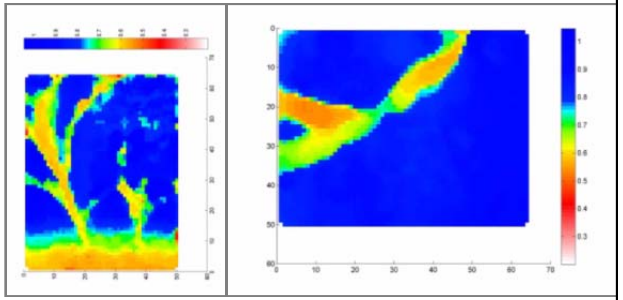
Phenotyping examples:

courtesy of

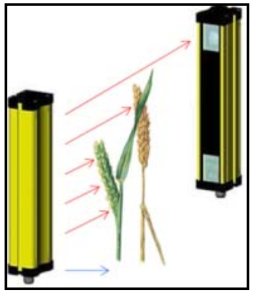
Hochschule Osnabrück
University of Applied Sciences

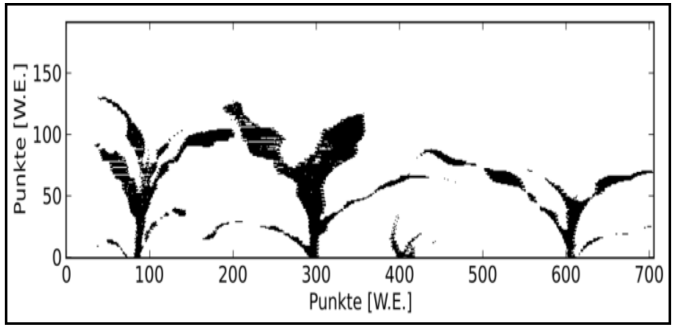
- 3D-ToF cameras

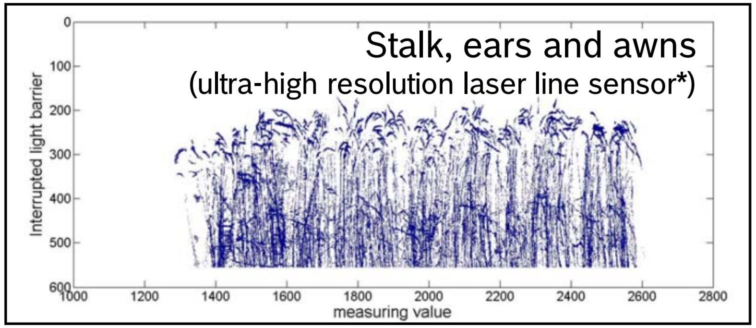




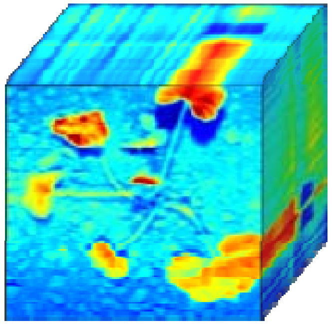
- Light curtains

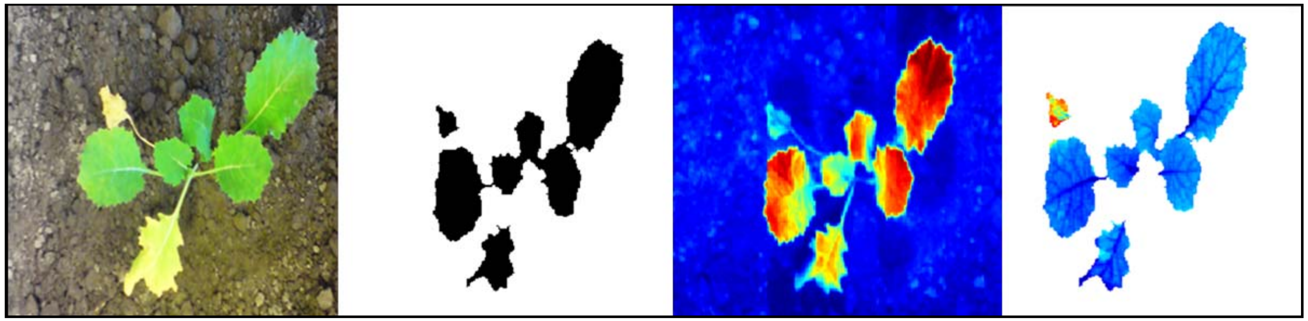






- Hyper-spectral Imaging





*Source: Ivana Kovacheva, University of Applied Sciences Osnabrück, CBA-Workshop (2014)

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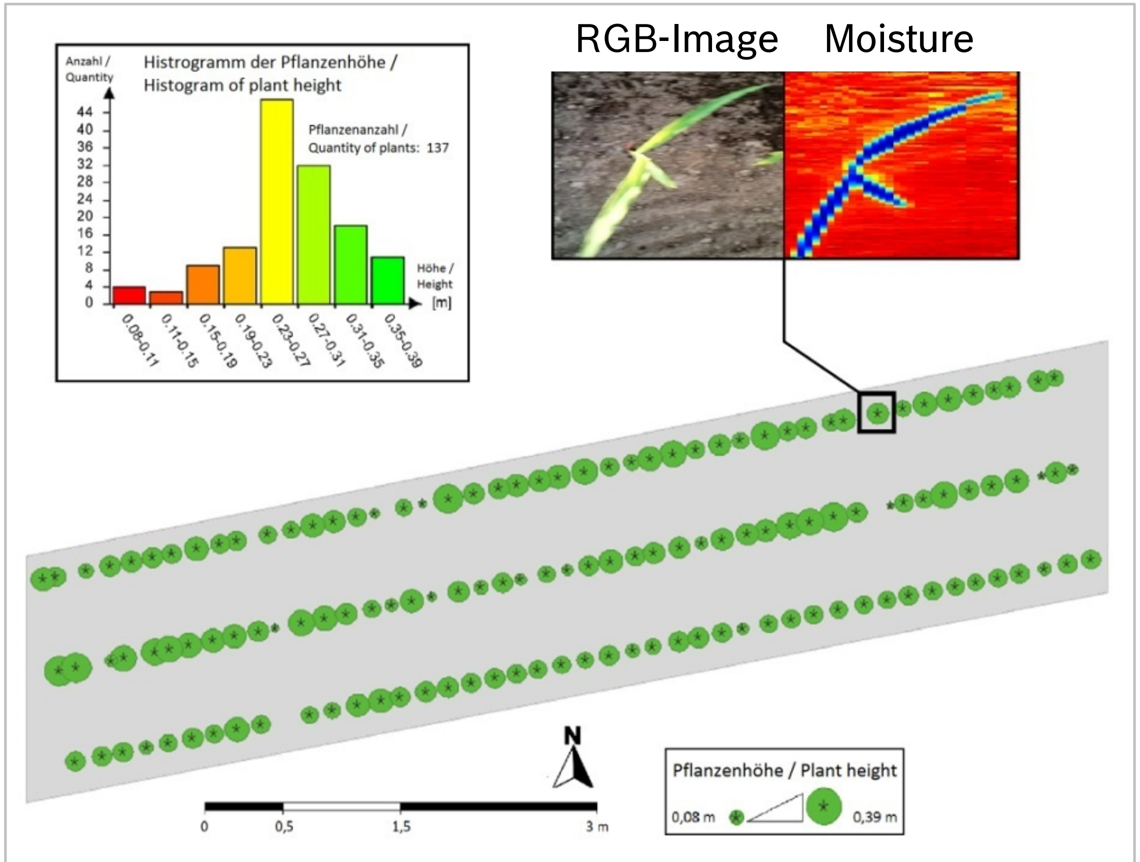
Phenotyping examples:

courtesy of Hochschule Osnabrück
University of Applied Sciences

- 3D-ToF cameras
- Light curtains
- Spectral Imaging



Spatially / timely correlated image data with high potential to deliver plant parameters, like bio mass, moisture, plant height, ear number, etc. But still challenging: Selection of 'right' sensor and data fusion

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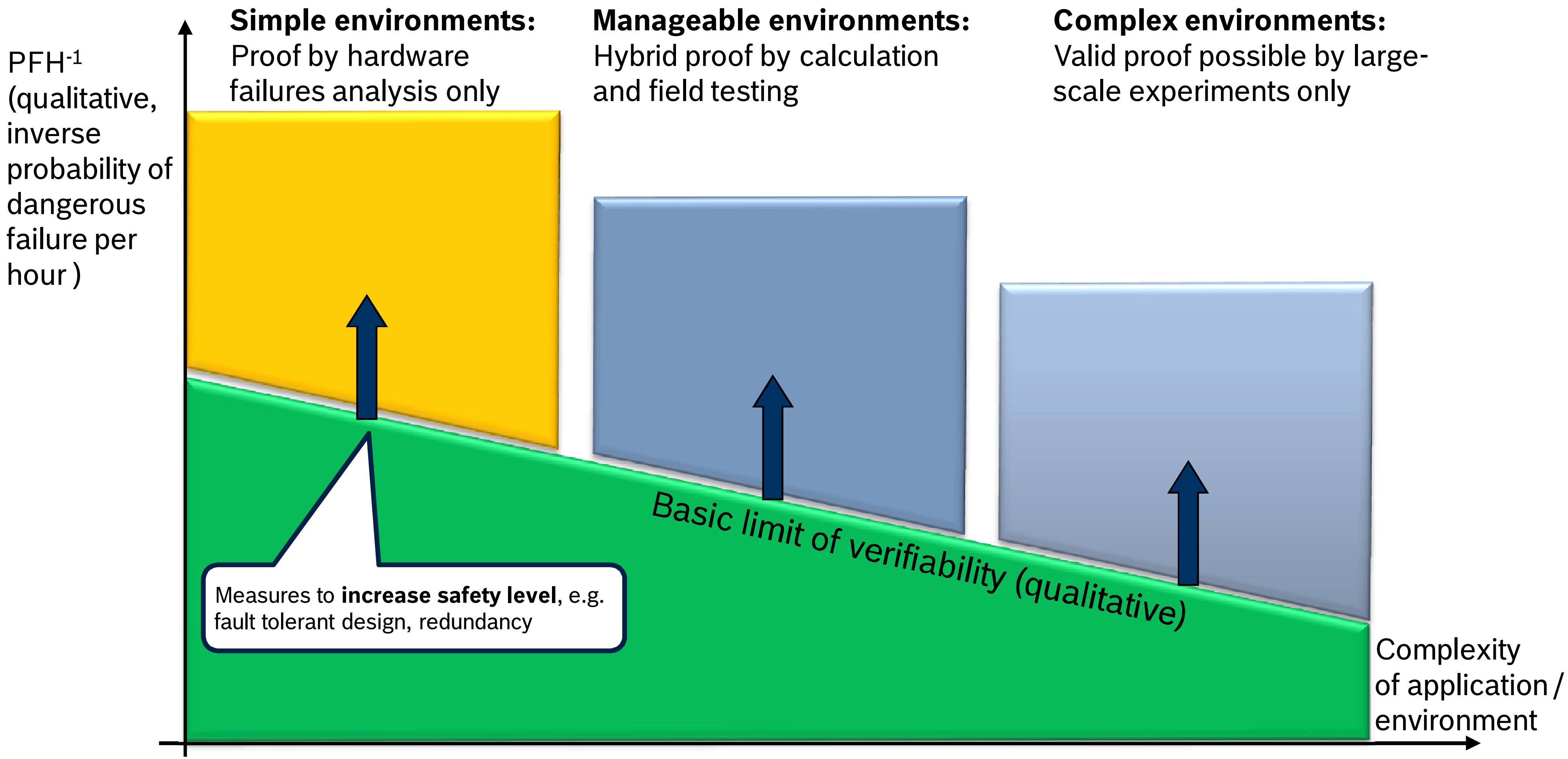
Statistical approach to safety case



A. ALBERT, B. MÜLLER: "**Herausforderungen und Perspektiven für Märkte im Bereich kognitiver und robotischer Systeme**", Robotik und Gesetzgebung, 1. Auflage, 2013

Multidisciplinary approach required to handle complexity

Integration and testing weeks

Integration mit Partnern: AMAZONE, Hochschule Osnabrück University of Applied Sciences

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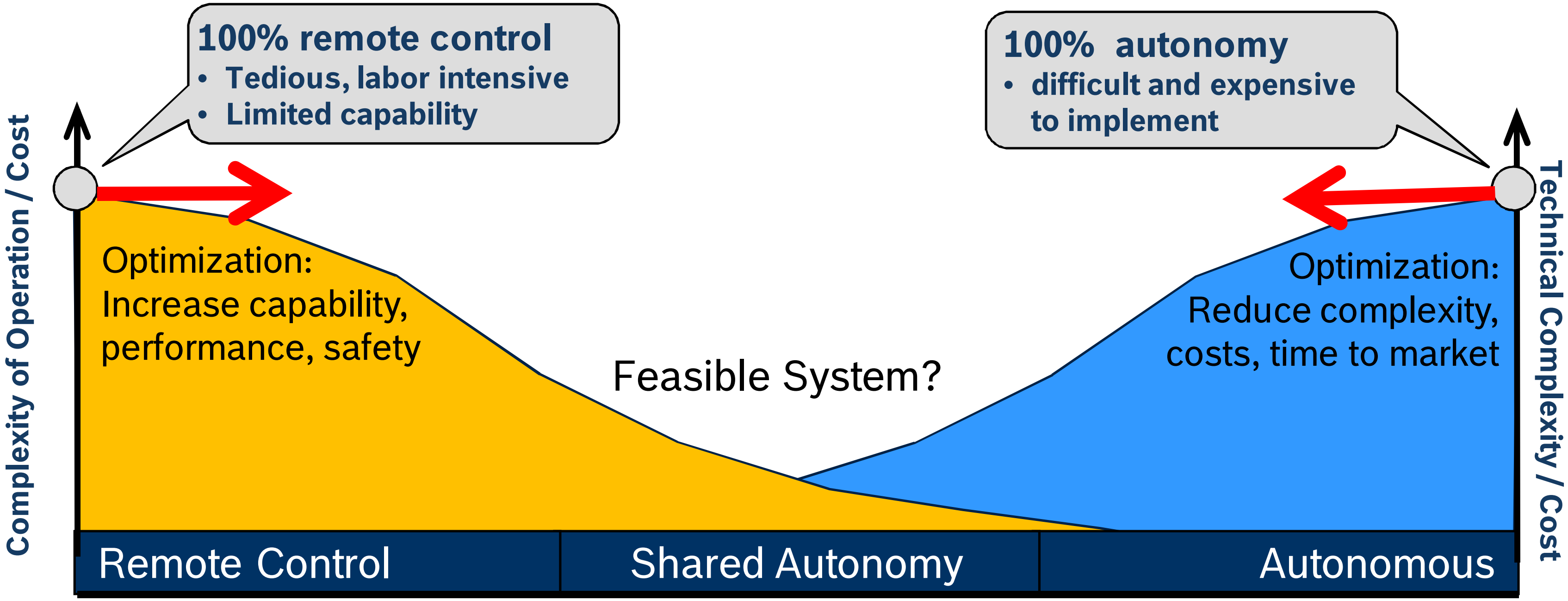
Shared Autonomy as one possible intermediate solution to reduce complexity and downtime

Basic Idea: Robotic system considers explicitely human in the loop

or catchy speaking "Let robots do what they are good at, let humans do what they are good at"



B. PITZER et.al : "**Towards perceptual shared autonomy for robotic mobile manipulation**", IEEE International Conference on Robotics and Automation, 2011

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Summary

- ➔ Technology demands are very high; other important barrier to be considered are: cost-efficiency, robustness, safety and reliability
- ➔ **Cost-efficiency**:
  - Market development starts with very specific use cases and/or multi-purpose systems
- ➔ **Safety and reliability**:
  - Risks and uncertainties can not be projected to system alone, hence classical engineering methods for safety case may not be adequate
  - Understanding of risks by the market (manuf./user) is a key to gain confidence
- ➔ **Robustness**:
  - Incremental introduction of products into the market, for instance by shared autonomy, is one promising solution path

Challenging the crystal ball

- **“The horse is here to stay but the automobile is only a novelty – a fad.”**
  — President of Michigan Savings Bank advising Henry Ford’s lawyer, not to invest in Ford, 1903
- **“There is no reason anyone would want a computer in their home.” —**
  Ken Olson, president Digital Equipment Corp. (DEC), arguing against the PC in 1977.
- **"[By 1985], machines [computers] will be capable of doing any work Man can do."** Herbert A. Simon, CMU, speaking in 1965.

"The best way to predict the future is to invent it.“
Alan Kay, Xerox's Palo Alto Research Center, 1971

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