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Robotics in Agriculture

Smart Farming

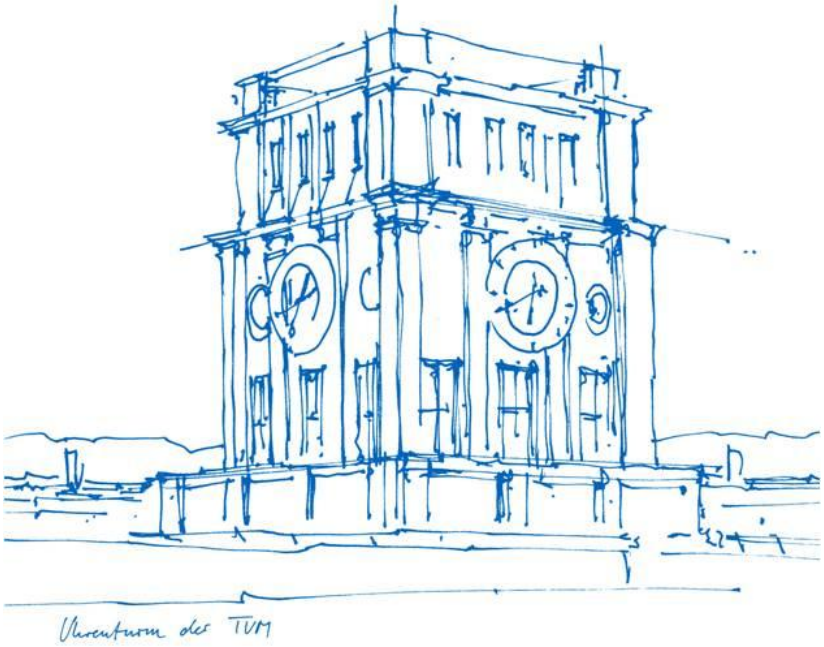
Technical University of Munich

TUM School of Life Sciences

Chair of Agricultural Systems Engineering

Josef Bauerdick

Maximilian Treiber



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Definitions & Concepts of Autonomy

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Robot definition I

Following Japanese Industrial Robot Association (JIRA):

- **Manual manipulator**: handling device with several degrees of freedom that has no program but is moved directly by the operator.
- **Robot with fixed action sequence**: Handling device that repeatedly operates according to a constant motion pattern. Changing the motion pattern is relatively complex.
- **Variable sequence robot**: Handling device as previously described, but with the ability to change the motion sequence easily and quickly.
- **Playback robot**: The motion sequence is demonstrated to this device once by the operator and stored in the program memory. With the information contained in the memory, the sequence of movements can be repeated as many times as required.

www.tu-chemnitz.de/informatik/KI/scripts/ws0405/KI_Schule/KI-Schule-04-lehr-3.pdf

Robot definition II

- **Numerically controlled robot**: handling device operates similarly to an NC controlled machine tool. The operator designs a computer program for the robot for its motion sequence instead of going through the task with it manually.

- **Intelligent robot**: This highest class of robot is intended for devices that have various sensors, enabling them to understand their environment and successfully complete a task despite changes in environmental conditions.

www.tu-chemnitz.de/informatik/KI/scripts/ws0405/KI_Schule/KI-Schule-04-lehr-3.pdf

SAE J3016™ LEVELS OF DRIVING AUTOMATION

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Historical development of Ag-Robots

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Historical development of robots

- Labor is scarce
- Labor is replaced by larger machines => increases the effectiveness of the individual worker (**clout** increase)

But:

- Machine sizes and weights become problem for efficiency and environment (soil damage compaction!)

→ Automation of machines: machines become smaller again

→ One worker can now control several machines

Example: Autonomous tractors (e.g. Fendt Guide Connect – Master/Slave System – **1 worker** controls **2 machines**)

Next level robot swarms: "Shepherd" - **1 worker - multiple machines**)

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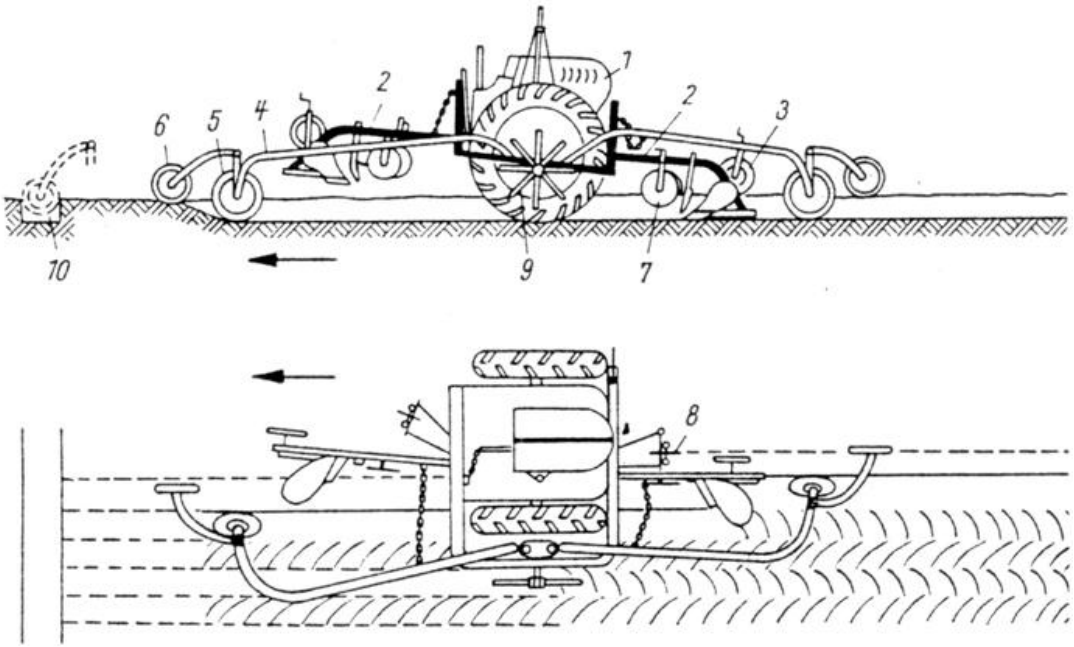
Historical examples

Scheme of an automated plow machine by MITTELBACH 1963



1. Diesel engine
2. Plow frame
3. Support wheel
4. Contact frame
5. Furrow wheel
6. Feeler Wheel
7. Disc coulter
8. Disc coulter for correction of furrow arcs
9. Impulse wheel
10. Cross furrow

- Electromechanical/electrohydraulic control.
- Special feature: virtually guides itself, mechanical feeler can lead to an over turn by “feeling” the trench in the headland

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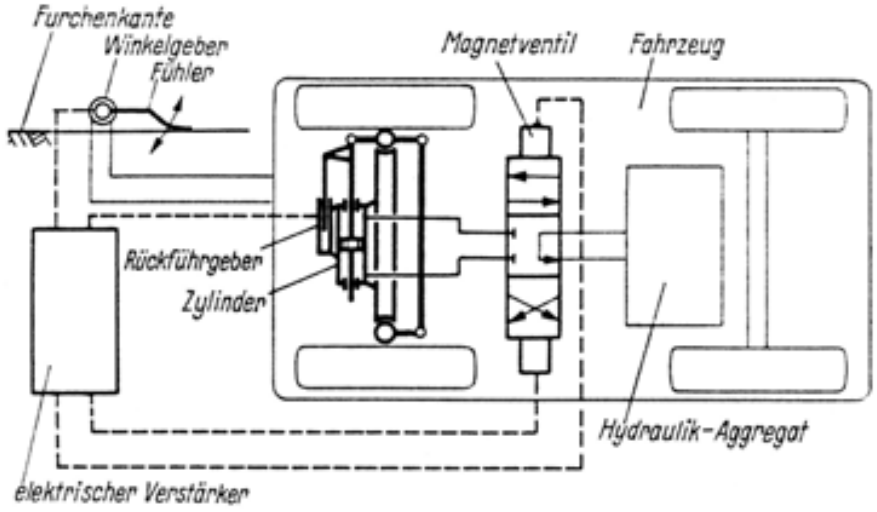
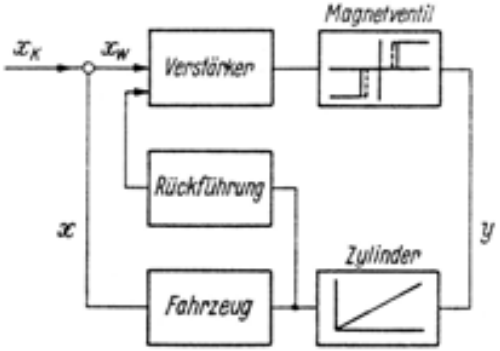
Eicher Agri-Robot, 1964

Elektrohydraulic Steering at ploughing





x Regelgröße
x_K Sollwert
x_w Regelabweichung
y Stellgröße

Automatic steering (elektrohydraulic) at ploughing,
(BATEL 1968)

Electronic Drawbar

- Virtual coupling between two agricultural machines
- An unmanned vehicle follows a manned one

Guide Connect Fendt, 2011

Quelle: Fendt

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Cyberphysical Systems & Swarm Robotics

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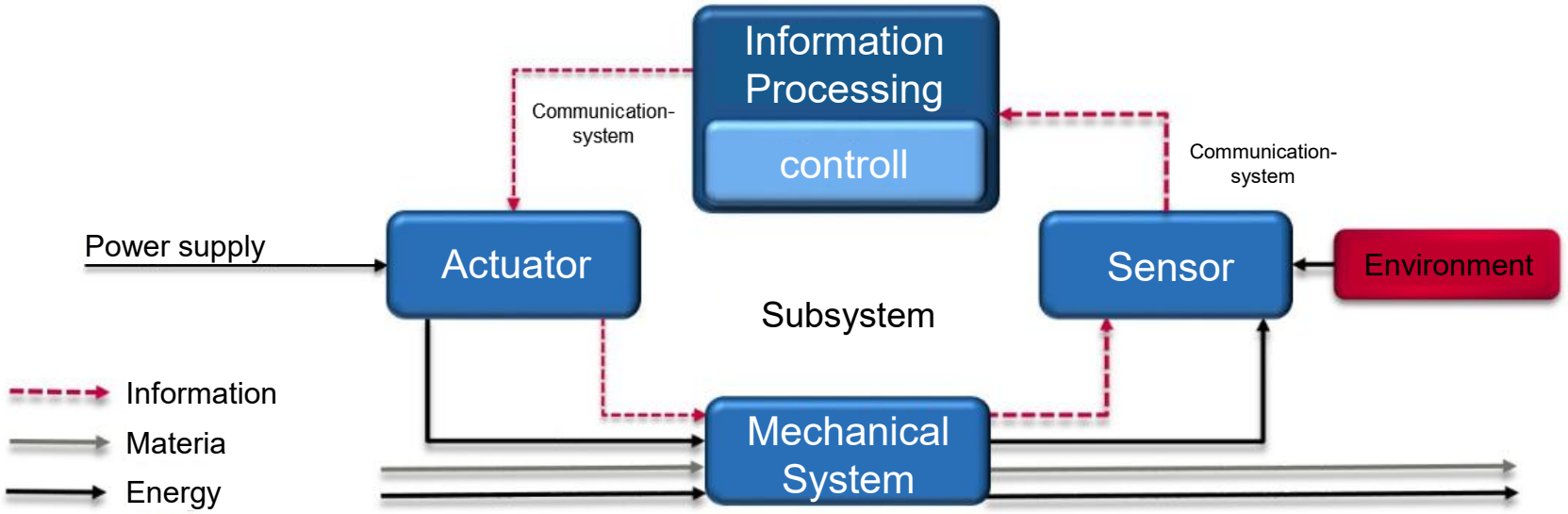
Cyber-physical Systems (CPS)

- Consist of mechanical components, software and modern information technology
- Networking of the individual components via networks (e.g. Internet)
- Control, regulation and monitoring of complex systems / infrastructures
- Information exchange of networked objects and systems in real time (wireless or wired)
- Functional principle based on sensors, actuators and networked software
- Can act autonomously
- Often integrated into cloud architecture
- Required components and technologies: sensors, actuators, embedded systems, network infrastructures, servers with computing and storage capacity, software for autonomes computing, real-time data processing, databases, graphical user interfaces, wireless user interfaces, wireless networking technologies, etc.
- Application areas: smart grid (intelligent power grids), tsunami or earthquake warning systems, military drones or air defense systems, driver assistance systems and autonomous vehicles.

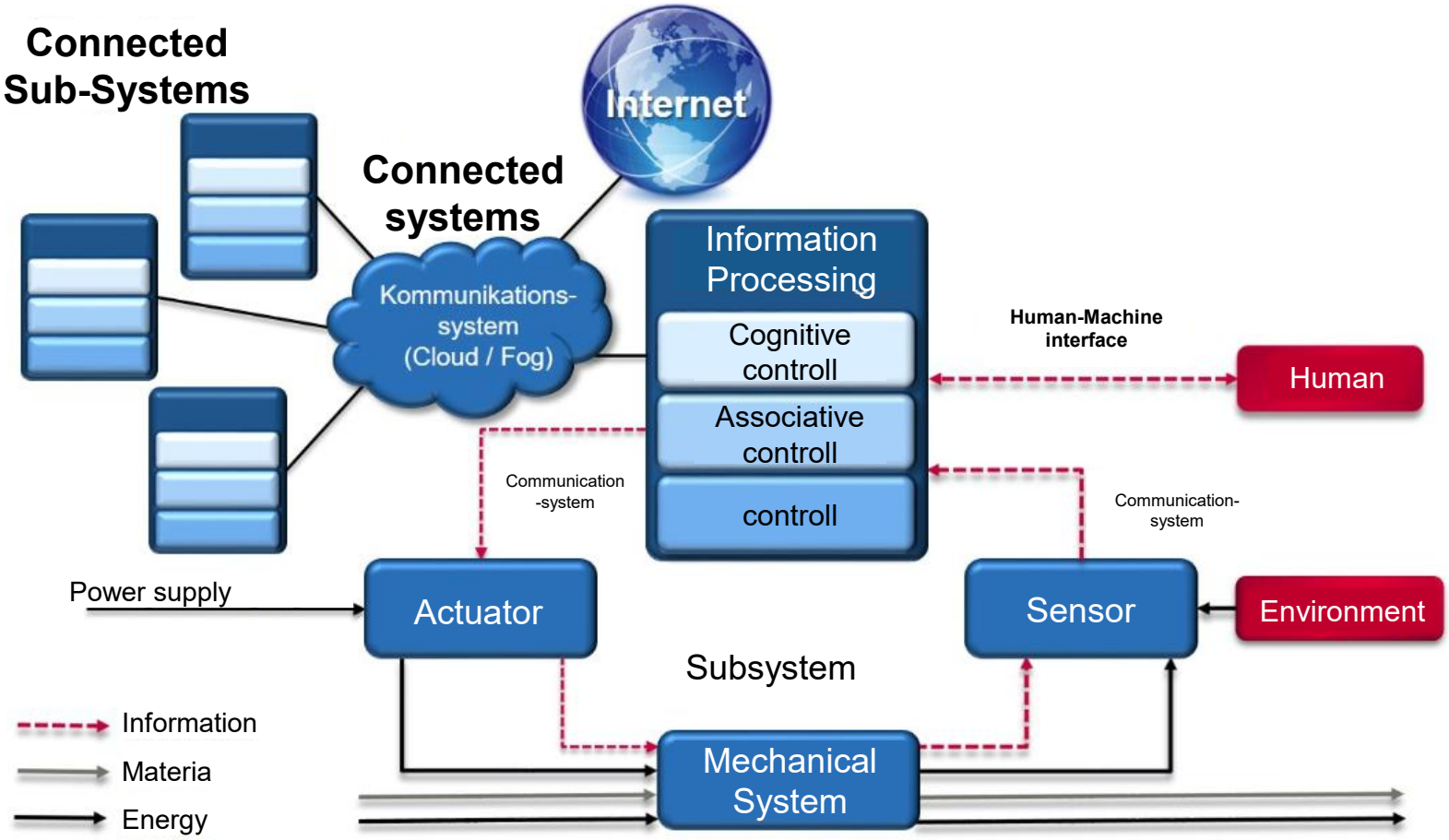
Source: Nico Litzel, BigData Insider, 2017

Mechatronical Systems



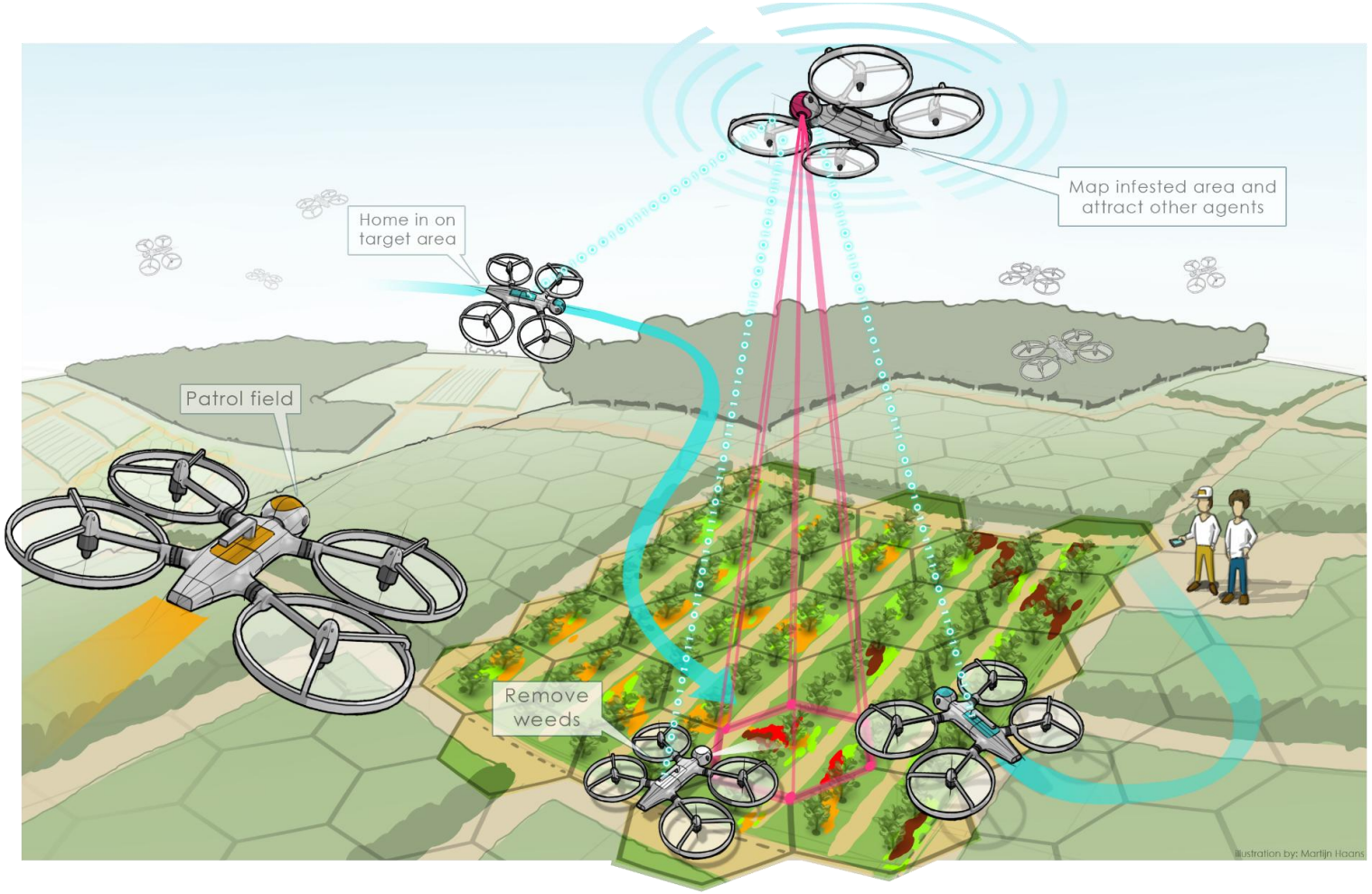
Source: Züricher Hochschule für Angewandte Wissenschaften (2017)

Cyber-physical Systems



Swarm Robots - MARS

Swarm Robots - SAGA



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Scaleability
-

Large-scale vs. Small scale scenarios

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Large-scale vs. small-scale technology scenario

What will the future of farming look like? Big or small robots?

- Small robots optimized for special tasks (sowing, plant protection, hoeing, harvesting - picking)
- Medium scale implement carriers prove to be interesting concepts (versatility)
- Large robots/autonomous retrofit of conventional agricultural equipment (retrofit + brute force e.g. tillage)

Logistics & Interoperability will be the challenges to overcome in mixed swarms!

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Autonomous Tractors

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Scaleability

- Opportunity of robotics for own mechanization: e.g. 1 Xaver for part-time farmer, 100 Xaver for 2,500 ha farm?

- Pay-per-Use concepts - Similar to contractors and inter-farm machinery use today

Scaleability

- Managing swarms of robots may require a lot of know-how.
- e.g. BayWa VitiRover → mowing robot swarm which is paid for "mowed ha vineyard", management is done by robot provider

https://i.ytimg.com/vi/1YhEUFVn77E/maxresdefault.jpg

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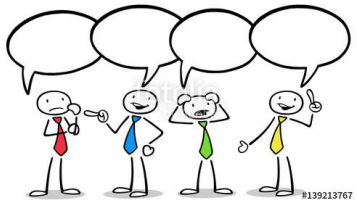
Discussion – are we making agricultural workers obsolete?



Robots replaces labor in rural areas!

- Not enough qualified machine operators available
- More vacancies in the low-wage segment
- Minimum wage policy
- Management of robots requires a lot of know-how
- Professionalization through pay-per-use concepts
- Further training opportunities for the farmer

$\Rightarrow$ Opportunity for new, well-paid jobs for Highly Trained professionals in rural areas

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Design Principles

-

Navigation

Design Principles

- **Navigation:** GPS, environmental perception, infrared, laser, ultrasonic and tactile sensors, navigation algorithms.
- Cloud-driven (problem of disconnection)
- Edge computing (keep data packets on hand if connection is possible)
- Swarm coordinates itself via own connection (documentation of own travelled paths, where?)
- Random movement patterns (cf. vacuum cleaner robot)

- **Security:** Humans must always be able to take control!

- **Ethics:** How are the logarithms to be designed according to which the robot moves and how is the decision made in case of danger?

Autonomous Volvo Truck, Cloud-driven

www.umweltwirtschaft.com/news/media/4/Volvotrucks-38522-detailpp.jpeg

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Design Principles
-
Locomotion

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Locomotion

Wheels:
- 2x4 oder 4x4 oder 6x6
- Conventional steering vs. torque-controlled steering with wheel hub motors
- Size of wheels
- Configuration normal vs. implement carrier with long bridge in the middle

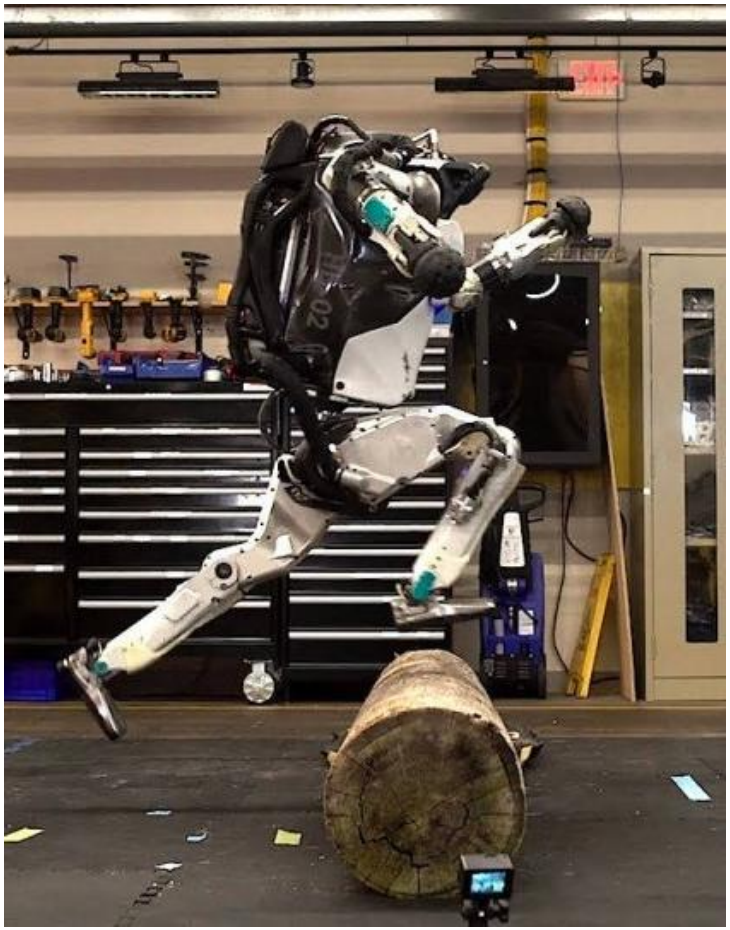
Legs:
- Spider legs (Boston Dynamics)

Tracks:
- Crawler tracks

Foto: Markus Breig/KIT

Cabled/tracks
- "Hop garden" with cable system and external power supply in viticulture under development
- Rails/frame concepts in horticulture

Boston Dynamics: Atlas robot



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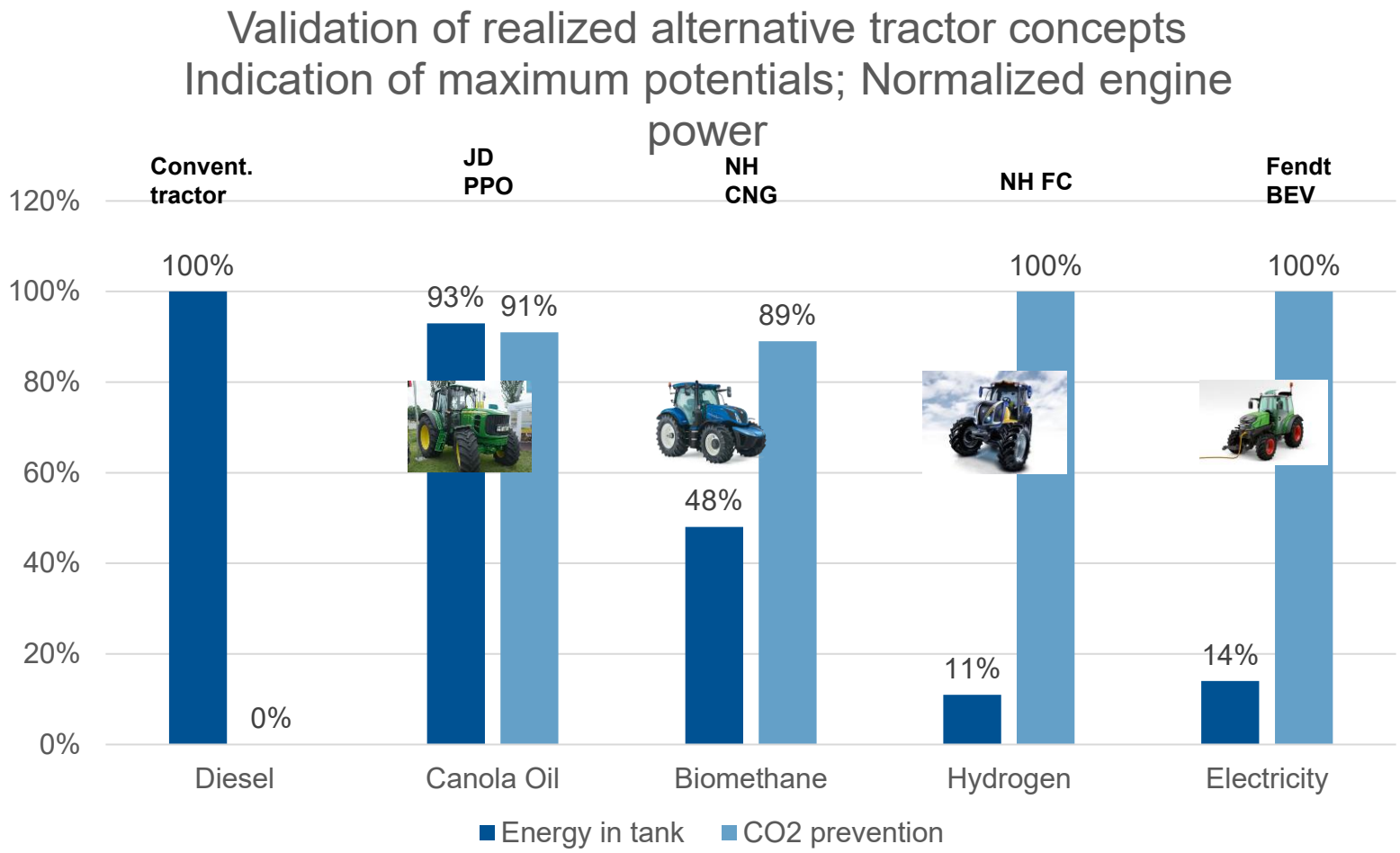
Design Principles
-
Energy Supply

Energy density vs. Carbon capture potential



Axel Kunz, John Deere, renewed

Energy supply

- Lithium Ionen batteries
- Energy Harvesting Concepts (e.g. Lithium battery with PV-panel)
- Combustion engines e.g. Yamaha RMAX Helicopter

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Internal combustion isn‘t dead!

However bring-your-own-grid seems en vogue

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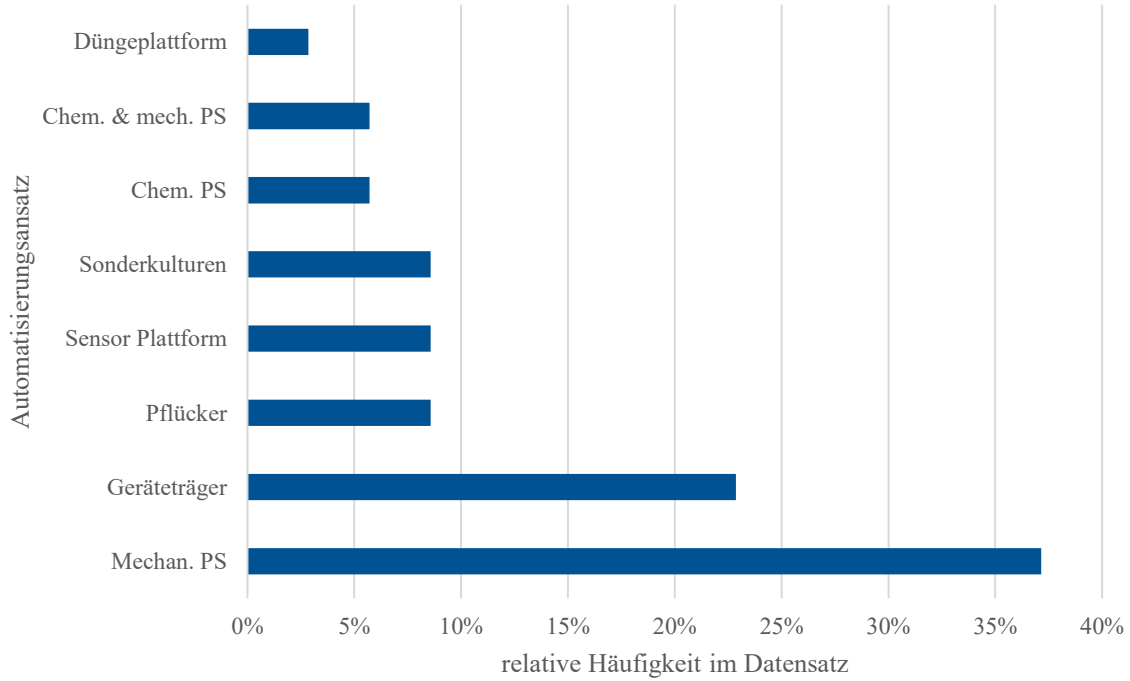
Design Principles
-
Tools & Manipulators

Design principles: Sensors, actuators, control and regulation

- Or how does the agricultural robot differ from conventional agricultural technology?
- Own investigation, which concepts are being worked on the most:



Tools and Manipulators

- Picker
- Sowing unit
- Harrows
- Sprayers
- Spreaders
- Etc.

www.innovations-report.de/upload_waf/Manipulator_593356.jpg

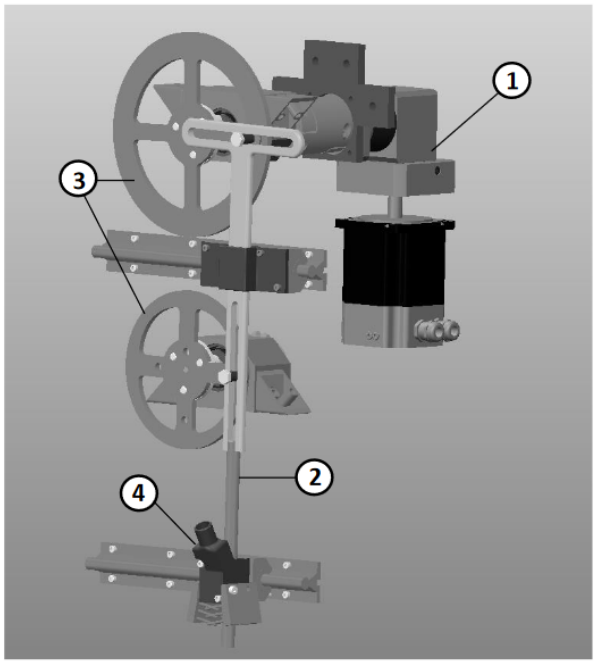
www.innovations-report.de/upload_waf/BoniRob_593353.jpg

Commonality:

Energy-saving design and Innovative approaches!

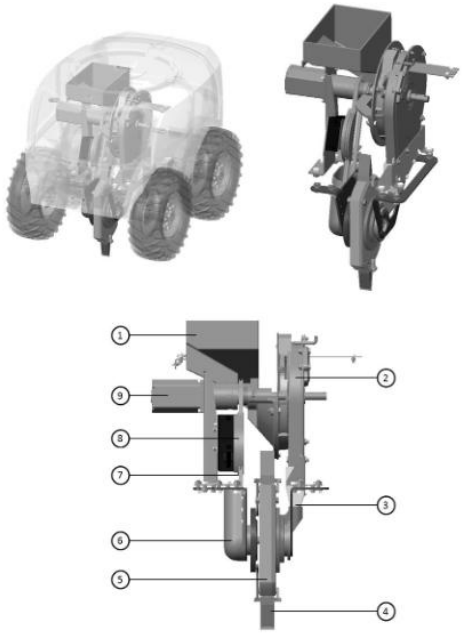
Example Xaver Manipulator Concepts

Design of seeding unit #1 (cycloidal stamping)



Position	Description	Details
1	Motor	Nanotec 24 V motor with angular gear
2	Stamp	Stamp for pushing seeds in the soil
3	Cam discs	Cam discs for stamping (upper disc) and compensation of robot movement (lower disc)
4	Supply system	Seed channel for handover between fixed and moving parts

Design of seeding unit #2 (rolling mechanism with flaps)



Position	Description	Details
1	Seed reservoir	Approx. 3 liters
2	Seed singulation	Precision Planting Finger meter for seed singulation
3	Supply system	Seed channel for handover between fixed and rotating parts.
4	Shovels	Shovels for punch seeding
5	Seeding unit	Seeding unit with internal seed channels Speed: 3 seeds per second (typical: 0.11 ha/h)
6	Chain guard	
7	Chain	Drive system for seeding unit
8	Chain tensioner	
9	Motor	Dunkermotoren BG 65x25, 92.2 W at 24 V, nominal rpm: 3100

Sources: MARS Final Report (2016)

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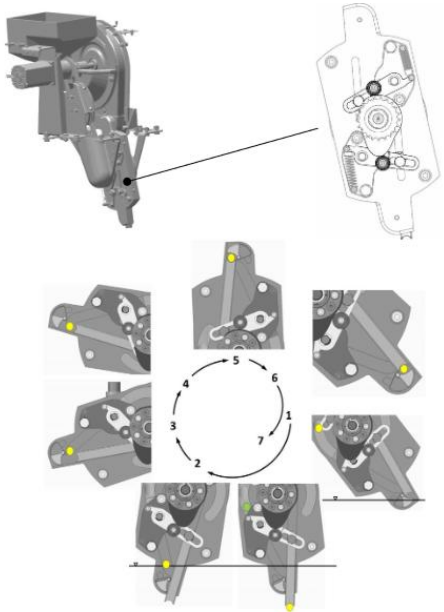
Example Manipulator Concepts

Design of seeding unit #3 (rolling mechanism with stamps)



Position	Description	Details
1	Handover	Seed enters the seeding unit (moving) from supply system (fixed).
2	Forwarding	Seed is pushed towards the stamp channel by gravity and centrifugal forces.
3	Entry	Seed enters the stamp channel in front of the stamp.
4	Closing	Stamp closes the seed supply channel (controlled by cam disc).
5+6	Lock	Stamp holds the seed close to the sealing cap of stamping channel.
7	Placement	Seed is placed in the soil through stamping motion.

Xaver as it stands today - looks like a conventional seeding disc coulter…

Sources: MARS Final Report (2016)
Fendt (2021)

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Example Vitirover

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Vitirover Manipulator

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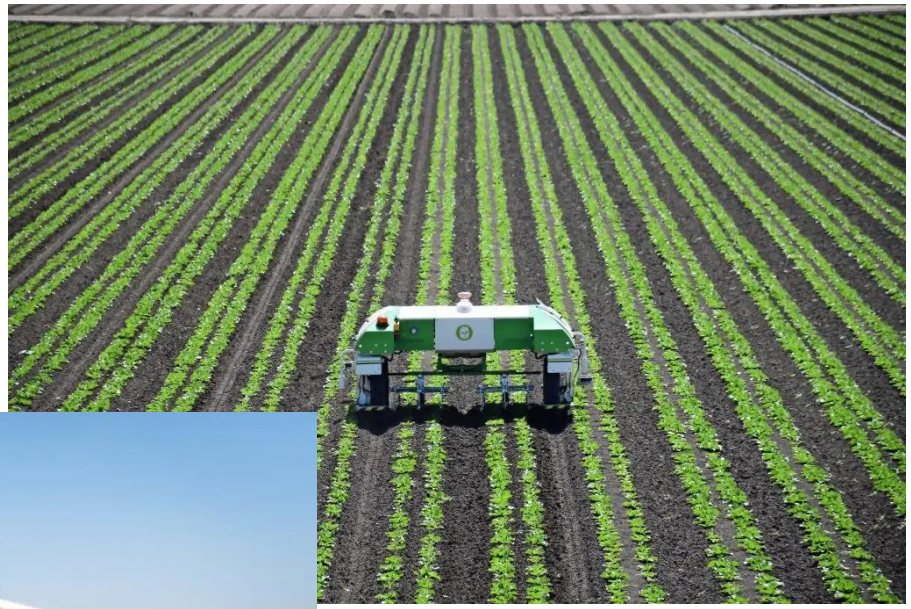
Examples of recent Robot Conepts for Agriculture

Overview of commercialy available robots

https://www.futurefarming.com/field-robots-catalogue/

„Commercialy available“ sometimes means entering a test-farmer program…

Naio Oz / Dino / Ted



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Agrointelligence Robotti

Implement Carrier

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Raven Dot /OMNi Power

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FarmDroid FD20

Implement Carrier sowing & weeding

Ecorobotix – ARA (implement) & AVO (robot)

Precision spraying

Carré Anatis

Weeding Co-Bot

AgXeed -> now Claas Agbot

Implement Carrier

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Robots for your backyard (FarmBot)

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Fun concepts

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AVLMotion Asparagus harvester

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VitiBot Bakus

Miscellaneous - Transportrobot

Trooper,
Instar Robotics

www.lid.ch/fileadmin/_processed_/csm_3406_Eppenberger4_a259742743.jpg?random=1547677404801

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Harvesting

Sweeper (Sweet Pepper Harvesting Robot)

www.agf.nl/nieuws/2018/0705/Sweeper2.jpg

https://www.gb-profi.de/typo3temp/_processed_/csm_IMG_20180614_125041_30cc46a858.jpg

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Autonomous Sprayer

Seeder

Kongskilde Vibro Crop Robotti

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Seeders

Horsch Robot

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Harvester Swarm early Concept TU Dresden

TU Dresden grain combine robots

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Feldschwarm Project

Examples Livestock farming robots

- AMS
- AFS
  - Automatic mixing robots
  - Automatic feeding robots
- Slat-cleaner

DeLaval, 2019

Lemmer-Fullwood, 2019

Lely.com

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Example drones

Application:

- Ichneumon fly egg application BayWa
- Agras MG-1
- Agronator (Rauch Agritechnica 2018 with fertilizer spreader)

www.agrartechnik.ch/fileadmin/_processed_/a/6/csm_agronator08R_b3c948d6ff.jpg

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Drone Swarm deployment concept

Volocopter meets John Deere

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Closure

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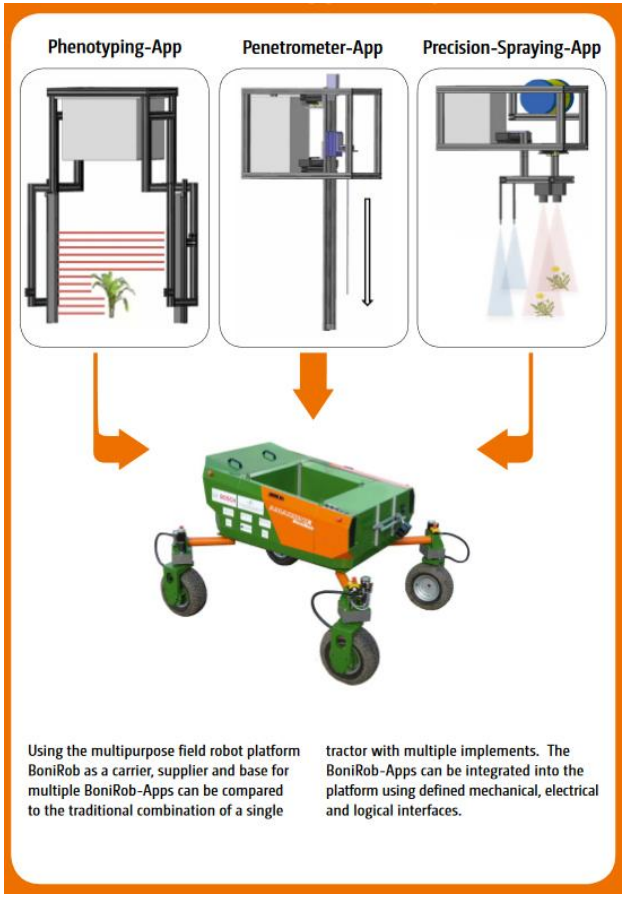
Sometimes we move backwards…



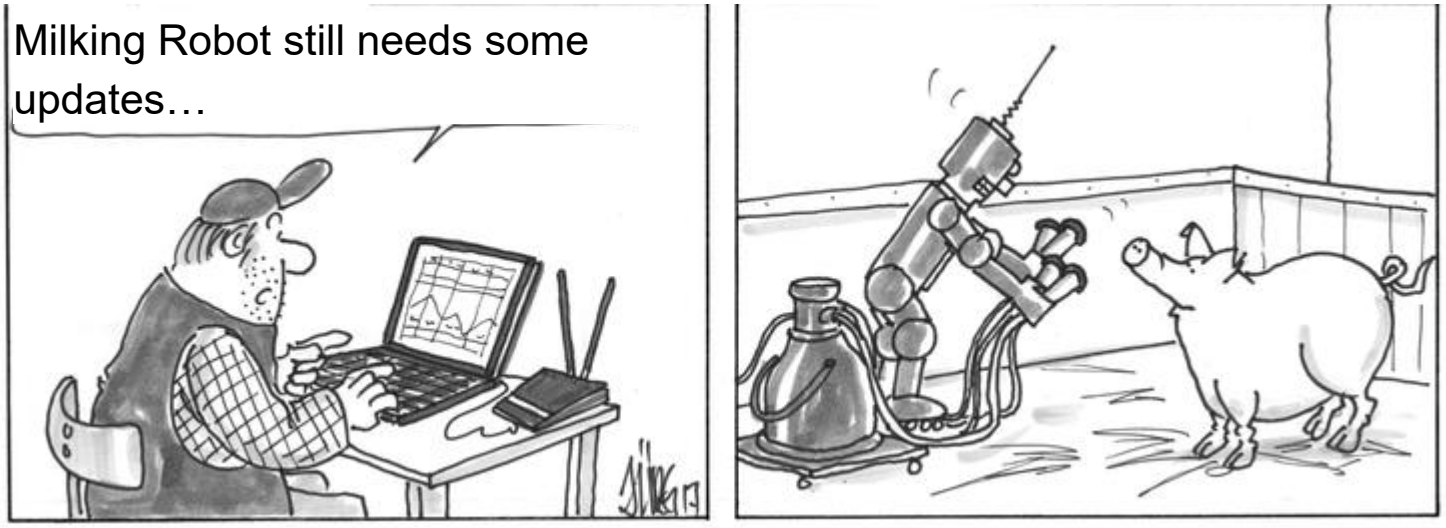
Using the multipurpose field robot platform BoniRob as a carrier, supplier and base for multiple BoniRob-Apps can be compared to the traditional combination of a single tractor with multiple implements. The BoniRob-Apps can be integrated into the platform using defined mechanical, electrical and logical interfaces.

Technology developed on robotic platform deployed on conventional farming machinery

Retrofit is key…

Remember…

- Big vs. Small debate
- Scaleability and how it translates to AgRobotics
- Design principles
- Powerful software absolutely necessary to bring them to the fields



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