BoniRob
An Autonomous Mobile Platform for Agricultural Applications

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AgRA Webinar - 23 Sept 2015

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**: 7.8 - 11.9 bn. people until 2050

→ Eating habits are changing, e.g. **organic farming** ($104.5bn)

→ **Chemically-resistant weeds** result in wasted cropland

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

→ **Sustainability** of way of cultivation becomes essential
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Megatrends lead to dramatic changes in agriculture

- **Shortage of resources**
  - Precision Farming
  - Autonomous Machines

- **Growing population, chemically-resistant weeds, healthy food demands**
  - Monitor Environment and Plants
  - Reduce Costs/Enable Organic Farming

- **Agriculture and climate change**
  - We need a “Sustainable Green Revolution”
State-Of-the-Art in Agricultural Robotics

Armadillo (2013), Kongskilde

Grizzly (2013), Clearpath Robotics

HV-100 (2013), Harvest Automation

Ladybird (2014), Univ. Sydney
Evolution of BoniRob

2008-2011

- Single use case: phenotyping

2011-2014

- Multi-purpose agricultural robot

2015-

- Rugged design version available for customers
The BoniRob: A Multi-Purpose Agricultural Robot

**Powered by batteries and a fuel-based range extender**

**Slot for Application Module** (electrical & data-link to robot)

**Reconfigurable joints** (adaptive trackwidth)

**High connectivity** (5GHz Wi-Fi, 2.4 GHz Wi-Fi, GSM/UMTS/LTE optional)

**3D sensing for autonomous navigation in row-based cultivations** (optionally navigation based on GPS)

**Total of 12 degrees of freedom**

**BoniRob Quick Facts:**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Chassis</td>
<td>2.2 m x 1.3-2.4 m x 1.8-2.8 m (height x width x length) (dep. on track width)</td>
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<tr>
<td>Clear height / Tare weight</td>
<td>Approx 0.85 m / approx 1090 kg</td>
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<tr>
<td>Track width</td>
<td>1.0 – 1.9 m (electrically driven)</td>
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<tr>
<td>Wheels, Speed</td>
<td>0.55 m / 0.2 m (diameter / width), speed: up to 150 cm/sec</td>
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<tr>
<td>Power</td>
<td>24V, 230 AH Batteries, 2.6kW Generator, up to 24h operation without refueling</td>
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<tr>
<td>Payload</td>
<td>150 kg for customized application module</td>
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<tr>
<td>On-Board PC</td>
<td>i7-based Industrial PC running Linux. Robot is fully integrated into ROS + Gazebo</td>
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The BoniRob: Basic Modules

Navigation, State Estimation + Semantic Localization

Robot sensors:

High Level Navigation ECU

Remote control and safety circuit

Drive ECU

propulsion
Steering
Track width

High-Level Navigation and Control
(Industrial PC, ROS); Simulation in Gazebo

Low-Level Control, Safety
(embedded real-time system)

Different Apps

App A
sensors / actuators / functions

App B
sensors / actuators / functions

App C

Plug & Play!

High-Level Navigation and Control

Low-Level Control, Safety

Customized Application Modules
(Communication via ROS)
Developing new Algorithms for Autonomous Navigation

- Test in simulation
- Test in controlled environment
- Test under real world conditions
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Autonomous Navigation, Semantic Localization, and Mapping

2D Lidar
3D Lidar

Probabilistic State Automaton

3D Lidar
Trajectory
End Point
Row

Semantic: Row End

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

- Growing population: 7.8 - 11.9 bn. ppl. until 2050
  - crop yield must increase by ~3% each year
  - currently only ~1.5% increase each year
- Breeders name it the “phenotyping gap”
  - “we don’t know enough about the plant”
  - “we don’t know enough about the environment”
- Today: Suboptimal breeding decisions are taken
Phenotyping Application Module

Light curtain

Imaging light curtain on maize field

A. RUCKELSHAUSEN et al., “Sensor and system technology for individual plant crop scouting”, ICPA 2011
Phenotyping: Soil Penetrometer Application Module
Soil Pentrometer Module: Delivers Compaction Map

M. GÖTTINGER et.al.,
“GNSS-based navigation for the multipurpose field robot platform BoniRob to measure soil properties”, VDI-Tagung, 2014
Phenotyping: Picture of the future
Weed Control: Spraying and Mechanical Weeding

- Weed Control in the U.S. (Mid 1990):
  - 3.5bn USD for conventional weeding (spraying)
  - 2.5bn USD for alternative methods
  - Between 5%-50% of total costs

- Today: facing resistances against herbicides
- Organic weed control up to 20x the costs of conventional weed control (spraying)

- Today: Organic farming market is 104.5bn USD

Source: Weeds are plants whose undesirable qualities outweigh their good points, 2015
Precision Spraying Application Module
Mechanical in-row Weed Control
Source: Langsenkamp et al., *Tube stamp for mechanical intra-row individual plant weed control*, 18th World Congress CIGR (2014)
AgriApps: Box Tree Nursing

Flourish: UAV + BoniRob
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We need a “Sustainable Green Revolution”

Autonomous Machines  |  Precision Farming  |  Monitor Environment and Plants  |  Reduce Costs / Enable Organic Farming

Navigation  |  Phenotyping  |  Soil Monitoring  |  Pres. Spraying  |  Weeding  |  Nursing

Monitoring Environment and Plants to Reduce Costs and Enable Organic Farming.

We need a “Sustainable Green Revolution” to advance Precision Farming and other agricultural technologies.

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What are your ideas?
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Our Reality >>> Your Visions?

Adjustable track width

Omni-directional drive

Remote control or autonomous driving

Row following and/or GPS navigation

Exchangeable application modules
Mechanical, electrical, and software interface for customized modules

Application module = sensors + actuators + functions

Combine BoniRob with UAVs for coordinated air/ground missions

Use BoniRob as base platform for swarm robotic applications

Talk to us!
We have the robot for your agricultural application.
Thank you very much for your attention!

Visit us at IROS 2015
Acknowledgements
The people that made it possible!