Plant Detection, Mapping and Differentiation for Autonomous Agricultural Robots

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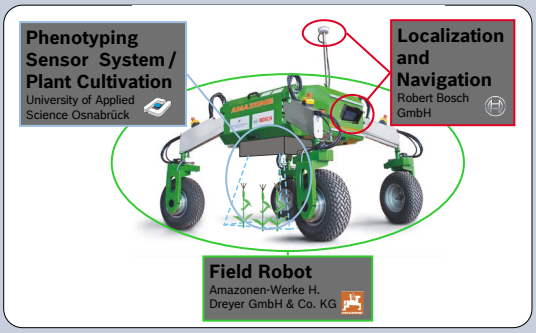
Abstract – In the context of the project BoniRob we are developing an autonomous agricultural robot, with the key objective of autonomous repeating phenotyping of individual plants on different days. For that it is necessary to detect, differentiate and map the single plants. In contrast to the state-of-the-art, we are using a 3D LIDAR sensor for this application. For the differentiation of the plants species we have developed a set of features and compared a large set of machine learning methods, like SVM and Simple Logistic by using the Weka toolbox.

The BoniRob Project [1]

- Development of an autonomous crop scout for individual plant phenotyping (first use case is maize)
- Publicly funded by the German Agricultural Ministry, supported by the Federal Agency for Agriculture and Food (BLE)
- Academic and industrial partners
- For a period of up to 3 years (launched at April 2008)
- Robot platform
  - Omni-directional and flexible
  - Ground clearance: 40 – 80 cm
  - Track gauge: 75 – 200 cm
  - Hydraulic arms and electrical wheel hub motors

Phenotyping parameters

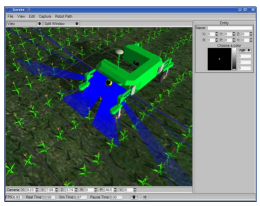
- Number of plants, crop density
- Spacing in the row
- Plant height
- Steam thickness
- Spectral reflection
- ...



Localization and Navigation

- Localization using a Kalman filter
  - Sensors fusion (GPS, Odometry and IMU)
  - RTK-GPS as main sensor
  - Sub-decimeter localization accuracy
- 3D LIDAR sensor for environment sensing, mounted on the robot's front, to recognize crop rows as well as single plants
- Development
  - In the 3D simulation environment Gazebo
  - With a small test robot in the laboratory
  - Tested on the real robot
- SLAM (future work)
  - Agricultural environment is semi-structured
  - Using previous knowledge about plant cultivation
  - Using plants as natural landmarks

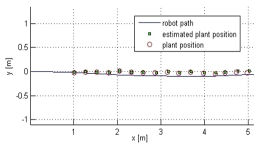
Simulated BoniRob on maize field



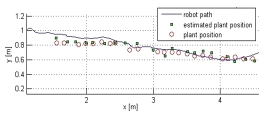
Plant Detection and Mapping [2]

- 3D LIDAR sensor for plant and ground detection
- Discrimination of ground and plants using RANSAC and SVD
- Using row model to support point cloud clustering
- Tracking of plants over time
- Plant detection rate of over 80%, with a position accuracy of about 3 cm.
- Building plant map for navigation, localization and mapping, as well as for plant retrieval

Mapping examples

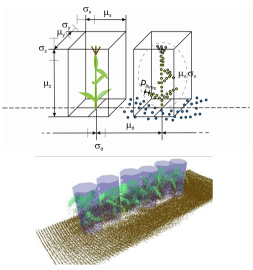


Simulated field



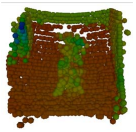
Maize field

Row Model



FX6 LIDAR sensor [3]

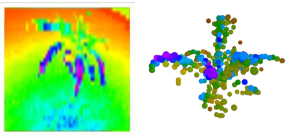
- Class 1 NIR Laser
- Oscillating MEMS mirror
- 29 x 59 rays, 16 fps
- Robust against illumination
- Mechanical robust



Differentiation of plant species using Machine Learning [4]

- For distinguishing between
  - Crop and weed
  - Plants in mixed crops
- Feature extraction
  - Using reflection and geometry
  - Independent of the plant size
  - Density and distribution of the point cloud
  - Statistical values (e.g. median, standard deviation, histogram)

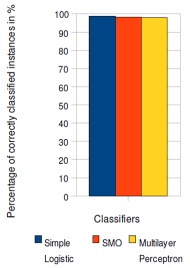
3D LIDAR sensor delivers two types of data



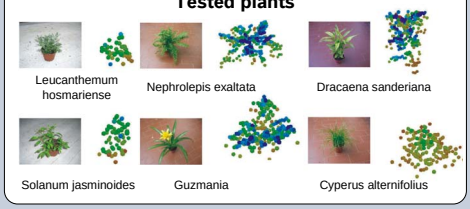
Reflectance 3D coordinates

- The best classifiers (using Weka [5]) provide classification rates of over 98% under laboratory conditions for six classes of species:
  - Simple Logistic (Linear logistic regression model)
  - SMO (Sequential minimal optimization using SVM)
  - Multilayer Perceptron (Neural network with back propagation)

Differentiation results



Tested plants



[1] Ruckelshausen et al., BoniRob - an autonomous field robot platform for individual plant phenotyping, In Proceedings JIAC 2009.
[2] Weiss, U., Biber, P., Plant Detection and Mapping for Agricultural Robots using a 3D-LIDAR Sensor, In Proceedings ECMR 2009
[3] Nippon-Signal, http://www.signal.co.jp/
[4] Stefan Laible, Klassifikation von Pflanzen anhand 3D-Laserscanner-Daten mittels maschineller Lernverfahren, Diploma Thesis, 2009
[5] Weka, http://www.cs.waikato.ac.nz/ml/weka/

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