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Imaging Sensor Systems – Key Technology for Innovative and Sustainable Agricultural Systems

Technology meets Nature

Agricultural processes in crop production are based on the experience of the people involved as well as on the processing and interpretation of data. Due to the multiplicity and complexity of variables, not all influences have been fully understood, whereby the interaction of the variables increases the complexity dramatically. The ongoing integration of electronics and computer science as part of the digital transformation in agriculture supports knowledge generation and its transfer to sustainable process automation and human-machine interfaces. In this context sensors have gained importance as one of the most important data sources, where GPS has the highest impact in practice so far. Sensors are measuring machine data (such as current or pressure), agricultural material properties (such as seed, fertilizer, herbicides, water, crop) or environmental parameters (such as soil parameters or weather). The robustness of the sensor data generation and interpretation is of highest relevance, in particular varying “noise sources” like dust, moisture, sun light or vibrations have to be taken into account. As a consequence sensor data fusion is crucial for reliable field operation and evaluation of crop quality.

Facing the complexity of the measurements, the focus has been on 1D (non-imaging) sensor systems, where calibration and statistical considerations have a strong relevance. Next to the technological aspects, the interpretation of the data in terms of practical instructions is continuously under discussion due to the large number of influencing parameters and large time constants of agricultural processing. Examples are given for fertilization, crop protection and harvesting.

Image-based sensors in agriculture

Pointwise measurements, however, only represent the average value of a small region, thus the interpretation of the data can be misleading. Image based systems, on the other hand, offer the opportunities for high spatial resolution. Due to the typically much higher data volume, unwanted big data have to be strongly reduced with high temporal resolution for “real time” applications. More recently, several applications for driver assistance, automation or quality control have been developed; even five imaging innovations based on multi camera data fusion, laser scanning or smart phone application have been awarded at the Agritechnica in 2015.

The increasing quality of imaging systems, reduced costs and weight as well as the usage of farm management information systems (FMIS) has resulted in an exponentially growing number of research and development projects focusing on agricultural applications. Examples for imaging sensor systems (for raw data generation) are: multispectral and hyperspectral cameras, 2D/3D distance cameras (such as laser scanning, stereo and time-of-flight imaging), shadow imaging (light curtains, laser sensors), thermal/UV/THz/x-ray imaging or high-speed, high dynamic range, radar and ultrasonic imaging. Moreover, low-cost imaging - using webcams, smartphones, Kinect cameras or Raspberry PIs for example - is strongly gaining importance.

Three types of sensor applications in research are presented: shadow imaging as a camera for crop characterization; hyperspectral imaging for field-based moisture measurements; the third system combines 3D and user-specific spectral measurements and is based on multiple laser projection (“multiwavelength laser line profile sensing – MWLP”), one application is the crop classification with in-field-labeling for crop/weed discrimination.

As an example for sensor data fusion, the concept “BreedVision” is described, consisting of a self-propelled platform with several image-based systems and data management for plant breeding (“phenotyping”). Several sensors with different interfaces, frame rates, data volume and position are implemented, the raw data are analyzed offline as for example for biomass detection.

Modeling environment

The availability of a large number of types and versions of imaging systems as well as the complexity of the field application has increased the relevance of the selection of an imaging system for a specific application. Moreover, it is important to integrate image processing in a process integrated model environment (process integrated imaging).

The middleware ROS (Robot Operating System) and the 3D-simuator GAZEBO have shown to be a helpful toolchain for developing imaging applications for agricultural purposes, in particular together with autonomous systems. Simulations can be performed before any hardware is developed, real sensor data can be used to verify and optimize the software which can be directly implemented in the real robot. The iterative combination of simulation, laboratory tests and field experiments is considered to be of high relevance for the development of robust solutions, thereby using sensor drivers instead of hardware in the first step.

Examples of sensor and robot developments are given. This includes the multi-purpose robotic platform BoniRob, elWObot for applications in wine and orchards and student projects (such as the International Field Robot Event) with small platforms.

Alternative (technological) concepts for agriculture

The integration of imaging systems on the field, in agricultural machines, drones, or satellites offers new opportunities for agricultural processing and working.

The precision of sensors and data processing allows individual crop farming, which offers a broad range of selective processing applications. The difference between agriculture and horticulture would become even smaller.

The project “RemoteFarming.1” is presented. For autonomous mechanical weed control in ecological farming a vision-controlled manipulator/actor system is attached to the autonomous platform BoniRob. A human remote worker is performing the weed control (RemoteFarming.1a) in the first approach, followed by step-wise increased automation (RemoteFarming.1b/c).

Autonomous agricultural machinery could be based on existing machines or new autonomous systems. The BoniRob projects and developments are based on small machines, where two different concepts are in focus: 1) The BoniRob platform serves as a platform (similar to a tractor) and application modules (Apps) are available for various processes (similar to an implement). 2) The technological components of the high-end platform BoniRob are configured in different ways, thereby focusing on the specific application (“Familiy”).

Sensor systems, robotic solutions and data management are technical key components for the digital transformation in agriculture. Together with process related ideas these technologies can be supporting tools for future alternative concepts in agriculture. In particular environmental impacts of state-of-the-art agriculture have to be reduced in parallel to an increased food production.