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Precision Farming -
Technology for highly efficient Production Systems

The principles and implementation of Precision Farming (PF) has provided new agricultural production processes in many different aspects. The main idea of PF is well known already for a long time but with the availability and combination of positioning sensors and robust electronic controls on agricultural machinery these new processes could be technically realized. Today the automation level of agricultural machinery is high documented by automated steering systems in tractor or self-adapting complex harvesting machinery to changing conditions.

The main theoretical benefit is perhaps that PF allows to describe and analyze the complex outdoor growing conditions in a better way. This better understanding enabled variable treatments within fields to address heterogeneous conditions in soil and crop properties as common on most agricultural farms. Therefore, new was that PF provided more information about the heterogeneous processes and it enabled precise application techniques to treat crop plants on sub-meter scales with variable dose rates. These techniques work even in real-time and on high general automation and reliability levels.

The early PF systems had adoption problems due to software not being able to integrate different data and information sources. The new and divers spatial and temporal data were difficult to analyze, to harmonize with existing crop management strategies and to convert into reasonable and executable application maps. Today the farm management software is much more advanced and able to process different information sources and types. Therefore, the farmers today are more efficient in time and the software helps to make the processes more transparent and adjustable.

Beside new and better management information software with decision support especially new and complex sensors are promising techniques to further improve crop management in terms of resource efficiency and in general to contribute to higher sustainability levels of the whole farm.

Sensors for positioning

A basic requirement for utilizing PF is a positioning system with an appropriate accuracy. In general positioning systems in PF are used for geo-referencing information of crop and soil parameters, for applying treatments and for being able to navigate a machine within a field. Some applications require a low accuracy like 10 to 20 meters e.g. for locating fields and some need few centimeter positioning errors for precise machine and actuator guidance. Common are positioning sensors which output absolute coordinates like Global Navigation Satellite Systems (GNSS) and sensors which output relative coordinates like 2D- or 3D-cameras and Light Detecting and Ranging sensors (LIDAR). Both types are commonly used and are often even fused for different purposes.

Common today is to use 3D-cameras for machine guidance by automated steering systems. 3D-cameras are used for letting a tractor follow a longitudinal contour profile or transversally guiding an implement parallel to crop rows. Newest developments of some manufacturers are camera systems which provide a 360-degree sight for the operator around the machine. For the operator of a big machine this helps him to see all details and objects close to the machine and specially to overcome dead angle problems. Due to the improved ease of use for the operator less accidents and repairs are the benefits for implementing these cameras.

Sensors for crop plant properties

Monitoring and real-time control of crop plants by sensors are a common technology in crop management. For this purpose, optical non-tactile sensors are used and are combined with fast data analysis and application control. These systems allow varying dose rates for providing optimized nutrient amounts to crop plants due to different growth conditions within the fields (site specific fertilization). Mainly active sensors are common which detect and analyze particular wave lengths of the reflected light from the crop canopy. Most of the indices of the spectral analysis correlate with the level of biomass of the crop plants. Based on this information the dose rate of the fertilizer is set and controlled in real-time. Problems show up when biomass variation is not caused by nutrient deficiency but e.g. by diseases (mildew) or additional non-crop biomass of weed patches. Until yet no scientific significance is documented for saving fertilizer or increased yields by using real-time sensors in site specific fertilization. However, farmers gain because of avoiding crop logging and of getting more homogeneous crop stands. In both cases it contributes to simplify the combine harvesting operation as an indirect effect.

Sensors for soil properties

Although sensors in PF get a lot of attention, especially in crop monitoring, sensors to capture information about varying soil properties are not much developed. Furthermore, when nutrient deficiencies are visible and detectable at crop plants this is often a delayed reaction to a change in soil chemical properties. Hence, varying soil properties during the vegetation period play an important role for optimizing agricultural fertilization. It must be concluded, that there is a big lag of information for dynamic soil properties in PF.

Beside missing sensors for chemical properties some physical properties can be detected even in real-time like soil density and soil type as well as soil moisture. These properties can be documented by creating maps not only in the horizontal plane by using GNSS but also as a 3D gradient in the vertical dimension including variations in top- and subsoil. The sensors which provide physical soil data can be used to minimize energy as fuel consumption and minimize operating time during tillage operation by adapting working depth to site-specific conditions.

Application technology

Today the technology for variable rate applications is quite developed. The dose rates as well as the distribution of fertilizer and other chemicals are adjustable in transversal direction (section control) as well as in longitudinal directions. The optimization in longitudinal direction is gaining from better mathematical models to describe the spatial offsets and temporal delays between the target areas and the application spots. Both effects contribute to minimize over and under dosing.

Farm Management Information Systems

A central IT system called farm management information system (FMIS) on the farm is essential for storing and analyzing data as well as for connecting information sources from on-farm machinery and the internet with specialized public and private information platforms. Many processes on the farm can be described and documented and hence optimized by the support in decision making.

More and more FMIS are moved to cloud based systems with better and flexible access from mobile devices. Another advantage is that more information sources and services can be utilized. Furthermore, problems of data formats and interface compatibilities are supposed to overcome more easily in cloud based systems. The information transfer is partly automated from machines used for different operations. Standardized data communication based on ISO 11783 (isobus) supports to harmonize format compatibilities but the standard needs to be expanded in order to match newest requirements.

Indirect issues as data security and safety are getting more and more important for farmers because the commercial interest in agricultural data is increasing. User profiles and big data models similar to consumer systems are regarded as threats and must be prevented. Commercial servicing systems with secure and reliable business agreements for farmers should be created and will be welcomed by most farmers.

Technologies as cloud based systems, internet of things and big data analysis are promising new tools to furthermore access optimization potentials in production processes. These tools are summarized under terms as smart or digital farming.

Conclusion

In the near future the farmer will still stay in the center of the decision making due to the high complex and unpredictable outdoor conditions. Automation levels and information technologies will help to make better decisions in terms of resource efficiency, reduce labor costs, protect the environment and improve the product quality. New senor technologies including data analysis and fusion are promising and will provide better information about the processes.