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The Project Advanced Optoelectronic System (AOS)

Part 1: On the Further Development of Sensor Assisted Weed Recognition and Control

Precision Farming in plant protection will be the future of weed control. Herbicides will be brought out in a targeted manner and mechanical weed control will only be used when a certain threshold of economic loss is exceeded. Optical methods are most used for the localization of weeds - primarily image analysis and optical sensors. At the Institute of Production Engineering and Building Research the aim is to use a "Spectral Fingerprint" to distinguish between weeds and useful plants, and to use a multi-sensor-system to ensure that within the same working process herbicides are unerringly brought out to those weeds which have to be controlled.

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Precision farming in plant protection will be a permanent part of plant production at the beginning of the Third Millennium [1]. This means that a weed will only be controlled when it exceeds an established threshold of economic loss. In order to do this, weeds must be localized, recognized and/or determined. The first efforts to create the prerequisites for targeted weed control were launched more than 15 years ago. The range of the approaches included manual coding of the weed population through high resolution aerial maps or multi spectral satellite data, and from the documentation of the geometry of plants through the combination of various optical sensors, up through the use of real time capability image analysis or optoelectronic sensors for targeted on-line spectral analysis. Each approach has a special area of implementation and advantages - but is also limited - by natural conditions, the environment, physical laws and the state of technology. In targeted weed control, both chemical and mechanical (as well as other) methods are used. Due to the high complexity, mechanical processes play a relatively low role. All approaches have in common that optically working sensors are used to localize or recognize weeds.

Targeted mechanical weed control with sensor assisted weed localization

A first multi sensor system was developed for use in maize and works with photo diodes to determine the growth height, which differs between the maize and the weeds [2]. Due to the costs and technical difficulty of this project, a breakthrough in practice is not to be expected. The implementation of new types of optical sensors was studied [3]. Electrical current can be used instead of mechanical tools to destroy weeds in special cultures [4]. The plants are localized with a two-level image analysis system. A robot was developed in which plants are detected with a FUGA camera for the implementation of chemical tools in weed control in wide row crops [5]. A self driving robot used for mechanical or chemical weed control is the goal of the „Robotic Weeding" project (RoBoWeed) in which image analysis is used to identify crops and weeds and high precision mechanical tools - but also chemicals - are used to fight weeds [6]. An autonomous robot was developed as prototype for use in sugar beets, and a research vehicle was developed, which on the basis of near infrared images, recognizes the rows of sugar beets [7]. The goal is to use mechanical tools to remove the weeds between the rows.

Targeted chemical weed control with sensor assisted weed localization

It is fairly simple to control weeds with herbicides before plant emergence in a targeted manner, since only the plants and soil need to be differentiated. It become much more difficult when a differentiation between plants and weeds is required. The localization or recognition of weeds takes place with optical methods. Differentiation is made between optical sensors and units in the area of image analysis.

Image analysis systems for plant recognition and differentiation

High resolution CCD shutter cameras are well-suited to the identification of plants. The images made by a camera attached to the front of the tractor are digitalized and an image evaluation program is used to differentiate between the various plant types [8]. For this purpose geometrical characteristics are determined and placed in a data file on the plants. The recognition rate is about 70 percent. Up until now GPS supported weed maps were created and the weed control was carried out in a second step [9]. The savings on herbicides is dependent on the amount of weeds, but an average of about 50 percent is often cited. A further prototype with 21 m working width works with three cameras and can choose between three different herbicides in the second passage [10].

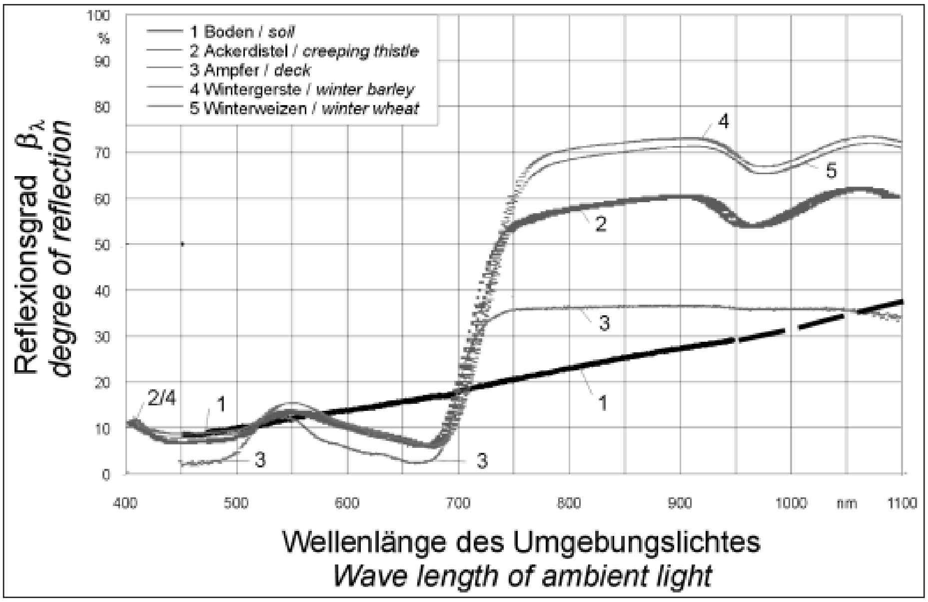

Fig. 1: Reflection of winter grains, creeping thistle and deck as well as soil in the wavelength range of ambient light between 400 nm and 1100 nm

Similarly, a CCD camera determines the level of weeds between rows of corn and then assumes that the level of weeds is the same in the row [11]. With the help of a fuzzy-logic algorithm, the level of herbicides used is varied depending on the level of weed coverage. Depending on the algorithm, between 10 and 16 percent herbicides were saved through the use of the weed maps in the simulation.

Optical sensors for plant recognition and differentiation

Optical sensors (i.e., photo diodes) are very fast and therefore well-suited to on-line use.

One approach uses such optical sensors in the traffic roadways to calculate the weed occupation [12]. This information is used to determine the level of weeds in the field and to bring more or less herbicides out in a targeted fashion - savings of between 20 and 40 percent are possible. A prerequisite is the comparability of weed growth on the traffic roadway and within the cultivated plant population, which is classified as good. A partial shut down of the system depending on weed population is not possible [13].

The use of optical sensors to distinguish between soil and plants in cooperation with a spraying nozzle at the normal distance of 50 cm on a field sprayer allows the sensors make the resolution of the targeted weed control finer and has been suitable for use on black fallow or in the pre emergent period for more than ten years [14]. Here savings of between 30 and 70 percent have been achieved [15]. Such systems are particularly suited to vineyards. Based on the previously mentioned system, an on-line plant differentiation system is being developed which makes use after plant emergence possible [16]. The methods chosen here are based on a Spectral Fingerprint of the plants with the help of an algorithm suited to differentiate between weeds and crops.

A stable differentiation between weeds (common speedwell, creeping thistle, common chickweed, shepherd's purse, common lamb's quarter, wild chamomile) and the crops (corn, sugar beets, winter barley) and soil as well as straw was studied with a Spectral Fingerprint at the wavelengths 530, 650, 870, 1450, and 1650 nm and according algorithms for the differentiation [17, 18]. In this case the relations were almost ideal, since only one plant was present in each container. In further studies improved algorithms will be studied in order to make differentiation in the field possible [19].

A similar approach is used with photo transistors and thin layered band pass filters in the area of 400 nm to 1700 nm. With various methods (color indicators, fuzzy logic, genetic algorithms), it was attempted to differentiate between wheat, soil and group of weeds grown in pots. The differentiation of certain weed stems from wheat and soil showed good success [20]. If more weeds are brought into the range of sight of the sensors, the recognition rate for a group of nine weeds is over 70 percent. For individual weeds it drops to under 50 percent [21].

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The concept of the AOS sensors for the differentiation of useful plants and weeds as discussed is based on the reflection spectrum of the plants for which a „Spectral Fingerprint" is made. In addition to published reflection curves (mostly laboratory measurements) own field and laboratory measurements were used to select the wavelength areas.

As can be seen in the example of *Figure 1*, there are significant reflection differences between creeping thistle, dock and winter wheat, above all in the wavelength area above 750 nm, which can be used to differentiate between the plants if suitable photo diodes and filters were to be positioned. These are lab results. For field measurements, a field wagon was created. The reflections of the plants to be studied were done with a sensor prototype which monitors five photo diodes each with a pre-switched wave pass filter for another wavelength of the ambient light. The measurement data is documented in a data collection system and saved in a laptop. An ambient light sensor documents the ambient light directly and makes the correction of measurement values according to the spectrum of ambient light possible. The light intensity is measured with a Lux meter. All plants are also photographed digitally. The measurements were carried out in a stationary manner and while crossing over.

Continuation and Literature in Part 2