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Digital Farming

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Abstract

Close monitoring of the most significant production processes is very important for any kind of production optimization. When talking about agriculture, gathering as much information as possible on soil condition and microclimatic conditions, which include insect activity, is essential for correct decision making in farming. Using a large number of various, low-cost sensors, gives us the opportunity to create a database for a smart farming algorithm. Processing such a database requires a software system, based on self-learning artificial intelligence. This system will later suggest an optimal agricultural activity. Using such a system, the farmer has better opportunities to take the right measures when needed. This article presents the method and the low-cost sensor system for analyzing soil in the field. It is integrated into the "digital farming" solution.

Keywords: Soil classification, Soil sensor cluster, Soil impedance spectra, Self-learning algorithm, Digital farming

Introduction

In Slovenia and in many European countries, food self-sufficiency is far from realization, even though there is more than enough agricultural land available. Unfortunately, it is not being used as it should be in order to attain this goal, and it is left to the uncultivated deterioration of the environment. There are several reasons for poor self-sufficiency. One is the fact that importing produce requires less effort compared to domestic food production. Typically, imported food is grown in distant regions using questionable methods and fortified with many types of chemical additives such as herbicides, fungicides, insecticides and similar. Most of these substances are harmful to people and can cause many serious illness. The agricultural system called ''bio-farming" was introduced in an effort to overcome this unhealthy practice. The system utilizes traditional methods, and thus requires more effort. The result is a healthier product, but the quality is worsened by plant pests that have not been treated by harmful spraying. Bio-farming is less attractive, because production costs are higher, and a less aesthetically pleasing product is sold at a higher price. An additional obstacle for modern sustainable farming is the fact that farm work is less appealing compared to other employment options, which makes it difficult to find farm labor nowadays. During the growing season, a farmer works from dawn to dusk and earns a salary that is lower than in other professions. Consequently, younger generations decide not to continue the family farming tradition and leave their homes to find a better life in larger cities. This paper gives some answers to these challenges, such as the introduction of new cultivation methods, the improvement of the yield and quality of harvest and finally the digitalization of the farm with final goal to achieve "smart farming". There are also some interesting studies available that are addressing the issue of improving the crop yield [1].

Materials and Methods

For any kind of production optimization, the key component is the proper monitoring of the production technology. The common practice in agriculture is that the farmer usually inspects the current condition of the crop visually and evaluates it according to his knowledge and personal experience. He then reacts with the necessary corrective measures. The qualitative change in this paper is to introduce as many cost-effective sensors as possible to monitor plant condition and other environmental parameters of soil condition. This includes moisture content, temperature, pH value and nutrient content. It is important that the soil classification is carried out at a depth of about 30 centimeters below the soil surface. This approach introduces a novel cultivation method. Sensors above the soil surface monitor the hourly microclimatic condition including outdoor temperature, weather conditions and wind parameters. Some sensors above the soil surface also monitor plant health, indicated by leaf color and leaf damage by plant pests. This is helpful for taking timely corrective measures. There are also sensors that detect bioactivity of bees and other insects. Figure 1 shows an example of the sensor cluster. With access to this wealth of data, the farmer has the ability to make the decision to intervene if necessary. He also has the possibility to store this data to enrich the database for the intelligent algorithm that suggests optimal agricultural activity. Processing such a large number of sensors requires an artificial intelligence supported method, which is used to extract the valuable and reliable information. It is worth noting that this proposal allows for constant self-learning, based on the introduction of additional data with the information on the actual annual harvest quantity and quality.

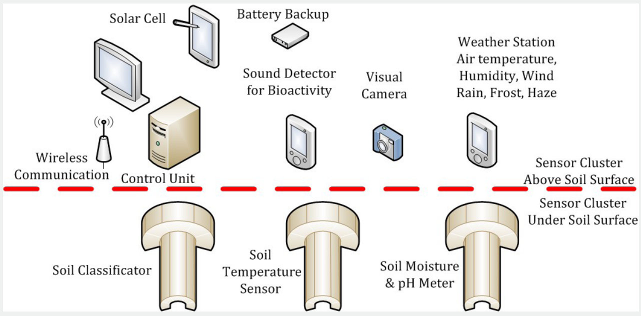

Figure 1: Typical sensor cluster for monitoring soil and microclimatic parameters.

However, the most important parameter for improving crop yields is the correct soil class, which is mainly determined by the amount of the nutrient mix for a given crop [2]. The immediate and on-site measurement of soil class is the most demanding task for sensor development. This was achieved with an acceptable level of confidence [2]. This is a breakthrough that allows us to connect such a sensor (based on the analysis of the soil impedance spectra) to the subsoiler, which applies the required dose of the respective fertilizer while driving the tractor on a field. The dose is based on the measurement results obtained during the underground sampling at a speed of up to 3m/sec. The subsoiler applies the fertilizer at a depth approximately 30cm below the soil surface. This means that the fertilizer is applied near the root structure, which is where it is needed the most. Only the required amount of fertilizer is used and delivered to the right place at the right time. Figure 2 shows an example of soil impedance spectra for 3 different soil samples. Each sample is measured twice to demonstrate repeatability. To achieve the digitalization of the farm, all sensors in the field are connected to the sensor cluster central unit. The central unit supplies power to both the underground sensors and the surface sensors. The central unit can be powered by a solar cell with battery backup. The central unit scans all sensors once per hour to reduce power consumption. It then transmits the data to a personal computer in the farmer's house. The farmer has an overview of his entire field without having to leave the house. The application software installed on the farmer's personal computer is actually the "brain" of the system. This is where the collected data is stored, analyzed and processed in the database. Such a database then further improves the artificial intelligence-based algorithm of "smart farming".

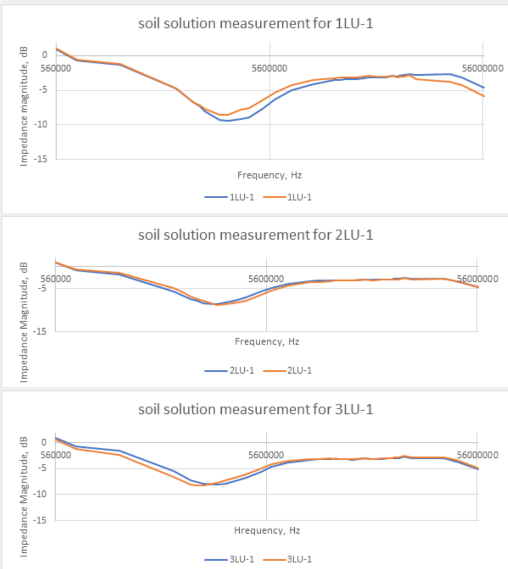

Figure 2: Example of three different soil spectra for soil samples 1LU-1, 2LU-1 and 3LU-1. Each sample is measured twice, to demonstrate the repeatability.

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Results

This approach significantly improves the crop yield in terms of quality and reduces the amount of fertilizer used, thus minimizing production costs. Table 1 shows the soil classification table. The soil classes A, B, C, D and E are determined according to the nutrient content. Table 2 shows the classification result for the soil samples 1LU-1, 2LU-1 and 3LU-1. This classification was achieved by the self-learning algorithm developed in this study. The results are compared with a reference laboratory where the chemical analysis approach was used [3]. Figure 3 shows the classification setup device. The classification algorithm is embedded in the firmware of the microcontroller. The classification device also uses an application-specific integrated circuit. It is shown on the right side of Figure 3 and was developed in our laboratory (LMFE) [4].

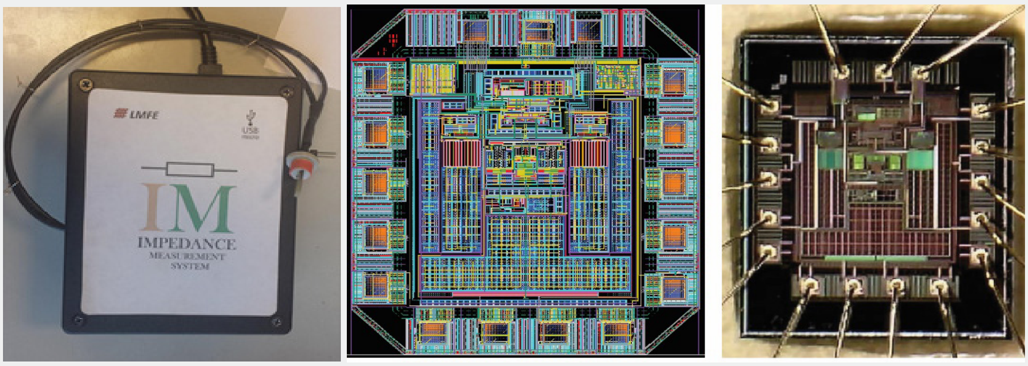

Figure 3: The measurement set-up on the left side of the figure includes the dedicated ASIC (Application Specific Integrated Circuit), which is shown on the right side of the figure. It was developed in our laboratory (LMFE).

Table 1: Presents soil classification table according to nutrition contents.

Class	Phosphorus mg/100g	Potassium mg/100g	Magnesium mg/100g
A	0<X10	0<X10	0<X10
B	10<X20	10<X20	10<X20
C	20<X30	20<X30	20<X30
D	30<X40	30<X40	30<X40
E	>40	>40	>40

Table 2: Shows three different soil samples classification results.

Soil samples	LMFE-Lab	Chemical lab
1LU-1	ABC	ACD
2LU-1	ABC	ABC
3LU-1	ABC	ABC

Conclusion

The paper represents the status of the project named Digital Farming. The project is based on the analysis of a multi-sensor system that captures a large number of parameters relevant to "smart farming" using a variety of different sensors. The sensor data provide an immediate overview of the situation in the field and enable the farmer to react in time if necessary. Additionally, the farmer's profession will become more attractive for the younger generation as farm work is less and less focused on manual labor and shifts to a modern digital technology. This change will also contribute to environmental protection by minimizing the amount of nutrients in the soil and pollution from harmful chemical additives used in crop spraying. This work is in progress. For the time being, several datasets will be collected on selected farms and evaluated for relevance. This will also expand the database for self-learning artificial intelligence.

Acknowledgements

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Conflict of Interest

The author declares that there is no conflict of interest.

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