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The Refractive Index Measurement Device for Continuous and Autonomous Irrigation Monitoring

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Abstract

In this work, a system based on time-domain reflectometry for continuous and pervasive monitoring of soil water content in agriculture is presented. The proposed TDR-based system uses elongated sensing elements. In a practical application, each wire-shaped SE is buried along the crop line to be monitored and through a single TDR measurement; a crop water content profile can be retrieved along the length of the SE crop. By connecting the TDR-based monitoring system to the irrigation machinery, it is possible to automatically start/stop irrigation based on the actual water needs of the crop, thus promoting precision farming and improving efficiency irrigation fruit. To demonstrate the feasibility of the proposed monitoring solution, a dedicated hardware + software platform was developed and the TDR-based system was tested on outdoor crops.

Keywords: Reflectometry; Crop; Water

Introduction

Irrigation is crucial in the economic and productive management of agricultural systems; therefore, water efficiency has become a priority also due to the increasing limitations of this natural resource. To alleviate this problem, there is a need to develop technologies and practices that can provide effective solutions that are still cost-effective and easy-to-use for farmers. Recently, precision irrigation technologies have been considered as a potential strategy to improve crop yields in the face of increasing water scarcity [1]. In addition, the application of machine learning on sensor data was considered to provide farmers with predictive irrigation recommendations. Properly designed and built irrigation systems are essential to optimizing irrigation processes, increasing crop profitability, streamlining available resources and reducing waste. In such a scenario, real-time and automated monitoring of actual water demand is the strategy for optimal management of agricultural systems. The first step in assessing a plant's water needs is to assess the water content of the soil. However, in the modern state, soil moisture sensors are usually point sensors; therefore, a large number of point sensors will be required to monitor large farming areas. This will ultimately limit real-time monitoring and automatic irrigation control that can only rely on pre-set irrigation schedules or weather stations. In such a context, the objective of this work is to develop and validate an improved system based on the use of time-domain reflectometry and low-cost stretch detection elements for monitoring Continuous and continuous soil water content in real time. SE is buried in the ground, close to the crop to be monitored [2-5]. A single SE can be tens of meters long and will allow the assessment of the water content characteristics of the crop.

The developed monitoring system will communicate with irrigation systems and can automatically control valves that, depending on the water content detected in the soil, can allow irrigation to be restricted in areas need water. . In practical applications, when the measured soil moisture falls below the warning threshold, the system opens automatic control valves, thereby starting irrigation. Similarly, if the soil water content is too high, for example due to rain, the system will prevent the pumping system from starting, thereby slowing down irrigation. The proposed system could include three key components of sustainable agricultural management as defined in, i.e. real-time monitoring, decision-making and remote access [6]. Here, first of all, the context is briefly described. The developed materials, methods, and hardware/software platforms are then described in detail. Then, the test validation outcomes of the system in two real-life application scenarios are reported, one test group involves planting trees and the other involves planting trees. TDR is an age-old measurement technique used in a number of fields. This technique has low implementation costs and provides remote control and continuous monitoring. Additional features such as adaptability and real-time response make TDR particularly attractive for a multitude of applications, e.g. wire fault location, liquid level monitoring, dielectric characterization of materials, monitoring of building structures, quality control of vegetable oils, monitoring of landslides and ground movement, leak detection in underground pipelines [7-9]. The literature regarding TDR-based soil moisture measurement is abundant; however, traditional TDR soil moisture measurement relies on short multi-rod probes for local moisture measurement. On the other hand, the monitoring system described here is based on extended SEs, similar to that used to locate leaks in underground pipes and to monitor building structures. TDR is based on the analysis of a reflected signal when an electromagnetic signal, usually a very fast rise time voltage jump signal or a pulse signal, propagates along a transducer or SE fitted into the system under test. In particular, a propagating TDR signal reflects the change in electrical impedance encountered along its path.

Monitoring system

For the measurement of diffuse soil moisture, the TDR-307usb instrument was used. This instrument was chosen because of the optimal compromise between measurement accuracy and a low cost of around 1,000 Euros; it is therefore ideal for agricultural applications typically characterized by stringent cost requirements. The TDR-307usb is a portable pulse signal generator whose duration can vary from 10

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ns to 50 μS. This instrument has powerful built-in electronics and is powered directly through the laptop's USB port [10]. Like the stretched SE, the sensing section consists of RG59 coaxial wire and cable, which are mutually insulated and parallel to each other. The axonometric section. In coaxial cable, the inner conductor is made of copper and has a diameter of 1.6 mm; the insulation is made of polyethylene and has a diameter of 7.1 mm; the outer protective conductor is a copper foil; the last is a protective plastic layer which is made of PE and has a diameter of 15 mm. For W1, the wire is made of copper and is about 2mm in diameter.

Application

In terms of the applicability of the proposed system, it is important to make some considerations regarding cost and implementation method. Regarding the cost of SE, it can vary from approx. €0.20/m to €7/m, depending on the quality of SE required for the particular application. For example, for seasonal crops, it may be a good idea to use low-cost disposable ES, which is used for one season, then removed from the ground and disposed of. On the other hand, for crop monitoring, a more robust and durable SE can be used. In fact, in this case, the lifespan of the SE is assumed to be equivalent to that of the tree. For TDR meters, as mentioned above, for some TDR devices, multiplexers can be used. This allows up to 512 SEs to be controlled with a single measuring instrument, thus significantly reducing deployment costs. Outline of a possible configuration of a multiplexed TDR-based surveillance system.

Conclusion

In this study, a TDR-based system for continuous and pervasive monitoring of soil water content in agriculture was presented. Unlike traditional point sensors, the proposed system allows monitoring of soil water content profiles along elongated SEs buried along crop rows. The suitability of the TDR-based system developed for the intended application has been tested on actual crops. The proposed system has considerable potential as a cost-effective solution for real-time monitoring of soil water content in agriculture. In practical applications, by connecting the proposed metering system to the irrigation machinery, it is possible to automatically start/stop irrigation based on the actual water needs of the crop. Integrating this proposed system with irrigation systems could promote precision agriculture and improve irrigation efficiency.

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