Workshop
SeSAM: Sensing Systems for Agricultural Management

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***Abstract*— This paper summarises four contributions in the workshop session "Sensing Systems for Agricultural Management". The research work included in this workshop deals with the following key issues of this track:**

- **The use of remote sensing and image processing for canopy cover of crop and weed.**
- **Optical sensors for detection of clogging caused by plastics in irrigation grid.**
- **Evaluation of spatiotemporal variability of oxygen concentration in phytodepuration system.**

This publication details how the papers in this track address research questions and propose suitable solutions crucial for agricultural management and current research directions, such as low-cost sensing systems and optimisation of image processing for agriculture.

Keywords-image processing; canopy cover; weed detection; optical sensor, irrigation grid; phytodepuration; dissolved oxygen concentration.

I. INTRODUCTION

Sensing Systems are highly demanded in several sectors for monitoring the performance and optimise the management. Focusing on Agriculture, different challenges appear related to the required robustness, limited energy, and the capacity of monitoring a complex environment. Therefore, the need for cost-effective, adapted, and specific systems for agriculture management is urgent to minimise and mitigate the effects of climatic change in our food chain.

Sensing systems for agricultural management includes sensing elements measuring the pant, water, soil, and fruit characteristics, smart elements receiving the generated data and decide the best management option, and communication elements that connect the sensing with the smart elements. Moreover, operational algorithms that adapt those systems to the changing environment and the existing limitations while ensuring its operation must be perceptively incorporated. The inclusion of farmers in those systems is vital.

This workshop focuses on the integration of sensing systems for agricultural management, including all the possible elements included in those systems. Systems can be based on wireless sensor networks, on the Internet of Things, and based on the use of smart devices or smart vehicles that can stand alone and optimise the management of agricultural practices. Minimising the waste of resources, maximising the production, defining the best harvest moment, monitoring the stress or the crop, or identifying pests and weed plants are only some examples of agricultural management.

II. STATE OF THE ART

Although we have established the need for sensing systems for correct agricultural management, its integration in real scenarios is rare.

Regarding remote sensing, several authors pointed out the suitability of these techniques for agriculture monitoring. Their use covers a wide scope of applications such as monitoring plant diseases and pests [1], fight against drought [2], and crop yield estimation [3], among others. The remote sensing englobes different types of data gathering systems, including unmanned aircraft systems or satellites. While some information is freely available in geoportals such as Sentinel data, unmanned aircraft systems involve certain costs. This is particularly relevant in the case of unmanned aircraft systems. In a recent publication, authors [1] claimed that costs for data acquisition with unmanned aircraft systems need to be reduced to extend its use. The prices are slightly lower when multi-rotor drones are used. A report from FAO recently indicates that remote sensing is still very low [2].

We can highlight their broad range of applications concerning the use of sensors as part of Wireless Sensor Networks (WSN) or IoT for agriculture monitoring. According to a recent survey [1], we can identify the most common applications of soil moisture monitoring for irrigation management and the air temperature and humidity monitoring for activating fans in greenhouses. On the other hand, very few proposals reviewed shows the use of sensing systems for crop monitoring. Limited contributions might be identifiable in which authors propose monitoring the plants [2, 3], mainly for monitoring plant vigour and chlorophyll. Nonetheless, as for remote sensing, the real application of sensors in real scenarios is marginal.

Thus, to maximise the use of sensing technologies for agriculture management, the adaptation of those systems is required. These adaptations might include the reduction of costs, the establishment of algorithms for image or data processing, or the demonstration of its operation in real scenarios. Therefore, the existing technological solutions might be easily transferred to the agricultural sector, scallable, and with reduce costs to promote an enhancement of its sustainability and profitability, ensuring food production in the future.

III. SUBMISSIONS

Following, we detail the included papers in the workshop, analysing in detail their contribution to the application of sensing systems for agricultural management.

A. *Remote sensing for agricultural management*

In this subsection, we detail the first and second publications, which focuses on remote sensing.

In the first publication, "Comparison of performance in weed detection with aerial RGB and thermal images gathered at different height" [1], by J. F. Marin et al., evaluate the use of remote sensing for weed detection. They focus the weed detection in sport turf. In this publication, authors first analyse if techniques previously applied to images gathered at 1.5m are suitable for images collected at higher height (4 to 16m). Once they check that the band combination can be used to detect the weed plant, they compare the performance of weed detection at all tested height in three areas of a golf course with different affection levels. Their results indicate that their methodology can be applied for images collected at 4, 8, and 10m without losing accuracy. Nonetheless, if the same methodology is applied with images gathered at 12m system fails in estimating the percentage of the affected area. Finally, they present the required time to fly the drone used in their experiments over different areas with sport turfs.

Their proposed methodology and their results related to the maximum height can be easily transferred to pastures monitoring for grazing or even for cereal cropping. Both agriculture scenarios are similar to the sport turf in terms of high and uniform coverage of the crop over the cropped surface.

With regards to the second contribution, "Estimating the Canopy Cover of *Camelina sativa* (L.) Crantz through Aerial RGB Images" by D. Mostaza-Colado et al.[2], compare the canopy cover of *C. sativa* under different treatments. The different treatments consist of the application of different concentrations of Urine derived Fertilizer and different seeding dates (December and February). The authors used a drone to gather images at 15m height to determine the canopy cover at the end of April. To estimate the canopy coverage, the authors use a combination of bands from the RGB gathered pictures. Their results indicate that higher canopy coverage is reached in the plots seeded in December than the ones seeded in February. Regarding the applied fertiliser doses, the results do not indicate any difference yet.

Their proposed approach might be transferred to evaluate the germination of rainfed crops with high extensions, which cannot be monitored by other means. The continuous monitoring of canopy coverage evolution is vital for detecting crop damages such as pests, diseases or herbivorous grazing.

The most relevant aspects of these two papers is the low cost of the equipment used for data gathering. Data is gathered using a drone at a low cost compared with drones generally used in agriculture. Moreover, the use of band combination avoiding the use of artificial intelligence technics allows its future use in regions without internet connection by processing the images locally in the drone if nodes such as Rasberry Pi are included in the node design.

B. *Sensing systems in water for agriculture*

In this subsection, we detail the third and fourth publications, which focuses on the application of sensing systems in water. The third one proposes a low-cost system for grid monitoring; meanwhile, the fourth one presents the results of analysing the water quality of probes in a phytodepuration station with an aquatic plant crop system.

The third paper, "Development of a Low-Cost Optical System for Monitoring Plastics in Irrigation System Grids" by Daniel A. Basterretxea et al. [3], proposes the design and development of a sensing system for irrigation channel. In this paper, the authors evaluate the use of optical sensor and image processing for detecting cloggings caused by plastics in the grid of the irrigation channel. The authors replicate an irrigation channel in the laboratory with partially clogged or unclogged gratings along with the experiment. The optical sensor was placed at a 10 cm distance from the grating. To recreate the expected changes in the environment, the authors test their proposal at different levels of turbidity. To show the operation of the system, an algorithm that combines different optical sensors are displayed. Their results indicate that it is possible to use the histograms obtained by the optical sensor to identify the presence or absence of clogging in the gratings under certain conditions of turbidity. The system cannot operate at high levels of turbidity.

Their paper has shown the effectiveness of a low-cost solution for the monitorisation of agriculture facilities. Considering the continuous increment of pollution caused by plastics in the inland water and the damages which can cause the plastics in the pumping system, this proposal has a high impact on the sector.

The last presented paper, "Evaluation of Temporal Stability of Dissolved Oxygen Conditions in a Small-Scale Phytodepuration System", by B. Stefanutti et al., [4] presents the performance of a phytodepuration system. The authors measured the spatiotemporal variability of dissolved oxygen (DO) in the ponds in which *Typha domingensis* (L.) is growing. Their results indicate that the DO has greater variability in the top of the pond compared with the bottom. The variability is also higher in the first pond compared with the second and third pond. Their results indicate that during most of the evaluated period, the anoxic condition in the bottom of the pond allows the biochemical reactions required to reduce organic matter content in the water. This mineralisation of organic matter serves as the input of nutrients for aquatic plants. At the end of the experiment, the crop is harvested to evaluate the profitability of the system.

This contribution represents the first paper that evaluates the variability of DO in the ponds of a phytodepuration system. Understanding this variability is crucial for the establishment of management options that maximises the performance of water treatment and crop growth.

IV. Current Challenges and Future Trends

In this section, we deal with the current challenges and future trends related to the sensing systems for agricultural management. First, we analyse the contribution of presented papers to the overcoming of current challenges. Then, we will focus on the expected future trends.

Based on the presented contributions, we can see that the advance beyond the state of the art is aligned with the requirements set in state of the art: low-cost solutions, adapted to real scenarios, and scalable Thus, presented solutions are easily transferable to the agriculture system.

On the basis of information collected from the published and reviewed materials in this workshop, we can identify to following current challenges for sensing systems to ensure its operation in real scenarios exposed to a high degree of uncertainty due to the changing circumstances caused by the fauna and flora, the meteorological conditions or even the actions of farmers.

High robustness:

- For data management/transmission: fault tolerance, data retrieval, and recognition of false-positives algorithms.
- For sensors: low maintenance requirement, simple and modular components, and no-calibration requisites.
- For nodes: low energy consumption, tolerance to adverse conditions, and high processing capacity.

Low cost:

- For data management/transmission: using technologies capable of integrating into a previously deployed system and having the capacity of using existing communication channels.
- For sensors: low-cost components without continuous replacement needs.
- For nodes: energy harvesting systems to avoid using batteries.

Easy-to-use for farmers:

- For data management/transmission: integrate data into friendly interfaces in existing devices such as smartphones or smart agricultural machinery.
- For sensors: plug and play, no modifications or adaptations requirement, and easy deployment.
- For nodes: plug and play, limited configuration required, and configuration using Apps.

Regarding future trends, a higher degree of integration and interoperability of sensing devices in the agricultural sector is expected. The integration of IoT will provide an increment on the generated data, which will lead to the creation of data observatories and wider knowledge about the interactions between the elements of agriculture (plant, soil, water, climate, etc). On the other hand, the blockchain and the artificial intelligence techniques will help in the development of decision support tools based on the created data observatories and the generated knowledge. Nonetheless, the integration of farmers and farmer associations from the initial stages of technology and systems development is critical to ensure its future adoption.

V. Conclusion

The research results presented in this workshop contributes to relevant progress beyond state of the art. Three out of the four presented papers are based on the use of low-cost solutions for agricultural management, which will be followed in future work tests with high exploitation potential for the agroindustry. The last paper is evident beyond state of the art since the provided information nonexistent to the date. The future work of the paper can be summarised as follows:

Regarding the papers using remote sensing technologies, their future work mainly aims to test their methodologies with other crops and use other equipment to reach higher heights. Particularly, on the one hand, the application of methodologies for canopy coverage estimation will be combined with data from the crop, such as the quantity of the yield. On the other hand, the methods proposed for weed detection will be modified to evaluate its suitability for diseases or pest detection.

Concerning the use of sensors in the water, both papers aim to extend their measurements. In the case of an optical sensor for clogging with plastics, authors will extend the number of objects to be detected by including leaves and other types of waste. With regards to the DO monitoring, the authors will extend the measurements by modifying the water input conditions.

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