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Editorial

Optics and Image Analysis in Modern Agriculture: Transforming Practices and Unveiling Opportunities

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Optics and image analysis technologies support modern agriculture, providing detailed insights into crop health, soil conditions, and environmental factors at both the macro and micro scales. We can include optical and image analysis as one branch of digital agriculture, or Agriculture 5.0, which integrates advanced technologies to enhance efficiency and sustainability in agricultural processes [1]. This modern agricultural environment enables farmers, the industrial sector, and research centers to make data-driven decisions, develop new techniques and protocols, optimize resource use, and enhance overall productivity. Artificial intelligence (AI) and the Internet of Things (IoT) are two examples of the technologies integrated into agriculture [2,3] that can be adopted to deal with the data provided by optics and image acquisition. In addition, the ongoing digital revolution continues to drive innovations in optics and image analysis, regularly introducing new protocols.

In this Special Issue, "Optics and Image Analysis in Modern Agriculture: Transforming Practices and Unveiling Opportunities", we sought reports of new developments across a broad range of advanced techniques in this domain applied to agriculture. These include remote sensing, multispectral and hyperspectral imaging, 3D reconstruction, digital image processing and analysis, and laser interferometric methods. Additional approaches such as near-infrared (NIR) and fluorescence spectroscopy, lidar (light detection and ranging), machine vision, and thermal imaging, sometimes integrated with deep learning and artificial intelligence (AI), further expand the possibilities for addressing challenges faced in agriculture. These cutting-edge methods enable the precise monitoring, analysis, and management of agricultural processes, promoting efficiency, sustainability, and innovation in farming practices.

The five contributions published in this Special Issue (SI) address some of those multiple techniques that represent applications in vegetal and animal systems, using image analysis techniques assisted by different computer vision methods. Hyperspectral imaging is reported in two outstanding works in this SI, for melon seed identification and fruit and vegetable grading. The interferometric laser technique, known as dynamic laser speckle, is described as a reliable way to assess seed vigor, and the adoption of a YOLO (You Only Look Once) model, version 5, is presented for piglet images as a feasible tool for real-time object detection.

Hyperspectral imaging technology has been increasingly used in agriculture in recent decades [4], and its adoption is associated with deep learning techniques [5], boosting the image processing and data analysis [6]. In this SI, hyperspectral imaging was applied in association with deep learning to melon seed identification. In addition, a four-dimensional hyperspectral imaging approach is also presented in this Special Issue (SI) for fruit and vegetable grading, based on the fusion of visible, near-infrared and short-wave infrared data with structured-light 3D scanning to evaluate internal and external defects in vegetables non-destructively.

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Hyperspectral imaging technology is a powerful optical sensing technique; however, it has rarely been used alone. The image datasets generated in its application demand a high computational cost. Supporting methodologies to process and to analyze the datasets are often adopted, as is the case for deep learning [7] and convolutional neural networks (CNNs), among many others. Therefore, the optics and imaging domain has provided a revolution in agricultural applications, with non-destructive techniques (NDT) opening the way for automation and accurate instrumentation; despite these breakthroughs, optical and imaging techniques still pose challenges for researchers and final users (farmers and industry) with the analysis of huge amounts of data, increasing continually due to the high definition of new digital cameras.

The adoption of computer vision algorithms, particularly YOLO, helps to reduce manual labor. In one contribution to this SI, a YOLOv5 model was applied to piglet image annotation, providing a semi-automated approach within an active learning framework.

To circumvent the limitations of machine and deep leaning, which often suffer from poor generalization, another contribution to this SI present a convolutional neural network model, WT-ResNet, where "WT" represents wavelet transform, which is used to capture different frequency components in sugarcane leaf images.

Laser speckle, representing an interferometric laser technique, is presented as a tool to measure, in a sensitive manner, the biological activity (BA) in seeds; it provides a reliable way to evaluate their vigor. Techniques based on dynamic laser speckle are gaining recognition in agriculture [7], particularly in seed analysis [8,9].

Together, the five papers presented in this Special Issue showcase a coherent narrative: optical and imaging technologies have become essential, versatile, and increasingly intelligent tools for agricultural innovation. Despite covering a fraction of the multiple optical and imaging techniques under development or recently presented, these contributions demonstrate the power of interdisciplinary integration—linking spectral sensing, dynamic imaging, machine vision, and deep learning—to advance productivity, sustainability, and scientific understanding across the agricultural spectrum.

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