THE ROLE OF COMPUTER VISION IN SUSTAINABLE AGRICULTURE

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Abstract: *Agricultural sustainability represents today a movement with ascending acceptance and support in the European Union, and knowledge, innovation have an important role to play in helping farmers and rural communities meeting challenges of everyday life. This is how the transition to digitalisation takes place also in practice, not only in research, in order to help making optimal decisions. Agricultural management systems can handle data in such a way that results are processed to obtain customized solutions for each farm. To develop intelligent farming applications using robotics and artificial intelligence, remote sensors are combined with computer vision or deep learning techniques. This paper wants to bring up both technical and economic aspects for some methods of applying computer vision, in order to highlight how, with the help of agricultural knowledge and innovation, we are moving towards a data-driven management with which we will be able to face much more easily the challenges in agriculture and food production in the 21st century.*

Key words: *agricultural knowledge and innovation system, smart farming, digitalisation, precision agriculture, computer vision*

INTRODUCTION

The world nowadays is constantly surrounded all-over in fields like social media or automotive industry to the financial fraud detection, by the deep learning algorithms and this has also a big impact on every person by the influences that came upon its daily decisions. For instance, reading and article, just because of the algorithm that stays behind it. The simplest version of answering „what deep learning is?" could be learning from examples; imitate how the human brain works in order to create a reality with an unprecedented level of accuracy - reaching up to the point where deep learning algorithms can outperform the human performance in classifying images and the world's best mind can be beaten on its own game through these algorithms.

In the last decades, extensive research has been conducted also in the field of smart farming and precision agriculture; and computer vision, as part of the deep learning, is one of the key technologies that have been integrated in this approach.

The terms precision agriculture and smart farming are used in a very general sense. Smart farming – also called the third green revolution – includes all types of agricultural methods that utilizes smart technology for better production efficiency optimizing production costs, which is reflected in a lower total cost and a higher profit. The term precision agriculture includes all types of agricultural methods using advanced sensors, cameras and software for high-throughput data collection and analysis aiming at higher yields, more sustainable land use and higher profits. Developing farming applications using robotics and artificial intelligence requires a combination of remote sensors and computer vision or deep learning techniques. The techniques used in smart agriculture utilise models to infer information about the environment and interact with it. The technologies used for this purpose are object detection, computer vision, deep learning or machine learning.

Precision agriculture and smart farming, with the help of Internet of Things (IoT), use efficient approaches for monitoring and processing information from farms, crops, forestry, and livestock aiming at more productive and less wasteful farming. IoT technologies offer options in the face of widespread environmental problems in agriculture and food production. [1, 3] The IoT, cameras, sensors, Big Data, GPS, unmanned vehicle devices are all important terms that have been collaborating to improve the quality and productivity of our world. [4]

The European Union recognizes how knowledge and innovation can help farmers and rural communities meet the challenges of everyday life. Promoting innovation and sustainable agriculture, research and development-driven is essential to the future of their business. The key factor for the success of any new technology is its acceptance by farmers. In order to achieve a sustainable agriculture it is also necessary to study the interactions between farms and ecosystems, because these interactions influence farmers' decisions about agricultural practices.

Today, sustainability is a movement with increasing support in the European Union. The European Union has set the challenge of achieving sustainable agriculture and food as one of its strategic objectives. In doing so, it has defined specific objectives and indicators for agriculture. The European Commission has also published guidelines on how to reach sustainability in farming and food production, including a discussion document on recent technological developments. While the currently available technologies do not include computer vision techniques, computer vision is expected to be widely used in the future.

According to the European Union website [25] it is essential to build stronger Agricultural Knowledge and Innovation Systems (AKIS) to help develop new and innovative projects, to spread the word about them, and to use the ideas for other purposes. AKIS strategies considered successful have four principal groups of measures:

1. Increasing the flow of knowledge and forging strong connections between research and practice.

2. Strengthening all farm advisory services and promoting their interconnection throughout the AKIS.

3. Enhancing cross-thematic and cross-national interactive innovation.

4. Advocating the transition to a digital agriculture.

The website [25] also informs that at this moment The EU Commission has proposed to set aside €10 billion of Horizon Europe funding for research in the fields of agriculture, rural development, and the bioeconomy. Horizon Europe and rural development will still be pooled with founding sources by the agricultural European innovation partnership (EIP-AGRI) for the purpose of fostering and sustaining farming and forestry [27].

In this context, computer vision techniques have great potential for a wide variety of purposes in this sector as well.

According to [9] every tier of society will need to work towards enhancing digital technology if the hope to see its full potential exists. The research should include commentary from a variety of sources including the farm, advisers, new technology providers and established researchers. Different analytic approaches and aptitudes should be mutually supported. Co-learning and collaboration should be an important focus for future development and research.

This is how the shift to digitalization takes place, not only in research, but also happening in practice to help make optimal decisions. The agricultural management systems can be customized for each farm based on data from their organization.

MATERIALS AND METHODS

This material is a work in which was made an overview of the real methods of image processing and computer vision that could be more intensely used in agricultural field. An overview regarding actual methods of processing images and computer vision used in agricultural fields was also made. The significant ideas were registered. The research method used is analytical. The material used consists of articles published on Web of Knowledge in the last decade. Based on the results, a comparison of the main solutions given in the last three years by scientists was accomplished.

RESEARCH RESULTS

Computer vision can be used in agriculture to control non-destructive actions, automated crop monitoring, or image processing to detect the presence of disease. Computer vision has been successfully used to measure fruit size and germination rates in crops and it can help growers to increase yields by making recommendations as regards irrigation. These technologies facilitate a continuous process of gathering data about the health of crops on individual farms and make this information available in real time on a farm management platform. It has opened up new possibilities for farmers by providing them with much more and quicker information on their crop status, enabling them to make better decisions when they grow crops. For instance, drone imaging collects data on a farm's whole canopy at a moment's notice and provides high-resolution images of the entire crop field, which helps farmers identify problems like disease or insect infestation in their fields before they become visible to human eye. This type of technology allow farms to be more efficient in limiting damage caused by pests while also improving soil health and reducing the need for pesticides and herbicides. [19, 23, 24]

State of the art in digital image processing and soft computing methodologies contains several concepts, application and theories. Starting with image-based plant identification tools used as search engine, very helpful to determine a plant among hundreds or thousands of species. The idea of the project presented in [11] was a collection and integration of raw botanical observation data, in order to facilitate access to botanical data.

Everything moved fast towards crop diseases detection, as imaging and computer vision based phenotyping offers the ability to study quantitative plant physiology. The computer vision based approach from [8] is used for classifying crop diseases: to extract feature diseases based on combination of marker controlled watershed segmentation and superpixels methods for avoiding over segmentation, reducing the complexity of subsequent image processing tasks, and improving the quality of the results.

An approach that uses image processing combined with machine learning is presented in [10]. The purpose is to is to allow diagnosing diseases from leaf images and classifying them (or absence thereof) on potato plants from a publicly available plant image database.

The studies of computer vision have grown in recent years, now also taking into consideration sustainable agriculture. In the following, a synthesis of the most notable solutions given by scientists in the last four years in the computer vision field integrated in a sustainable agriculture is presented.

- Most of the papers refer to crops: either to detect weeds or to detect diseases.

In [7] a novel crop/weed identification system that relies on a combination of fine-tuning pre-trained convolutional networks with the "traditional" machine learning classifiers trained with the previously deep extracted features. This approach avoided overfitting and achieved a consistent, reliable performance. To test this approach, a dataset of two different crops (tomato and cotton) and two types of weeds (black nightshade and velvetleaf) was created.

A new graph based method for plant segmentation in image based phenotyping is proposed in [18]. This method relies on the graph algorithm, colour features and Circular Hough Transform. The proposed method can be commonly used to extract leaves not only in rosette plants but also in all plants having green leaves. Leaf counting procedure is applicable to all the plants having round or elliptical shaped leaves.

The team of researchers from [5] is developing a stereo vision system for distinguishing between rice plants and weeds, as well as two types of weeds in a rice field by using artificial neural networks and two types of algorithms. Stereo videos were taken from the field and separate frames were extracted for this purpose. The two metaheuristic algorithms were wont to optimize the neural network for choosing the foremost effective options and classifying differing kinds of weeds, respectively.

In [6], to quantify the impact of the pest Jacobiasca lybica on vineyards and to develop representative cartography of the severity of the infestation, a neural network combined with geometric techniques was used to create computational vision algorithms. These algorithms were then applied to geomatic products using consumer-grade cameras in the visible spectrum. The proposed method for determining the impact of pests is more accurate because it eliminates the soil effects.

- Many papers also refer to the part of grading and sorting of fruits and vegetables:

In [15] a system has been proposed, a system that is non-destructive and also causes no harm to the fruits. The proposed methodology is designed using Image processing and Deep Learning techniques which are apt and are the best solutions for preserving the quality and safety of fruits while they are being processed in the right way.

In [17] were developed grading and sorting techniques for dragon fruit using machine learning algorithms based on a thorough review of techniques or algorithms available to detect and classify fruit quality using various features of fruits and vegetables. Work of these algorithms is based on the, shape, size, weight, colour and diseases of dragon fruits.

- Some papers refer only to the technical part, the algorithms that can be applied to the data sets:

In [16] a computer vision technique was developed for image features analysis and interpretation on crop health statuses based on deep neural networks. Given the huge volumes of images generated by drones and satellite technologies periodically on land use and coverage, there is need for computer vision techniques that can aid in farming data processing and management applications. Experiments of this research demonstrate effectiveness convolutional neural networks for computer vision tasks on huge volumes of image datasets.

According to [22] “one of the essential steps towards precision agriculture is using annotated images to train convolutional neural networks to distinguish weed from food crops, which can be later followed using mechanical weed removal or selected spraying of herbicides”. In [22], a dataset of manually annotated images for weed detection is proposed, which is open-access.

- Insect detection and classification in field crops is also an interesting topic. [13] presents the insect pest detection algorithm that consists of foreground extraction and contour identification to detect insects for datasets in a highly complex background.
- [2] refers to the use of computer vision in aquaculture. Computer vision technologies are being employed for aquaculture applications for a range of examination tasks like numeration, size measuring and mass estimation, gender detection and quality examination, species and stock identification, and monitoring of welfare and behaviour. To

produce more and improve the quality of the fish products, it is important to monitor and control the process of production.

- Some papers deal with the whole problem from the point of view of an integrated system. For instance, [12] presents a system architecture which is like a hodgepodge of recent technologies such as WSN (wireless sensor networks), UAV (unmanned aerial vehicles), last generation meteorological stations, cloud computing and the valuable tools of machine learning and computer vision. The advantages of the proposed architecture are summarized in the paper.
- There are also reviews and survey papers where several relevant papers in the field are analysed in detail and compared:

A review about automatic identification of diseases in grains crops through computational approaches was made in [14] focusing on five significant steps like preprocessing, segmentation, extraction of features, feature selection, and classification. The authors state that disease detection is still difficult because it can be hard to tell the difference between crops and diseases that often have similar properties there are still many issues that's need to be addressed in each phase of the automated disease detection system

Machine learning with computer vision are reviewed in [20] for the purposes of classifying different crops. This classification is to help monitor crop quality and yield assessment. The approach can be included to increase the production of cattle by foreseeing fertility patterns, diagnosing food disorders, livestock farmers based on machine learning models utilizing information collected by collar sensors, etc.

[4] concludes that the automatic feature extraction capabilities of deep convolutional neural networks to classify plant seedlings can successfully classify crops and weeds in various phenological growth stages. Training these neural networks from scratch can achieve state of the art performance for weed classification tasks and model performance can be improved by fine-tuning a pre-trained model.

- Some papers [19, 21] go further and think about the future of this field in full ascent:

In the face of a changing climate it will be necessary to design food and bioenergy crop ideotypes that thrive in future environments at microscale levels. [21] An artificial intelligence-driven paradigm shift is significantly transforming plant omics and breeding research. At present, large amounts of multiomics, imaging, ecophysiology, and field-based data are becoming available for large-scale population-level studies, revealing subtle differences in plants' genetic-based adaptation potential and allowing design interventions.

CONCLUSIONS

There are several factors as socio-cultural, economic, technological and infrastructure that also determine the use of agricultural land, crop patterns and agricultural processes as well as the ownership of these agricultural lands, the availability of labour that can be used in the area, the facilities of irrigation, money capital and the level of technological development, the placing on the market of agricultural products but also governmental plans and international policies that have the strongest impact on agricultural activities.

The impact of these socio-economic factors on agriculture can be controlled through deep learning and computer vision, obtaining optimized results at a high level.

Computer vision technology is transforming agriculture in adopting state of the art techniques at a speed to reduce production time and enhance productivity, in crop-yield quality and quantity enhancement, plant diseases, phenotyping and grading and sorting of fruits and vegetables [26].

"What are the implications of digitalisation for agricultural knowledge and innovation system?" is a question that arises in [9]. New data-driven processes have been implemented to support the farming industry. This has brought about new demands, relations, and tensions. In this context, it is important to create a healthy balance between the old and new. It is possible to take what we know and build on it while simultaneously innovating. This idea is also found in the development strategies proposed by the European Union.

Agricultural modernization through computer vision could be a foundation with important impact of national modernization and positive effect on the European Union, it is also the source of power for the sustained and healthy development of countries like Romania and its long period of economic stability, with fundamental impact to change the delay of harvests in rural areas and to improve the poor life of farmers. This can be considered the great revolution in modernizing the way agriculture is done.

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