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Robotic Applications and Management of Plant Diseases

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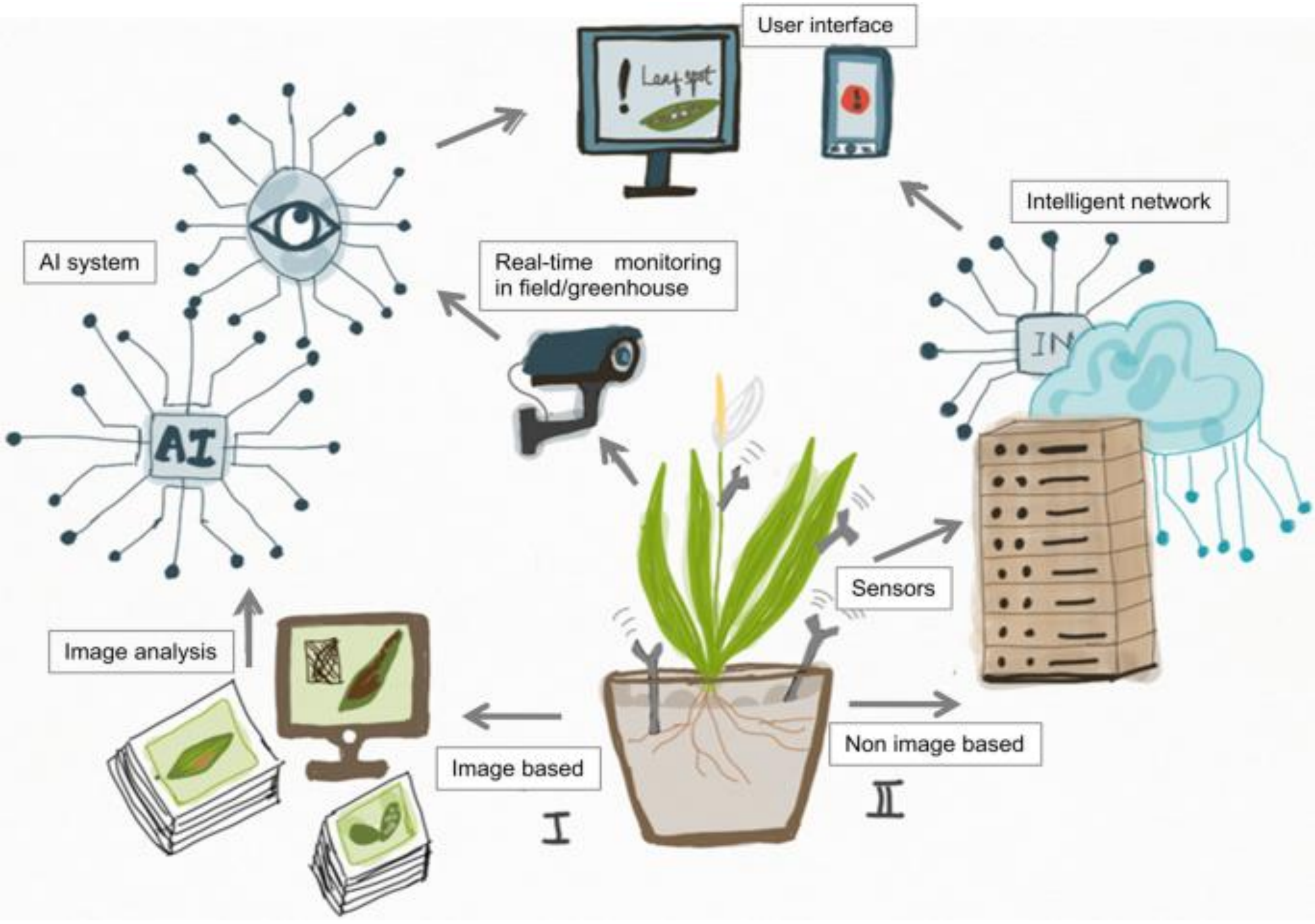
SUMMARY

Computer vision, global positioning systems (GPS), laser technology, actuators, and mechatronics advancements have allowed the production and deployment of robotic systems and intelligent technologies for precision agriculture. Computer vision/learning-based intelligence technologies (Artifical intelligence) have been developed not only for planting, irrigation, weeding (to some extent), pruning, and harvesting, but also for plant disease detection and identification.

INTRODUCTION

Agricultural robot research has expanded in recent years as a result of potential applications and industry efforts in robot production. Their position in many agricultural tasks was investigated with a focus on increasing the automation of conventional farming machines and covering processes such as field preparation, seeding, fertilization and harvesting. Systematic, repetitive and time-dependent tasks appear to be the best fields of application for robots, especially in the context of arable farming with a temporary crop. Aside from agronomic practises robotic plant safety has been studied, but it may pose the most difficult challenge for researchers and developers because pathogen diagnosis concerns must be considered alongside common robot-related issues. Recently, research in the automated detection of diseases has accelerated, with possible applications for creating robots capable of identifying single plants locating and identifying diseases, and initiating disease management routines. This article will go over the latest generation of robots that could help plant pathologists.



Disease sniffing robots to apps fixing plant diseases: applications of artificial intelligence in plant pathology

Robotic Precision Plant Protection:

Precision plant defence is a subset of precision agriculture, in which site-specific pesticide applications play an important role in agricultural sustainability. Monitoring and controlling environmental parameters is a critical function in this area for automating machines and robots. Furthermore, precision agriculture is a recurring method in which measures are divided into data collection and localization, data analysis, management decisions on applications, and assessment of management decisions; data are stored in a database and can be used as historical data for potential decision-making, which is a very useful function for plant safety. Although environmental regulation in open fields is extremely restricted, greenhouses are the best setting in which to introduce precision farming protection systems. Even if further research and development are needed, several parameters in well-defined spaces can be monitored or even managed. Pre-defined physical and biological objects, as well as the availability of infrastructure (e.g., wires, pipes, roofs), can facilitate the deployment and mobility of smart machinery.Smart systems for greenhouse management have advanced significantly in recent years, owing primarily to rapid developments in information technology and wireless sensor networks. Sensors can calculate greenhouse indoor environmental parameters such as temperature and humidity.

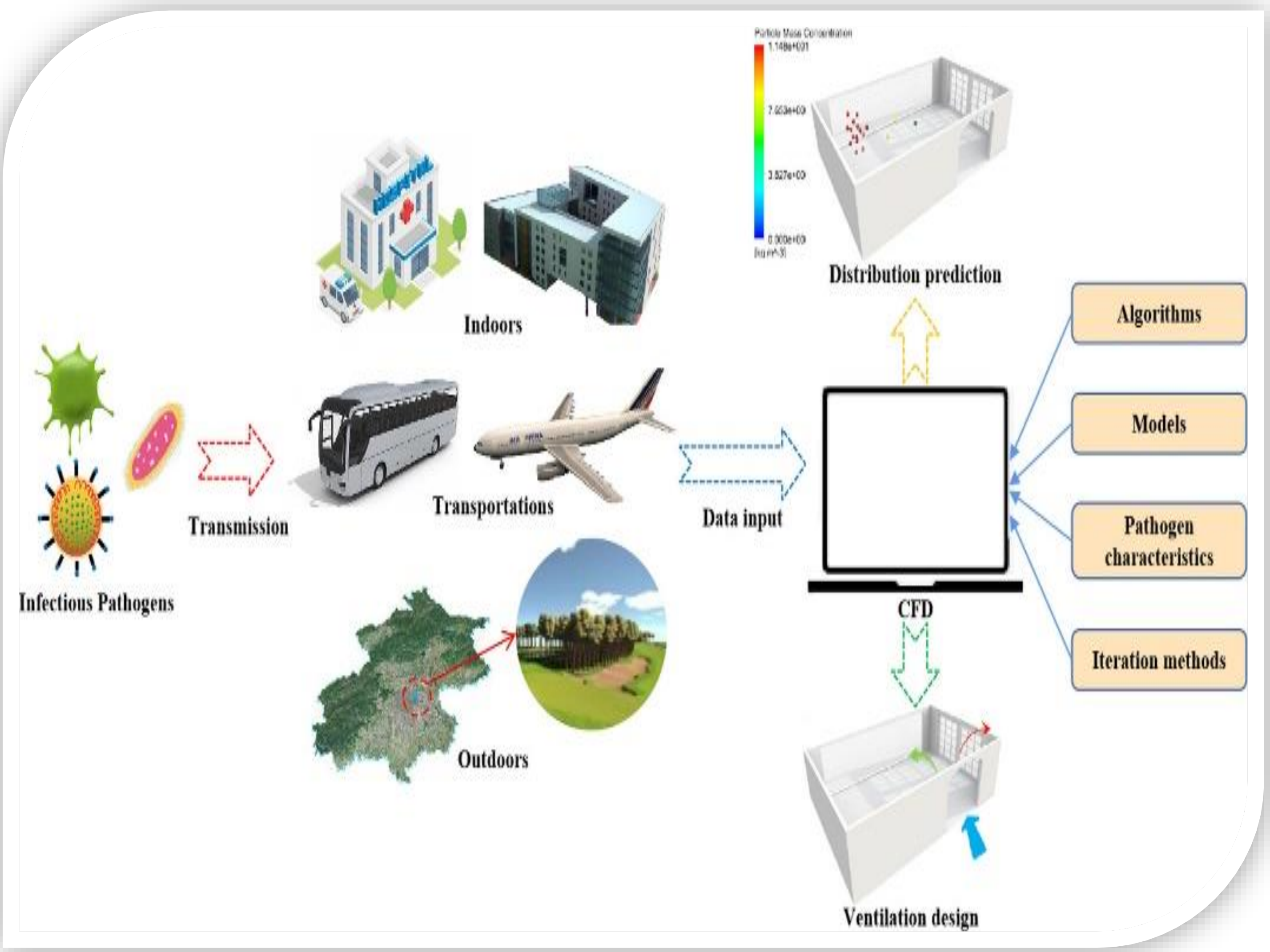


Fig1: The role of computational fluid dynamics (CFD) tools on investigation of pathogen transmission: Prevention and control.

Plant parameters such as humidity lasting time on leaves and leaf temperature are also related to disease occurrence and growth. Systems that can collect information and monitor greenhouses effectively and automatically on-site or remotely through a web browser have been created. Further challenges associated with the high non-linear interaction between the physical and biological subsystems have suggested using the filtered Smith predictor to boost disturbance rejection dynamics while maintaining the robust stability of a greenhouse environment. The high level of technology involved in greenhouse environmental control has been highlighted by using CFD (Computational Fluid Dynamics) software to identify suitable vent configurations and opening management procedures for indoor climate control. (Fig.1) Although environmental parameter control may help to control diseases, protect plants, and maximise production, humans (and machinery) must still interfere on individual plants or in close proximity to robotic controls. Plant identification systems, on the other hand, do not explicitly support automation.

Abiotic stresses

Water management is a key subject in robotic management because of its significance in greenhouses, gardens, and urban greening. Because of the small extension of surfaces or objects to be tracked, partly regulated environmental conditions, and the high value of plants, these are areas where robots and automated systems suit well. In greenhouses, automated and smart irrigation systems are variable because growth efficiency is heavily reliant on highly efficient water management. Pathogen production is also dependent on water disposal, and a surplus of water can increase costs or cause problems with water discharge in urban greening. Symbiotic robot-plant bio-hybrids suggest an intriguing approach in plant management, with possible results in abiotic stress defence. The development of a symbiotic relationship between robots and plants in order to build plant-robot societies capable of creating meaningful architectural structures; the robots may trigger artificial stimuli in addition to natural stimuli from the environment. As a result, a robot-plant bio-hybrid may act as a green wall capable of adapting to environmental stimuli (Hamann et al.). Since it is difficult to differentiate between a number of diseases with identical symptoms, machine learning techniques may help in the detection of abiotic stress (e.g., biotic or abiotic stress).

Diagnostic Specificity: The Challenge of Microorganism Control:

Plant classification based on morphological parameters is a difficult task, particularly through visual (human) observation. As a result, distinguishing diseased plants from symptomless ones is a difficult challenge. The inherent complexity is attributed to the non-specificity of certain symptoms that may be present. Furthermore, the degree of morphological parameter changes caused by biotic or abiotic stress (such as dimension, shape, or colour) may be very low when compared to the variability of appearance in healthy plants, particularly during the first stage of infection. Control strategies against microorganisms must be implemented prior to disease outbreaks in order to be efficient, and diagnostic specificity is needed for effective plant defence.

In the last fifty years, disease diagnosis has moved away from symptom observation or symptom-based diagnostic procedures (i.e., indexing with responsive hosts) and toward protein-based or molecular-based tests. Even though the human eye and pathologist skills may still play a role in certain cases, such as yellows caused by phytoplasma or detecting cultured pathogen in vitro, tests such as ELISA or PCR are widely regarded as the only response to biotic infections. As a result, advances in pathogen detection techniques (via sensors) depend on a more complex vision principle.

In the last few decades, non-destructive methods for plant disease detection have been established, which fall into two categories: spectroscopic and imaging techniques, and volatile organic compound-based techniques. Sensors, in particular, can determine the optical properties of plants in various regions of the electromagnetic spectrum, and they may detect early changes in plant physiology due to biotic stresses, which can result in changes in tissue colour, leaf form, transpiration rate, canopy morphology, and plant density. The most promising technologies are thermography, chlorophyll fluorescence, and hyperspectral sensors.

Plant phenotyping is also essential for understanding plant phenotype behaviour in response to genetic and environmental cues. Nonetheless, the use of spectral analysis in plant pathology is debatable due to similar symptoms or physiologic changes induced by different diseases. The number of pathogens identified by image processing is increasingly growing. Often involving common pathogens that reoccur in arable agriculture systems. This is the primary area of application since this technique has the potential to significantly reduce the workload of routine pest control, but quarantined pests may also be involved in research.

The need for large-scale monitoring diagnostic techniques (and relative quick and low cost of execution) and high diagnostic specificity, due to the substantial workload and social effect that may result from positive plant identification, may necessitate a different set of diagnostic tools in these cases. (Deng et al. developed a recognition system based on visible spectrum image processing to detect) symptoms of citrus greening diseases (caused by Candidatus Liberibacter spp.).

The experimental results revealed that the detection accuracy was 91.93 percent. A pre-symptomatic HLB detection method based on polarised imaging (Pourreza et al). Citrus canker caused by Xanthomonas axonopodis resulted in foliar symptoms that were examined to determine the efficacy of image analysis. For different symptom types, image analysis outperformed visual raters. However, symptom heterogeneity or lesion coalescence may cause inconsistencies in outcomes, making complete automation of the system unaffordable for the time being. A vision-based, novel transfer, and deep learning technique for detecting symptoms of leaf scorch on Olea europaea leaves infected with Xylella fastidiosa, with a true positive rate of 95.8 %. (Cruz et al.). These vision-based systems can be installed on mobile vehicles (e.g., autonomous vehicles) to improve disease detection and management procedures.

Environmental and Social Sustainability of Robotic Plant Protection

The growing interaction between robotics and plants, enabled by the creation of sensors, actuators, and mechatronics, must be evaluated in terms of social and environmental sustainability. Agricultural robotic systems and tools can include dangerous materials and chemicals, which may increase the cost and environmental impact of disposal. Further problems for the implementation and widespread use of effective robotic solutions are related to the social aspects of labour automation in a post-industrial society. Aside from sensational headlines and differences in historical technological influences among countries, the potential effect of robots, artificial intelligence, cloud-based computing, and big data on unemployment should be investigated. Human-robot partnership (co-robot) has the ability to change the traditional division of labour between workers and machines. For the last few years, robots have been collaborating with human employees in factories; robots and robotic systems, separated behind safety fences, have now been smart enough to cooperate with people on manufacturing production lines, providing greater productivity and versatility. The creation of efficient co-robot systems in agriculture and open field environments is more difficult and demanding, and warrants further study.

CONCLUSIONS

Image analysis's function in robotic management should also be examined. The core subject of research for automatic crop safety is image interpretation and identification, regardless of the object of the image (disease signs, weeds, abiotic stress). However, disease diagnostic methods are still in the early stages of growth, and the availability of standardised applications is not as predictable (Mahlein,). Aside from regular crop monitoring, such as cereals, where robotic control may not be truly plant- or organ-specific, vegetables and fruit plants necessitate single-plant inspection, diagnosis, and management. Is image processing the most effective method for achieving this goal? This area of study is relatively new, and significant progress is being made all the time. Diagnostic specificity can fit traditional diagnostic tools for some diseases, but not for all diseases or at all stages of disease development. Based on the application and plant health criteria, we need to examine the inherent limitations of image processing techniques and technologies for plant disease detection further. Robots may serve as highly qualified pathologists, recalling thousands of photos to make a diagnosis. A robot's "eye" is much superior to a human's, and it can gather vast amounts of data that are invisible to us. However, we must accept the possibility that data mining/image processing would not be sufficient for every pathogen/host/environment combination. A parallel line of research for improving "robotic pathologists" may include the further development of manipulators and sampling hardware, moving the research emphasis from "experienced robotic observer" to "robotic observer and analyst." In recent years, on-site detection assay research has accelerated, and methods such as Loop-Mediated Isothermal Amplification (LAMP) may allow rapid molecular diagnosis in the field. These tests, due to their speed, robustness, and simplicity, should be incorporated into conventional vision-based robots, improving their diagnostic specificity when required.

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