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Drone and Robotics Roadmap for Agriculture Crops in Pakistan: A Review †

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Abstract: Precision agriculture is getting immense attention from researchers and farmers across the world due to the threatening situation of the demand and production gap. Evolution in the electromechanical system and the emergence of intelligent monitoring and conditioning systems have enabled closing the gap to make agronomy quicker, lesser prone to infestations, and still profitable at the same time. Whereas the Internet of Things (IoT) has enabled access to relevant data remotely and automates essential response systems to any threat or requirement by a plant in a particular environment. This study concentrates on gathering such advanced mechatronic techniques in the agricultural sector and analyses of the benefits and disadvantages of the modern method.

Keywords: mechatronics; precision agriculture; IoT; robotics; UAV

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1. Introduction

The agricultural development [1,2] is the most important factor in Pakistan's economic growth. Around 45% of the labor force and 23.4% of the country's GDP are dependent on agriculture. Numerous constraints and difficulties are faced by local farmers, including the need to increase sustainability, increase yields to satisfy demand, maintain margins, and control water usage. Local farmers usually collect field data manually by monitoring their crops and use the field data to analyze the number of pesticides to be sprayed, soil enrichment chemicals, time to harvest, and yield predictions. Even though this procedure can be as simple as going across a field and making observations, farmers are restricted by time, data recording, and the capabilities of analysis tools while making visual observations and are required to take suitable actions to boost crop yield. Farmers all over the world are employing precision agricultural techniques with the help of aerial/ground robots equipped with sensors/actuators and related decision-making software to overcome problems. These approaches assist farmers at various phases of crop growth.

More than 60% of the people in Pakistan [1–3] are dependent on agriculture for survival. Past supporting an agrarian economy, one of the biggest challenges faced by the agriculture sector is a low per-acre yield due to the lack of using precision agricultural techniques. There is a huge opportunity for innovators and entrepreneurs to bring ideas that can help to integrate information systems, current mobile networks, and sensors/actuators equipped with automated machines and mobile platforms to bring a system that can revolutionize precision agriculture in Pakistan.

Mechatronics engineering [4,5] is the practice of designing electromechanical systems under computer control. Because the mechanical system design must be implemented along with the electrical/electronic and computer control components that will make up the overall system, it might be referred to as "current mechanical engineering design." Examples of mechatronic systems include wired aircraft controls, anti-lock brakes, computer hard drives, CD/DVD players, and videocassette recorders (VCRs) (ABS). These products are all mechanical, but they all rely on integrated electrical and computer control systems to operate.

Electromechanical systems [6] have been used in agriculture for decades. With the advancement of technology, these devices are increasingly being diverted towards mechatronics, as electromechanical equipment is becoming more and more 'intelligent.' In a modern and complex agricultural facility, we can find a lot of embedded systems, such as microcomputers and microcontrollers. These independent parts make up the majority of an agricultural complex in the modern era. Currently, precision agriculture is the cornerstone of modern agriculture (PA). Given instances of mechatronic technologies used in modern agriculture and demonstrates the possibilities of precision farming (such as the Internet of Things). It discusses trends and also defines a vision, as agriculture technologies are in a single network with both pre- and post-technologies.

2. Smart Applications and Robotics

J.B. Grau et al. [7] has done a project with different universities and other agriculture companies to make an optimized system to help with the precision of agriculture with the help of mechatronics. The project's components comprised the analysis and decoding of images of the soil surface, fertility evaluation and the production of a fertility map, signal creation for mechatronic dosing devices, intelligent fertilizer dosing, testing of prototypes, modeling of human-machine interaction, and the development of training materials. This study resulted in the creation of an intelligent and autonomous system that helped identify various soil types and make decisions for the fertilization of the soil under those findings.

Khairul Azmi Mahadhir et al. [8] made an agriculture robot that helped in the identification of terrain conditions. This was a smart robot that learned to adapt to its environment by using Support Vector Machines (SVM), a sort of machine learning. This robot has distinguished between three different types of terrain: sand, gravel, and flora. Figure 1 shows the mechanism of the proposed robot.

Figure 1 shows the hardware and software of the proposed robot, SVM was used to identify terrain by the data given by MEMS sensors vibration. The controller received the identified signal to control the speed of the DC motors and the robot's movement, and if the terrain was sandy, the controller increased the current to the DC motors to provide more torque for the robot's movement.

Slaughter et al. [9] reviewed the four methods used today for autonomous robotic weed management: navigation, detection and identification, precision in-row weed control, and mapping. There was a lot of work done in the fields of guidance, precise row weed management, and mapping. To exploit the weeds for the intended commercial purpose, a lot of work had to be done to identify and discover them.

Saptasagare and Kodada [10] created a sensor and microcontroller system to aid with precision farming. In this scenario, a sensor was used to collect real-time data from the field, such as temperature, water level, and soil moisture. This information was delivered by a microcontroller to the global system for the Mobile communication node. The farmers' computers received the information that had been gathered. This allowed farmers to evaluate the condition of the soil from a distance.

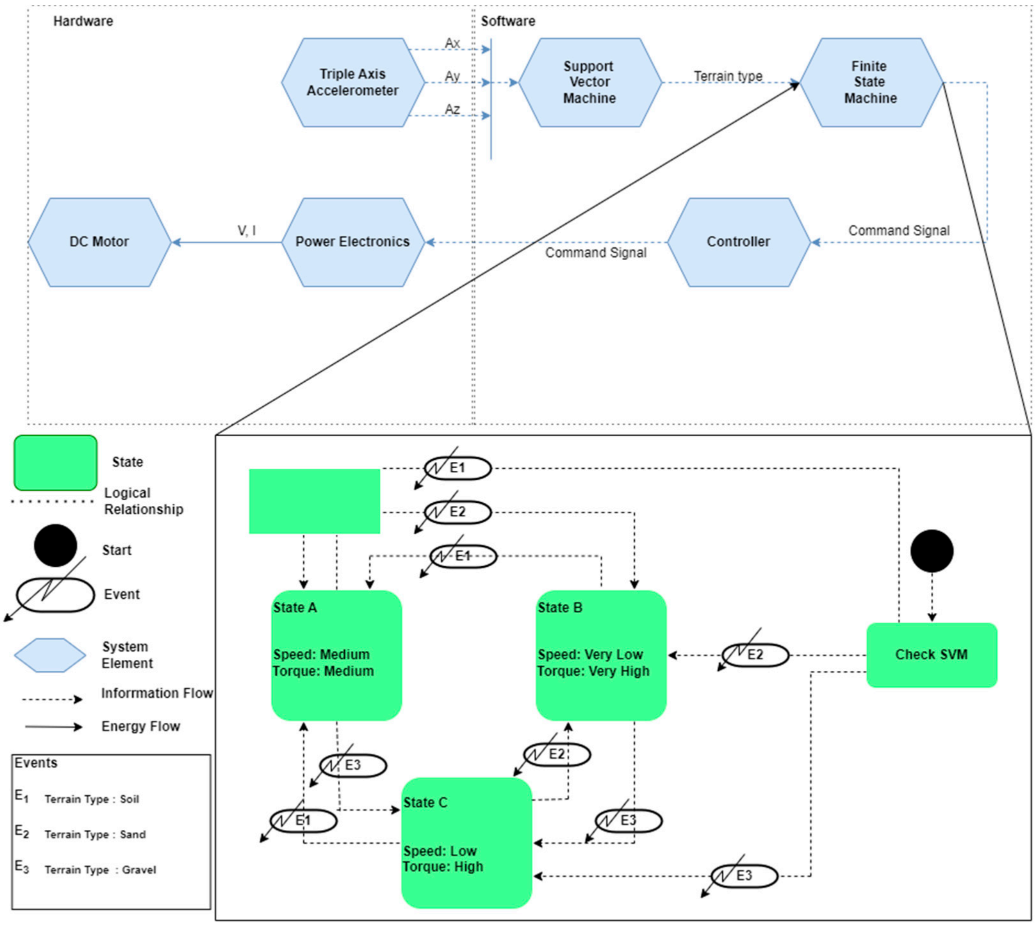

Figure 1. Proposed Robot Mechanism by Mahadhir et al. [8].

Amrutha et al. [11] made a system that took care of soil fertility. Soil fertility depletes during every harvesting of a crop while nutrition, which is needed for the soil, is ignored by the farmer. For this, a system was developed which consisted of a microcontroller, sensor, and mechanical system which gave the needed amount of nutrition automatically after testing the soil. Figure 2 displays the suggested method's flowchart.

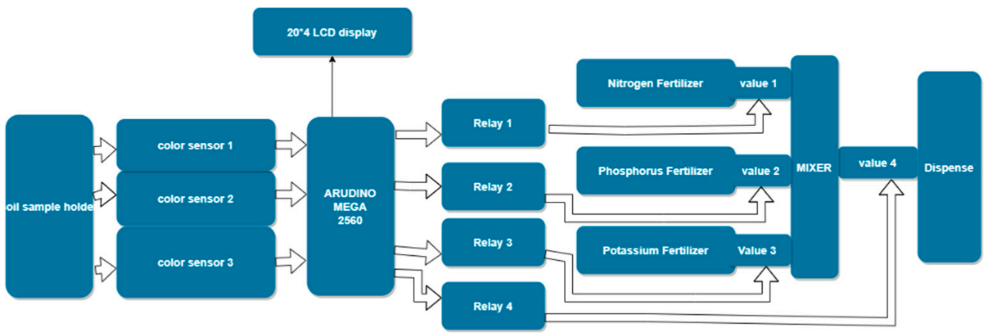

Figure 2. Block representation of the suggested system by Amrutha A et al. [11].

The system consisted of three parts: The first was the testing of the soil. For this purpose, 'colorimetry' was used, on which sensors were used to test the soil color for the needed nutrition. The second was the microcontroller consisting of Adriano mega, which tested the soil and instructed the third section. The third section consists of the mechanic part which took instructions from the microcontroller and opened the valve of the nutrition accordingly.

Kuan-Ming Lin and Chung-Liang Chang [12] offered a concept for a small-scale, intelligent agricultural machine that could perform multiple tasks at once and use artificial vision to automatically weed and regulate the irrigation rate inside a farm. HSV (hue (H), saturation (S), value (V)) color conversion and threshold estimation are two examples of image processing techniques. To confirm the positions of the plants and weeds, the morphological operator's methods and approach were applied. The results are being used to direct watering and weeding operations.

G. Vellidis et al. [13] proposed a method including a smart sensor system for a cotton field to schedule the irrigation system. The system consists of 20 sensors placed in the field and sends data to the circuit board. The circuit board collected the data and sent it to an RFID system which then sent the data to a receiver. Data was then analyzed by the computer software, which determined the amount of water and timing in the cotton field.

Aqeel-ur-Rehman et al. [14] proposed a context-aware sensor grid system for agriculture. This system consists of sensors, temperature, ambient light, and soil moisture probes placed in the field. These sensors give data transmitters to transmit data over satellites, and a grid system receives the data over the network. The system analyzes the data and gives a signal to the actuators to sprinkle or irrigate the field.

Li Qing-Hua et al. [15] gave a system for the tagging of seeds using Radio Frequency Identification (RFID). This system was an implementation of RFID in agricultural seed quality management, covering everything from seed production, storage, and transfer to quality control by relevant enforcement and supervision departments, all the way up to quality assurance and plant information for the end-user, the grower. A seed quality tracking system uses several key strategies, including function design, tag type selection, frequency selection, protocol selection, data security design, anti-collision technology planning, etc. There were several insightful discoveries.

Prathibha S R et al. [16] presented a method employing the Internet of Things (IoT) for precise smart agriculture. The system had a humidity and temperature sensor that transmitted data to a microcontroller unit, which processed and transmitted it to the farmer through Wi-Fi. Additionally, a mounted camera took pictures and relayed them to the farmer after a predetermined amount of time. The internet was used in this fashion to keep the farmer informed about his property while he was away. The block diagram of the IOT-based system is displayed in Figure 3.

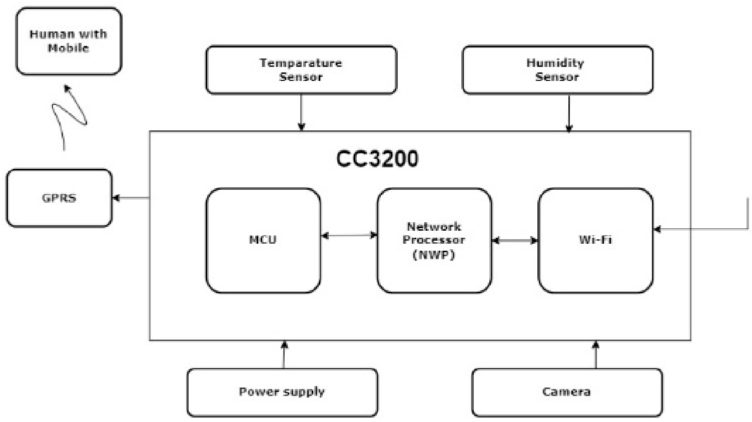

Figure 3. Block diagram of IOT Based System proposed by Prathibha S R et al. [16].

Aarne Halme et al. [17] proposed a robot Work Partner (WP) that was a mobile service robot prototype with a centaur-like look that was made to interact with people outside. It had four wheels and four legs and had a humanoid appearance in the upper torso. The robot was able to complete tasks just as well as a human could. Robots may be used in place of or in addition to humans in the workplace

Arindam Giri [18] suggested developing a system called AgriTech to automate agricultural processes using smart devices, WSN networks, and an Internet device. The farmer might be able to better monitor crops and farmland from a distance if they have a mobile device in hand. A farmer could operate agricultural equipment like an autonomous water sprayer to use in the field of agriculture using smart mobile phones. Therefore, this technology may lessen the need for human labor in the agricultural industry.

Peng Zhang et al. [19] has proposed that IoT and Big Data can be used to irrigate and fertilize agricultural fields. It consists of two parts, and each part has four modules. The first module's data collecting layer collected a sizable amount of data from the farmers and stored it in the system. The intelligent layer stored the data accordingly in the big data center and connected it to the decision layer. The second part is all the field management, and it decides whether the crops need fertilizer or water based on the data stored in the Big Data system and sent to the farmer using the IoT system. Figure 4 shows the structure of the Big Data system.

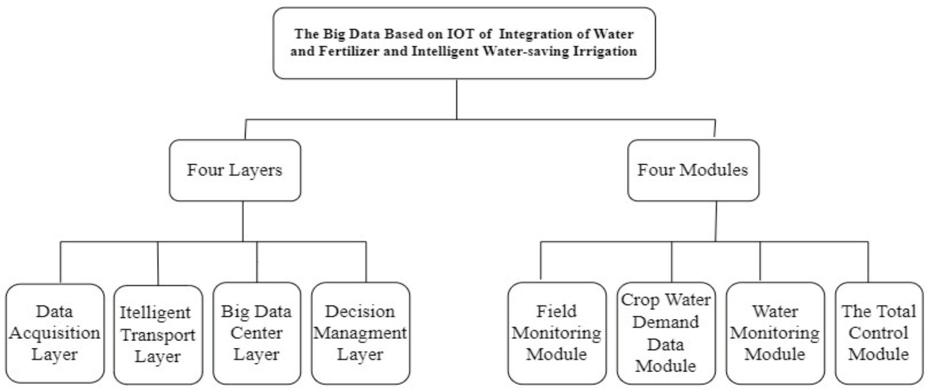

Figure 4. Structure Diagram [19].

Sinung Suakanto et al. [20] and Manlio Bacco [21] proposed an IOT based system for smart farming. The conceptual model and system are designed to assist smart farming decisions, and many are constructed using network sensor applications that execute the tasks that farmers need to be able to accomplish the activities. Agriculture will adopt a comprehensive system based on an Internet of Things (IoT) strategy. Data analysis, task management, control, and sensor-based data collection are the primary areas of emphasis in model creation and system design. This method addresses the issues farmers experience with task management, planning, evaluating environmental conditions, and information exchange.

Min Zhang and Qinggang Meng [22] proposed a detection method of the canker lesion disease citrus canker from field-collected leaf photographs, which were more difficult to obtain than leaf images created in a lab. In order to segregate the lesions from their background using an upgraded AdaBoost algorithm, the most crucial properties of citrus lesions were first determined. Then, a canker lesion descriptor that integrates the color and local texture distribution of canker lesion zones as advised by plant phytopathologists is presented.

Rumpf et al. [23] discussed a method to find the disease in the early stages in sugar beets. After inoculation with the pathogens Cercospora beticola, Uromyces betae, or Erysiphe betae that cause Cercospora leaf spots, sugar beet rust, and powdery mildew, respectively, hyperspectral data were collected from healthy leaves and leaves treated with those pathogens for 21 days. The computerized classification used nine spectrophotometric vegetation indices linked to physiological factors. The support vector machine with a radial basis serving as a nucleus allows for early separation between healthy and infected plants, as well as between particular diseases.

S. Meivel [24] suggested a project that used an unmanned aerial vehicle to monitor and apply urea in the field (UAV). The project offered a high-performance quadrant model with a focus on high execution; it enabled all directions (0°–360°) with large payloads and lighter-weight materials, as well as cutting-edge brushless BLDC motors. The drone had a maximum height of 8 kilos, a diameter of 1.8 m, and a total weight of 3 L. The maximum flight time was about 60 min without the payload. The Arduino was used to remotely program the drone. The RTOS system in the drone provided a solution for every urgent circumstance. The UAV created for the suggested project is shown in Figure 5.

Figure 5. Designed UAV by S. Meivel [24].

3. Conclusions

The modern era is evolving towards smart technology while agronomy, being an integral ecological constituent, is seeing its fair share of such advancements. Mechatronics, being a multi-discipline engineering field, intends to aid the agriculture sector through robots and automation. Concerned literature shows an increasing trend in the usage/prospection of such electromechanical systems that could assist farmers in various aspects of agronomy. From seeding to harvesting, several devised/proposed systems could automate labor-intensive procedures such as implanting the seed, cutting or spraying weeds, and collecting the fruits, crops, and vegetables from the fields with precise actuators controlled by high-end control systems. Such systems make agricultural procedures precise, cost-effective, and more profitable. UAV and on-ground robots have been proposed and have pros and cons of their own, such as on-ground robots being more functional but tricky to operate in humid and rough terrains while UAVs have better reach but limited energy and capabilities.

On the other hand, the studies in this field suggest smart systems for online information collection/access through IoT and smart monitoring systems that use state-of-the-art Machine Learning (ML) and clustering methods. Greenhouse and outdoor temperature, soil humidity, nutrition monitoring, and broadcasting or online data access make it convenient for farmers to retrieve vital information remotely in real-time. Although the proposed ML methods for detecting/segregating diseases, organs, and weeds are fairly accurate but need more maturity for being robust and readily adaptive for any kind of terrain and plants.

Mechatronics could help the industry in the following methods:

1. The use of automation and intelligent systems in irrigation will help to improve irrigation efficiency and lower water waste.
2. The use of automation and intelligent systems in the food industry also aids in determining the best chemicals and pesticides to use for agricultural purposes.
3. Automatic and intelligent systems help pick out and manage weeds. The multitasking robots will support agricultural activities and processes, as well as finish the task quickly, preserve the product's quality, and reduce the need for human effort.
4. We will be able to supply information on the humidity, temperature, and water level thanks to the hybrid agricultural systems.
5. We can streamline the agricultural process and choose the best weed, crop, and pesticides by better utilizing automation and IoT in the sector of agriculture.

6. On the other side, automation and IoT systems offer solutions and make the agricultural process more predictable.
7. These technologies will contribute to reducing human labor requirements and raising production.

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References

1. Azam, A.; Shafique, M. Agriculture in Pakistan and its Impact on Economy—A Review. *Int. J. Adv. Sci. Technol.* **2017**, *103*, 47–60. [CrossRef]
2. Waqas, M.S.; Cheema, M.J.M.; Hussain, S.; Ullah, M.K.; Iqbal, M.M. Delayed irrigation: An approach to enhance crop water productivity and to investigate its effects on potato yield and growth parameters. *Agric. Water Manag.* **2021**, *245*, 106576. [CrossRef]
3. Malik, S.; Hussain, S.; Waqas, M.S. Effect of water quality and different meals on growth of *Catla catla* and *Labeo rohita*. *Big Data Water Resour. Eng.* **2020**, *1*, 4–8. [CrossRef]
4. Altintas, Y.; Croft, E.A. Electro-mechanical design engineering: A progress report and future directions for mechatronics education. *Int. J. Mech. Eng. Educ.* **2002**, *30*, 325–339. [CrossRef]
5. Waqas, M.S.; Cheema, M.J.M.; Waqas, A.; Hussain, S. Enhancing water productivity of potato (*Solanum tuberosum* L.) through drip irrigation system. In Proceedings of the 2nd International Conference on Horticultural Sciences, Faisalabad, Pakistan, 18–20 February 2016; pp. 18–20.
6. Kuru, K.; Yetgin, H. Transformation to advanced mechatronics systems within new industrial revolution: A novel framework in automation of everything (AoE). *IEEE Access* **2019**, *7*, 41395–41415. [CrossRef]
7. Grau, J.; Anton, J.; Packianather, M.; Ermolov, I.; Aphanasiev, R.; Cisneros, J.; Cortina-Januchs, M.; Jevtić, A.; Andina, D. Sustainable agriculture using an intelligent mechatronic system. In Proceedings of the 2009 35th Annual Conference of IEEE Industrial Electronics, Porto, Portugal, 3–5 November 2009; pp. 3416–3421.
8. Mahadhir, K.A.; Tan, S.C.; Low, C.Y.; Dumitrescu, R.; Amin, A.T.M.; Jaffar, A. Terrain classification for track-driven agricultural robots. *Procedia Technol.* **2014**, *15*, 775–782. [CrossRef]
9. Slaughter, D.C.; Giles, D.; Downey, D. Autonomous robotic weed control systems: A review. *Comput. Electron. Agric.* **2008**, *61*, 63–78. [CrossRef]
10. Saptasagare, V.S.; Kodada, B.B. Real-time implementation and analysis of crop-field for agriculture management system based on microcontroller with GPRS (M-GPRS) and SMS. *Int. J. Comput. Appl.* **2014**, *98*, 1–6. [CrossRef]
11. Amrutha, A.; Lekha, R.; Sreedevi, A. Automatic soil nutrient detection and fertilizer dispensary system. In Proceedings of the 2016 International Conference on Robotics: Current Trends and Future Challenges (RCTFC), Thanjavur, India, 19–20 December 2016; pp. 1–5.
12. Chang, C.-L.; Lin, K.-M. Smart agricultural machine with a computer vision-based weeding and variable-rate irrigation scheme. *Robotics* **2018**, *7*, 38. [CrossRef]
13. Vellidis, G.; Tucker, M.; Perry, C.; Kvien, C.; Bednarz, C. A real-time wireless smart sensor array for scheduling irrigation. *Comput. Electron. Agric.* **2008**, *61*, 44–50. [CrossRef]
14. Aqeel-ur-Rehman, Z.A.S.; Shaikh, N.A.; Islam, N. An integrated framework to develop context-aware sensor grid for agriculture. *Aust. J. Basic Appl. Sci.* **2010**, *4*, 922–931.
15. Li, H.; Wang, H.-j.; Shang, Z.; Li, Q.-h.; Xiao, W. Application of RFID in agricultural seed quality tracking system. In Proceedings of the 2010 8th World Congress on Intelligent Control and Automation, Jinan, China, 7–9 July 2010; pp. 3073–3077.
16. Prathibha, S.; Hongal, A.; Jyothi, M. IoT based monitoring system in smart agriculture. In Proceedings of the 2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT), Bangalore, India, 16-17 March 2017; pp. 81–84.
17. Halme, A.; Luksch, T.; Ylönen, S. Biomimicing motion control of the WorkPartner robot. *Ind. Robot Int. J.* **2004**, *31*, 209–217. [CrossRef]

18. Giri, A.; Dutta, S.; Neogy, S. Enabling agricultural automation to optimize utilization of water, fertilizer and insecticides by implementing Internet of Things (IoT). In Proceedings of the 2016 International Conference on Information Technology (InCITe)—The Next Generation IT Summit on the Theme-Internet of Things: Connect your Worlds, Noida, India, 6–7 October 2016; pp. 125–131.
19. Zhang, P.; Zhang, Q.; Liu, F.; Li, J.; Cao, N.; Song, C. The construction of the integration of water and fertilizer smart water saving irrigation system based on big data. In Proceedings of the 2017 IEEE International Conference on Computational Science and Engineering (CSE) and IEEE International Conference on Embedded and Ubiquitous Computing (EUC), Guangzhou, China, 21–24 July 2017; pp. 392–397.
20. Suakanto, S.; Engel, V.J.; Hutagalung, M.; Angela, D. Sensor networks data acquisition and task management for decision support of smart farming. In Proceedings of the 2016 International Conference on Information Technology Systems and Innovation (ICITSI), Bandung, Indonesia, 24–27 October 2016; pp. 1–5.
21. Bacco, M.; Berton, A.; Ferro, E.; Gennaro, C.; Gotta, A.; Matteoli, S.; Paonessa, F.; Ruggeri, M.; Virone, G.; Zanella, A. Smart farming: Opportunities, challenges and technology enablers. In Proceedings of the 2018 IoT Vertical and Topical Summit on Agriculture-Tuscany (IOT Tuscany), Tuscany, Italy, 8–9 May 2018; pp. 1–6.
22. Zhang, M.; Meng, Q. Automatic citrus canker detection from leaf images captured in field. *Pattern Recognit. Lett.* **2011**, *32*, 2036–2046. [CrossRef]
23. Rumpf, T.; Mahlein, A.-K.; Steiner, U.; Oerke, E.-C.; Dehne, H.-W.; Plümer, L. Early detection and classification of plant diseases with support vector machines based on hyperspectral reflectance. *Comput. Electron. Agric.* **2010**, *74*, 91–99. [CrossRef]
24. Meivel, S.; Dinakaran, K.; Gandhiraj, N.; Srinivasan, M. Remote sensing for UREA Spraying Agricultural (UAV) system. In Proceedings of the 2016 3rd International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 22–23 January 2016; pp. 1–6.