Study And Analysis of High-Yield Farming Using IoT-Based UAV

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Abstract:
The use of IoT-based Unmanned Aerial Vehicles (UAVs) has become increasingly popular in recent years due to its ability to collect, transmit, and analyze data in real-time. IoT technology enhances UAVs with sensors, connectivity, and computing power, enabling them to gather and process information in various applications such as agriculture, inspection, surveillance, and delivery. The integration of IoT and UAVs enables faster, more efficient, and cost-effective data collection and analysis. It also enables the creation of a connected network of devices that can communicate and share information in real-time, improving decision-making and providing valuable insights. Overall, the use of IoT-based UAVs has the potential to revolutionize the way various industries collect, process, and analyze data, leading to increased productivity and efficiency.

Keywords: Unmanned aerial vehicles, Farm Monitoring, IoT, crop spraying, crop mapping

1. Introduction

The use of drones in agriculture has been growing rapidly in recent years and has shown significant potential for improving efficiency, reducing costs, and increasing yields. While drone farming is still a relatively new technology and there are some challenges to overcome, it is likely to play an increasingly important role in the future of agriculture. As drone technology continues to evolve, it is likely that drones will become more affordable, more capable, and easier to use. This could lead to wider adoption of drone technology in agriculture, especially among small-scale farmers and in developing countries where there is a need for more efficient and sustainable farming practices, shown in figure 1 and 2. In addition, the data collected by drones can be analyzed and used to improve crop management practices and inform decision- making, which can lead to more sustainable and profitable farming operations. As such, the use of drones in agriculture is likely to continue to grow in the future as farmers and researchers continue to explore the potential benefits of this technology.

Many problems are associated with the Existing Agricultural System. To carry out the activities of agriculture various factors needed to be correct to produce satisfactory results these factors include suitable climatic conditions, fertility of the soil, and a larger plot of land required to produce a high amount of crops [2]. The agricultural sector like all other sectors has to deal with different kinds of issues and these issues are needed to be resolved very carefully to receive satisfactory results. Major issues that are related to the agricultural sector include the land holdings of most of the farmers are either small or fragmented States which are actively farmed and highly inhabited the mean size of the land is generally estimated to be less than one hectare and in some areas, it is less than 0.5 hectares as well. This issue of small and fragmented land is one of the major issues that the farmers have to face. As a result of this, there is a huge gap between small, medium, and big farmers. Laws that are inherited previously are the main causeof this problem and only solution to this issue corporate farming can be a solution to this problem as farmers can collectively farm and later distribute the cost and the profit among each other. This is one of the solutions to this problem.

Distribution and Quality of Seeds are also major problems in the agricultural sector as the seed is one of the major components in the field of agriculture. Seeds help in increasing crop yield and maintaining steady progression in the agricultural sector [1]. The distribution of seeds of good quality is as important as the production of seeds but it is very difficult for the farmers to buy good quality seeds since the cost of good quality is high thus it is not so easy for the farmers to afford good quality seeds throughout the year. Therefore the distribution of good quality seed is also a major issue that farmers have to deal with [3]. The solution to this problem can be for the government should take initiative to distribute good quality seeds among the farmers this would not only solve the issue to some extent if this idea is implemented correctly the annual income ofthe farmers will also increase gradually. Usage of Fertilisers and Manures is one of the issues that a farmer has to face since agricultural activities are going on a plot of land for several years. The fertility of the soil at a particular plot of land tends to reduce thus fertilizers and manures are needed to be used to make the soil fertile. It is estimated that because of the usage of fertilizers, 70% of production is increased but the application of fertilizers and manures throughout the country happens to be very challenging as in a country that has low income applying fertilizers can be very costly and can consume a lot of money as a result of which the average profit that is incurred by the farmers might reduce.

Figure 1: Farmers have tapped into aerial technology to manage acres of farmland at a time

1.

Figure 2: Autonomous UAV

2. Review on Topic

Unmanned aerial vehicles (UAVs), also known as drones, are becoming increasingly popular andhave a wide range of applications including aerial photography and videography, delivery, search and rescue, and military operations. Advantages of UAVs include their ability to cover large areas quickly and reach locations that may be difficult or dangerous[4] for humans to access.

Additionally, drones equipped with cameras and other sensors can collect data and imagery that can be used for various purposes. However, there are also some challenges associated with dronetechnology. Privacy concerns have been raised regarding the use of drones equipped withcameras, and there are also concerns about the potential for drones to interfere with commercial air traffic and compromise national security [8]. Overall, UAV technology continues to evolve and improve, offering new opportunities and capabilities while also presenting new challenges and ethical considerations.
Agricultural drones have become an important tool for modern farming, helping farmers tomonitor their crops, improve their yields, and increase efficiency. UAVs equipped with sensorsand cameras can provide farmers with detailed information about their crops, including planthealth, growth, and yield. This information can be used to make informed decisions aboutfertilization, irrigation, and pest control, helping to optimize yields[7] and reduce waste. UAVscan be used to monitor crops and livestock, providing farmers with real-time information aboutthe state of their farms. This can help to detect and prevent issues such as disease outbreaks, pestinfestations, and soil erosion, allowing farmers to take timely action to mitigate these problems. **Irrigation:** Agricultural drones equipped with multi-

spectral cameras and sensors can helpfarmers to monitor crop moisture levels and soil moisture content. By capturing images and datafrom the field, farmers can make informed decisions about when to water their crops and howmuch water to apply, reducing water waste[9] and improving crop yields.

Farm Monitoring: Agricultural drones can be used for a variety of farm monitoring tasks, including crop mapping, crop health analysis, and yield estimation. By capturing high-resolution images and data from the field, drones can provide farmers with valuable information about the health of their crops, allowing them to make informed decisions about planting, fertilization, and pest control [10]. Additionally, drones equipped with thermal imaging cameras can help farmers to identify areas of the field that are experiencing stress, helping them to address problems before they become too severe.

Agricultural drones have become a valuable tool for modern farmers, helping them to improve their operations and increase their yields. With their ability to provide real-time data and images from the field, drones have the potential to revolutionize the way that farmers approach agriculture, making farming more efficient, sustainable, and profitable.

According to DG et al 2019, the various kind of parameters related to agriculture which are mainly monitored through the usage of IoT explains the different parameters such as the temperature of the soil, moisture, and humidity can be measured using a sensor network [5-6]. The sustainability of the crop and the crop life can be predicted further based on climatic changes. The IoT for the most part helps farmers to connect to the request to fill in the void of agriculture.

In 2020, the use of agricultural drones continued to grow in popularity as farmers sought to improve their farming operations and crop yields. With advancements in technology, drones became more advanced and versatile, with new models such as the DJI Mavic 2 Enterprise Dual, AgEagle RX60, and Skydio 2 being introduced [15]. These drones offered features such as improved imaging capabilities, increased flight time, and more advanced navigation systems. As a result, drones became an even more valuable tool for farmers, helping them to perform tasks such as crop mapping, soil analysis, and crop spraying more efficiently and accurately.

The COVID-19 pandemic also had an impact on the drone industry in 2020 and 021. Supply chain disruptions and increased demand led to price hikes and longer wait times for drones, while travel restrictions made it more difficult for farmers to receive training and support. Despite these challenges, the use of agricultural drones in 2020-21 was still widely seen as a positive development, with farmers continuing to adopt this technology to improve their operations and increase their yields [14].

In 2022, there were several notable developments in the field of agricultural drones. Some of these include:

Improved mapping and data collection capabilities: Agricultural drones equipped with advanced sensors and cameras are able to collect data such as crop yields, soil moisture levels, and plant health with greater accuracy and detail [13]. This data can then be used to improve crop management and farm efficiency.

Autonomous operations: Some agricultural drones are now equipped with autonomous navigation and flight systems, allowing for more efficient and safe operations [16]. These drones can also be programmed to perform specific tasks, such as crop spraying or seeding, without the need for human intervention.

Increased efficiency: Advances in drone technology have allowed for larger and more efficient drones to be developed, allowing for more acreage to be covered in less time. Additionally, some drones are now equipped with multiple rotors and other features that enhance their stability and maneuverability, making it easier to perform tasks in challenging environments such as orchards and vineyards.

Increased use of precision agriculture: Agricultural drones are helping to drive the growth of precision agriculture, a farming method that uses technology to optimize crop production and minimize waste [11]. With the help of drones, farmers are able to gather more accurate data about their crops and use that information to make more informed decisions about fertilization, irrigation, and pest management.

As such, the use of agricultural drones continues to grow and evolve, offering farmers new tools and capabilities to improve the efficiency and sustainability of their operations.

There are several drone models[12] that are currently being used in agriculture, each with their own specific features and capabilities. Some of the latest models which has seen their popularity grown in 2022 include:

1. DJI Agras T30: This drone is equipped with a large capacity tank for spraying, and a powerful propulsion system that allows it to cover large areas quickly and efficiently.
2. Yamaha RMAX: This drone has been used in agriculture for over 20 years and is known for its durability and reliability. It is particularly useful for spraying crops in steep or uneven terrain.
3. Parrot Bluegrass Fields: This drone is designed for crop mapping and monitoring. It is equipped with a multispectral

camera that can capture images in both visible and non- visible light spectra.
4. Sense Fly eBee X: This drone is designed for high-precision mapping and data collection. It is equipped with a variety of sensors, including a high-resolution RGB camera and a multispectral sensor.
5. Intel Falcon 8+: This drone is known for its stability and precision. It is equipped with a high-resolution camera and can be used for mapping, monitoring, and inspection tasks.

3. The problem of the Existing System

1. Regulation and legal restrictions:

UAVs are subject to a complex and evolving regulatoryenvironment, and many countries have laws and regulations that restrict their use. This can make it difficult for farmers to use UAVs effectively and can limit their potential to revolutionize agriculture.

2. **Cost and accessibility:** UAVs can be expensive and may not be accessible to all farmers, particularly those operating on a smaller scale. This can limit the widespread adoption of UAV technology in agriculture.
3. **Technical limitations:** UAVs face a number of technical limitations, including limited flight times, payload capacity, and flight range [17]. These limitations can make it difficult for UAVsto perform complex tasks and may limit their usefulness in some agricultural applications.
4. **Privacy and security:** UAVs can raise privacy and security concerns, particularly when used for monitoring and surveillance. There is a need for clear guidelines and regulations to address these concerns[18] and ensure the responsible use of UAVs in agriculture.
5. **Technical skill and training:** Using UAVs effectively requires a certain level of technical skill and knowledge. This may pose a challenge for some farmers who are unfamiliar with UAV technology, and may limit their ability to fully leverage the benefits of UAVs in agriculture. UAVs offer a wealth of potential benefits for agriculture, but these benefits can only be fully realized by addressing the existing problems that UAVs face. By addressing these challenges, UAVs will become an even more valuable tool for farmers, helping to increase efficiency, reducewaste, and improve the sustainability of agricultural operations.

3.1 Propose solutions

1. **Regulation and legal restrictions:** Governments and industry organizations can work together to develop clear, concise, and consistent regulations for the use of UAVs in agriculture. This will provide a stable and predictable legal environment for farmers and UAV operators, helping to facilitate the widespread adoption of UAV technology in agriculture.
2. **Cost and accessibility:** The cost of UAVs can be reduced by improving manufacturing processes, increasing competition, and promoting innovation [19]. In addition, public and private initiatives can provide training and support to help farmers adopt UAV technology and improve their understanding of the benefits of UAVs in agriculture.
3. **Technical limitations:** Advances in UAV technology can help to address technical limitations, such as limited flight times, payload capacity, and flight range. By improving the capabilities of UAVs, farmers will be able to perform more complex tasks, making UAVs even more useful in agricultural applications.
4. **Privacy and security:** Governments, industry organizations, and UAV operators can work together to develop clear and effective guidelines for the responsible use of UAVs in agriculture [21]. This will help to ensure that UAVs are used in a manner that respects privacy and security, while still providing farmers with the information and capabilities they need to optimize their operations.
5. **Technical skill and training:** To ensure that farmers can fully leverage the benefits of UAVs, it is important to provide training and support to help farmers develop the technical skills and knowledge they need to use UAVs effectively [22]. This can include training programs, online resources, and technical support from industry organizations and UAV manufacturers.

4. Research gaps to be defined

Despite their widespread use, there are still many research gaps in the field of UAVs that need tobe addressed in order to fully realize their potential. Some of the key research gaps in UAV technology include:

1. **Autonomy and decision making:** There is still a need for more advanced algorithms and systems that can allow UAVs to make decisions and perform tasks with minimal human intervention [20]. This includes the development of autonomous navigation, obstacle avoidance, and target tracking capabilities.
2. **Flight safety and reliability**: UAVs still face a number of safety and reliability challenges, including the risk of mid-air collisions, malfunctions, and other operational failures. There is a need for improved systems and algorithms to ensure the safe and reliable operation of UAVs.
3. **Energy efficiency and end**urance: UAVs typically have limited flight times and are limited by their available energy sources [7]. There is a need for more efficient and longer-lasting energy sources, as well as improved aerodynamics and propulsion systems,to extend the flight time and range of UAVs.
4. **Payload and ca**pacity: UAVs are limited by their payload capacity, making it difficult to carry heavy payloads such as cameras, sensors, and other equipment. There is a need for the development of lighter and more compact payloads, as well as improved airframesand power systems that can support increased payload capacities.
5. **Integration with other systems:** UAVs need to be integrated with other systems, such asground control stations,

communication networks, and satellite navigation systems, in order to be effective. There is a need for improved integration and communicationsystems that can allow UAVs to work seamlessly with other technologies.

While UAVs have come a long way in recent years, there is still much research that needs to be done in order to fully realize their potential and address the challenges they face. By addressing these research gaps, UAVs will become even more useful and versatile tools in a wide range of applications.

5. Propose Conceptual and Mathematical Model

In this paper we propose a conceptual and mathematical model of IoT based drones which are generally used for various areas of agriculture, shown in figure 3. These model will enhance the yield of farmers using various functions of the drone like to collect the details of unwanted insects that may affect the yield of farmers, distribution of pesticides for the removal of unwanted insects, timely and evenly distribution of water to enhance the yield, weather conditions etc.

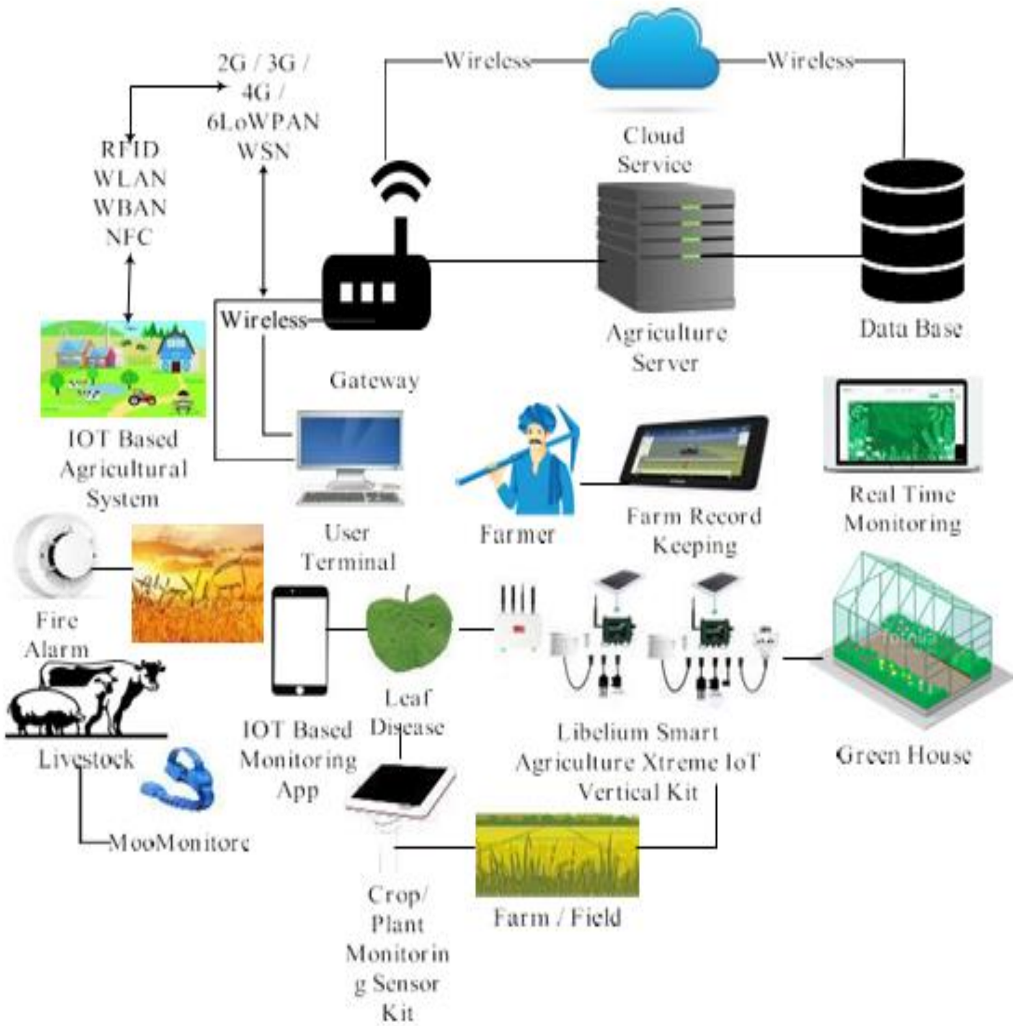


Figure3: IoT used in different areas.

The importance of UAVs in various domains is given by dividing into three broad categories – Types, Sensors and Research Domains. Figure 5 shows various categorization of UAVs based on their structure and functionality. Figure 6 highlights the various sensors needed for theoperation of UAVs and for the use of these UAVs in agriculture. On the basis of this features of the UAVs we have propose a conceptual model IoT based UAV shown in figure 8. Figure 7 highlights to the various components of IoT used in smart forming.

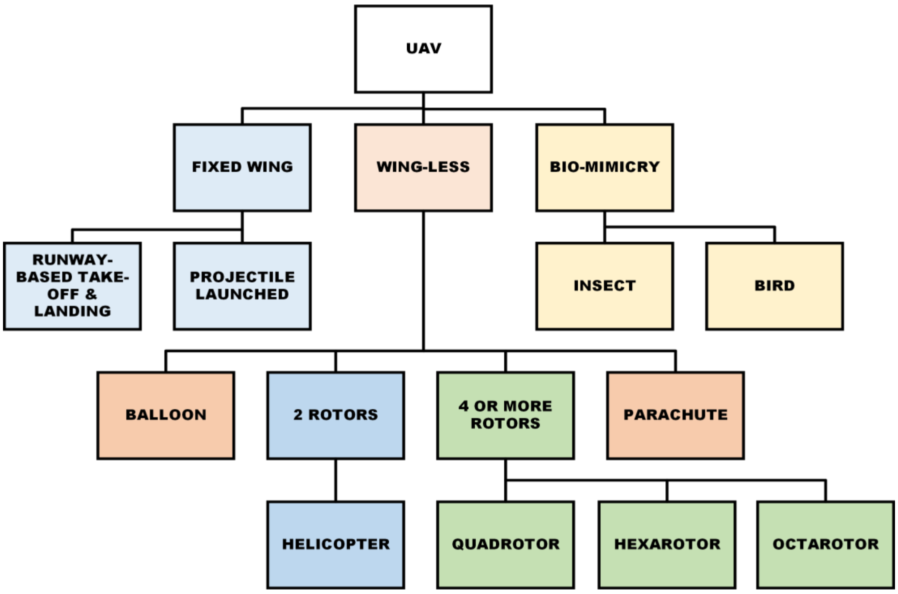


Figure 4: Categorization of UAVs, based on their structure and functionality.

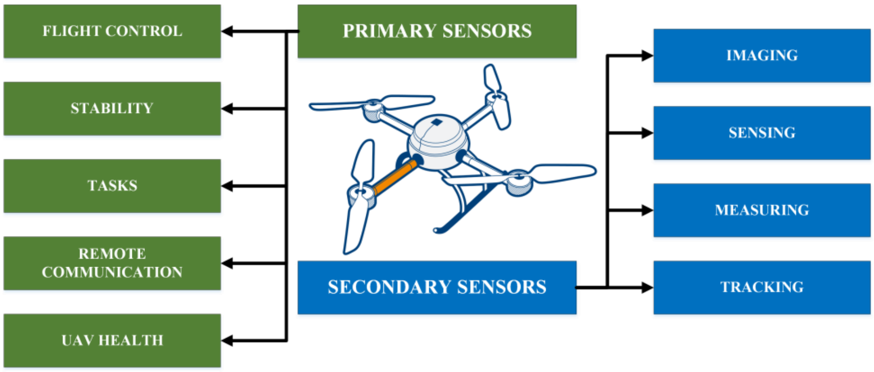


Figure 5: A broad outline of UAV sensor types.

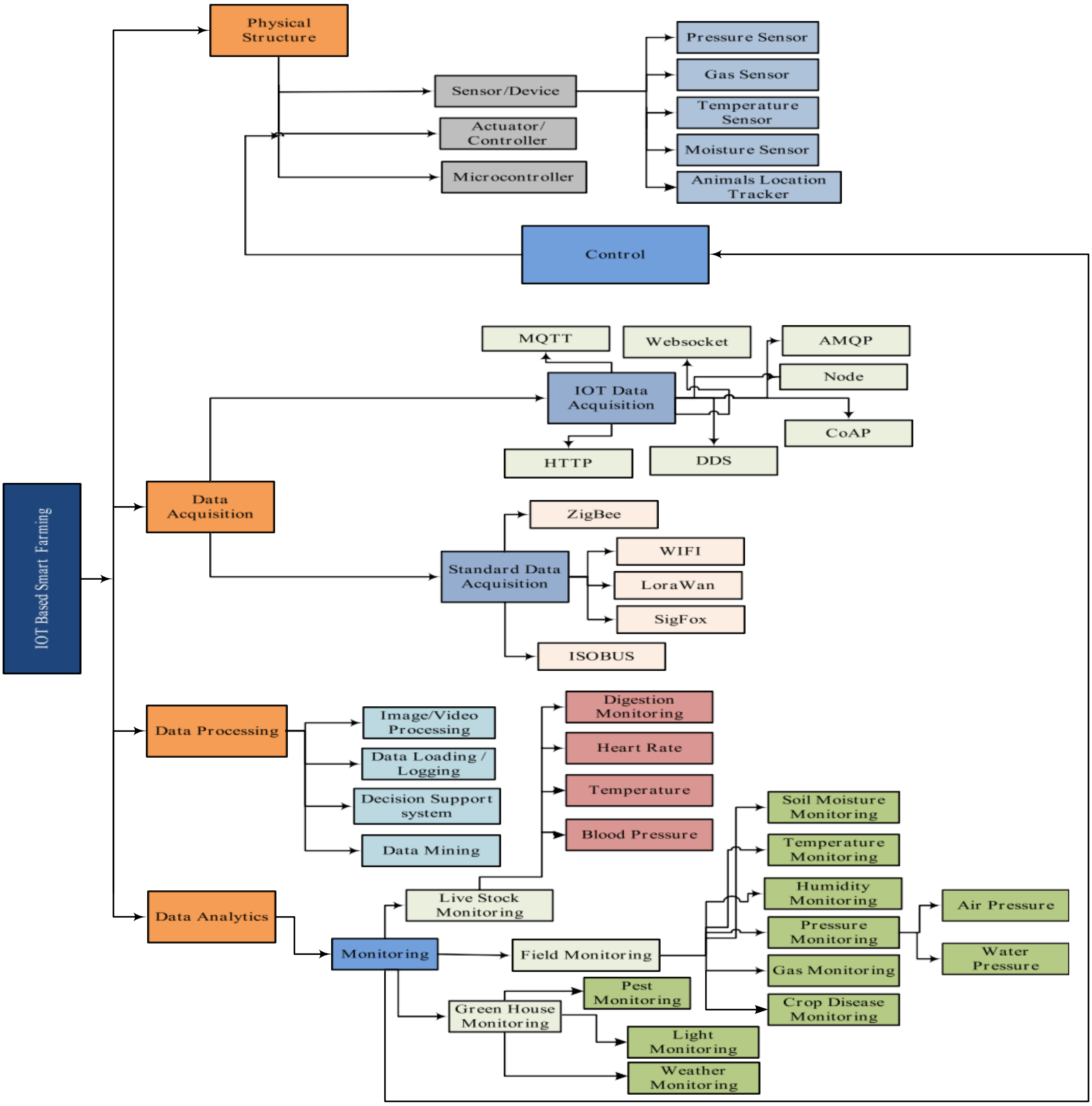
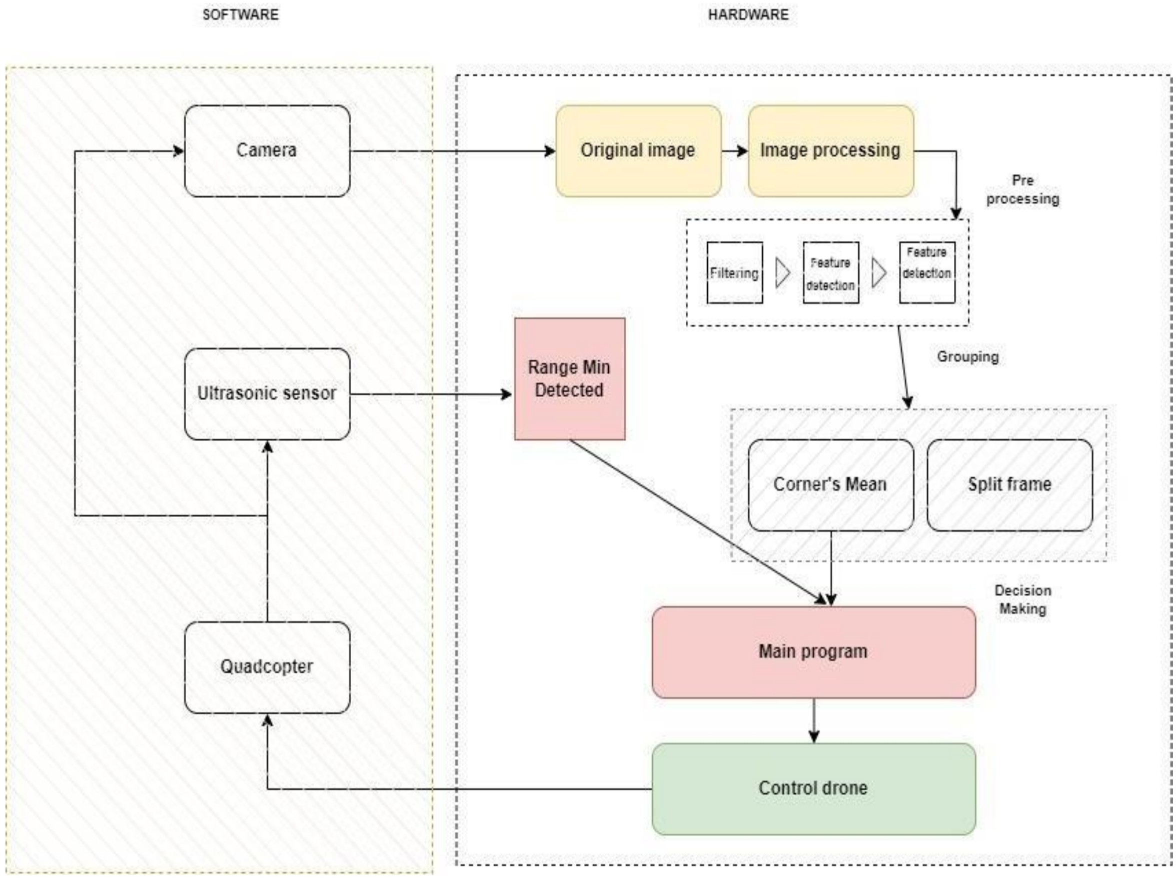


Figure 7: Various components of IoT

IoT based smart farming consist of four major components as shown in Figure 7. These four major components are physical structure, data acquisition, data processing, and data analytics. The physical structure is the main factor for precision agriculture to avoid any unwanted happening. Whole system is designed in such a way which controls the sensors, actuators, and devices. A sensor performs multiple tasks like soil sensing, temperature sensing, weather sensing, light sensing, and moisture sensing. Similarly devices perform many control functions like, node discovery, device identification and naming services etc. All these functions are performed by UAV which is controlled through a microcontroller. This controlling operation is performed by any remote device or a computer which is connected through Internet.



A mathematical model specifies how an agricultural drone will move and behave in relation to the model's input values and outside impacts on the agricultural drone. This is observed as a mathematical model as a function that maps inputs to outputs. Knowing the four angular velocities of the drone's propellers allows one to forecast its position and attitude using a mathematical model, allowing for computer simulation of the agricultural drone's behaviour under various circumstances. Computer simulation is a reasonably quick, inexpensive, and risk- free way for confirming control algorithms. More complex mathematical models more correctly describe the behaviour of agricultural drones, but they also consume more computer resources, lengthening simulation times or perhaps making them impossible to finish. It is crucial to strike a balance between model complexity and accuracy depending on the requirements. For the sake of the mathematical model, the angle velocities of the propellers directly affect how the agricultural drone moves. Only the agricultural drone frame with propellers will be taken into account in this mathematical model.

Two coordinate systems are necessary to be considered when developing a mathematical model:
- Earth fixed frame (E-frame, FE)
- Body fixed frame (B-frame, FB)

Some agricultural drone’s physical characteristics (such as roll, pitch, and yaw angles and angular velocities) are measured in FE, while other characteristics are monitored in FB (linear accelerations). The positive direction of the ZE axis is away from the earth in the inertial right- handed coordinate system known as FE. In FE, the positions and attitudes of agricultural drones are defined. On the agricultural drone's body, FB is fixed. The propulsor 1 on the drone’s front side determines the positive direction of the XB axis. Propulsor 4, which is on the left side of the drone, is where the YB axis' positive direction passes. The ZB axis is perpendicular to the XB and YB axes, and it points in the direction of the thrust forces generated by the propellers. The centre of gravity of the drone is assumed to be where F B originates. Forces f B, angular velocities B, torques B, and linear velocities v B are specified in F B.

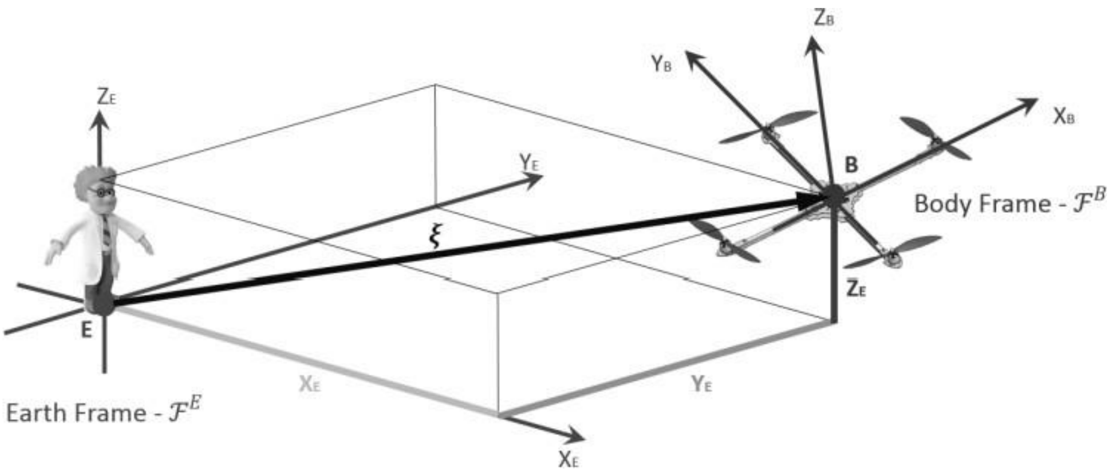


Figure 6: Earth and Body frames

The position of the drone is determined by the vector between the origins of F E and F B.

$$\boldsymbol{\xi} = [X\ Y\ Z]\ ^\wedge\mathbf{T}$$

The orientation of F B with respect to F E is used to describe the agriculture drone attitude.Three consecutive rotations around the F and E coordinate axes define the orientation.

Applying the roll-pitch-yaw order $\eta = [\boldsymbol{\phi}\ \ \boldsymbol{\psi}]\ ^\wedge\ \mathbf{T}$

For several reasons, including the fact that the system inertia matrix is time-invariant, drone frame symmetry allows for equation simplification, sensor measurements can be easily converted to F B, and control variable equations can be simplified, motion equations are better formulated with respect to the F B.

A rigid body's kinematics with six degrees of freedom can be given with:

$$\varepsilon = \mathbf{J}\ \boldsymbol{\nu},$$

“Where ε is generalized velocity vector in $\mathscr{F}$ B , $\boldsymbol{\nu}$ is generalized velocity vector in F B , and $\mathbf{J}$ is generalized rotation and transformation matrix. ε consists of drone position $\boldsymbol{\xi}$ and attitude”.

$$\boldsymbol{\varepsilon} = [\boldsymbol{\xi}\ \eta]\ ^\wedge\mathbf{T} = [X\ Y\ Z\ \phi\ \theta\ \psi]\ ^\wedge\mathbf{T}$$

FB (Generalized velocity vector) is defined the same way

$$\boldsymbol{\nu} = [\mathbf{v}\ \mathbf{B}\ \omega\mathbf{B}]\ \mathrm{T} = [u\ v\ w\ p\ q\ r]^\wedge\ \mathrm{T}$$

Velocities are transferred from F B to F E by the generalised rotation and transformation matrix, which is a more realistic method of seeing drone motion. The submetrics are:

$$\mathbf{J} = [\ \mathbf{R}\ \mathbf{0}3\times3$$
$$\mathbf{0}3\times3\ \mathbf{T}\ ]$$

Rotation matrix $\mathbf{R}$ = [$\cos\psi\ \cos\theta\ \cos\psi\ \sin\theta\ \sin\phi - \sin\psi\ \cos\phi\ \cos\psi\ \sin\theta\ \cos\phi + \sin\psi\ \sin\phi\ \sin\psi\ \cos\theta\ \sin\psi\ \sin\theta\ \sin\phi +$ $\cos\psi\ \cos\phi\ \sin\psi\ \sin\theta\ \ \cos\phi\ - \cos\psi\ \sin\phi$

$-\sin\theta\ \cos\theta\ \sin\phi$

$\cos\theta\cos\phi$].

The rotation matrix, which through matrix multiplication transfers the linear velocity vector fromone coordinate system to another, is introduced in order to translate observed values from one coordinate system to another. The orthogonal matrix is matrix R. In F E, angles and angular velocities are expressed. The matrix T is used to translate the angular velocities from F B to F E.

$\mathbf{T}$ = [1 $\sin\phi\ \tan\theta\ \cos\phi\ \tan\theta$

0 $\cos\phi\ -\sin\phi$

0 $\sin\phi/\cos\theta\ \cos\phi/\cos\theta$]

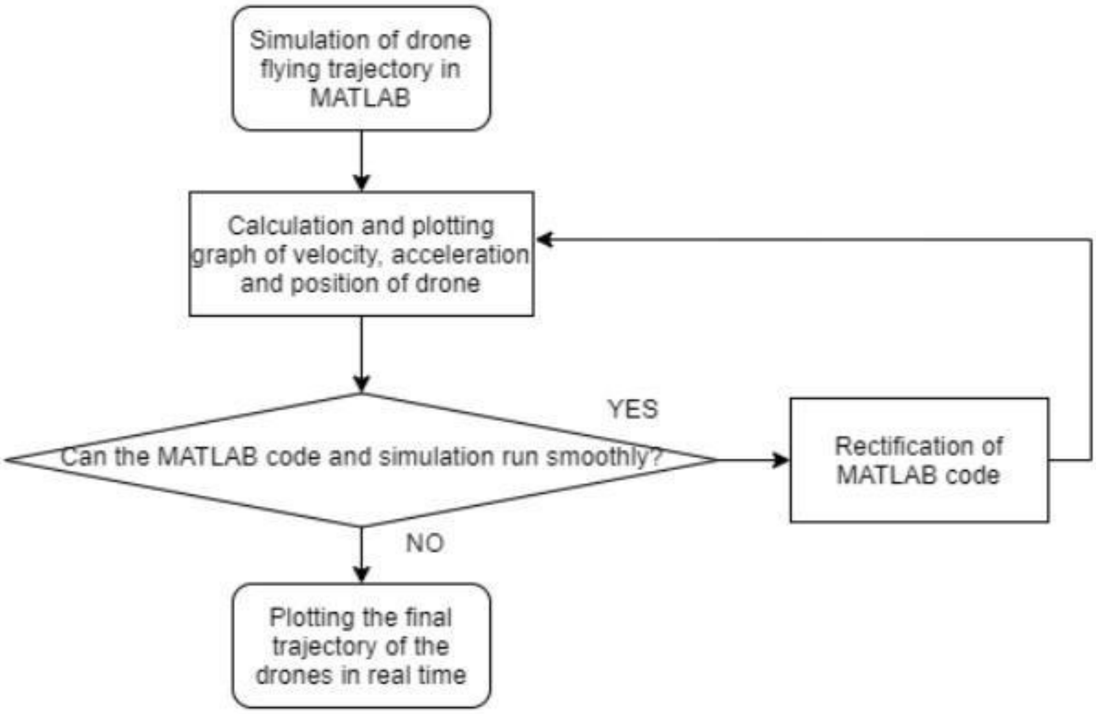
Drone dynamics

The Newton-Euler method was used to generate differential equations that describe the dynamicsof drones. The mass m and the inertia of the body I are taken into account while analysing the dynamics of a stiff 6 DOF body. The principal inertia axes correspond with the F B coordinate axes when the drone frame is assumed to have a symmetrical structure with four propulsor carriers in line with the XB and YB axes. As a result, the inertia matrix is transformed into a diagonal matrix where Ixx = Iyy.

$$\mathbf{I} = [\ I\mathrm{xx}\ 0\ 0$$

0 Iyy 0
0 0 Izz].

5.1 Simulation of an Agricultural Drone's Flight Pathway



Matlab can be used for the purpose of drone simulation. The code can be made to mimic how an agricultural drone would fly in order to water a certain area, at a particular height, and at a set speed. The position, velocity, and acceleration of the agricultural drone are calculated. The final trajectory graph of the agricultural process can be plotted if the MATLAB code contains no mistakes and is able to calculate all of the parameters mentioned. The plotted graph makes it possible to see the spraying efficiency. A lim is the maximum acceleration, pre rad is the turning radius, and there are three pre-set initial conditions at the beginning of the cod. Based on the drone's physical characteristics, these parameters are modified.

The preset conditions are: dt = 0.1; a_lim = 1; pre_rad= 2;
The user will be asked for the intended x and y starting point and then the desired x and y finishing point by the code. The agricultural drone's beginning and stopping points are configured to fly in a precise pattern, and the size of the area being sprayed can be visualised. The start and end point can be defined as:
Prompt = ' Enter starting position x: ';x_start = input(prompt);
Prompt = 'Enter start point y: ';y_start = input(prompt); prompt = 'Enter end point y: '; x_stop = input(prompt); prompt = 'Enter end point y: '; y_start = input(prompt);

Once the simulation paratmeters have been defined, the number of turns would be measured and plotted through graphs.

Conclusion

Most of the agricultural operations are done using hands in certain parts of the world, if not hands other traditional tools like ploughs, and sickles are used to carry on with the agricultural operations. Major activities like ploughing, seeding and supply of water to crops involve nousage of any modern equipment and as a result of this large human efforts are needed but the results of so much human effort are not so satisfactory as the productivity per worker is very low [18]. The solution to this problem is modern equipment like drones should be implemented to do more effective work without wasting much time and energy. A drone can be used as one of the modern equipment by farmers to carry out the process of farming. The main usage of drones is inthe field of agriculture to give productivity, capacity, and precision to defeat any sort of hindrance. Likewise, it is utilized as though the estimation is precise, it additionally assists with social occasions with more exact information because of which the harvest yield is high. With the execution in the field, the stock interest hole of the farmers is satisfied. Applying the ideas of IoT will accomplish something useful for the field of farming. With the execution of drones inthe field of agriculture robots can finish the work of reviewing crops by taking photos at regular intervals to such an extent that the farmers can take a gander at the movement of the yields and work in like manner to come by good outcomes, splashing synthetic compounds on the harvests additionally they are utilized for the screening of the rural field.

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