Application of UAV in pest detection using IoT

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Abstract
Unmanned Aerial Vehicle (UAV) can perform site-specific farm management operations with higher precision.Remote sensing of crop and pest conditions could be made more efficient with the use of UAVs by acquiring data, managing inputs, and detecting pests on time using the Internet of Things (IoT). This can be accomplished through large data, advanced wireless communication technologies, smart computer vision, cloud computing, and high-end security techniques. In agricultural modernization, IoT and UAV can track crop diseases and pests from micro and macro perspectives, respectively. Sitting in one place they can detect, monitor, and treat the problem.Thus, the present work is focused on the application of IoT based drones in agriculture industry. Particularly, a IoT based drone system is first designed and analyzed using CAD and CAE, then assembled and tested for its performance of more than 30 minutes' endurance. The present IoT-drone system is such that it can be repaired component wisein case of failure due to that component. Further, it provides low-cost solution regarding pest detection and their treatment which could ease the lives of ourIndian farmers.

Keywords: Unmanned Aerial Vehicle (UAV), Internet of Thing (IoT), Agriculture modernization, Hexacopter, Pest detection

1. Introduction

In India, farmers still use traditional methods of farming which are time consuming and ineffective. Moreover, they feed the most populated nation of the world with the population size of 1.4 billion people. Inspite of the 17% contribution of agriculture to India's GDP, there are some concerns related to traditional farming like crop loss due to pests and other disease which affect the overall agriculture production. According to a study by the Associated Chambers of Commerce and Industry of India [1], 50,000 crores ($500 billion) agriculture raw goods are annually lost due to the pest diseases, which is about 30-35% of the total crop yield [2]. One of the reasons of 60 million tones crop loss is the Nematodes, a microscopic wormlike animal which cause damage to the crop. If this amount of crop loss is saved then around 200 million people can be feed which could result in increase in the world hunger index ranking of India. One way to control the crops loss is the use of modern farming techniques as practice by some of the developed country like Israel. Collectively, emerging modern farming technique can be used to minimize the crop losses and will help farmer to get better crop quality and price.

In India, currently, majority of the farmers uses traditional farming technique and uses pesticides in order to control the pest. In general, the pest spray is done by manual unskilled workers which some time can under- or over-spray the pesticides. However, the over spray of the pesticides can damage crops and under spray will results in crop loss. More specifically, our most farmers primarily use the traditional pest management method of spraying regularly according to schedules. The chemicals in these sprays kill helpful insects that help eradicate pests. Pests and insects start from a point in the field and start growing in that region. This results in crop failure in that area. Crop monitoring to detect pest-affected areas is manually done by the farmers which is time consuming and ultimately leads to inefficiency. Particularly, pest species damage crops, machinery, equipment, and other property, especially if left untreated; in addition, they destroy livelihoods and crops, thereby lowering productivity. Pest species can include insects, birds, and rodents. Apart from pesticides, moisture control, crop monitoring, and pest detection are some of the important factor that need to be cared for the better crop yield. The level of control of the conducive environment for particular crop is not possible using traditional farming technique. Thus, a system of effective pest control is lacking and must be improved via means of newly developed farming technologies.

In modern farming practice, the use of unmanned aerial vehicles (UAVs) is prominent. UAVs are small flying devices which are either program-based control or manually remote controlled. To extend these further, smart drones with sensors attached to it allow further details about crop and make process autonomous via feedback from sensor. With the advent of the Internet of Things (IoT) in agriculture, different crop sensors, smart drones, water management, and pest control process can be automated for both small and big farms. Further, as the development of digital technology accelerates, image processing technology can be applied to agricultural research, which could assist in solving this complex problem of detection of pest-affected areas. Using the knowledge of Deep Learning (DL) and Image processing of crop, the detection of insect and pest can be detected. For comprehensive analysis, a literature survey has been conducted on various areas of agriculture which utilized drone-IoT system in the areas of pest detection, crop monitoring, and irrigation. It has been argued for years that precision agriculture, crop management that uses GPS and big data, can reduce food and water shortages while increasing crop yields [3,4].
Utilizing these technologiesfor pest detection and crop monitoring, the IoT based services include data acquisition from sensors and internet, and agriculture operation automation[5,9]. The decision at various steps are taking by the manual reinforced information by consulting expert or Cloud based machine learning. For digital data, Television White Spaces (TVWS) with high bandwidth can be utilized to facilitate thetransmission of high-quality digital data in form of videos or images from optical sensors placed either on the Drone or on the crop field at different locations. Similarly, data collected from multiple sensors then must be transmitted to the gateway using LoRa technology to cloud data center. In cloud data center, data fusion and data analysis services are performed. This LoRa devices data will be processes and analyzed in the cloud centers and appropriate path is decided on the precision map and communicated back through TVWS communication system for next step [6].

Considering all these above points, we aim to design a low-cost drone that would detect pests, so that the majority of the farmers can benefit from this technology for better productivity. Theaim of the present workis to design a drone using IoT for pest detection. The present objective can be further divided into four scopes as (1) modelling, designing and analyzing our UAV model; (2) to do a detailed pest detection stud; (3) detailed study of IoT and model that can be used comprising of TVWS, Lora sensors and cloud data center; and (4) combining the design and IoT modelforthe application of pest detection.

2. Mathematical modelling

For the modelling and analysis of drone, various parametric aspects are required which are discussed as follows:

2.1. Endurance

The endurance or flight time is calculated from the battery constraints, i.e., voltage, power, battery discharge and battery capacity as

$$\text{Flight Time} = \left(\frac{\text{Battery Capacity} \times \text{Battery Discharge}}{\text{Average amp drawn}}\right) \times 60$$

in which, Average amp drawn can be obtained as

$$\text{Average Amp Draw} = \frac{\text{All Up Weight} \times \text{Power}}{\text{Voltage}}$$

where, Power is the power required to lift 1 kg of equipment, expressed in watt/kg and Voltage is Battery Voltage.
For present work, endurance is calculated for 80%, 90%, and 100% use of the battery as these are most common occurring cases in practices.

2.2. Coefficient of Drag

After performing the CFD analysis onthe CAD model using Ansys Fluent, the drag force can be obtained as:

$$C_D = \frac{D}{\frac{1}{2}\rho V^2}$$

Where, D is the drag force, ρ is the density, V is the velocity and C_D is the coefficient of drag

In present work, hexacopter is assumed to and a rigid body. Therefore, the Euler angles can be used to obtain the differential equations for the dynamics of the hexacopter. In order to describe the hexacopter motion only two reference systems are necessary [7]: earth fixed frame and body frame.
The motion of an aircraft is always planned by using geographical maps, so it is useful to define an earth fixed frame tangent to the earth's surface.

The X, Y, and Z axes are pointed in the directions of North, East, and Down, respectively, and the origin of this reference system is set at a single point on the surface of the earth. The definition of the hexacopter's absolute linear location (x, y, and z) is made using this earth-fixed frame, which is viewed as an inertial frame. A fixed mobile frame (XB, YB, and ZB) is positioned in the hexacopter'scenter of gravity. The angular position of the body frame with respect to the inertial one is usually defined by means of the Euler angles: roll ϕ, pitch θ, and yaw ψ.

The inertial position vector and the Euler angle vector are denoted as $\xi = [x\ y\ z]^T$ and $\eta = [\phi\ \theta\ \psi]^T$, respectively. The 'T' used in the position vector and Euler angle is the matrix transpose.
Further, rotational rate vector can be defined as

$$w = \dot{\phi} + \dot{\theta} + \dot{\psi}$$

Roll, pitch, and yaw moment information can be obtained from the hexacopter's geometrical structure and from the parts above the body frame.

$$\begin{bmatrix} \tau_\phi \\ \tau_\theta \\ \tau_\psi \end{bmatrix} = \begin{bmatrix} \frac{3}{4} kl(w_2^2 + w_3^2 - w_5^2 - w_6^2 \\ kl(-w_1^2 - \frac{w_2^2}{4} + \frac{w_3^2}{4} + w_4^2 + \frac{w_5^2}{4} - \frac{w_6^2}{4} \\ b(-w_1^2 + w_2^2 - w_3^2 + w_4^2 - w_5^2 + w_6^2) + I_M(\dot{w}_1 + \dot{w}_2 + \dot{w}_2 + \dot{w}_3 + \dot{w}_4 + \dot{w}_5 + \dot{w}_6) \end{bmatrix}$$

For translational dynamics,

$$\ddot{x} = \frac{k}{m}(\cos\phi\cos\psi\sin\theta + \sin\phi\sin\psi)(w_1^2 + w_2^2 + w_3^2 + w_4^2 + w_5^2 + w_6^2)$$
$$\ddot{y} = \frac{k}{m}(\cos\phi\sin\psi\sin\theta + \sin\phi\cos\psi)(w_1^2 + w_2^2 + w_3^2 + w_4^2 + w_5^2 + w_6^2)$$
$$\ddot{z} = \frac{k}{m}\left((\cos\phi\cos\psi)(w_1^2 + w_2^2 + w_3^2 + w_4^2 + w_5^2 + w_6^2) - g\right)$$

Where, k is the lift constan.t

For rotational dynamics:

Velocity vector is written as

$$v = \begin{bmatrix} p \\ q \\ r \end{bmatrix} = \begin{bmatrix} 1 & 0 & \sin\theta \\ 0 & \cos\phi & \cos\theta\sin\phi \\ 0 & -\sin\phi & \cos\theta\cos\phi \end{bmatrix} \begin{bmatrix} \dot{\phi} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

While acceleration is formulated as

$$\dot{p} = \frac{I_{yy} - I_{zz}}{I_{xx}} qr + \frac{I_r}{I_{xx}} qw\Gamma + \frac{\tau_\phi}{I_{xx}}$$
$$\dot{q} = \frac{I_{zz} - I_{xx}}{I_{yy}} qr - \frac{I_r}{I_{yy}} pw\Gamma + \frac{\tau_\theta}{I_{yy}}$$
$$\dot{r} = \frac{I_{xx} - I_{yy}}{I_{zz}} pq + \frac{\tau_\psi}{I_{zz}}$$

Where, I = Moment of Inertia vector and Γ represents the gyroscopic forces

3. Methodology

The work is initialized with modeling, designing, and analyzing the drone. Through the use of UAVs, the advanced pest recognition approaches are based on the processing of raw images over the crop area. Utilizing the IoT platform for pest detection is dependent on three steps: sensing, evaluating, and treating [6]. An agricultural IoT platform consists of several main components, including IoT base stations, energy supplying devices, gateways, a cloud data center and the APP software (Application Software). A typical IoT base station is comprised of TV White Spaces (TVWS) and LoRa sensor modules. With LoRa technology, data from multiple sensors can be collected and transmitted to the gateway over a long distance. TVWS technology with high bandwidth is used to transmit video or photos in UAVs equipped with specially designed optical sensors. The cloud data centre offers services for data fusion and analysis. The cloud gateway will receive the data from LoRa devices and TVWS first because the cloud data centre is typically remote from the farms. [8]. In order to send data to cloud data centres via these networks, the gateway can be deployed in farmer homes. The information provided by the TVWS communication system is used to create a precise map and plan the routes for UAVs. Data acquired by LoRa devices is monitored in cloud data centres. Data processing takes place at the cloud data center, which is one of the core components of the framework [5].

4. Results and discussion

Currently, we have worked on modeling, designing, and simulation the UAV. A multirotor UAV is selected for its ease of hovering and flying. Since there were a number of multirotor UAVs, a hexacopter is selected as the best alternative, for the stability it offers. Even if a motor fails, other motors can work to reduce the impact of the failure. A CAD model of the hexacopter is designed in NX-Nastran software. The design has been made such that it could be dismantled, for any part that fails could be replaced instead of repairing/replacing the entire UAV. The CAD model is made by considering the important aspects of the camera as well as the electronic components, i.e., battery, motor, propellers, and Electronic Speed Controller (ESC). The final design is shown in Figs. 1 and 2.

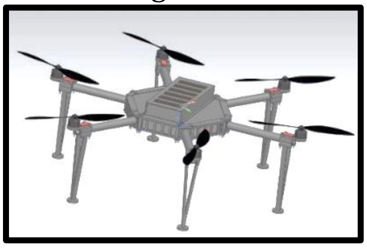

Figure 1: Top isometric view of the hexacopter CAD

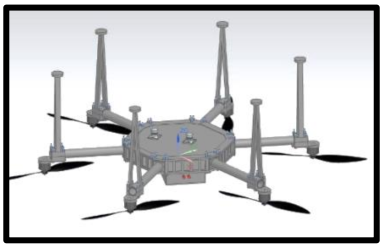

Figure 2: Bottom isometric view of the hexacopter CAD

The material selected for the model is Polyamideimide (30% carbon fibre)due to great tensile strength with low density. The electronic components used are:

1. The battery used for the hexacopter was Orange 5200 mah 4S 40C (14.8V) - Lithium Polymer Battery Pack (Lipo).
2. The motor that is used is Turnigy D2836/8 1100KV Brushless- Outrunner Motor.
3. The propeller used is 10.45".
4. ESC used is 20-30 amp

As a part of drone modelling, stress analysis is also performed on the structure to test if it could sustain the loads and boundary conditions.The loads and boundary conditions provided are as follows

Loads	
Lift due to propeller and motor	7.85N per arm
Weight of propeller	0.275N per arm
Weight of motor	0.49N per arm
Weight of battery	13.734N
Weight of two cameras	0.0685N
Weight of Rasberypi	0.49N per arm
Gravitational force	1.06 kg
Boundary condition	Foot of all the landing gears are fixed

Table 1: Loads and boundary conditions

For the material PAI (30% carbon fibre), the stress analysis showed a deformation of 10^{-5} m which can be neglected as it is very small and won't affect the design. The deformation result is shown in Fig 3.

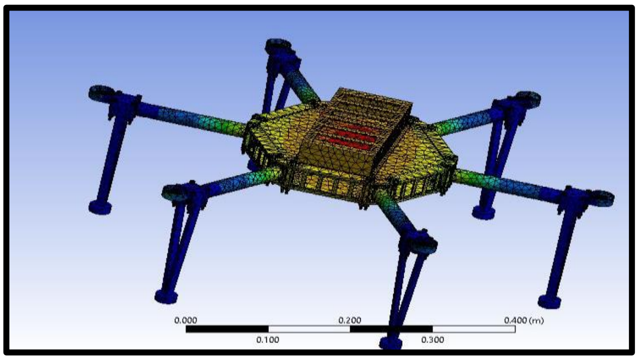

Figure 3: Deformation in hexacopter

The CFD simulation using Ansys software has been performed on the design to obtain pressure and velocity plots, path lines and streamlines. Also, the drag values is obtained from simulations as

1. For vertical motion the drag force 51.56 N and corresponding C_d value comes out to be 1.08. The pressure plot, path lines and streamlines are shown in Figs. 4, 5 and 6
2. For horizontal motion the drag force 3.7 N and corresponding C_d value comes out to be 0.664.
3. Also, the grid independence and convergence test were performed during the simulation for accurate results.

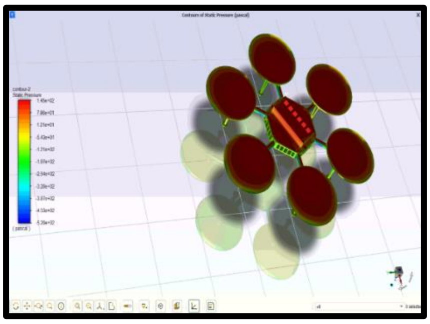

Figure 4: Pressure plot for vertical motion

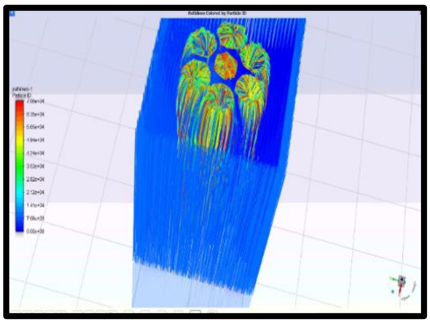

Figure 5: Path lines for vertical motion

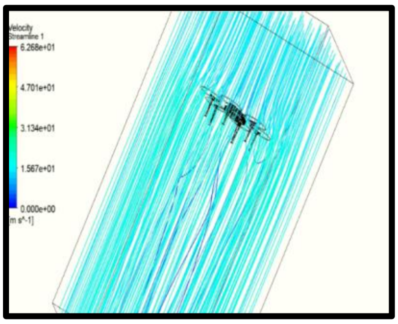

Figure 6: Streamlines for vertical motion

We calculated the endurance of the drone for which it could fly at different battery conditions. From battery life and flight time endurance was calculated. We have achieved the endurance of 30+ minutes with 10 % of the Battery remained during mission which is good enough.

- Endurance with 20% battery remained = 27.26 minutes
- Endurance with 10% battery remained = 30.666 minutes
- Endurance with Full Use of Battery = 34.073 Minutes

5. Conclusions

Indian farmers rely on traditional methods for the practices, which makes it extremely difficult for them to manage and improve efficiency. Traditionally, crop protection methods include manual inspections of farms and the application of pesticides and fertilizers. Drone technology has gotten most of the recognition in the industry because of its diversity and is considered the future for the agrarian community. Hence, a drone model is proposed in the present study to aim for pest detection using IoT technology. In present work, only drone design and modelling part has been carried out. In this, a hexacopter has been designed in CAD in conjunction with structural analysis. Polyamideimide (30% carbon fibre) is selected as the material for the frame. The forces are calculated using CFD analysis of the CAD in ANSYS. Appropriate electronic components were selected for the drone. Using electronic assembly selected, thrust and endurance has beencalculated.The mathematical modeling was done to know the orientation and determine the rotational and translational dynamics of the hexacopter. The remaining IoT modeling will sense angle perception of sun illumination. Thus, in future work, IoT model will be developed using the TVWS, LoRa sensors, and cloud data center which can detect pests using image sensing. The IoT platform will provides an easy way of sensing, evaluating, and treating pests.

6. References

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