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Application of Drones in Agriculture domain

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Abstract*: The Technology interventions have affected the agriculture production in positive manner. The Unmanned Aerial vehicles (UAVs) or drones are the latest addition in this domain. These UAVs or drones hover around in the target area and provide images of the field including crops and vegetations. Analysis of these images is done at the later stage which provides an insight into what can be done to improve the crop production. The major research areas in the use of UAVs/drones for improving the agriculture are: (1) line identification in tree orchards, (2) spraying of pesticides, (3) field data collection of various parameters like temperature, humidity etc. (4) differentiating between weeds and crop plants (5) crop health monitoring (6) harvest size monitoring (7) precision agriculture (8) smart agriculture and (9) safeguarding crop. In this paper, we listed, compared and reviewed the present research works involving drones in agriculture. This review will help to solve the farmers problems using drones and will also help in understanding the successful case studies of drones in agriculture domain.

Keywords* : *IoT based drone, Unmanned Ground Vehicle (UGV), Wireless Sensor Network (WSN), Smart Agriculture.

I. INTRODUCTION

There are five types of unmanned vehicles: (1) Unmanned Aerial Vehicle (UAV), (2) Unmanned Ground Vehicle (UGV), (3) Unmanned Surface Vehicle (These vehicles are operating on the surface of the water), (4) Unmanned Under-Water Vehicle and (5) Unmanned Spacecrafts. Drone is also known as Unmanned Aerial Vehicle. It is named so because it does not require any human pilot on board to operate it. It can be controlled either via dedicated remote control or it can control itself via Global Positioning System (GPS) and pre programmed instructions. Drones come in a variety of shapes and sizes, ranging from commercial "toys" with four or more propellers, to more professional and expensive airplane shaped crafts with one propeller and a long wingspan [8]. Propellers basically provide thrust and torque which is helpful in continuous flying of drone. A drone having 4 rotors is known as quadcopter, having 6 rotors is known as hexacopter and having 8 rotors is known as octocopter. Cost of drones depends upon its type and use. A drone having more functionality will have more price than the drone having limited functionality. The drones used in agricultural environment, e.g. Honeycomb AgDrone which is a fixed wing drone with a very high specification camera and software can cost as much as $20,000 [8].

There are various types of cameras that can be used in drone. Researchers and farmers working in the agriculture domain have different needs. Basically the field information like water content underground, chlorophyll levels, degree of pest infection and the plant temperature etc is required for analysis purpose. To see and interpret such information, a high quality specialized camera is often required. The most commonly used camera in agriculture fields are:

- Near infrared*:* This camera is basically used to predict the level of crop production by measuring the chlorophyll level.
- Hyper spectral camera*:* This camera is used to see across the whole spectrum. The hyper spectral camera is mostly suited for agriculture surveys. It can show all the light frequencies in a single image, reducing the time and hardware needed to get all the necessary information [8].
- Multispectral Imaging Camera*:* These cameras are able to capture visible and invisible images of vegetation and crops which can help farmers to manage the crops, irrigation, soil and fertilizing more effectively.

Drone gets power to fly from batteries. These batteries are rechargeable. Basically an electric motor which converts electrical energy into mechanical energy is used to spin the propeller. Some drone uses solar panel in order to recharge their batteries. Heavy weight drone consume more power as compare to the light weight drone. So drone flight time and range depends upon their weight and size of battery. Drone can fly as far as the power source will take them. Professional drones like DJI Phantom series have larger batteries and can manage around 15-25 minutes of flight time [8]. To overcome the limited power, researchers envisage laser-power beaming as a future technology to provide supplemental energy at night when solar energy is not available or is minimal at high latitude during winter. This would enable such UAVs to fly day and night for weeks or possibly months without landing [10].

In this paper, we have reviewed about how the drones are used in the field of agriculture for increasing the efficiency of the farmers and minimizing their efforts in irrigation, killings parasites, collection of field data like temperature, soil data, humidity etc. Further, the works of various researchers who have used drones in the agriculture domain have also been discussed briefly. We have also summarized the results and findings by the researchers who have used drones in agriculture.

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This paper is further divided into 6 sections: in section 2 uses of drones in agriculture field is discussed. Section 3 discusses about the work done by various researchers in agriculture field using drones. Section 4 summarizes the findings by the researchers. Section 5 discusses about the issues and challenges regarding the use of drones and those faced by the researchers. Section 6 provides conclusions.

II. DRONE USES IN AGRICULTURE

Drones have wide spread use in agriculture domain. According to PWC report, the total addressable market for drone-based solution across the globe is $127.3 billion and for agriculture it is at $32.4 billion [2]. Some of the popular uses of drones in agriculture are discussed in this section. Figure 1 illustrates the uses of drones in the agriculture domain.

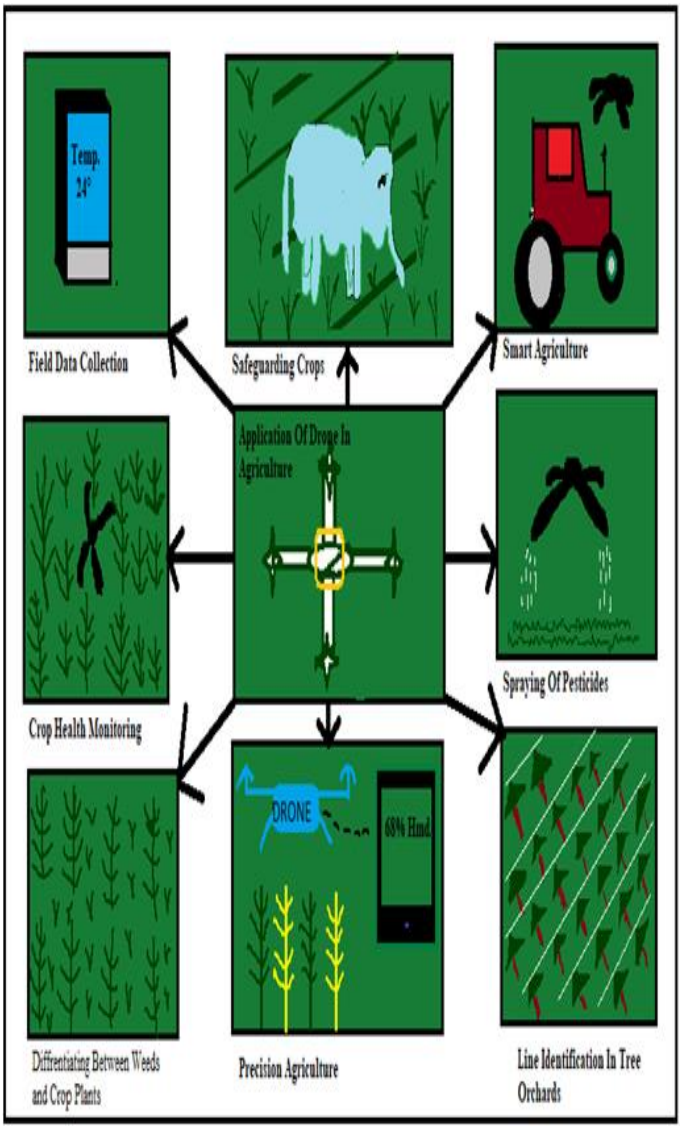

Figure 1. Uses of drones in Agriculture domain

A. Line identification in tree orchards

Automatic crop line identification from images will be very beneficial for farmers as the food production will increase in limited arable land. UAV and UGV (Unmanned Ground Vehicle) uses the crop line data for autonomous navigation through crop field with the purpose of fertilization, planting, plant detection, harvesting and weeding [6].

B. Field data collection

Drones can be equipped with appropriate measurement devices to collect field information. Drones can be equipped with Infrared thermometer sometime called pyrometers to collect leaf temperature. Leaf temperature data is very essential as photosynthesis and transpiration activities can be estimated from this. Similarly drone can be equipped with hygrometer to collect humidity data which is nothing but amount of water vapor held in the air [4].

C. Spraying of pesticides

Drones can be equipped with insecticide tank to kill the insect present on the field. If we do spraying manually, it will take a lot of time. A single drone cannot carry as much insecticide required for covering the entire field at once. So using a sub team of drones, the entire field can be covered with insecticide at once. In such case, the most important task is the coordination between these drones. Distributed search algorithm is basically used here to search and destroy the insects in the surveyed field [7].

D. Precision Agriculture

In order to improve agriculture industry, various Internet of Things (IoT) devices can be integrated with drones. IoT is defined as: Connecting everything embedded with electronics, software and sensors to the Internet enabling them to collect and exchange data. Different sensors like RGB (red, green, blue) – D (depth) sensor, Gas sensor etc can be embedded in the raspberry pi model for the purpose of collecting data and storing it into the cloud-based storage area. The stored data in cloud can be used for monitoring as well as analyzing the information [9].

E. Smart Agriculture

UGV reduces the physical effort of farmers. Autonomously planting seeds, autonomously reaping the crop by harvester are some of the examples where UGV helps farmers to reduce their physical efforts. When UGV is doing its task, a UAV or drone can be used to monitor the task performance by UGV from above [1].

F. Crop health monitoring

An aerial image of crops can be taken at the start of the season, at the mid of the season and just before they are harvested. These images are analyzed for the purpose of highlighting those rows of plants which shows slow growth i.e. to observe where plants are smaller than the rest of the field. The reason behind slow growth may be poor irrigation, poor spray of fertilizers etc. These reasons may be worked out later for further improvements [8].

G. Differentiating between weeds and crop plants

Herbicides are used to destroy unnecessary weeds present in the fields, but they have several side-effects on human health. In conventional farming, the entire field is considered as one and herbicides are sprayed to the entire field to kill the weeds, but this step will increase the unnecessary use of herbicides.

UAV equipped with high specialized camera can be used to distinguish between crop plants and weeds in the field.
If the farmers know about the spatial distribution of crop and weeds present in their fields, then they can easily allocate the herbicides in the respective place where weeds are present. This step can reduce the amount of herbicide applied in the field [3].

H. Safeguarding crops

Drones can also be used to safeguard the fields and boundaries not only from animals but from thieves also. Such use of drones reduces shortcomings like human security personnel taking bribes and permitting the thieves [8].
It is evident from (A) - (H) that drone utilization for effective and modern farming is on the rise and soon it will lead the new technological advancements for increasing the farm productivity.

III. WORK DONE BY RESEARCHERS

In paper [8], Reinecke and Prinsloo have discussed about the benefits, features, cost, camera, flight time and range, power source along with limitation of drones in agriculture. They also discussed about the UVIRCO, a South American company which manufactures specialized camera and Aerobotics, a well known company which specializes in the manufacture of drones. Drones equipped with specialized cameras have several uses in agriculture such as drones equipped with cameras that can be used to see each and every centimeter of a piece of land from different angles, images taken from drones can be used to create a digital map of the field, etc.
In paper [9], Saha et al. have discussed about integrating the concept of Internet of Things, Machine learning with drones in order to fulfill the demand of increased population. They have also discussed about embedding the sensors like GAS sensor, RGB-D sensor in Raspberry Pi model to collect the data and send data through Raspberry Pi to cloud storage.
In paper [7], Rango et al. have discussed about the team of UAVs carrying pesticide tank to destroy the parasites present in the field. For this purpose, they have designed a simulator with various parameters like number of drones, number of parasites, maximum time etc. Here the most critical task is to provide the coordination between UAVs in order to avoid visiting more times the same region of the land which can hence save pesticide, time and energy. To search the parasite, they proposed two algorithms: Random Search Algorithm and Distributed Search Algorithm and compared the algorithm results in terms of Number of killed parasites vs. Number of deployed drones.
In paper [5], Potrino et al. compared the different types of parasite search algorithm: Random Search and Distributed Search. To search the parasite a team of UAVs is established. In case of Random Search, there is no need of coordination between the UAVs but in case of distributed search, coordination between UAVs is necessary to avoid the revisiting the same region. To provide coordination among the UAVs, communication between them is necessary. The distributed algorithm uses a Distributed Search Message (DSM) which is nothing but information regarding the field area already visited. Each drone when visiting new area inserts the information regarding this area in its memory and represents it by DSM. This DSM is exchange between the drones. The size of a DSM is 25 bytes.
In paper [1], Bacco et al. have discussed about the use of IoT technologies in several smart farming scenarios. They also discussed about the joint use of UAVs and UGVs which will reduce the human physical effort as the cameras on the UAVs will monitor the working of the self-driven harvesting vehicle, while the vehicle is reaping the crops.
In paper [4], Moribe et al. have discussed about collecting the leaf temperature data over the entire farm efficiently. They used drone in the sky and sensor nodes on the ground and both are equipped with non contacted infrared thermometer to measure the leaf temperature. They also proposed a wireless communication protocol for WSN. The purpose of doing this
is to study about the fluctuation in temperature data when measuring from ground using sensor node and when measuring from sky using drone. This temperature data is very essential as transpiration and photosynthesis activities can be estimated from it.
Quiroz et al. in paper [6] proposed a method to automatically identify crop lines in drone image from a mango tree plantation. This crop line data is use by UAV and other agriculture machines for automatic navigation through crop which is beneficial in fertilization, planting, weeding, harvesting etc.
Lottes et al. in paper [3] have proposed method for detecting value crops such as sugar beets as well as typical weeds using a camera installed on a drone. Classifying crops and weeds will help in reducing the amount of herbicides and pesticides applied to them. This will reduce the human effort in the detection of unwanted herbs and weeds on the field and will efficiently nullify the effect of herbicides on the crops and will also eliminate the unwanted herbs and weeds from the field.

IV. DISCUSSION

Table 1 provides the brief outline of work, techniques used and the major findings given by different researchers that uses drones in the agriculture domain.

Table 1. Summary of Research works that uses drones in the agriculture domain.

RESEARCHERS NAME	BRIEF OUTLINE OF WORK	TECHNIQUE USED	FINDINGS MAJOR/RESULTS
Reinecke and Prinsloo [8]	Detect underground water content to determine if a crop row is parched or over-hydrated.	Multispectral camera is equipped with drone.	Helps farmers to adjust their irrigation system.
Saha et al. [9]	Raspberry pi (credit card sized computer) is used and equipped with different sensors in order to collect field data like temperature, moisture, humidity etc and stored this field data into cloud-based storage	IoT technology is use to collect and store the data into cloud.	The field data is very useful for farmers to take the decisions like if they will have moisture and temperature data, then they can decide whether to supply water or not.
Rango et al. [7]	Designed a simulator in which they created a team of drones equipped with pesticide tanks for the purpose of searching and killing the parasites.	Random Search Algorithm and Distributed Search Algorithm are used to Search the parasites.	It was observed that Distributed Search Algorithm is more efficient than Random Search Algorithm.
Bacco et al. [1]	Combine use of UGVs and UAVs to achieve smart farming.	M2M/IoT wireless communication scenario is used for a cluster of UGVs and UAVs.	It will reduce the human physical effort as field work will be done by UGVs and their work will be monitored by UAVs from above.
Moribe et al. [4]	Collect the leaf temperature data over the entire farm using drone flying in the sky and sensor nodes on the ground. Both drones and sensors are equipped with thermometer. The authors observed the differences in the measurement of temperature by both drones and sensors.	Design a WSN and proposed a communication protocol between drone and WSN.	It has been found that as the drone flies higher, the leaf temperature difference between the data measured by drone and sensor nodes increases.
Quiroz et al. [6]	Automatic identification of crop lines in drone image from a mango tree orchard.	Tree segmentation is done by using YCrCb Color space, Gaussian Adaptive Segmentation and Line detection is done by using Hough Transform (HT).	Proposed method is able to identify the lines with 86 percent of efficiency.
Lottes et al. [3]	Classification of crops such as Sugar beet and typical weeds.	Multi-class Random Forest Classification algorithm	Provides estimate of the distribution of crops and weeds in the field. This can help in reducing the amount of herbicides and pesticides applied in the field.

V. ISSUES AND CHALLENGESE

Following are some major issues and challenges that may arise in using drones in the agriculture domain:

1. *Battery:* One of the major issues in involving drones in agriculture is that it has limited battery that can last up to a few minutes, therefore if the field is very big in its landscape it will be very difficult to monitor that field or to provide the services of the drone at once.
2. *Cost of drone operator:* The drones are generally operated manually by the pilot. The pilot will need to have special training in flying the drones and he may also require some amount of salary/perks.
3. *Cost of Cameras:* The multispectral and hyperspectral cameras are very expensive. Putting them on the drones will make drones even more expansive.
4. *Weather:* In case of extreme weather condition like heavy rainfall, sand, storms, etc. the drone services will be reduced as the risk of damaging the drone will significantly increase under such weather conditions.
5. *High-weight payload:* It is a very challenging task for a light-weight UAV to carry a high-weight payload. So it is very difficult for a light-weight UAV to carry an integrated system which includes high resolution and thermal cameras, multiple sensors, etc.

6. *Coordination between drones:* When killing the parasites using Distributed Search Algorithm and Random Search Algorithm, the key challenge for researchers is to detect the parasites in the field and provide the coordination between drones so that the revisit of the drones in the same area of the field will reduce [7].
7. *Tree segmentation and identification:* There are a lot of issues and challenges that arise in the automatic identification of crop lines in drone images. The first step in crop line detection is to identify individual tree i.e. segmentation. In case there are two or more trees that are very near to each other, these trees are counted as one and will provide the error. There is also a possibility that a big tree which can be counted as more than one tree. If there is a dense forest in the neighbor of the tree orchard, then that forest will be counted as a single tree and this will lead to the generation of false crop lines that occurs in the second step of crop line identification i.e. line detection stage [6].
8. *Knowledge of computer and data analysis:* The integrated system utilizing various IoT technologies and Raspberry pi module equipped with sensors to collect data will be very costly for farmers. This system will provide information to the farmers to take decisions. Such kind of system requires knowledge of computer technology and capability to analyze the data collected from such a system. In developing country like India the majority of the farmers are not familiar with the use of computers. Thus, farmers need to be trained to use such technologically advanced system. Also, awareness regarding technological aspects of such system needs to be spread among farmers [9].
9. *Communication between UAVs and UGVs:* To use UAVs and UGVs simultaneously, continuous machine to machine/IoT wireless communication is required to share the necessary data for smooth functioning. This task is very crucial and challenging due to uneven terrain, irregularities in communication and physical hindrances in the path [1].

VI. CONCLUSION

Food is the basic and important need of human beings. All of us are dependent upon agriculture for our food. World's population increases day by day and we have limited resources and limited arable land. According to UN Food and Agriculture Organization, the population will increase by 2 billion by 2050. However only 4% additional land will come under cultivation by then [2]. To fulfill the requirements of people and to increase the food production, it is very necessary to introduce new technologies and integrate them with agriculture. Drone is an important device as it provides aerial view of the field, monitors the field, can reduce physical effort of humans and hence is very helpful for farmers. In this paper we have reviewed how drones can be used to spray pesticides, herbicides to kill the parasites and weeds. Drone can also be used to spray seeds and it will save a lot of time and physical effort of farmers. Drone equipped with high specification camera can be used to detect water contents underground, this can helps farmers to provide water content to the crops appropriately (not less not more). Combine use of UGVs and UAVs are used to achieve smart agriculture. IoT based drone can also be used to collect data from fields and save it into the cloud which can be used for further analysis. Data provided by drone is useful in machine learning and deep learning algorithms for exploring and extracting the information. As evident from this work that drone application in agriculture is many folds and thus a study of the work done by researchers will prove useful in broadening the possibilities.

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