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Review on Application of Drone Systems in Precision Agriculture

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Abstract

In the present era, there are too many developments in precision agriculture for increasing the crop productivity. Especially, in the developing countries like India, over 70% of the rural people depends upon the agriculture fields. The agriculture fields faces dramatic losses due to the diseases. These diseases came from the pests and insets, which reduces the productivity of the crops. Pesticides and fertilizers are used to kill the insects and pests in order to enhance the crop quality. The WHO (World Health Organization) estimated as one million cases of ill effected, when spraying the pesticides in the crop filed manually. The Unmanned aerial vehicle (UAV) – aircrafts are used to spray the pesticides to avoid the health problems of humans when they spray manually. UAVs can be used easily, where the equipment and labors difficulty to operate. This paper reviews briefly the implementation of UAVs for crop monitoring and pesticide spraying.

Keywords: Unmanned aerial vehicle, Spraying System, Crop Monitoring, Quad copter, BLDC, ESC, PWM, NDVI.

1. Introduction

As much as India depends upon the agriculture, still it is far short from adapting latest technologies in it to get good farm. Developed countries have already started use of UAV's in their precision agriculture [23, 21], photogrammetry and remote sensing [25, 33]. It is very fast and it could reduce the work load of a farmer. In general, UAVs are equipped with the cameras and sensors for crop monitoring and sprayers for pesticide spraying. In the past, Variety of UAV models running on military and civilian applications [45]. In agriculture, the first UAV model is developed by Yamaha [15].Unmanned helicopter Yamaha RMAX was introduced for agriculture pest control and crop monitoring applications. However, Yamaha stopped their production in 2007. A technical analysis of UAVs in precision agriculture is to analyze their applicability in agriculture operations like crop monitoring [32], crop height

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Estimations [13], pesticide Spraying [9], soil and field analysis [11]. However, their hardware implementations [36] are purely depended on critical aspects like weight, range of flight, payload, configuration and their costs. A research involving technologies, methods, systems and limitations of UAVs are examined [39]. In order to select the suitable UAV in agriculture more than 250 models are analyzed and summarized [2]. Techniques and crucial components involved to build a mini autonomous mini unmanned rotorcraft vehicle, which includes the construction of hardware components, integrates with the software system, autonomous flight controlling, aerodynamic modeling, design and implementations [26]. In past few decades a heavy weight NASA's solar powered pathfinder plus used as an image collection platform to demonstrate the 3500ha coffee plantation in Hawaii [20, 46]. After that a low cost and low weight UAVs, VIPtero [11] for site specific vineyard management by taking 63 multispectral pictures in 10min of flight and MK-Okto [32] for acquisition of multispectral and thermal imagery. To increase the flight time of a UAV using by a Laser power beaming technology [28]. An aerodynamic domain, tuning and trimming phases of UAV is done by proportional integral derivative (PID) controlling algorithm [19, 31, 38]. Then pictures were processed and analyzed based on NDVI. The results clearly represent the conditions of the crop. Adding of sensors and vision systems are also enhance the potential of the UAVs [22].

Another strategy came on ground i.e., a sprayer system is mounted on UAV for pesticides spraying. The integration of UAV with sprayer system results a potential to provide a platform to pest management and vector control. This is accurate site specific application for a large crop fields. For this purpose heavy lift UAVs [29, 30] are required for large area of spraying. The efficiency of the spraying system which is mounted to the UAV increases through the PWM controller [9, 27] in the pesticide applications. A petrol powered unmanned aerial vehicle Yamaha RMAX [15] developed for pesticide spraying in rice fields of Asia. In comparison with ground based sprayers, deposition of pesticides from the developed UAV is almost similar. The RMAX is a crop sprayer for a high value crop environment. A prototype extendable to develop a UAV with increasing volume mean diameter droplet size up to 300mm [10].The uses of UAV in spraying operations are increasing because of its speed and accuracy. But, some factors reduce the crop quality like some area in the crop field is not covered properly while spraying, Crop areas overlapping and outer edges of the crop field in the spraying process. To overcome these factors, a swarm of UAVs [35] were used in a control loop of algorithm for agriculture operations, where unmanned aerial vehicles are the responsible for the spraying pesticides. The process of spraying the pesticides on the crop is organized by the feedback coming from the WSNs deployed in the field [1]. The communication with each one is done by a control loop to adjust the route of unmanned aerial vehicle to changes in the speed of wind and number of messages exchanged in between [3]. A short delay in the control loop, so that the unmanned aerial vehicle can analyze the data from WSN to further route. It could also minimize the waste of pesticides [5]. An automatic navigation UAV spraying system MSP430 developed to direct the UAV in desired spray area [18].

A blimp integrated quad copter aerial automated pesticide sprayer (AAPS) was developed for pesticide spraying based on the GPS coordinates in lower altitude environment [14]. To, overcome this a low cost user flexible pesticide spraying drone "Freyr" was developed which is controlled by an android app [4]. A laboratory and field evolutions are analyzed for discharge and pressure rate of the liquid, spray uniformity and liquid loss, droplet density and sizes of a developed hexa copter mounted sprayer [7]. To reduce the wastage of pesticides an electrostatic sprayer introduced and designed on electrostatic spray technology with a hexa rotor UAV [40]. A particle image velocimetry method was used to measure the downwash flow field droplet movement and deposition over the crop at different rotating speeds of the rotors of an octacopter using a double pulsed laser [42]. Drift of ultralow altitude UAVs downdraft produced by the rotors are penetrated the deposition of the droplets in the lower layers almost all equal to when compare to Upper layers of the paddy and wheat fields [43, 47]. Moreover, filter papers and water sensitive papers [43] are used to study the spraying deposition and droplet coverage over the fields in multi spraying swath [41, 48].

Keeping in view of these facts, a crop monitoring and Pesticide spraying UAVs are developed consisting of an automated drone system and sprinkling system with multi spectral camera. The sprinkling system is attached to the lower region off the UAV which has a nozzle beneath the pesticide tank to sprinkle the pesticide towards downstream. First monitoring is done by multi spectral camera, the camera scans the whole crop field and generates a spatial map. This map manifest the condition of the crop through NDVI and then the farmer evaluates which type of pesticides/fertilizers apply on the crop.

2. Methods and Materials

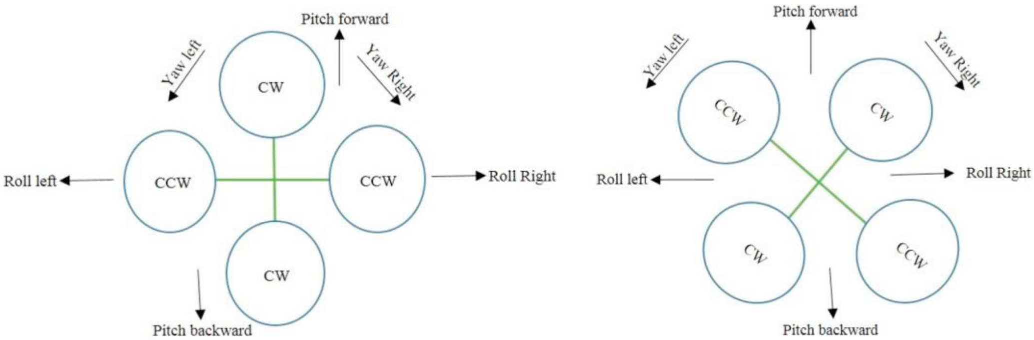
2.1. Unmanned Aerial Vehicle

A UAV is an aircraft which can flight without a human pilot and controlled by the radio channel. Multi rotors are the one type of UAVs, further which are classified into number of rotors in their platform. Different types of UAV models are used in last two decades are shown in Table 1. Fixed wing (Fig. 1(a)) UAVs are entirely different in their design compare to multi rotors and aerodynamic shape of two wings are gives an easy glide of UAV. Single rotor helicopter (Fig. 1(b)) is a model has just one big sized rotor on top and one small sized on the tail of the UAV. Quad copter (Fig. 1(c)), Hexa copter (Fig. 1(d)), Octo copters (Fig. 1(e)) are multi-rotors that is lifted and propelled by four, six, eight rotors.

a b c d e

Fig. 1. UAV types, Fixed Wing [49] (a). Single rotor [9] (b). Quad copter [4] (c). Hexa copter [7] (d). Octo copter [32] (e).

A quad copter, is unique design of UAVs which has four rotors in their model. The lift of quad copter is generated by these rotors. In four rotors, the two opposite rotors are turn in clockwise direction (CW) and the other two turn in counter clockwise direction (CCW).The quad copter movement around the axis includes pitch (Backward and forward), roll (left and right) and yaw (clockwise and counter clockwise).Basically, the configuration of a quad copter is divided into two ways one is plus (+) model shown in Fig. 2(a) and another one is cross (X) model shown in Fig. 2(b).Cross model is very popular and more stable compare to plus model [44].



a b

Fig. 2. Quad copter Plus Configuration (a). Cross configuration (b).

Table 1: Different types of UAV models developed in past studies for precision agriculture.

Type	Reference
Quad copter	[4][5][6][8][12][14][16][17][19][22][28][31][38][44][48]
Hexa copter	[7][11][13][29][34][37][40][41]
Octo copter	[30][32][42]
Fixed Wing	[20][36][46][49]
Single Rotor Helicopter	[9][10][15][18][26][27][36][41][43][47]

2.2. Methodology

The flight controller is the main board in the UAV is embedded with the most advanced firmware and responsible for the actual flight. Flight controller controls lot of things simultaneously during the flight or UAV. It built with a micro controller and communicates to the four brushless motors. BLDC motor connect with the rotors in directions of the UAV configuration model. These BLDC motors are controlled by the Electronic Speed controllers (ESC). The UAV controlled by the Radio channel transmitter and receiver. Ever RC transmitter have number of channels for individual activity to control the UAV. A sample block diagram shown in Fig. 3. Different methodologies, controllers, load and speeds of UAVs are shown in Table 2.

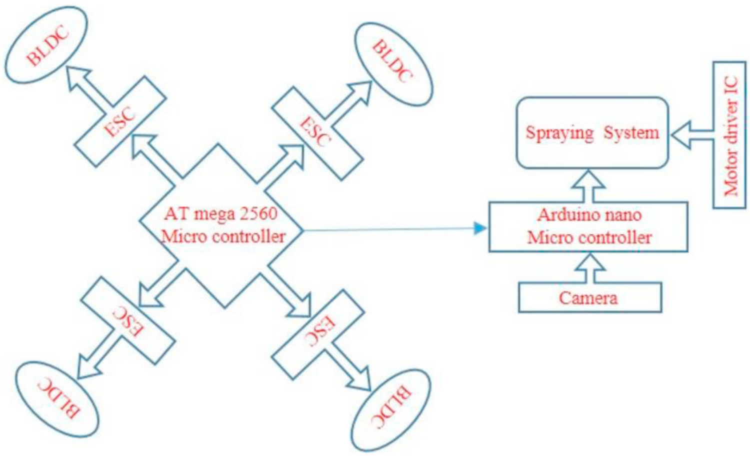


Fig. 3. Block diagram of a Model UAV.

Table 2. Different methodologies and controllers.

Reference	Controller	Strategy	Load	Speed
[4]	Arduino mega 2560	WIFI module	-	-
[5][17]	Arduino At mega 328,	Radio receiver	-	-
[6]	KK v5.5 Atmega 168	RC Transmitter , WSN	-	-
[7]	FC	RC Transmitter	5 lit	3.6 km/h
[8]	-	RC Transmitter	1.5 to 3 lit	-
[9][10][27]	Rotomotion's SR200	RC Transmitter	22.7 kg (5kg)	-
[11]	Hexa-II Atmega1284p	WIFI	1 kg (camera)	10 min
[12]	Atmega 8bit AVR	-	-	-
[13]	Atom board processor	-	600 g (Laser scanner)	-
[15]	Yamaha RMAX	-	100 kg	20 km/h
[16][31][44]	Arduino	Radio frequency	8 kg	5 m/s
[18]	MSP430 single-chip	RC transmitter	25 kg	3-6 m/s
[19]	Ardu 2.8 FC	RC transmitter	-	-
[20][46]	Pathfinder-plus	Radio link	67.5 kg	<50 kmh^{-1}
[28]	LLP & HLP	Radio Link	1 kg	-
[29]	-	-	25 kg	5 m/s
[32]	ARM processor	-	1 kg	30 km/h
[37]	DJIs 900 model	-	-	1.3 m/s
[38]	-	Radio Transmitter	1.46 kg	-
[40]	-	-	10 kg	16 m/s
[41]	-	-	10-15 lit	4-5 m/s
[42]	TTA M8A	TR-PIV	10 kg	0-15 m/s
[43]	Z-3	-	20 lit	3 m/s
[47]	N-3 type	-	25 lit	4 m/s
[48]	UAV ZHKU-0404-01	-	15 lit	3.5 m/s
[49]	Aero drone PAM-20	Radio Link	25 kg	80 km/hr

2.3. Hardware Components

There are various components embedded to the UAV, for its motion control according to the sensed environments. Further, more components that concern the UAV including distinctive sensors, applications and their focal points are explained by [22, 53]. Different types of hardware components and peripherals are used in UAVs are shown in Table 3.

Table 3. Hardware components and peripherals.

Components	Reference	Purpose
Accelerometer	[4][5][9][10][11][17][28][38][54]	For measure the acceleration
Gyro	[4-7][9][10][17][18][28][32][36][38]	For rotational motion
Magnetometer	[4][9][10][11][18][27][28][36][38]	To measure magnetic field
WSN	[1][3][5][17]	Sensing environmental conditions
IMU	[9][10][12][13][19][27][28][31][38][44]	Measures angular rate and forces
GPS	[4-7][9-11][14][16-19][27][28][32][38][47][49]	Provides geo location of an object
Camera	[4][7][11][12][15][16][19][28][42]	To record visual images
Multispectral Camera	[20][32][46]	Images at specific frequencies
Hyper spectral camera	[20][46]	Images at narrow spectral bands
Thermal Camera	[32]	To record low light imaginary
Video Camera	[9][27]	Electronic motion of objects
Laser scanner 2D	[13][28][42]	Captures shape of the object
Telemetry	[18][20][27][38][46]	To get live data from UAV
Altimeter	[18]	To measure altitude
Air Pressure Sensor	[28][32][36]	Measurement of gases or liquids
BLDC	[4-7][11][12][14][16][17][19][31][38]	To motion control
ESC	[4-7][11][12][14][16][17][19][31][38]	Regulates the speed of BLDC
Microsoft Kinect	[19]	To motion sensing
Barometer	[13][38]	For atmospheric pressures
Solar	[20][46]	Energy source
PWM controller	[9][27][31]	For pulsing signal
Digital Temperature	[43][47][48]	Temperature detectors
Humidity indicator	[43][47][48]	Measures moisture in air
Water sensitive paper	[47][48]	For assessing spray coverage
Filter papers	[48]	To separate fine substances
Anemometer	[48]	To Measure Speed of wind

3. Crop Monitoring

UAVs are capable of observing the crop with different indices [34]. The UAVs are able to cover up hectares of fields in single flight. For this observation thermal and multi spectral Cameras [32, 33] to record reflectance of vegetation canopy, which is mounted to downside of the quad copter. The camera takes 1 capture per second and stores it into memory and sends to the ground station through telemetry. For this wireless communication it uses MAVLINK protocol. The pictures are captures in the visible five brands with different wave lengths: i.e. (i) Blue wavelength 440-510nm, (ii) Green wavelength 520-590nm, (iii) Red wavelength 630-685nm, (iv) Red edge wavelength 690-730nm, (v) Near infrared wavelength 760-850nm.

The data coming from the multispectral camera through telemetry was analyzed by the Geographic indicator Normalized Difference Vegetation Index (NDVI) [24, 50, 51] represented in equation. 1.

$$NDVI = (R_{INR} - R_{RED}) / (R_{INR} + R_{RED}) \tag{1}$$

Where, R_{INR} = Reflectance of the near infrared band,
R_{RED} = Reflectance of the red band.

The calculations gives the values -1 to +1; near to 0 (ZERO) indicates no vegetation on the crop and near to +1 (0.8 to 0.9) means highest density of green leaves on the crop. Based upon these results, farmers easily identify the field where can spray the pesticides. The inbuilt GPS module maintains GPS coordinates of the every captured picture. Then The GPS coordinates of that pictures are stored in UAV to spray pesticides automatically without manual control.

4. Sprinkling system

Generally, the sprinkling system is attached to the lower region off the UAV which as a nozzle beneath the pesticide tank to sprinkle the pesticide towards downstream. The sprinkling system as two modules one is sprinkling system itself and second one is Controller. The sprinkling system contains the spraying content (pesticides or fertilizers) and a nozzle for spraying. Second one is controller used to activate the nozzle of the sprayer. A pressure pump is a component of the sprinkler system which pressurizes the pesticide to flow through the nozzle. A motor driver integrated circuit is used to pressure the pump as per the requirement. Analysis of different spraying speeds and nozzles used in UAVs for spraying are shown in Table 4.

Table 4. Analysis of different spraying systems.

Reference	Sprinkling Speed	Nozzle Type
[4]	Depends on immersable pump	-
[5][17]	Depends on Communication between UAV and WSN	-
[7]	1.15 ha/h	Flat fan
[8]	4.45 m/sec	-
[9][10]	0.4 ha/min (1 acre/min), 2.2 m/s	Micron air ULV–A+
[15]	47 l/ha	Flat fan
[16]	1 l/min	Universal
[18]	0.6-1 l/min	Centrifugal
[27]	13.61 g/30s	Micron air –A+
[37]	0.2 MPa (Pressure)	Flat fan
[40]	0.3 MPa (Pressure)	Fan-shaped (electrostatic)
[41]	0.3-0.8 l/m	Flat-fan, Centrifugal and cone
[42]	1.25 l/min	conical
[43]	850 ml/min	Electric centrifugal
[47]	850 ml/min	Rotary atomizer
[48]	0.2–1.0 MPa (pressure)	Flat fan

5. Conclusion

In the past decade latest technologies are included into the precision agriculture to improve the productivity of the crop. These technologies are useful where human interventions are not possible for spraying of chemicals on crops and scarcity of the labor. It also helps the spraying job easy and faster. The proposed system describes the crop monitoring through the multispectral camera which is mounted in UAV. In one flight the camera takes pictures and analyze by the geographic indicator. Based on the results it could be easy to find the area where to spray the pesticides. The UAV sprinkling system auto navigated with the GPS coordinates to spray the pesticides on the infected areas where no vegetation identified by the NDVI. This could also be reduced the wasting of water and chemicals.

6. Future Scope

UAVs in precision agriculture is still in its early stage and maybe a scope for further development in both the technology and the agriculture applications. Providentially, it is expended that with the development of UAV'S technology, improved image processing techniques, lower costs, flying times, batteries, new camera designs, low volume sprayers, and nozzle types. A significant number of experimental studies of UAV'S based remote sensing for agriculture application. It will be a more prominent advantages of these systems in precision agriculture and environmental monitoring.

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