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Review on effective role of UAV in precision farming

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Abstract
Recently, unmanned aerial vehicles (UAVs) have rapidly emerged as a new technology in the fields of agriculture. Small, unmanned aircraft systems (UAS) provide an opportunity for multiple uses in agriculture sectors *viz* land mapping, soil testing, pesticide spray application, weed management etc. in which the applicator can be displaced from close proximity for its effective application. As the world population will exceed, to feed them, the agricultural sector must increase production by 70%. The number of resources suitable for use in agriculture - land, water, energy - will decline. Here the farmers have to rely primarily on support of new technologies that not only increase production with limited resources, but also improve its effectiveness. The object of the review paper is the analysis of the latest technology available in the market and its effective use in Agricultural field. As well as advanced direction of crop capacity increasing in agriculture with help of Unmanned Aviation System. The use of modern unmanned aerial vehicles will extend the benefits of small aircraft. This paper also presents an embedded hardware/software architecture specially designed to be applied on mini/micro Unmanned Aerial Vehicles (UAV).

Keywords: UAV, USA, hardware, precision, agriculture

1. Introduction

In recent evolutions one area that is quickly becoming revolutionized by drone technology is agriculture. As a result, drones have now been mainstreamed for farming, it is expected that the introduction of these multi-utility technology can increase a massive production by 70%, drones can be a one of the solution to this exponential increase in demand, along with closer collaboration between governments, tech leaders, and industry. Unmanned aerial vehicles (UAV's) are operated remotely where the operator maintains visual contact with the aircraft or autonomously along preprogrammed paths using GPS and inertial guidance [1]. The initial uses in agriculture through remote sensing, is for a visual inspection of crop or field conditions. This technology has utility in agriculture, forestry and vector control for not only observation and sensing but also for delivery of payloads, including application of agrochemicals [2]. Drones can assist farmers in a range of tasks from analysis and planning, to the actual planting of crops, and the subsequent monitoring of fields to ascertain health and growth. As farms operations becoming drugereous and consumes more man power, in such conditions for more efficient operations and escalating demands, drones will prove invaluable in precisely managing a farm's vital operations. The application of crop inputs such as fertilizers and pesticides by Unmanned Aircraft System (UAS) presents an engineering opportunity where the power demands for spraying or granular applicator are significantly reduced as compare to the other spraying application technique and improved economic returns [3].

Review work shows that the design of agricultural spray systems for small UAV's gives the better performance [4] which was further continued with specialized electrostatic rotary atomizers [5]. The requirement for low volume spraying, in consideration of limited capacity, has been emphasized. Other work has given a more emphasis on the use of multi-utility UAV's flying in coordinated fleets for spray application [6] and the system was developed for on-board monitoring systems to aid the ground-based operator's situational awareness of the UAV's status [7].

The UAV system provided with enhanced cameras, lasers and GPS navigation systems. At the same time, an Unmanned Ground Vehicle (UGV) was tasked with the collection of soil samples, while an UAV was monitoring the work from above. A further technological challenge is constituted by a drone driving an autonomous vehicle, while the terrestrial vehicle has a limited view of possible immediate obstacles, the drone can update the prescription maps in real-time from above [8]. Whatever the scenario is, communication is a fundamental aspect among UAVs and UGVs [9].

This paper presents the relevant application of drone in precision agriculture, and paradigm in smart farming scenarios. To assist the identification of the differences that characterize the UAV missions.

2. Material and Methods

An Unmanned Aerial Vehicle (UAV) is an expression that identifies an aircraft that can fly without pilot; that is, an airframe and a computer system which combines sensors, GPS, servos and CPUs. All these elements combined have to pilot the plane without any human intervention [10]. The UAV's size, type and configuration could be different and depends on the actual application. There is no doubt today that a huge market is currently emerging from the potential applications and services that will be offered by unmanned aircrafts. In general all the drone applications are divided into four large groups: environmental applications, emergency security applications, communication applications and monitoring applications. Basically, an UAV is automatically piloted by an embedded computer called the Flight Control System (FCS) [11]. This is a system that reads information from a wide variety of sensors (accelerometers, gyros, GPS, pressure sensors) and drives the UAV mission along a predetermined flight-plan.

A) The construction details

An UAV is a complex system composed of six main sub modules that work coordinately to obtain a highly valuable observation platform [12]. The UAV airframe, have a simple, lightweight, aerodynamically efficient and stable platform with limited space for avionics, and obviously no space for a pilot. The heart of the UAV, is a flight computer system, which is designed to collect aerodynamic information through a set of sensors (accelerometers, gyros, magnetometers, pressure sensors, GPS, etc.), in order to automatically direct the flight of an airplane along its flight-plan via several control surfaces present in the airframe. The payload is a set of sensors composed of TV cameras, infrared sensors, thermal sensors, etc. to gather information that can be partially processed on-board or transmitted to a base station for further analysis. The mission/payload controller is computer system on board the UAV that has to control the operation of the sensors included in the payload. This operation should be performed according to the development of the flight-plan as well as the actual mission assigned to the UAV. The base station is a computer system on the ground designed to monitor the mission development and eventually operate the UAV and its payload. The communication infrastructure is a mixture of communication mechanisms (radio modems, microwave links, etc.) that should guarantee the continuous link between the UAV and the base station. Current UAV technology offers feasible technical solutions for airframes, flight control, communications and base stations [13, 14, 15]. Additionally, payload is most times remotely operated with very little automation support. Economical efficiency requires the same UAV to be able to operate in different application domains. This necessity translates into stronger requirements onto the mission/payload management subsystems, with increased levels of flexibility and automation [16, 17].

A. For Precision Agriculture Application

With advances modernization and GPS guidance that have already changed the farming industry, drones are now poised to modernize it once again. Application of this developed technology in precision agriculture has been discussed as below [18, 19, 20].

a. Analysis of Soil

Drones are able to capture and produce a precise map for soil analysis before the plantation of crop over the field, which helps to direct seed planting patterns. After planting, this data also helps in determine nutritional and irrigation management.

b. Monitoring Crop Growth

Currently, the agricultural industry's largest obstacle is the low efficiency in crop monitoring resulting from the massive scale of industrial farming. Drone technology can provide a continuous monitoring on the crop development aspect which gives the major concern data regarding the crop growth *viz.* Moisture content, deficiency in nutritional values or overall cop vigor in order to help to keep crops healthy, and able to achieve the and estimated yield. Drones allow real-time monitoring at a far more accurate and cost-effective level than previously used satellite imagery.

c. Irrigation Management

Drones equipped with hyper-spectral, multi-spectral, or thermal sensors, which are able to identify areas that require changes in irrigation management level. Once crops have started growing, these sensors are able to calculate their vegetation index, and indicator of health, by measuring the crop's heat signature. Micro drones' +m kit uses the acclaimed Micasense Rededge sensor to capture images on five spectral bands, allowing farmers a faster and more accurate method of assessing their crop and irrigation conditions.

d. Crop Health Monitoring

Drones can identify which plants may be infected by bacteria or fungus, helping to prevent Multi spectral disease from spreading to other crops by scanning crops with visible and Infrared (IR) light and with images. Micro drones with the +m kit, are able to identify and measure crop issues like disease, pest problems, weeds, and water-stress.

e. Seed Planting

Seed dropping through drone is the latest technology and not as widely used, which can reduce the farm labours. Drone system is capable of delivering up to 57 pounds of load in the form of tree seeds, herbicides, fertilizer and water per aircraft per flight to assist reforestation and replanting projects. This technology helps to minimize the need for on-the-ground planting, which can be costly, time-intensive, and strenuous work.

f. Crop Spraying and Spot Spraying

Any agricultural crop requires consistent fertilization and spraying for getting high yields. Traditionally this was done manually, with vehicles, or even via airplane. These methods are not only inefficient, and burdensome, but they can be very costly as well. Drones can be equipped with large reservoirs, which can be filled with fertilizers, herbicides, or pesticides. Using drones for agricultural crop spraying is much safer and cost-effective. Drones can even be operated completely autonomously and programmed to run on specific schedules and routes. Even of there is a certain section of the crops which has been infected by fungus or bacteria, drones can be used to spot treat the issue. With the fastest technique drones can operate, diagnose and treat potential crop issues before they become a widespread decease across the entire farm.

Spot spraying of crops used to be incredibly difficult. It is specially adopted on an issue with weeds or a certain crop. Spot spraying afforded by drones, the task can be accomplished in less time, with fewer monetary resources, and a reduced environmental cost.

g. Crop Mapping and Surveying

One of the biggest advantages of using drone technology is the ease and effectiveness of large-scale crop and acreage monitoring. In the past, satellite or plane imagery was used to help a large scale view of the farm, while helping to spot potential issues. However, these images were not only expensive but lacked the precision that drones can provide. Drone technique can be used effectively to obtain real-time footage and also time-based animation which can illuminate crop progression in real-time. With drone mapping and surveying, technology decisions can be made based on real-time data. With near infrared (NIR) drone sensors it becomes easy to determine plant health based upon light absorption, it gives a birds-eye view of the overall farm health.

h. Real-Time Livestock Monitoring

Drones can equipped with thermal imaging camera (TIC) that enable a single pilot to manage and monitor livestock. This allows farmers to keep track of livestock a much greater frequency, and with less time and staff investment. The drone TIC cameras can quickly check any injured or missing livestock. Drones can also be used to keep an eye on the heard at all times, which is a costly and time-intensive task.

B. Drone application in spraying

The use of drone in intensive agriculture has several negative impacts on the environment. It adds significant and environmentally detrimental amounts of nitrogen and phosphorus to terrestrial ecosystems [21]. Also, the research study is still under process to study the excessive fertilizers application risk for the environment. As the insufficient fertilizer used to replace nitrogen and phosphorus lost through intensive cropping can lead to soil degradation and loss of fertility. Additionally, pollution of water courses and bodies, and consequent degradation of water-related ecosystems are rising due to agricultural chemicals seeping into nearby water. Furthermore, serious soil degradation, which threatens the productivity of the different soils [22].

Additionally, pesticides are absorbed by crop and natural resources (i.e. water and soil) and end up as concealed substances in the food chain, with the increasing risk for both livestock and humans, with huge negative impacts on the public health this issue must be under taken in research study. Through autonomous precision farming, these effects can be mitigated since chemicals, such as fertilizer and pesticides, are only administered where needed instead of being applied over a large area. In such a context, the use of drones in agriculture has recently been introduced for big areas inspection and smart targeted irrigation and fertilization [23, 24, 25]. The possibility of detecting, by a drone and an infrared camera, the areas where a major irrigation is needed or where a foliage disease is spreading, can help agronomists to save time, water resources and reduce ago-chemical products. At the same time, such advanced farming techniques may lead to increased crop productivity and quality. Specifically, water deficiency, nutrient stress or diseases can be localized and measured and decision can be made to fix the problem. Special camera systems are able to acquire data from an invisible part of the electromagnetic spectrum called Near-Infrared (NIR) and extract quality information, such as the presence of insects, pests on the specific area of crop [26, 27].

The major purpose of drone used during spraying are to spray herbicides, insecticides/pesticides, fungicides, biological pesticides and Nutritional spraying. The things that are to be taken into consideration are concentration of chemicals, capacity of the tank, speed of the drone, type of nozzle used, drift while spraying. The major challenges in spraying are

1. Chemical spraying using drone is not permitted legally.
2. Central insecticide board yet to approve the chemicals suitable for the drones spray.
3. Concentrations for drone spraying are not yet defined.
4. Studies on efficacy of drone spraying are not yet completed.
5. Huge scope for institutes to do such studies.

C. Utility of multi-spectral and thermal cameras

Usually, for agriculture the terrain is scanned by using satellites with multi-spectral and thermal cameras. For precision agriculture, due to the needed high spatial resolution, drones aremore suitable platforms than satellites for scanning. They offer much greater flexibility in mission planning than satellites. The drone multi-spectral and thermal sensors provides the sample spectral wavebands over a large area in a ground-based scene. After post-processing, each pixel in the resulting image contains a sampled spectral measurement of the reflectance, which can be interpreted to identify the material present in the scene. In precision agriculture, from the reflectance measurements, it is possible to quantify the chlorophyll absorption, pesticides absorption, water deficiency, nutrient stress or diseases. There are four sampling operations involved in the collection of spectral image data: spatial, spectral, radiometric, and temporal. The spatial sampling corresponds to the Ground Sample Distance (GSD) [28, 29]. The GSD is the distance in meters between two consecutive pixel centers measured on the ground. It depends on the sensor aperture and the flight altitude. The spectral sampling is performed by decomposing the radiance received in each spatial pixel into a finite number of wavebands. The radiometric resolution corresponds to the resolution of the Analog to Digital Converter (ADC) used for sampling the radiance measured in each spectral channel. Furthermore, the temporal sampling refers to the process of collecting multiple spectral images of the same scene in different instants. Those four sampling operations have to be taken into account for the design of a flight mission and for choosing correctly the multi-spectral camera and the drone platform [30, 31].

D. Role of RGB cameras in precision agriculture

The images acquired by drones embedding RGB cameras are used for extrapolating digital terrain model (DTM) and digital surface model (DSM) related to the surveyed area. To this aim, it is important to define the flight mission parameters according to the spatial resolution, and the measurement accuracy of the reconstructed DTM and DSM. As in case of multi-spectral and thermal cameras, the spatial resolution is defined in terms of ground sample distance (GSD). According to the GSD that would be reached, the camera resolution and the flight altitude are chosen. The height measurements of the terrain and of the objects in the scene are obtained by taking two consecutive images from the camera in two different way points [32, 33, 34]. The two images have to overlap the same objects in scene. Usually, an overlapping factor of the 70%

between the two images is adopted. From the two acquired images, by knowing the camera parameters, the position and the altitude of the way points, it is possible to extrapolate the heights of the objects in the scene.

The output generated form from RGB imagery can be used for following requirement [35, 36, 37].

1. Area measurement.
2. Measuring land slope.
3. To prepare land usage plans.
4. Plant count.
5. Plant Population Distribution.
6. Developing AI and ML algorithms for pest and diseases.

3. Future challenges in drone technology

1. Battery life of Drone: The limited battery life of drones making it hard to cover large area and also as the time passes the capacity of capturing good images through cameras also affected.
2. Vision destruction: The regulations requiring the drone always hurdled in the visual line sight of the pilot. Which directly impacts on the accuracy of the data capturing.
3. Costing : The major challenge may have in the time and cost of deploying the technology, and then in processing it to glean insights.
4. Literacy about technology to end user: Farmers and agronomists need to be able to act upon the information delivered by these systems in a way that shows a tangible return on investment,
5. Processing of images: Many early drone technologies for agriculture have relied on uploading images to the cloud for processing or even returning to a PC to upload and then push through to an analytics program to create the normalized difference vegetation index (NDVI) maps. With limited cellular coverage in many agricultural regions, and large distances to travel between fields and the office, farmers and agronomists faces the problem that it can become an arduous process. Without the benefit of real-time, actionable insights in the field, many believe the tech is not worth the time and cost [38, 39].

4. Conclusions

In this paper, a review on the effective area of performance of drones technology for precision agriculture has been presented. In particular, the general construction of a drone along with multiple sensors has been discussed. The effective study on wider area spraying and spot spraying has been discussed. The effective use of RGB, multi-spectral and thermal sensors has been discussed. Some technical details about the control system have also discussed. Furthermore, for the effective application in precision the main limitations or future challenges were discussed. Future trends in this research field showing trend towards the use of different sensors with mini or micro drones which also includes the research study on the effect of spraying and spot spraying on the environment, pollution of water courses and bodies, and consequent degradation of water-related ecosystems rising due to agricultural chemicals seeping into nearby water. However, in doing so, the measurement accuracy will be major challenging from weather condition point of view, For example, the wind influence, the low GPS accuracy and the strong drift may play destructing effects in drone stability and image acquisition [40].

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