A Review on Using Drones for Precision Farming Applications

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Abstract: Precision farming is an emerging technology that prepares the prescription plans for optimum fertilization, disease, and pest control. Variable Rate Application (VRA) is an important part of the precision farming technology with the aim of the application of field inputs while maximizing production across the entire field. To be successful in the VRA, soil and plant properties should be identified and geo-located on the maps. There are three approaches to identify soil and plant properties: historical yield maps, soil sampling, and multi spectral and hyper spectral imagery. Today, one of the most popular methods to identify soil and plant properties is aircraft imagery and most popular vehicle is unmanned aerial vehicle (UAV), commonly known as drone. Drones provide real time and high quality aerial imagery compared to satellite imagery over agricultural areas. Also, applications for localizing weeds and diseases, determining soil properties, detecting vegetation differences and the production of an accurate elevation models are currently possible with the help of drones. This paper presents an overview of research involving the applications of drones for precision farming. Furthermore, structure of the drone technologies and the availability of the agricultural production processes are examined and suggestions are made.

Key words: Drones, precision farming, remote sensing, aerial imagery

INTRODUCTION

Precision agriculture is an agricultural production system based on the information and technology which is used for the purpose of determine, analyze and manage of the factors such as temporal and spatial variability in the field to obtain maximum profit, sustainability and environmental protection (Unal et al., 2013). Nowadays, most precision agriculture (PA) research is oriented towards the implementation of new sensors and instruments, able to remotely detect crop and soil properties in quasi-real time (Primicerio et al., 2012). For remote sensing, aerial images are a very precise and convenient source of data for agricultural management. Mostly, satellite images have been used as the primary source of information for analyzing crop status in precision agriculture. However, obtaining up-to-date aerial photography is very expensive, the quality is variable, and data processing is also intensive and complicated (Swain and Zaman, 2012). However, satellite and aerial remote sensing can be severely limited by cloud cover, and may not be available at desired times (update frequency can be from 3 to 26 days) (Tokekar et al., 2013). In the last decade, the development of drones known as unmanned aerial vehicles (UAV) platforms, characterized by small size has offered a new solution for crop management and monitoring, capable of timely provision of high resolution images, especially where small productive areas have to be monitored (Lelong et al., 2008).

Drone is an unpiloted, autonomous unmanned aircraft that can be remotely controlled or autonomously flown based on pre-programmed flight plans or more complex dynamic automation systems. Drones typically fly at low altitudes to acquire the remotely sensed data. For low altitude remote sensing (LARS), the most agricultural drones are mini model fixed-wing airplanes or rotary-winged helicopters of low cost, low speed, low ceiling altitude, light weight, low payload weight capability, and short endurance (Huang et al., 2013). Besides fixed-wing airplanes or rotary helicopters, remote controlled (RC) kites, balloons, gliders, and motorized parafolks have been used for agricultural LARS imaging as well (Pudelko et
The distinct feature of this drone is that it must be equipped with low-cost imaging system, autonomous flight, stabilized by inertial navigation sensors that include GPS (Global Positioning System) that is able to geocode aerial photographs. The desirable resolution is about 1 – 2 centimeters, a relatively better image resolution than that of any satellite-based images (Yusof et al., 2006).

Drones have recently become the subject of a number of studies that evaluate their applicability for precision agriculture applications. A number of successful studies have been conducted using small, lightweight cameras on board drone and the research area is given a lot of attention worldwide (Nebiker et al. 2008; Bergo et al. 2010; Laliberte al. 2011; Zarco-Tejada et al. 2012). This paper presents an overview of research involving the applications of drones for precision farming. Furthermore, structure of the drone technologies and the availability of the agricultural production processes are examined and suggestions are made.

**Drone Types**

Drones are generally classified into two main categories, which are the fixed wing and rotary wing drones. Fixed wing drones have the advantage of being able to fly at high speeds for long duration with simpler structure. These drones have the disadvantage of requiring runway or launcher for takeoff-landing and not being able to hover. On the other hand, rotary wing drones have the advantage of being able to hover, takeoff and land vertically with agile maneuvering capability at the expense of high mechanical complexity, low speed and short flight range. This makes them the perfect instrument for detailed inspection work or surveying hard-to-reach areas. The structure of the fixed and rotary wing drones is presented in Figure 1.

![Figure 1. The structure of the fixed and rotary wing drones (Andrade, 2013)](image)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Close Range</th>
<th>Short Range</th>
<th>Endurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (km)</td>
<td>~50</td>
<td>~200</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Flight Time (h)</td>
<td>0.5-2</td>
<td>8 – 10</td>
<td>&gt;24</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>&lt;5</td>
<td>&lt;5000</td>
<td>&lt;10500</td>
</tr>
<tr>
<td>Speed (kmph)</td>
<td>&lt;60</td>
<td>&lt;485</td>
<td>&lt;730</td>
</tr>
<tr>
<td>Altitude (km)</td>
<td>&lt;6</td>
<td>&lt;16</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Cost (Dollar)</td>
<td>500-70000</td>
<td>&lt; 8 mil</td>
<td>&lt;123 mil</td>
</tr>
</tbody>
</table>

**Comparison Of The Existing Pa And Drone Based Pa Process**

In current PA applications, there are some image processing methods that are used to determine the soil and plant characteristics. These are historical yield maps, core samples and leaf samples, aircraft imagery and, satellite imagery. These methods have some problems. Historical yield maps do not reflect current year’s conditions. Core samples and leaf samples are costly and have low sample densities. Aircraft imagery has limited revisit frequency, moderate resolution, and is somewhat costly. Satellite imagery has
restricted revisit times, poor revisit frequency, poor resolution, and problematic cloud cover. Illustration of the existing PA process is shown in Figure 2. The basic problem in these methods is imagery resolution. Image pixels include mixed colors from soil and plant. Aircraft and satellite imagery has large pixel sizes. For this reason, it is difficult to separate soil from plant. Also, pixel demixing is a major problem for the aircraft and satellite imagery. To resolve this problem, there is a need to collect imagery from low altitude. For this, the drone technology is a powerful method to meet the required resolution levels. Drone based PA process is shown in Figure 3.

Figure 2. Illustration of the existing PA process (Boeing, 2013)

Figure 3. Drone based PA process (Boeing, 2013)
Drone Technology in PA

Stefanakis et al. (2013) created a fully autonomous airborne remote sensing platform, for the production of various vegetation indices to determine growth, development, yield crop and provide considerable information in real time and at low cost for the study area. The primary tool for extraction and production of the information is an unmanned aerial system (UAS) that carries sensors and cameras flying over the study area, transmitting real time data that has been programmed to collect. The collected data is land cover, geographic location, weather data, geomorphologic and cadastral data, ortho-corrected derivatives and qualitative data type coverage, biomass and other parameters that have been introduced to the platform via computational GIS (Geographical Information System) routines. Developed drone image is shown in Figure 4.

The developed platform has been tested as remote sensing platform for precision agriculture. As the aircraft flies over the study area it collects information from cropland and outputs, yield crop, current biomass, indicate the stressed plants and possible lack or adequate irrigation and fertilization in real time through computational routines.

Zhu et al. (2010) have developed a new Pulse Width Modulation (PWM) controller for UAV precision sprayer for agriculture using a TL494 fixed-frequency pulse width modulator together with a data acquisition board and developed software (Figure 5). An UAV can be remotely controlled or flown autonomously by pre-programmed flight plans. The PWM controller was implemented through the guidance system on the UAV with control commands sent between the UAV helicopter and the ground control station via a wireless telemetry system.

The PWM controller was tested and validated using LabVIEW 8.2. Several analyses were performed in a laboratory to test different control signals. The researchers reported that the PWM controller has promise as a higher precision technique for spray applications, which will improve efficiency of pesticide application, especially in crop production areas.

Honkavaara et al. (2013) have investigated the processing and performance of a new Fabry-Perot Interferometer (FPI)-based spectral camera weighing less than 700 g that can be operated from lightweight UAV platforms (Figure 6). By collecting frame-format images in a block structure, spectrometric, stereoscopic data can be obtained. Researchers developed and assessed an end-to-end processing chain for the FPI spectral camera data, together with image preprocessing; spectral data cube generation, image orientation, Digital Surface Model (DSM) extraction, radiometric correction and supervised biomass estimation.

Pudelko et al. (2012) have investigated the suitability of an unmanned aerial vehicle (UAV) for the
evaluation of experimental fields and crops (Figure 7). The aim of this study was to assess the possibility of monitoring experimental plots by using a remotely controlled flying model adapted to perform low altitude non-metric photographs. In the first part of the research, the advantages and disadvantages of a moto-glider construction flight as a platform were discussed. The second part presents issues associated with the acquisition and development of photographs taken with this type of construction. Researchers reported that this type of drone is useful for use in agricultural research and in precision agriculture. An additional advantage of UAVs is the low cost of obtaining aerial photographs, and operation and maintenance.

Swain et al. (2010) used an unmanned helicopter for low-altitude remote sensing to estimate yield and total biomass of a rice crop (Figure 8). The objective of this study is to determine the effectiveness of LARS images obtained by a multispectral imaging platform mounted in a radio-controlled unmanned helicopter to estimate rice yield and total biomass as a function of varying nutrient availability. The study indicated that the LARS platform could substitute for satellite-based and costly airborne remote sensing methods for estimation of yield and biomass as a function of nutrient status for rice, a staple crop in developing countries. Images were obtained successfully by the multispectral camera mounted on a radio-controlled helicopter at a height of 20 m over rice plots.

Van Bueren and Yule (2013) used two remotely controlled platforms, a HexaKopter and a QuadKopter, to acquire multispectral imagery of pasture paddocks. The HexaKopter has six rotors and the QuadKopter has four rotors (Figure 9). Two different multispectral sensors are mounted on the remotely controlled platforms: The Tetracam MCA (Multispectral Camera Array) and a consumer grade Canon PowerShot digital camera that has been converted to detect near infrared light. Processing of the image data involves correction for radiometric aberrations, calibration to ground reflectance and orthorectification. Researchers reported that the UAV based multispectral imaging system will produce high quality multispectral image data and lead to an increased understanding of the spatial and temporal variability of pasture quality cover and biomass.

Tores-Sanchez et al. (2013) described the technical specifications and configuration of a UAV used to capture remote images for Early Season Site-Specific Weed Management (ESSWM). Image spatial and spectral properties required for weed seedling discrimination were also evaluated. Two different sensors, a still visible camera and a six-band
multispectral camera, and three flight altitudes (30, 60 and 100 m) were tested over a naturally infested sunflower field. A quadrocopter platform with Vertical Take-off and Landing (VTOL), model md4-1000 (microdrones GmbH, Siegen, Germany), was used to collect a set of aerial images at several flight altitudes over an experimental crop-field (Figure 10). This UAV is equipped with four brushless motors powered by a battery and can fly by remote control or autonomously with the aid of its GPS receiver and its waypoint navigation system. Researchers reported that the UAV showed ability to take ultra-high spatial resolution imagery and to operate on demand according to the flight mission planned, due to its flexibility and low flight altitude.

![Figure 10. Quadrocopter platform (Tores-Sanchez et al., 2013)](image)

Turner and Lucieer (2011), has developed a UAV capable of collecting hyper resolution visible, multispectral and thermal imagery for application to Precision Viticulture (PV). Their UAV is based on the Oktokopter platform (Mikrokopter, 2011), a multi-rotor electric powered system purpose designed for aerial photography (Figure 11). The Oktokopter has been fitted with a stabilized camera mount to which they mount their sensor systems. A Canon 550D digital SLR camera is used to capture visible imagery which is then processed with feature matching and photogrammetric software to create Digital Surface Models (DSMs). The same camera mount has been adapted to carry a Tetracam mini-MCA (Tetracam, 2011) multispectral camera that operates in six bands set by fitting specific filters. This imagery is used to examine vegetation reflectance in critical wavelengths allowing the calculation of vegetation indices. Finally, a FLIR (Flir, 2011) Thermal Infrared (TIR) camera can be attached to the Oktokopter to measure surface temperature.

![Figure 11. Oktokopter platform (Turner and Lucieer, 2011)](image)

RESTRICTIONS OF THE PA BASED DRONES

PA based drones have any restrictions such as standards, cost, payload, operation and reliability for practical applications in agriculture. There is no standard protocol for any single project both technically and economically. Although the costs of the aircraft and the camera could be minimized, the assembly and integration require significant labor and time even for highly skilled technicians and engineers which may increase total cost. Lightweight done payload is the most important limitations in PA applications. For the users and designers of UAV systems choosing the optimum payload for the mission requirements is of prime importance (Torun, 2000). Payload design, mechanical, and electrical accommodation for drones are critical concepts for successful PA applications. Drones can operated both automated and manually. GPS based autonomous flight is a highly desirable component for practical use of drones in agriculture. Crashes and component failures are driving up the cost of drones and limiting their availability for agricultural operations. Researchers in the field believe the low cost requirements are causing designers to limit safety requirements, and that increased safety and reliability is needed to ensure UAVs are trusted to perform tasks (Bhamidipati and Neogi, 2007).

CONCLUSIONS

Today, soil and plant properties can be determined by image processing methods such as historical yield maps, core and leaf samples, aircraft and satellite imagery. But, image resolution is the
most important problem in these methods. Also, these methods often can be incomplete or time consuming, and when data is collected it can take a long time to process and analyze. Today, one of the most popular methods to identify soil and plant properties is low altitude aerial images. For this purpose, UAV, commonly known as drone is the most popular vehicle. Drones provide real time and high quality aerial imagery compared to satellite imagery over vehicle. Drones are not suitable for the variable rate applications in PA, drones are very useful autonomous vehicles. Drones enable farmers to know more about their fields. Therefore, farmers will be assisted with producing more food while using fewer chemicals. However, due to the legal restrictions, drone payload does not exceed 5 kg. For this reason, drones are not suitable for the variable rate applications.

REFERENCES


