The Use of Unmanned Aerial Systems (UAS) in Agriculture

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Abstract. Unmanned aerial vehicles (UAVs) represent technological developments used for precision agriculture. They provide high-resolution images taken from crops and when specific indices are applied, useful outputs for farm management decision-making are produced. The current paper provides a literature review on the use of UAVs in agriculture and specific applications are presented.

Keywords: Precision agriculture, UAS, unmanned aerial vehicles.

1 Introduction

Unmanned Aerial Systems (UAS) are aerial vehicles, which come in wide varieties, shapes and sizes and can be remotely controlled or can fly autonomously through software-controlled flight plans in their embedded systems working on the basis of GPS.

A UAS is made up of light composite materials to reduce weight and increase position-changing capability. Due to the usage of composite material strength they may fly at extremely high altitudes. They may have embedded various navigation systems or recording devices such as RGB cameras, infrared cameras, etc.

Some of the advances of the use of UAS are that they are lightweight and easy to transport, they capture high resolution and low cost images, they can fly at variety of altitudes depending on data collection needs, they can travel areas which are not accessible via car, boat, etc., they are extensively used in rescue operations, helping in delivering medicines and food, providing the live status of affected area, communicating in crisis, etc, quick availability of raw data.

2 Unmanned Aerial Systems

In recent decades, there have been significant efforts around increasing flight duration, the payload, and tolerance to various weather conditions, resulting in different UAV configurations with different sizes, duration of autonomy and

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competencies. A key criterion currently used to distinguish among aircrafts is the size and flight duration:

- Large autonomy, high altitude (HALE) UAV, such as for example, Northrop- Grumman Ryan 's Global Hawks (65.000 feet altitude, flight time 35 hours, payload 1,900 lbs).
- Medium Altitude Long Endurance (MALE) UAV, such as the General Atomics Predator (27.000 feet high, 30/40 hour flight, and beneficial load 450 lbs).
- Regular use UAVs as Hunter, Shadow 200, and Pioneer (15.000 feet high, Flight time is 5-6 hours, and 25 kg payload) and
- Small and portable UAVs from a man as the Pointer / Ranen (AeroVironment), Janelin (BAL) or Black Pack Mini (Mission Technologies).

3 Software and Hardware Technologies

The technologies developed for the UAV are specific in the sense that in order to compensate for the absence of the pilot and thus enable the flight of unmanned vehicles and their autonomous behavior, they are mainly based on the technologies of sensors and microcontrollers, of communication systems of Ground Control Stations and of UAS intelligence.

A very important issue in UAS is the automation system, which is used to control the machine. This system is separated into two parts. From the one side are the Control systems for the machine and in most cases they can be autopilot systems, which are used to control flights with several characteristics. Such systems contain GPS waypoint navigation with altitude and airspeed, fully integrated multi-axis gyroscopes and accelometers, GPS systems, pressure indicators and meters, pressure airspeed sensors, etc. All these sensors are mounted on hardware circuit boards. They have completely independent operation including autonomous take off and landing and Fail-safe commands programmed into the fly control system to address loss of altitude, loss of GPS connection, or loss of modem communication. The autopilot recognizes problems and initiates the land command, so that the UAS immediately flies back to the start point. The UAS can also be controlled manually with a lot of controlling systems through wireless communication.

On the other side are the control systems for the communication with the computer. The UAS have Ground Control Software, which provides the interface between the UAS and computer. This software enables programming of flight patterns and their pre-flight simulation, selection of flying files and transfer to other systems, tracking the flight path and monitoring the conditions during the flight with a computer-UAS online flight communication system. Finally a log file is available, with all the flight information, also available once the flight is completed.

Christophersen et al (2004) provide a small guidance, navigation, and control system based on FPGA (Field Programmable Gate Array) and DSP (Digital Signal Processor) technology to satisfy the requirements for more advanced vehicle behavior in a small package. Including those two processors into the system enables custom vehicle interfacing and fast sequential processing of high-level control algorithms (Christophersen, H., et al.,, 2004). Primicerio et al. (2012) provide a UAV platform ‘‘VIPtero’’ which is an open-source project that is available with pre-assembled flight and brushless control boards, the main board responsible for the actual flight of the mikrokopter is built around an ATmega1284P microcontroller (Atmel Corporation, San Jose, CA, USA) and communicates to the six brushless controllers via a bi-directional two-wire serial bus. An additional navigation control board (NaviCTRL) equipped with an ARM9 microcontroller (Atmel Corporation, San Jose, CA, USA) and MicroSD card socket for waypoint navigation data storage is also present (Primicerio, J., et al., 2012). Pankaj Maurya (2015) uses a single board computer system development on Soekris net4521. It is based on a 133 Mhz 486 class processor. It uses a Compact Flash module for program and data storage. The Soekris net4521 a special electronic circuit controlled via linux platform. The data acquisition and filtering is done on an FPGA. The sensor data is digitized using an Analog to Digital converter card and then fed to the FPGA. The FPGA runs Kalman filtering on the received data. It provides the filtered values of the physical quantities – Velocity, Angle, angular velocity and the navigation quantities in the three axis (Maurya, 2015)

In many cases the construction of the UAS is integrated with Wireless Sensor Networks (WSN). The information retrieved by the WSN allows the UAS to optimize their use. For example to confine its spraying of chemicals to strictly designated areas. Since there are sudden and frequent changes in environmental conditions the control loop must be able to react as quickly as possible. The integration with WSN can help in that direction (Costa, F.G., et al., 2012).

5 Use of UAS in Agriculture

Agriculture couldn't be left out of the technological advances taking place worldwide in any scientific field. Furthermore, the need to secure food and water supplies for a global population that grows rapidly is a challenge to be addressed using information technology. Unmanned aerial vehicles (UAVs) represent these technological developments used for precision agriculture. They were initially used for chemical spraying while they were the solution to visibility problems due to cloudy weather or inaccessibility to a field of tall crops, like maize (Sugiura, Noguchi, & Ishii, 2005). They also have the strong advantage compared to satellite and airborne sensors of high image resolution (Jannoura, R., et al., 2015)

The production's increase, the improvement of the efficiency, the enhancement of profitability, the reduction of environmental impacts and the availability of quantifiable data from large farms are some of the benefits that precision agriculture using UAVs provides (Herwitz, et al., 2004, Xiang & Tian, 2011).

Questions, however, have risen regarding the usefulness of UAVs in agriculture. Questions regarding their effectiveness as far as the pictures taken are concerned, the inability of UAVs to fly in diverse weather conditions like rain that affects the quality of images or high wind, or finally the price of data elaboration.

It is currently financially viable for a farm manager to purchase a drone, when in 2005 it cost as much as an 120kW tractor (Sugiura, Noguchi, & Ishii, 2005). However, the purchase price is the least of the problems since the cost of image processing software to produce maps is far bigger. As the cost of purchasing and utilizing UAVs within the agriculture industry falls, interest in the sector is rapidly increasing.

5.1 Indices used in UAVs in agriculture research

Vegetation indices in remote sensing of crop weed plants is very common. Some indices use only the red, green and blue spectral bands (Meyer & Neto, 2008). The most common indices used are:

Green - Red Ratio Vegetation Index (GRVI) or Normalised Green - Red Difference Index (NGRDI): Reflectance in the green and red parts of the spectrum

Leaf Area Index (LAI): It characterizes plant canopies. One-sided green leaf area per unit gound surface area (LAI = leaf area / ground area, m2 / m2)

Normalised Difference Vegetation Index (NDVI): Ratio of the reflectance in the near-infrared and red portions of the electromagnetic spectrum NDI = G – R / G + R

Visible Vegetation Index (VVI) provides a measure of the amount of vegetation or greenness of an image using only information from the visible spectrum. The VVI is given by

$$\mathrm{VVI} = \left[\left(1 - \left|\frac{R - R_o}{R + R_o}\right|\right)\left(1 - \left|\frac{G - G_o}{G + G_o}\right|\right)\left(1 - \left|\frac{B - B_o}{B + B_o}\right|\right)\right]^{1/w}$$

where R, G, and B are the red, green, and blue components of the image, respectively, RGBo is vector of the reference green color, and w is a weight exponent to adjust the sensitivity of the scale.

Excess Green Index (ExG): Provides a near - binary intensity image outlining a plant region of interest (ExG = 2g – r– b)

5.2 Case studies

Coffee plantations were traditionally small (<50ha) and hand picking was the standard harvesting procedure. However, the plantations grew enormously, exceeding 200ha, and mechanical harvesting is currently used. Herwitz et al., used in 2004 the NASA's Pathfinder - Plus UAV as an image collection platform, with multispectral and hyperspectral digital imagers over land areas and coastal zone waters, for the Kauai Coffee Company, the largest coffee plantation in the US (approx. 1400ha).

Authors used the data gathered to spot differences in overall ground cover within fields. The acquired data revealed a positive relationship between brightness of the coffee tree canopy and the harvested yield of ripe coffee cherries.

In 2005, Sugiura et al, used an unmanned helicopter, flying over a sugar beet field and a corn field, where they adopted a real-time kinematic global positioning system, an inertial sensor (INS) and a geomagnetic direction sensor (GDS) to acquire the leaf area index (LAI), an important value when estimating the crop growth. To evaluate the crop status using LAI, the accurate segmentation of crop and soil area is needed.

An autonomous UAV-based agricultural remote sensing system was used to monitor turf grass glyphosate application (Xiang & Tian, 2011)

Detection of the vegetation in herbaceous crops is the initial important stage when precision agriculture is applied. Thus high resolution images (mm or very few cm) is highly required. UAVs is the perfect tool for such a mission (Torres-Sánchez, J., López-Granados, F., & Peña, J.M., 2015).

Torres-Sanchez et al. in 2015 used two cameras (a conventional visible camera and a multispectral camera) on a UAV. Then they used the software eCognition Developer 8.9 which offers various options related to Object Based Image Analysis (OBIA) based on the Otsu's method to detect vegetation in fields of three different herbaceous crops (maize, sunflower and wheat). They initially used the multiresolution segmentation algorithm (MRSA). The two vegetation indices: Excess Green (ExG) index and Normalized Difference Vegetation Index (NDVI) were used. The plants were in their early growth stages that corresponds to the principal stage 1 (leaf development) of the ‘‘Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie’’ (BBCH) extended scale. Since there were different spaces for crop separation (17 cm, 70 cm and 75 cm for wheat, sunflower and maize, respectively) whereas the plant morphology also varied (wheat and maize are monocotyledonous plants, and sunflower is a dicot), the images were very different among them, forming a complete image set to test the algorithm.

NDVI was also calculated after the application of herbicide on two plots using an UAV in 2007 (Fig. 1)

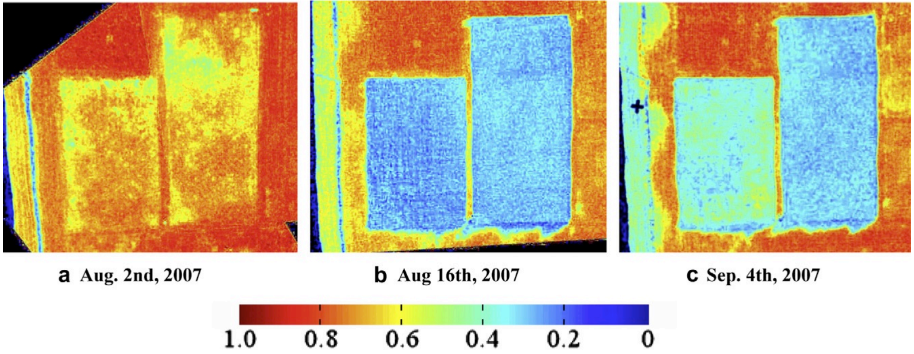

Fig. 1. Pseudocolor NDVI map for the turf grass field on 3 dates in 2007. Source: (Xiang & Tian, 2011).

Jannoura, R. et al., conducted a research in 2015 to evaluate crop biomass over a field with peas and oats. An RGB digital camera was adopted on a remote - controlled hexacopter (Fig.2) and, based on the aerial pictures, the Normalised Green - Red Difference Index (NGRDI) was calculated and related to aboveground biomass and Leaf Area Index (LAI). The Green - Red ration vegetation index (GRVI), the Normalised Difference Vegetation Index (NDVI) and the Visible Vegetation Index

(VVI) were also calculated in the research. ((Jannoura, R. et al., 2015)

Fig. 3. e Hexacopter used to take low-altitude aerial photographs (Jannoura, R., et al., 2015)

6 Conclusion

Results of recent studies indicate that true colour images allow determining crop variation maps of an entire field. The results are encouraging for the development of UAVs as a tool for site-specific precision agriculture in a small field area given their low cost of operation. It is suggested that to provide a reliable end product to farmers advances in platform design are required and the farmer needs to be actively involved in image acquisition, interpretation and analysis in order to have reliable assistance in farm management decision making.

Data analysis has to be able to explain what is causing a variation in agricultural production, not just identify that there is a variation. The way forward for the industry now is to ensure that we can move from UAVs simply producing data to providing the agricultural industry with knowledge. We have to be able to produce high precision data that can improve farming in practice if UAVs are to become a key component of the agriculture industry. Predictions for the industry see growth over the next 2-3 years, with UAVs fully integrated into the agriculture sector within 5 years. By 2018 agricultural UAVs are also predicted to be cheaper, autonomous and a key part of the agriculture industry.

The future of precision agriculture is very exciting and the term Unmanned Aerial Vehicles (UAV) will eventually be referred to as Unmanned Aerial Systems (UAS) to correctly identify these highly engineered, safe and valuable tools that will increase profitability for future crop production.

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