Mateusz ŁUKOMSKI, Krzysztof KOSZELA, Janina RUDOWICZ-NAWROCKA
Uniwersytet Przyrodniczy w Poznaniu, Instytut Inżynierii Biosystemów
ul. Wojska Polskiego 28, 60-637 Poznań, Poland
e-mail: koszela@up.poznan.pl

Received: 2017-05-10 ; Accepted: 2017-06-14

THE BENEFITS OF APPLICATION OF UNMANNED AERIAL VEHICLE IN AGRICULTURE

Summary

This thesis presents fields in the agricultural sector, in which modern solutions are successfully utilized. Those solutions are related to unmanned aerial vehicles also our own researches carried out at Institute of Biosystems Engineering. This article outlines the near future connected with the development of the market of UAVs and their huge involvement in the agricultural sector, informs about problems with legal regulations in Poland according to air traffic license and warns against the dangers that is accompanied by the increasing popularization of unmanned aerial vehicles and often a lack of appropriate qualifications. This article also provides the reader with basic information about the structural components of unmanned aerial vehicles. The article provides knowledge about the several electronic components as flight controller, electronic speed controller, RF receiver module that appear in every UAV machine.

***Key words**: unmanned aerial vehicle, unmanned aircraft, airspace over the plantations, modern solutions in the field of agriculture, monitoring of grassland, the future of precision agriculture*

KORZYŚCI Z ZASTOSOWANIA BEZZAŁOGOWYCH MODELI POWIETRZNYCH W ROLNICTWIE

Streszczenie

Przedstawiono obszary sektora rolniczego, w których z powodzeniem wykorzystuje się nowoczesne rozwiązania powiązane z bezzałogowymi modelami powietrznymi, uwzględniając przykład wypracowany w Instytucie Inżynierii Biosystemów Uniwersytetu Przyrodniczego w Poznaniu. Nakreślono niedaleką przyszłość związaną z rozwojem rynku bezzałogowych maszyn i ich ogromnym udziałem w sektorze rolniczym. Dostarczono podstawowych informacji dotyczących elementów konstrukcyjnych bezzałogowych modeli powietrznych. Przybliżono wiedzę nt. poszczególnych elementów elektronicznych, tj. kontrolera lotu, regulatora prędkości, modułu odbiornika fal radiowych, znajdujących się na pokładzie każdej bezzałogowej maszyny powietrznej.

***Słowa kluczowe**: bezzałogowy model powietrzny, bezzałogowy statek powietrzny, przestrzeń powietrzna nad plantacjami, nowoczesne rozwiązania w rolnictwie, monitoring użytków zielonych, przyszłość rolnictwa precyzyjnego*

1. Introduction

The increasing number of the world's population along with its constantly increasing needs significantly affected the rate of application of modern technology in many scientific disciplines, also in agricultural engineering. Technological and biological progress directly contributes to increase in the efficiency of agricultural production [1]. The use of the global satellite system (GPS-NAVSTAR) for positioning agricultural aggregates, which has contributed to the development of precision agriculture [2], may be a flagship example.

Today's agricultural engineering is currently at a very high level of technology, however, we are constantly looking for newer solutions in order to increase the efficiency of production processes.

Over the past few years unmanned aerial vehicles (UAVs) have become increasingly popular. For UAVs is typical to have no person as a pilot - the flight is supervised by wireless communication from the base on the ground. The dynamic development of the microprocessors has led to the development of advanced solutions (modes of flight) that allow to stabilize and automate the entire flight in such a way that each ordinary user is able to control and cope with unmanned aerial vehicle [3]. In addition, the entire process of flight (start, ascent, gliding, landing) can be done autonomously by using the satellite positioning system.

Before unmanned aerial vehicles have become available to the public, they were used mainly by the military air forces for observation, a search of enemies and combat action [4]. Currently simple unmanned air models are available at shops, as toys for children, or as a practical tool for photo hobbyists and those who passionate about filming from air. More advanced UAVs, for professional use, are built by companies specializing in manufacturing those kinds of solutions or even on special request by enthusiasts interested in building flying machines.

These days unmanned aerial vehicles are used in many different places, e.g. to obtain geoinformation, inspect urban areas, determine the volume of mining excavations, inventory of marine cliff edges, monitor crops or flora and also to register forest areas [4].

2. Application of UAV in agriculture

Until recently, despite the huge possibilities, unmanned aerial vehicles were not as widely used in agriculture as they are today. Each year the situation in the sky over agricultural land and plantations is dramatically changing. Today's UAVs has improved production processes significantly, especially in precision agriculture. They may bring up to 30% of savings from expenditure on fertilizers [5]. UAVs equipped with multispectral cameras allow you to create agricultural orthophoto maps and maps of plantation in near-infrared to calculate the normalized differential vegetation index (NDVI). The aerial photos made before harvests and showing the places where the grain is still immature, even green, may indicate places of decreased yield potential [6]. Generally, it is possible to precisely determine the areas of agricultural parcels, and estimate the damages caused by wild animals, as well as natural disasters by using created maps. It has been proved in the Institute of Biosystems Engineering project (2010-2013) conducted at the Poznań University of Life Sciences [7]. This method of obtaining data is also used by insurance companies.

Big agricultural companies, holding hundreds of hectares of soil and extensive farm buildings, have a huge problem with the monitoring of their space. Unmanned aerial vehicles, equipped with live streaming cameras, help farmers to monitor their crops, property, or other goods, without necessity of leaving the house (not including the operator). By that means they can quickly respond to the disturbing incidents, e.g. outbreak of fire. In addition, UAVs can be used to scare away the uninvited guests like wild animals, by sound module. The operator can also supervise people employed on the farm during field work. The benefits of using unmanned aerial vehicles in monitoring crop and material goods consist mainly in time and fuel saving, also in the ability to look at crops from a different perspective – bird's eye view.

However, it is very important to be aware of the fact that he correct understanding of the photographic material requires the appropriate knowledge, experience, and precise analysis of the obtained data, so in many cases experts' help is necessary [8].

From year 2010 to 2013 a remote-controlled octocopter was used at the Institute of Biosystems Engineering as a part of a national project devoted to monitoring grassland [9, 10]. In the context of global initiatives of agricultural monitoring (among others GEO-GLAM of the G20 group, MARS the European Commission) the research in local monitoring automatization has been started. Monitoring was based on aerial photos gained from octocopter analyzed by computer (image analysis) using artificial neural networks [11, 12]. As part of the project, a device for image acquisition (octocopter) was purchased in parts, assembled and ran. The launch range included calibration of sensors and on-board systems, launching stabilization and positioning systems of the camera, changes in the software that allow to control the camera. Subsequently, flights tests were made, which revealed the need of resolving the technical problems, however, they have also confirmed the rightness of the multirotor choice, that stands out for increased carrying capacity and stability. Series of training flights were conducted in order to take aerial photos of the floodplains of the Warta river basin. During the tests, it was found that the established accuracy of the GPS system mounted on the vehicle was not sufficient for exact photo-positioning. Therefore, it was concluded that the aerial photos must have been made much more densely, combined and positioned as a group using a coordinate grid.

During the usage of the octocopter it was impossible to avoid equipment damage, resulted from technical problems, e.g. a sudden lack of communication between workstation and the octocopter also the weather conditions, e.g. a sudden blast of strong wind. Therefore, it was concluded that the preparation of the octocopter to the image acquisition is a continuous task. According to the assumptions of the project grasslands were mainly photographed in the Warta river basin, for example Łęgi Rogalińskie. An image interpretation of the collected aerial photos was performed to generate identification models, which have been verified and optimize. Conclusions have been made [10, 11]. Examples of samples used as photo interpretation keys for learning neural networks are presented in Table 1. For the purpose of monitoring grasslands, aerial photos allow you to identify, e.g. flooded areas, rills, bushes and clusters of high weeds. Furthermore, it was concluded that aerial photos of up to 30 meters' height allow you to distinguish meadow vegetation.

Table 1. The classification of samples
Tab. 1. Klasyfikacja próbek

Example	Symbol	Class	Population
	Z	Grassy and green	2723
	B	Grassy and flowered	463

Source own studies / Źródło: opracowanie własne

A modular IT system was also created. It included for example, application supporting the process of collecting and processing test results that are primarily spatial data in both vector and raster formats. In the case of the latter ones is it possible to save those test results using filestream in the optimal and safe form in a database management system and there is also an ability to merge photos (Fig. 1). As a result, we obtain a flat panorama of the meadow, which is associated with the other character data and saved in the popular .shp (shape file) format.

Source own studies / Źródło: opracowanie własne

Fig. 1. Effect of panorama meadow composing using produced software
Rys. 1. Efekt złożenia panoramy łąki za pomocą wytworzonego oprogramowania

This module also has the ability to load other spatial data in the form of .shp files and gives us a chance to combine aerial photos with spatial data of grasslands. The application for cataloging sets of data that refers to GPS position was also created. It allows you to perform group operations on photos - basic color transformations, reductions and determination of image statistics and groups of images. There was created a module for free Hugin application, that prepares images for merging. An application to automate the elements of image detection operation and process sets of aerial photos to form that allows analysis using artificial neural networks was also designed and created [11, 12].

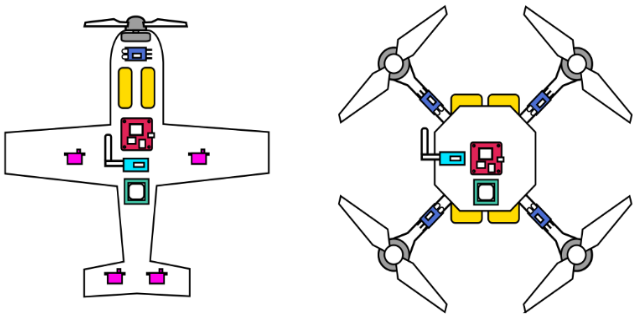
3. Selected components of UAV

Aside from typical structural elements (e.g. a fuselage, wings, arms) in unmanned aerial vehicle there is also a wide range of electronic components. The most important of these is the Fly Controller (FC) which is responsible for controlling and processing information gained from other electronic components on UAV's board. Currently a wide range of flight controllers, including Polish production, is available on the market [13]. Each of the available flight controllers gives us a chance to lift machine into the air. The differences between several models refer mostly to the amount of additional integrated components, e.g. display, barometer, magnetometer (compass) and the implemented software which is associated to increased functionality. More expensive controllers usually stand out for better quality of components and their increased efficiency - computing power, which helps to improve flight safety - decrease the risk of failure. The main differences in the software consist in user-friendly interface and new features that enhance the capabilities of unmanned aerial vehicles, e.g. continuous flight at a fixed height, following the selected point or an autonomous flight – without the action of the pilot, on a scheduled route.

Propulsion unit is another important component of any unmanned aerial vehicle. Usually, electric motors are used, but in bigger structures, especially in large aircraft and helicopter models, combustion engines can be found. Pointing out the ease of use and total operating costs, most of the people interested in designing unmanned aerial vehicles, stand by electric motors, more precisely the brushless direct-current motor. They stand out for their increased efficiency and durability compared to brush motors. Additional service as exchanging brushes is also unnecessary [14]. The only drawback of brushless direct-current motor consists in need of voltage supply to the winding in a strictly defined time period. According to this, the electronic speed controller is an inseparable part of the entire kit. In multirotors, the motors are selected so that the sum of the thrust generated together with matching propellers was at least twice as big as weight of the machine. The propeller is the last component of the propulsion set and is needed to process the torque energy to thrust. It is described by two parameters - diameter and pitch of the propeller, both given in inches. They become matched with engines by use of the tables prepared by the producers, or their parameters are determined on a suitable engine dynamometer. The required balance of the propellers is a key element of proper entire propulsion system working. It affects the fuel consumption (electricity) and flight safety - elimination of vibration.

For manual control of the model from the base, it is necessary to have control apparatus with integrated transmitter. The transmitter transmits information about the tilt of the several rods of the control apparatus and the value of the potentiometers and switches variations to the receiver on the unmanned aerial vehicle. The transmitter communicates directly with the flight controller, which is responsible for the processing of received information. Receiving and transmitting modules are usually the only elements connecting directly communication through radio waves between the model in the air, and a human. Another way of communication includes a Satellite Internet connection, that allows to fly much closer to the base than standard methods do. This solution is used by military air forces [15]. Losing communication with the machine during the flight, e.g. caused by interferences from buildings, hills or high trees, can lead to money waste or, in the worst possible case, human life endangers (irresponsible flight over densely populated areas). Most popular flight controllers have protection against loss of communication with the unmanned aerial vehicle. They may remember the starting coordinates of the machine and perform an autonomous return to the base by means of the Global Positioning System (GPS) and magnetometer (for measuring the direction of flight) installed on the board.

For several electronic components activity, a power source is required. Aerial vehicles use lithium-polymer batteries most often. One of the electrodes in battery is made of porous carbon, and the other one from the metal oxides which are known more widely as the Li-Pol among aerial vehicle makers [16]. This type of batteries stand out of a very high current efficiency and the lack of the memory effect - they can be recharged at any time using electricity, without loss of battery capacity or efficiency. The disadvantage of lithium-polymer cells lies in their high susceptibility to mechanical damage, which in the vast majority of cases leads to auto-ignition. An additional threat to the Li-Pol cells are damages caused by overcharging during the charging process, therefore, the completion of electricity should be controlled by a charger equipped with an advanced electronic circuit (microprocessor).



● - flight controller (FC), ● - radio receiver (RX), ● - GPS module, ● - electronic speed controller (ESC), ● - brushless engine, ● - power source, ● - servomechanism

Source own studies / Źródło: opracowanie własne

Fig. 2. Distribution of selected electronic components of unmanned aerial vehicle

Rys. 2. Rozkład wybranych podzespołów elektronicznych bezzałogowych modeli powietrznych

Complete and the most common distribution of several electronic components of unmanned aerial vehicle is presented in Figure 2.

4. Summary

Unmanned aerial vehicles currently bring many benefits in the agricultural sector - one of the most important is the ability to collect a huge amount of data as aerial photos. After analyzing the collected data, you can determine the precise degree of plant health (reflectance index) and to plan protection treatments or fertilization, taking into consideration the production potential of the soil. Furthermore, the research conducted at the Institute of Biosystems Engineering as a part of a national project devoted to monitoring grassland, confirmed that the collected aerial photos can be rightly used as photo interpretation keys for learning neural networks.

Unmanned aerial vehicles are certainly not developed yet, especially in Polish agriculture. Even today, their ubiquity is evident, but over the years they will be well established in many modern farms, contributing significantly to the efficiency of their production. Implementation of solutions based on unmanned flying machines is of interest for our neighbors in the West. Unfortunately, those solutions are not as popular in Polish agricultural sector, as in Germany or France. Polish farmers are getting used to the view of flying machines above their plantations.

UAVs are only tools that have to cooperate with the appropriate software for decision process support. This software can only be created due to the cooperation of specialists from different fields. The entire construction of the machine together with the matched elements and the suitable propellers, should be planned in advance by the constructor. Correctly designed unmanned aerial vehicle will not only make the most of their capabilities, but also will increase the safety of flight.

5. References

[1] Święcki W.K., Surma M., Koziara W., Skrzypczak G., Szukała J., Bartkowiak-Broda I., Zimny J., Banaszak Z., Marciniak K.: Nowoczesne technologie w produkcji roślinnej – przyjazne dla człowieka i środowiska. Polish Journal of Agronomy, 2011, 7(102-112).

[2] Doruchowski, G.: Postęp i nowe koncepcje w rolnictwie precyzyjnym. Inżynieria Rolnicza, 2008, 9(107).

[3] Tomczak R.J., Nowakowski K., Kujawa S., Koszela K., Nowak P.J.: Możliwości stosowania zdjęć lotniczych niskiego pułapu jako danych fotointerpretacyjnych do oceny użytków zielonych. Inżynieria Rolnicza, 2012, 4(139).

[4] Sawicki P.: Bezzałogowe aparaty latające UAV w fotogrametrii i teledetekcji – stan obecny i kierunki rozwoju. Archiwum Fotogrametrii, Kartografii i Teledetekcji, 2012, Vol. 23,

[5] http://www.fotomapy.eu/precyzyjne-rolnictwo.

[6] http://www.farmer.pl/technika-rolnicza/maszyny-rolnicze/drony-nad-polem,44899,1.html.

[7] Rudowicz-Nawrocka J., Tomczak R. J., Mueller W., Nowakowski K., Kujawa S.: Fotointerpretacja zdjęć wykonanych z oktokoptera do monitorowania użytków zielonych. W: Lipiński M., Przybył J. (red.) Aktualne problemy inżynierii rolniczej. Poznań, Wydawnictwo UP w Poznaniu, 2014. 73-82. ISBN 978-83-7160-731-8.

[8] http://mariuszchrobot.innpoland.pl/116803,wykorzystanie-dronow-w-rolnictwie.

[9] Tomczak R., Rudowicz-Nawrocka J., Kujawa S., Mueller W.: Autonomous flying system for grasslands and fields monitoring. Fourth International Conference on Digital Image (ICDIP 2012). Proc. SPIE 8334, 83340M, 2012. DOI: 10.1117/12.946047.

[10] Rudowicz-Nawrocka J., Koszela K., Otrząsek J., Tomczak R. J., Mueller W.: Grassland monitoring using autonomous flying system and spatial analysis. Proc. of: 13th SGEM GeoConference on Informatics, Geoinformatics And Remote Sensing, Vol.: 1, 2013, 427-432 pp. DOI: 10.5593.

[11] Rudowicz-Nawrocka, J., Tomczak R. J., Nowakowski, K., Mueller, W., Kujawa, S.: Development of Software for Airborne Photos Analysis, 6th International Conference On Digital Image Processing (ICDIP 2014), Proc. of SPIE 9159, 915928, 2014. DOI: 10.1117/12.2064836.

[12] Mueller W., Nowakowski K., Tomczak R. J., Kujawa S., Rudowicz-Nawrocka J., Idziaszek P., Zawadzki A.: IT system supporting acquisition of image data used in the identification of grasslands. Fifth International Conference on Digital Image Processing (ICDIP 2013), Proc. SPIE 8878 88781T, 2013. DOI:10.1117/12.2031602.

[13] http://www.rc-fpv.pl/viewtopic.php?t=7783/.

[14] https://pl.wikipedia.org/wiki/Bezszczotkowy_silnik_elektryczny.

[15] http://whatnext.pl/uavia-firma-ktora-tworzy-drony-sterowane-internet/.

[16] https://pl.wikipedia.org/wiki/Akumulator_litowo-polimerowy.