Automated Field Monitoring by a Group of Light Aircraft-Type UAVs

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Abstract. This paper provides an overview of some existing methods of Earth remote sensing (ERS) using for agricultural needs. Special emphasis is placed on sensing with the help of UAVs. The paper describes the developed software and hardware complex for an aircraft-type UAV group. The proposed solution significantly increases the operating time and automates the process of monitoring agricultural areas. In addition, legislative restrictions on the use of UAVs are considered.

Keywords: Agriculture monitoring, precision agriculture, unmanned aerial vehicle (UAV), Internet of Things (IoT), image analysis

Introduction

The agricultural sector faces many threats, such as pests, plant diseases, climate change and theft. In the Russian Federation, the total area of arable land in 2017 was 116709.5 thousand hectares [1]. Ground-based research and monitoring do not allow for full-value analysis, evaluation and control of such vast agricultural areas. Thus, Earth remote sensing systems are used for timely elimination of pests and diseases, evaluation of fertilizer effectiveness, and protection of agricultural lands.

1 Applications of ERS in Precision Farming

Remote sensing means include satellite systems [2, 3], guided aircrafts and unmanned aerial vehicles (UAVs) [4-6].

The use of satellite imagery is a very common tool for Earth remote sensing. Satellites are constantly making shots of the Earth's surface in conditions of cloudless weather. It is very convenient to use these shots to diagnose the state of objects. One disadvantage of these images is their low spatial resolution. The probe of the Sentinel-2 satellite has from 10 to 60 meters in one pixel at a right angle of shooting, depending on the spectrum used. This resolution is enough for identifying the existence of a "problem", but not enough for establishing its cause and for accurate assessment of the affected area. Another disadvantage of sensing with satellites is the temporal resolution - the time gap before the second (repeated) sensing of the given place. The temporal resolution depends on the trajectory and speed of the satellite. On average, it is between two and seven days for civil satellites that provide access to their images. If it is cloudy or overcast during shooting, the waiting time for the next images increases. In certain cases, more frequent monitoring may be required (up to daily) – for example, during the critical phases of plant growth, testing of new fertilizers, or the harvesting period.

In agriculture, images in the visible range are not of great value. Multispectral images are more important, as they are used for calculating the vegetative index NDVI. Multispectral images have very low spatial resolution. Thus, for full analysis of the NDVI index it is better to use data from several satellites, not just from one. This gives more pixels, and, therefore, more accurate data.

Some services load their images with a delay. There are even free services, for example, Sentinel, but the frequency of image downloading can reach up to 2 weeks, which is not real-time data anymore. All of the above makes the use of satellite imagery useful, but not sufficient for precision agriculture.

The use of manned aircrafts makes it possible to get a high-quality picture at the necessary points of the field in any weather conditions. A significant disadvantage of manned aircrafts is the cost of equipment: not every farm, especially if it is a small one, can afford such expensive machinery as an airplane. Considering the prices for the camera, fuel and the work of pilots and mechanics, the cost of one flight will be significantly higher than the use of UAVs.

UAVs provide more accurate data, in comparison with satellite imagery. Depending on the installed camera, UAVs can provide data of the scale 1:100, 1:2000 and 1:5000, instead of 1:10000 for the "space" satellite imagery. The geodesic accuracy of images reaches 1-3 cm. Using UAVs, data can be obtained in any weather conditions, regardless of the clouds, in contrast to satellite systems that can operate only in clear weather. The cost of one UAV flight is several hundred times cheaper than the flights of "traditional aviation".

Another way to monitor the state of agriculture is real-time systems, consisting of measuring tools and computer centers linked by the Internet of Things [7-9]. Such devices consist of temperature and humidity sensors for soil and environment, soil and light conductivity sensors, sending data via the Internet. Such systems are set up in fields. The obtained local climate data is used to make decisions related to the health of crops. The cost of such monitoring increases with expansion of the investigated territory. The data obtained from the sensors is not sufficient for accurate analysis of uniformity of crop growth and development.

Of course, achieving automation of monitoring and evaluation of agricultural areas is possible only using all of the above-mentioned means, combined via the Internet. Nevertheless, affordable prices of commercial unmanned aerial vehicles, and relative ease of their operation make UAVs the main tool in the tasks of precision agriculture.

2 UAV Group Management System

2.1 Problem statement

Today many farms use single UAVs in field diagnostics. This practice is common in the Samara and Rostov regions. UAVs of the multi-rotor type have become most widespread. For them, flying over the field costs 50-70 rubles per hectare. In a season it is necessary to make from 5 flights. The cost of monitoring costs 2.5 million rubles a year.

In conditions of small farms, multi-rotor UAVs have proved very successful. However, for large agricultural companies with areas of tens of thousands hectares, and fields often removed from each other, there is a need not just for single UAVs, but for a group of unmanned vehicles controlled from a single center. Implementation and operation of the UAV aircraft type group pays off in 2 years compared to the operation of the single UAV multirotornogotipa. In the case of manual control of the UAVs, special training of the operator is required. Complexity of his work increases with the number of devices. According to rough data, about 60% of accidents in the fields involving UAVs occur due to human factor. Therefore, there is a need for an automated system that would ensure constant monitoring of agricultural fields.

At the moment, the UAV groups are not used in the agricultural tasks. The reason is the absence of a stable working solution for the UAV group. Developments of the UAV group are available from the following companies: Boeing and Lockheed Martin, Naval Postgraduate School, Ehang.

The purpose of the work is to set up an automated control system for a group of UAVs in real time for agricultural tasks.

To fulfill this goal, the complex solves the following tasks: UAV group management, monitoring of the mission satisfaction index, real-time data acquisition and analysis, optimal route construction according to selected parameters, machine learning.

2.2 Used equipment and software

The structural diagram of the developed software and hardware complex is presented in Figure 1, and consists of a group of UAVs with on-board computers, and an operator control center communicating with UAVs via wireless technologies.

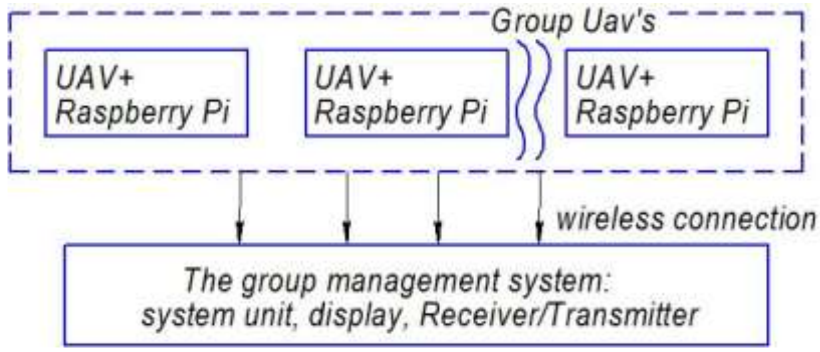

Fig. 1. Structural diagram of the developed software and hardware complex

UAVs are equipped with a camera of the visible and multispectral range. When choosing a UAV, it is necessary to take into account its payload, average flight time, speed and reliability. Tests have shown that the most effective in remote areas would be the use of aircraft UAVs, not the multi-rotor type. Despite active development of the industry of multi-rotor unmanned vehicles, most of them have a flight time limit of 20-35 minutes for industrial vehicles, less often - 50-60 minutes. The cost of the latter devices is up to 5 times higher than of drones with shorter flight time. For this cost, it is economically more advantageous to purchase aircraft UAVs providing flight time from two to four hours while maintaining the other functional characteristics. Tests were carried out to compare characteristics of UAVs of aircraft and multi-rotor types. The results obtained are presented in Table 1.

Table 1. Comparison of characteristics of multi-rotor and aircraft types of UAVs

	PHANTOM 3 Advanced (Multi-rotor UAV)	Sovzond Air-Con 4 (Airplane UAV)
Flight time with one battery charge, min.	23	150
Maximum monitoring area on one battery at an altitude of 120 meters, ha	~25	~220

These tests were carried out using the DJI PHANTOM 3 Advanced with a camera of 12.4 Mp with 4000x3000 resolution. The territory of 100 hectares was covered at the height of 120 meters. This task required 4 flights, while the landings were carried out to change the battery. Spatial resolution is tens of centimeters. With an aircraft UAV, only one flight is required for a similar mission, which saves the operation time and eliminates the need to purchase a large number of spare batteries. In addition, a multi-rotor UAV can develop the speed of about 16 m/s, while an aircraft UAV develops the speed of up to 25 m/s. Fig. 2 shows results of UAV comparison for flights at maximum speed at the height of 120 meters. The "Number of flights" means the flights on one battery charge. Depending on requirements for image resolution, it is possible to fly at a higher altitude, and, consequently, to cover a larger area. At the height of more than 500 meters, spatial resolution decreases so much that the quality difference with satellite images disappears. Therefore, the greatest efficiency can be achieved when operating a system with aircraft UAVs.

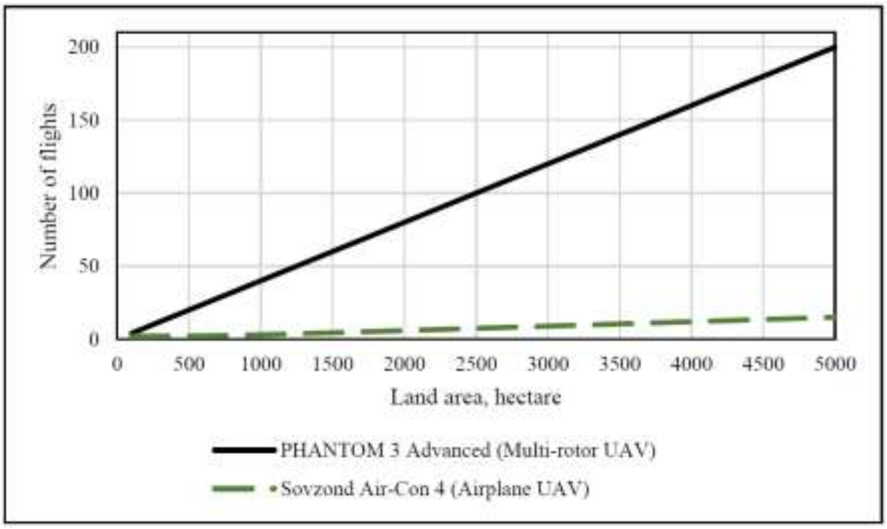

Fig. 2. Comparison of characteristics of multi-rotor and aircraft UAVs

Raspberry Pi was chosen as on-board computer, since it has the necessary functionality and relatively small weight.

The operator control stand is shown in Fig. 3. The stand has a number of displays, receiving and transmitting devices, a personal computer and peripheral devices.

Connection between the group and the control stand can be established in different ways, depending on the mission and operating conditions. Possible options include Wi-Fi, mobile network, or radio communication. Depending on the chosen option, the communication range will change.

Fig. 3. The swarm control system stand

Multi-agent technology is used to solve the tasks of group monitoring and continuous automated patrolling of territories [10].

2.3 Multi-agent scheduler

Initially, operator draws up the mission and team plan, which contains defined areas for the flight, optimal flight parameters, departure times and mission objectives. Commands are sent to the UAV group. In standard flight conditions, the general task is decomposed into sets of subtasks (territories for flight) comparable to characteristics of the group members. The system creates optimal plans to cover the selected observation squares, as well as the task schedule for each UAV. The operator receives data from UAVs in real time on the control stand, having the ability to modify, extend and terminate missions at any moment.

The scheduler balances action plans of the group members in response to dynamically occurring events. For example, when flying over a square at an altitude of 500 meters, one UAV detects non-uniformity in crop growth (Fig. 4). There is not enough spatial resolution for accurate assessment of the affected area and for identifying the cause of this problem at the selected altitude. The system decides to lower the altitude to the optimal value of 100 m, with recalculation of parameters, taking into account the remaining battery life of this UAV, the required area of detailed flight and the remaining uninspected territory. The scheduler decides that the second UAV is required for the detailed flight, and the rest of the territory is distributed among the remaining members of the group. As a result, the group inspects all the fields and diagnoses slug invasion on field A.

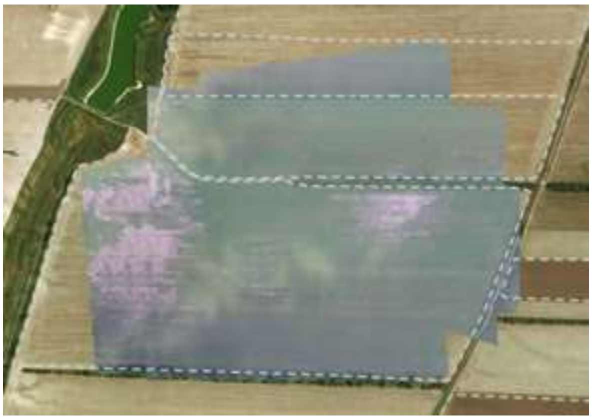

Fig. 4. Analysis of images taken by satellites and UAVs. Pink color indicates the area of the crops destroyed by pests (slug).

Depending on the time of year, the flight schedule and task distribution can vary. Thus, during the ripening season, the following situation is possible (Fig. 5). The data is obtained by stitching NDVI images. Red color shows the territories with mature crops, and green color – with ripening crops. Different cultures mature at different time intervals. Besides, in the fields, it is possible to point out accelerated or slow maturation: along roads, pipelines, on the hills and lowlands. All these areas require detailed monitoring during the harvest period. For example, if the crops over a pipeline are not harvested on time, they can begin rotting by the time the main part of the field is harvested.

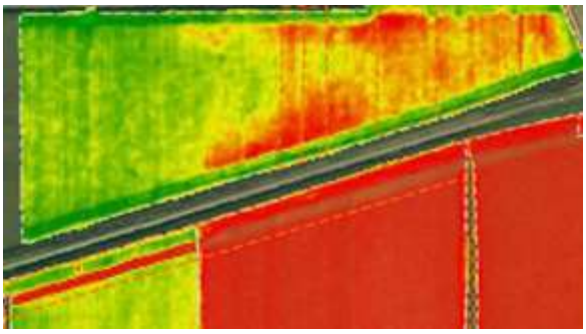

Fig. 5. Analysis of images taken with the help of a satellite. Red areas indicate ripe harvest.

Information about the cultivated land (culture, processing technology) and problem areas is loaded into the system by the operator and is formed on the basis of experience of fulfilling such missions in the previous years. All this data forms the knowledge base. Based on this information, special missions are formed for the group of unmanned vehicles, with marked areas of increased monitoring importance.

The knowledge base also contains object classes, relations between them, and UAV satisfaction indices. The use of a swarm of unmanned vehicles combined into a single software complex makes it possible to automatically fly over agricultural lands, assess the information received, distribute missions among all UAVs, identify problem areas in a timely manner and take measures to eliminate them, monitor effectiveness of the fertilizers used, issue full reports and upload the obtained information into the cloud.

The described software and hardware complex was developed by our team. It successfully passed the tests with a group of multi-rotor UAVs. The use of the complex on aircraft UAVs will make it possible to cover larger areas in less time and solve not only the tasks of local patrolling, but also monitoring of rather extensive agricultural areas.

2.4 Existing System Restrictions

The use of UAVs in Russia is inhibited by the new amendments to the Air Code [11], according to which all aircrafts over 250g are subject to mandatory registration, and for each flight it is necessary to obtain a permit. Formally, each landing is considered as completion of the flight and, consequently, cancellation of the current permit. For each next take-off it is necessary to obtain a new permit, even if the landing was done only for battery replacement. Under the current code, aircraft UAVs that can stay in the air for up to 4 hours have advantages over drone (multi-rotor) UAVs with flight duration up to only about 30 minutes.

In agriculture, the flight usually takes place over large areas with no secret or guarded facilities and without crowds of people. Thus, it would be good to simplify the flight procedure and, for example, issue flight permits in advance for the entire agricultural season only for the territories of the particular farm. This would facilitate the use of the proposed software and hardware complex and UAVs, as flights will depend only on the current needs and weather conditions, not on legislative requirements and bureaucratic runaround.

We suppose that it is highly advisable to consider amendments to the Russian Air Code for the needs of the agricultural industry.

3 Conclusions

In today's world with constantly growing population, it is important to develop precision agriculture using remote sensing technology. The most promising and requested trend is the use of a group of aircraft UAVs, combined into a single system, consisting of the UAVs with installed Raspberry Pi on board, the software developed by our company and a single flight center. The hardware and software complex can plan flight tasks, automatically analyze the footage during the flight, make independent decisions on monitoring tasks, and issue reports and recommendations based on the performed analysis. The system has proved itself in tests on a group of multi-rotor drones. In order to extend the capabilities of the system and save time for end users, we recommend using the system on aircraft UAVs. The key factor currently limiting the civil application of UAVs of any kind is the legislative restrictions in Russia.

Acknowledgements

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