RPAS AS A TOOL FOR THE RESEARCH, DOCUMENTATION AND MONITORING

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ABSTRACT: This contribution deals with the fast growing industry of unmanned aerial systems (UAS, UAV or RPAS) and the use of their capabilities especially in archaeology and vegetation monitoring. The first part is focused on general information and the legislation of RPAS, the second part is about the methodology of RPAS data processing and results accuracy, and the last part deals with case projects in archaeology and the monitoring of biodiversity. RPAS (remote piloted aircraft systems) are gaining importance in mapping and monitoring tasks of our environment. At the CTU in Prague, projects in photogrammetry, archaeology and the monitoring of the biosphere, based on RPAS, were launched in 2011. The project´s aim was to develop and verify simple and low-cost technology for the monitoring of small areas such as archaeological digs, historical objects and small orthophoto projects. Our research is also focused on camera settings and the evaluation of remote sensing methods for low cost RPAS. We found a very good solution in the eBee drone (good price-performance ratio) and multikopters. The EBee drone is equipped with two cameras (VIS and NIR). NDVI can be obtained by changing the cameras and conducting a second flight over the same area, which makes a little bit of a problem. In the near future, a miniature multispectral sensors and hyperspectral sensors will be applicable; it will be a great possibility for low cost research in intelligent and precise agriculture and biodiversity monitoring such as searching for new archaeological areas. In our first case project, our interest was in the use of RPAS for vegetation analysis and biodiversity documentation of the Božídarské rašeliniště Natural Reserve. The second case project is focused on the localization of archaeological objects based on vegetation indices using images taken in visible and near infrared channels. NDVI was computed from RPAS collected image data. A precision of results is discussed.

1. INTRODUCTION

UAV (unmanned aircraft vehicle), which nowadays in the U.S. is called UAS (unmanned aircraft systems) or RPAS (remote piloted aircraft systems) are a modern technology for mapping and monitoring small areas. The UAV method of acquisition combines the benefits of close range and aerial photogrammetry. As a result, higher resolution and mapping precision can be obtained over larger and possibly less-accessible areas such as precise digital terrain models (Eisenbeiss, 2009, 2011, Verhoeven, 2009, Pavelka et al., 2011).

1.1 Legislation of RPAS

Not everything is beneficial when using RPAS; there are security problem and problems with protection of personal data. It is necessary to minimize negative cases like crashes and accidents, threats to air traffic, privacy protection, spying and terrorism. Next, there are still misconceptions in RPAS regulations.
In the European Union, there is a lack of legislation – as each member tries to regulate separately, which increases bureaucracy, leading to problems with the use of RPAS. Instead of using RPAS´s as a helper, it is officially often used as a more dangerous toy or weapon. Price rises and complications of RPAS legal use seem to be typical of the introduction of a new technology. It is wrong and unsustainable, while there is big business pressure. In 2014, the European Commission introduced "A new era for aviation – Opening the aviation market to the civil use of RPAS in a safe and sustainable manner". This Communication sets out the Commission's views on how to address civil drones, or remotely piloted aircraft systems (RPAS), operations in a European level policy framework which will enable the progressive development of the commercial drones market while safeguarding the public interest.
The US Federal Aviation Administration (FAA) came through this year with a new proposed rule for small-unmanned aircraft systems. The FAA announced in April that the first of six test sites chosen to perform RPAS research was operational, as demanded for the program by Congress. The main goal of this site's initial operations is to show that RPAS can check soil quality, the status of crops and other agricultural information at a low-cost. Precision agriculture is one of many industries that represent areas for significant economic opportunity and RPAS-industry expansion (McGovern, 2014).

2. METHODOLOGY OF RPAS

At the Czech Technical University in Prague, a first case project for using RPAS in photogrammetry and monitoring was launched in 2011. The project´s aim was to develop and verify simple and low-cost technology for the monitoring of small areas such as archaeological digs, historical objects and small orthophoto projects. Based partly on this project, a wider four-year project was granted by the Czech Ministry of Culture and started in 2013 with the partial aim of using RPAS for cultural heritage documentation. Nowadays, RPAS are equipped with sophisticated micro-instruments such as IMU, gyroscopes, GNSS receivers, wireless image insights, wireless controls, automatic stabilization, flight planners, etc. The financial and technical availability of RPAS parts leads to the tightening of their use; nowadays, registration and fees are applied for commercial use in the Czech Republic. For safety reasons, in some countries, their use is restricted (Koska, 2013, Pavelka, 2013, 2011, Reznicek 2013).

We tested our two RPAS´s (hexakopter and drone) for different projects. The use of RPAS depended on its type: the electrically powered hexakopter (or multikopter) for typical historical object documentation (for example, the documentation of inaccessible parts like façades or roofs and archaeological sites mapping) or small areas reconnaissance; classic photogrammetry is a typical projects for drones. Of course, there are special professional RPAS, which cannot be named "low cost" instruments – they are intended for military, scientific or special purposes (gasoline powered drones or helicopters). Their equipment depends on usage; scientific RPAS are equipped with a wide variety of instruments like hyperspectral scanners, thermal cameras or laser scanners. Nowadays, there's already big demand for low cost RPAS applications such as aerial mapping and monitoring for precision agriculture to optimize crop yields, mapping of less accessible areas (e.g. moorland, mines) public security and safety for managing natural disasters, and monitoring infrastructure such as construction sites, power facilities, cargo ports and pipelines. Low cost RPAS can provide not only photographic data, but also other data types like multispectral (with NDVI possibility) or thermal data too (depending on sensors and type). The RPAS method of acquisition combines benefits of close range and aerial photogrammetry. As a result, higher resolution and mapping precision can be obtained over compact and possibly less accessible areas (e.g. mountains, moors, swamps, small natural reserves).

We found a very good solution in the eBee drone (good price-performance ratio). The EBee - drone (www.sensefly.com) is very small and light (less than 1kg), consists of a styropor airframe, an electrically powered engine with a pusher propeller, battery, GNSS and IMU unit, compact digital camera (14MPix), radio-modem and control system. An ordinary notebook for flight control is needed. For flight control there is special software (E-Motion), in which it is possible to easily manage all necessary project information like area (based on free Google and other maps or orthophotos), pixel resolution, image overlapping, flight time, distances etc. Maximum flight time depends on the battery, its condition and temperature and is approximately 45 minutes. The typical flight altitude is 100-200m, and typical documented area about 1 sqr km; pixel size can be set from 1.5cm, normally reaches 3-5cm. Primary outputs from a set of taken photos (typically hundreds of photos) are digital terrain model (DTM) and orthophoto. This can be done using additional software (Agisioft Photoscan, Pix4D etc.) nowadays there is a lot of software for photo processing based on image correlation (Marčiš, 2013). Geometrical precision of created orthophotos is based on georeferencing. It is possible to use only data from GNSS and IMU or - for more precise output – control points (geodetically measured and signalized). For vegetation monitoring, there is the possibility to use a camera sensitive to the near infrared range (600-850nm). If you have two flights over the same area with different cameras (one in visible range, one in near infrared), you can compute normalized vegetation index (NDVI) by red channel separation from both created orthophotos.

3. CASE PROJECS

3.1 Monitoring of biodiversity - Božídarské rašeliniště Natural Reserve

The Božídarské rašeliniště NNR was declared a reserve in 1965 and re-declared in 1987 on an area of about 1000 ha. The reserve lies on the Ore Mountains on the northwest border of the Czech Republic with Germany near the small city Boží Dar at a height of about 1000 meters above sea level. The predominant forest communities are the natural climax spruce forests and waterlogged spruce stands. A total of 12 forest types have been identified in the NNR, ranging from beech-spruce stands to bog pine scrubs. Numerous interesting fauna species are also represented on the NNR territory. The main negative feature, which still affects the peaty biotopes, is the intensive drainage works, which were carried out in the past. The NNR management plan has the long-term aims of reducing these negative influences (Pavelka et al., 2013).

Our result in this case project is a set of maps of vegetation cover in the area in different seasons. Data will be collected to a small GIS. It will then be compared with our long-term Landsat data analysis and with our drone measurements and terrestrial data. Satellite and RPAS data are very important because the whole area of Božídarské rašeliniště is not opened to the public and partly purely incisive because it is moorland (Daniel,et al., 1998).

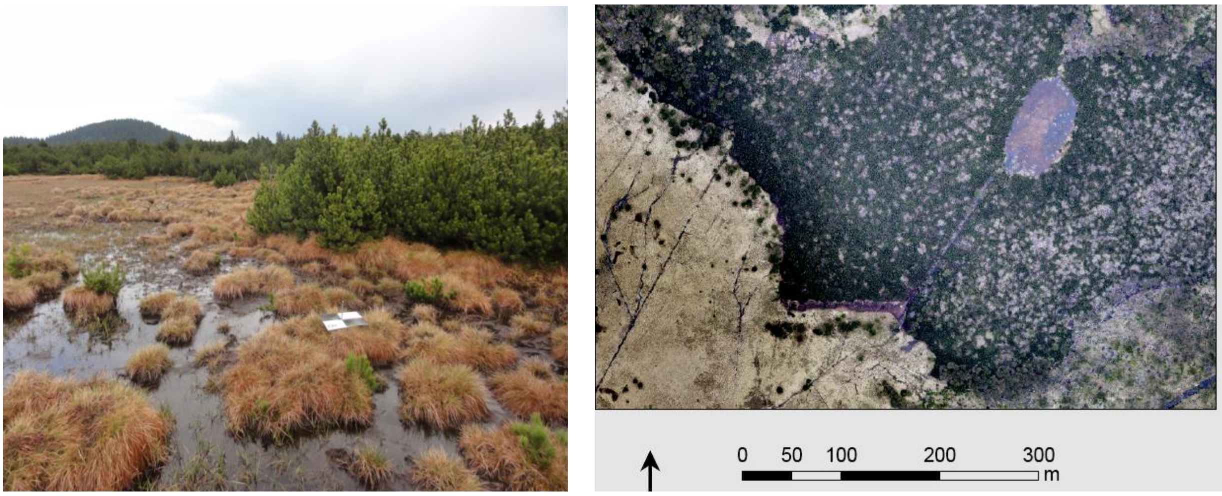

Fig.1: View on central part of Božidarske rašeliniště NNR , central part (orthophoto) VIS

Fig.2 eBee drone (left), hexakopter (right)

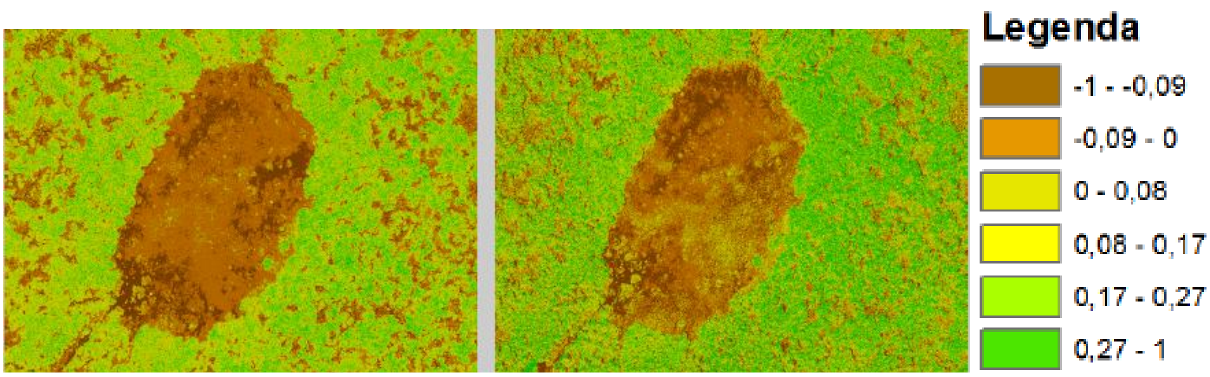

Fig.3: NDVI derived from VIS and NIR photos

In the area of interest (NNR) eight control points were stabilized and geodetically measured with precise GNSS station Leica Viva (precision cca 1cm with using online correction of CZECHPOS net). Some control points were in very difficult terrain (moorland). The precision of outputs is indicated by deviations of control points, which were not included to general adjustment. Deviation reaches 5cm in position and 7 cm in height (but in moorland is difficult to stabilize any fixed point.

However, the geometrical precision is not the principal result of our work. Main results are thematical layers showing vegetation status during season and demonstration of RPAS capability. NDVI are computed from three flights (April, May, and August).

Kamera	RMS X [m]	RMS Y [m]	RMS Z [m]	Total RMS [m]
IXUS	1.42	2.03	2.72	3.69
ELPH	0.81	1.36	2.17	2.69

Kamera	RMS X [m]	RMS Y [m]	RMS Z [m]	Total RMS [m]
IXUS	1.25	2.31	2.97	3.97
ELPH	4.86	5.85	9.93	12.508

Tab.1: Accuracy based only on INS

Kamera	RMS X [m]	RMS Y [m]	RMS Z [m]	Total RMS [m]
IXUS	0.03	0.05	0.02	0.06
ELPH	0.05	0.04	0.01	0.07

Kamera	RMS X [m]	RMS Y [m]	RMS Z [m]	Total RMS [m]
IXUS	0.09	0.12	0.01	0.15
ELPH	0.31	0.16	0.07	0.36

Tab.2: Accuracy based on control points after adjustment

3.2 Archaeology

For archaeology, the two most well known RPAS can be used (drone and multikopter). The multikopter systems use electric power from batteries and are constructed as a quadro-, hexa- or octo-copter with an adequate number of engines and propellers. With the new powerful battery the flight can last up to 15 minutes. As the altitude range is several hundred meters, the system reacts to signal loss by automatically returning to the starting position using GPS/IMU. Scientific equipment often contains a remotely controllable digital camera. It is possible to obtain video or single images. Image resolution is given by the respective camera used and the height of flight; if the GPS / IMU is installed, the approximate exterior orientation elements of all images are known. Multikopters can be use on small areas as there started and landed vertical. For this reason, they are exploited for the monitoring of historical objects such as castles, historical buildings etc. We use the Mikrokopter (hexakopter) RPAS. The typical output is a small orthophoto of archaeological excavations and their monitoring or detailed photos of historical objects (for monitoring or documentation). In our project, many small archaeological places are monitored. It is low cost, very simple, and speedy. From these photos, a DTM can be derived, which is useful for archaeologists. Based on the type of processing software, a textured virtual model can be obtained (Marčiš, 2013, Pavelka et al., 2011, 2013).
The second type of use is the EBee drone. It was primarily designated for the searching of new potential archaeological objects or the precise documentation of known places with infrared range or by vegetation signatures or symptoms. After some missions, we obtained hopeful results in an archaeological area near Louny city (a new potential object) and the precise documentation of a known historical military object near Litomerice city (an old military fortification - redoubt, from the Prussia-Austria war in the 19th century).

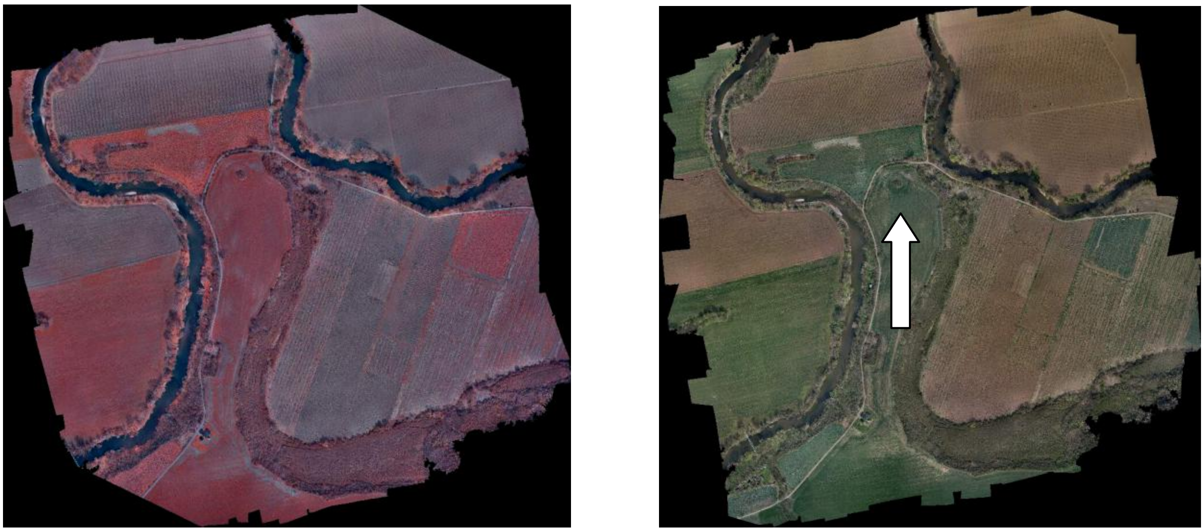

Fig.4: NIR orthophoto and VIS orthophoto

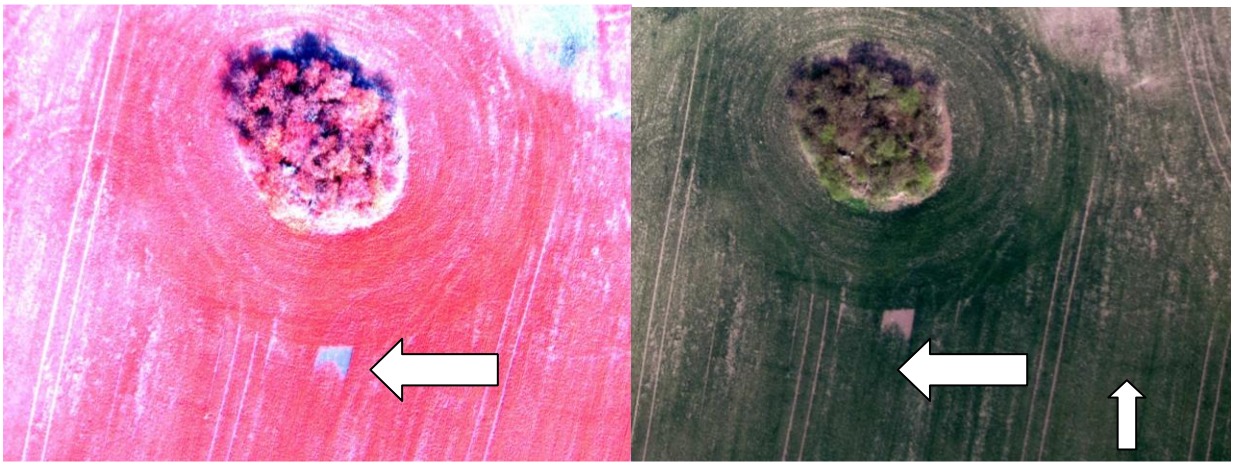

Fig.5: Archaeological objects found on images

4. CONCLUSION

We found RPAS to be a very good instrument and technology in small area monitoring not only for low cost reasons, but for precise data capturing and operability. The main results in our first case project are thematical layers, which show vegetation status during the season. The outputs are high precision ortophotos based on geodetically measured control points (accuracy 5-7cm in pixel position). In the second case project, the use of RPAS for archeology has been shown. A new potential archaeological object was detected in near-infrared range. The RPAS technology will be interesting for many customers and will provide new and efficient ways to manage both large projects and common 2D, 3D or special measurements using thermal, hyperspectral or other instruments. Rapid, effective, ecological and, in many cases, low-cost data acquisition capability is indisputable. The main results in our case project are thematical layers, which show vegetation status during the season. The outputs are highly precise based on geodetically measured control points (accuracy 5-7cm in pixel position). An interesting contribution of RPAS can be in cadastre; of course it is necessary to modify the relevant legislation.

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