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RPAS – ROBOT PLANES IN THE SERVICE OF ARCHAEOLOGY

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Remotely piloted flying devices represent one of the most dynamically developing technologies today. The expansion of their use is due to increasingly more reliable devices and the programming background resulting from the development of robotics, as well as their falling prices. However, it still can't be said that they are in common use, since the safe control of the devices still requires significant expertise and financial support. The scientific experiments we carried out show that in addition to a variety of other areas of application they could also soon become indispensable aids in archaeological work. In our study, we would like to give a brief summary of the role of robot planes in archaeology and of the observations we have made in our research in the past few years.

Surveys were carried out in the early days of aerial photography with cameras attached to hot air balloons or kites and model planes were used decades ago to take aerial footage. However, the real breakthrough was brought about by 21st century developments: enormous progress was made in the field of remote devices and their control, and also in the taking of images and video footage.

In addition to remote controlled planes, various multi-rotor copters can be used in more and more areas, and these provide a high degree of freedom in flying and making documentation, while leaving some areas and roles still for traditional aerial archaeological techniques.

Opinions are divided in Hungary concerning the possibilities for the use of unmanned remotely piloted flying devices in archaeology, but the development of the technology and research results support the significance of their use.

Fig. 1: Multi-rotor copter survey in Miskolctapolca

Fig. 2: Hot air balloon vertical photography at the Miskolctapolca excavation site

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WITHOUT A PILOT?

The devices we are introducing are known by various names. Mainly due to their military use they are known as UAVs (Unmanned/Uncrewed Aerial Vehicles) or UASs (Unmanned Aircraft Systems), but these generally widespread expressions can be considered incorrect. While it is true that the planes stay in the air without a crew, during a "mission" they are under constant control.[3] So, in our case the use of the expression RPAS (Remotely Piloted Aircraft System) is more accurate, which could also dispel several preconceptions.

Fig. 3: The "FPV camp" on site

One of these is that their use is (possibly) limited by the fact that, unlike conventional planes, unmanned technology is considered unreliable, and there is some truth to this. It must be pointed out however, that the main objective of the operator is to guarantee both ethical and technological security, as well as ensuring responsible use. This is what the success of the surveys and the development of this forward looking and often indispensable technology depends upon, within a legal framework that varies from country to country or has not even been worked out in many locations.

Remotely piloted aircraft systems are one of today's extremely innovative and dynamically developing technologies. In addition to the military developments, the increasingly wide-ranging civilian use of RPASs is on the rise throughout the world. In addition to the numerous companies in the market, there have been some developments made by individuals, universities or research institutes, in terms of both devices and control programs. Independent experimentation is in part behind these developments, while they also entail the customisation of manufacturers' devices, so the technology follows an almost untraceably diverse path of development. The areas of its use are constantly developing and archaeological research makes up only one segment of this.

Fig. 4: Flight control based on live video footage

During their archaeological and other uses, the (remote) control of planes or multi-rotor copters is largely performed by a several people, ideally a minimum of three. One must be an experienced model pilot responsible for the control of the device. The co-pilot controls the cameras, reads and continuously

[3] There are development trends in which the flight of the device is pre-programmed, and although they are under supervision, the controlling crew primarily control the flight related observations and not the flying device itself. In our opinion, however, it is of the utmost significance that the ground crew should be able to control the remotely piloted aircraft systems, because the lack of this entails several safety risks.

monitors the data that appears on the screen and substitutes for the pilot if necessary. The third person constantly monitors the devices, keeping them under unaided visual observation, and ensuring the flight path is clear of approaching aircraft or at take-off or landing. The operators of remotely piloted aircraft systems are professionals who are responsible on the one hand for the safe operation of the device and, on the other hand, have experience relevant to the research objectives.

RPAS DEVICES IN THE SERVICE OF ARCHAEOLOGY

Hungarian and international results show that remotely piloted aircraft systems are excellently suited for several tasks in archaeological research. One of the most important areas is the reconnaissance and observation of archaeological sites, where they are deployed as one of the tools of aerial archaeology.

They can also play an important role in the documentation of excavations: with their assistance the excavation trenches and the surroundings of the site can be photographed and filmed. The footage made in this way is an important part of the scientific documentation, since a more detailed survey can be carried out from a lower altitude with these devices than with the traditional tools of aerial archaeology.

Last but not least we can expect them to help in the assessment of preserved archaeological and cultural heritage sites and in the monitoring their condition.[4]

Aerial archaeology is an indisputably important segment of site exploration and monitoring, and remotely piloted aircraft systems can expand the available techniques to a significant extent. From the point of view of research, the application possibilities for RPASs can be divided into two areas.

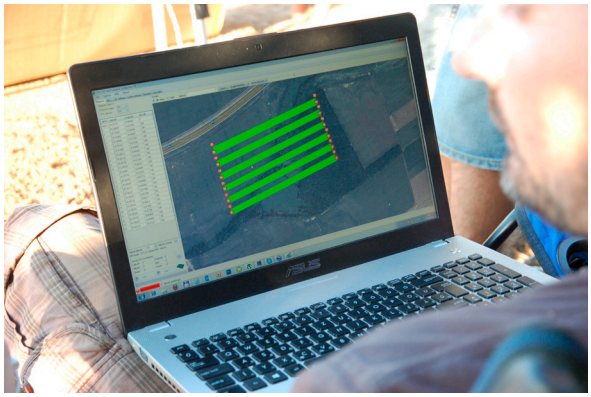

Fig. 5: The computerised preparation of the vertical photography of the research area. The image shows the turning point of the planned flight path and the area covered by the survey.

1. Because of their flight time and manoeuvrability, fixed wing FPV (First Person View) planes can play a role in the exploration and monitoring of smaller sites covering an area of approximately 1–2 km^2, as well as in the examination of the immediate surroundings of known sites. The more limited exploration range is due to the approx. 40-60 minute flight time and to the quality of radio frequency signal transmission. After replacing the battery, the flight can be repeated/continued of course, and in the case of larger distances the take-off sites can also be changed. The on-board control and observation camera systems ensure satisfactory observation opportunities during surveys with the help of high resolution live footage.[5] In addition, there is a room for another device on the plane. This can be a camera or a camcorder adapted to the research objectives, which – depending on the type of the plane – is in an orthogonal position on the wing or in the body of the plane, or can be positioned at a different angle. The remote-controlled plane can either be flown on a pre-programmed flight path or independently.[6] In more advanced systems, automatic route planning is also possible based on known site parameters and on the data of super-impositions necessary for mapping. Here, the controlled exposition of the camera is carried out by a robot. This highly detailed imaging of great precision provides an excellent basis for

[4] Our research development project on this topic is currently underway under the name SziMe3D AR. In this project we are studying the role and use of this technology as compared with other surveying techniques. Further information at: http://szime3dar.com/hu/

[5] Technology is developing at such a rate that in a few years 3D live footage might even offer opportunities close to human observation. A good example of this is that a year ago the general quality of live footage was substantially worse than that available today. Szabó, Maté: Non-invasive methods in the research of Pannonian villas. *Hungarian Archaeology* Autumn 2012, 3. http://www.hungarianarchaeology.hu/wp-content/uploads/2012/11/eng_SzaboM_12O1.pdf

[6] In our research we use the C4S robot pilot developed in Hungary.

mapping, even to the extent of creating a photo3D or a relief map.[7] Before performing FPV flights, it is worth investing more time in selecting the potential take-off and landing sites, as a number of aspects must be taken into consideration. For flight and control considerations the terrain, the vegetation in the area and the exact location of inhabited areas between the take-off and landing strips and the area to be photographed are important. The use of the Google Earth program is very helpful in planning since favourable locations can be marked with great precision even without previous knowledge of the terrain. It is worth selecting a number of locations, so that it is possible to modify one's position during research as necessary.

Fig. 6: Launching an FPV robot plane

2. The use of multi-rotor copters also has great potential in aerial surveys. Their range of applications varies with their technical capacity, which is mainly reflected in their useful transportation capacity and their limited, 6–10 minute flight time. By developing a suitable ratio, the aerial archaeological documentation of particular sites can be performed with their help, providing perfect background information for mapping, photo3D work and high precision relief maps, as well as for making promotional videos. Their flight and positioning abilities and the automation of their route planning provide an extremely versatile device for aerial archaeologists.

Fig. 7: Multi-rotor copter taking vertical photographs

Based on surveys performed with RPAS devices, it has been established that just as with surveys carried out with other devices – including traditional aerial archaeological flights – it is worth returning to the given site, since atmospheric conditions can significantly influence the results.

[7] Photo 3D documentation also makes it possible to produce a precise, orthographically corrected aerial photo map, as well as a model of the terrain made from this.

At the currently available quality level of image transmission, the precise selection of flight altitude is also very important since at a certain height and in certain atmospheric conditions the evidence indicating a site may be lost in the transmitted image. On several occasions during our flights the archaeological phenomena could only be identified in the HD resolution footage viewed after the flight, or on high resolution vertical photographs. This confirms that this method of observation can presently play a complementary role together with traditional aerial archaeological surveying, and can primarily be used for the examination of known sites and their surroundings.

Fig. 8: Surveying a Roman villa with a multi-rotor copter. With the help of the transmitted live image viewable through the goggles the survey can be modified according to the needs of the specialists.

The large amount of video and aerial footage produced during these flights provides significantly more information for researchers compared to earlier methods. In addition to live images, subsequent processing and analysis is a priority, and these may provide new or even unexpected results.[8]

Due to modern technology radical changes can be expected in the near future in the methods of preparing excavation documentation. The general spread of digital data recording and 3D modelling[9] will allow much more detailed surveying and processing than before, as well as ensuring the storage of the necessary and interpreted information. These technologies may have a significant effect primarily on illustrated archaeological documentation.

It is especially in the creation and refinement of surface drawings where orthogonal aerial footage, which records certain periods of the excavation with cartographic accuracy, is of great help through the elimination of the imprecision of human measurements and drawings. To produce footage such as this, multi-rotor copters have proved themselves to be the obvious devices, and with them aerial footage can be taken according to the required parameters. In addition to all these aerial photographing possibilities, RPAS devices also provide an opportunity for the photo3D documentation of a whole section, so not only surface drawings, but high precision full 3D models can also be created with them. Furthermore, in most cases it is much simpler to make a photo3D survey from the air than to record the necessary details from a ground position in the traditional way.

Fig. 9: Taking photos of a Roman Age villa with a fixed wing FPV robot plane. The distortion of the wide-angle optics of the camera used in flight navigation is easily noticeable in the image.

[8] We would like to report on the processing of the digital footage by robot planes in a later study.

[9] Fehér, András: Using 3D scanners in archaeology. *Hungarian Archaeology* Summer 2013, 1–5. http://www.hungarianarchaeology.hu/wp-content/uploads/2013/07/eng_Feher_13ny.pdf

Due to the complex technology of the devices, the serious remote control skills necessary for their safe operation, and their significant cost even today, we believe that they still will not become generally widespread in the near future as tools operated by research archaeologists or archaeological technicians.

Remotely piloted aircraft systems can also play an important role in the documentation of preserved archaeological and cultural heritage sites. In this field, architectural photogrammetry and so-called close range photogrammetry has a century of tradition.[10] Among RPAS devices, it is primarily the multi-rotor copters that are novel in surveying work, but they can also play a prominent role in post-survey checking and monitoring.

RPASs could become a complement to land measurement in surveying, since multi-rotor copters provide an opportunity for photo documentation in places where the use of terrestrial devices such as laser scanners may be difficult – primarily at great height and in confined areas. Remotely piloted aircraft systems can also be used for full surveys, for supplying missing elements and perhaps for recording precise textures. Today one can encounter technological solutions where a multi-rotor copter carries a laser scanner to perform high precision surveys.

SUMMARY

Remotely piloted aircraft systems (RPAS) represent one of today's dynamically developing and extremely innovative technologies. Archaeological research is only one segment of their diverse range of applications, where they can be successfully used – depending on expertise. Due to the ability to customise the device and its programming, FPV planes and/or multi-rotor copters can be used that are adapted to the research objectives and are always controlled by professionals. In archaeology their three main areas of use are: aerial surveying, the preparation of excavation documentation and the documentation of built heritage. Due to the development of robotics, research targets can even be documented by these devices in a pre-programmed and automatic manner, but there always remains an opportunity for real time intervention and the modification of plans. The great amount of video and aerial footage produced during the surveys provides an opportunity for accurate mapping or even photo3D processing. Although the spread of RPAS can be expected in archaeology, due to the complexity of its technology and its price, devices currently can only be operated by people with considerable expertise.

Fig. 10: Live video footage broadcast in mid-flight, containing the most important flight data as well

[10] Kiss Papp, László: *Architectural photogrammetry* (Budapest: Műszaki Könyvkiadó, 1981)

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