USE OF RADIO-CONTROLLED MODEL HELICOPTERS IN ARCHAEOLOGY SURVEYING AND IN BUILDING CONSTRUCTION INDUSTRY

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ABSTRACT
Creation of a photogrammetric image acquisition system at low altitude, using a radio-controlled model helicopter, and development of a specific methodology based on digital photogrammetry, for the rapid and effective surveying of archaeological sites, excavations and/or monuments in general. This system includes radio-controlled aerial photography with the help of a model helicopter, digital photogrammetry, image processing, and Global Positioning Systems (GPS) for the measurement of checkpoints. Soon after the acquisition of stereoscopic images by the model helicopter, it is possible to obtain the final surveying products, i.e. digital models of the excavations' ground, linear designs in digital form and/or printed, rectified images, aiming at a thorough surveying of archaeological sites, monuments, or generally exterior constructions of interest not easily accessible using conventional methods. Furthermore, the derived digital files contain three-dimensional (3-D) information and can also be used in 3-D modelling programmes for photorealistic computer representations.

1 INTRODUCTION

Archaeologists in Greece, in order to supervise the excavation works, need an accurate topographic plan of the site, which also illustrates the archaeological finds. The ways and means archaeologists are producing those kind of plans are traditional and, very time and money consuming.
A string-made grid is originally generated all over the site, which is going to be surveyed. All the details of objects that fall inside a grid are then sketched by hand or with the help of a meter. This is a trial-and-error method and the results very often do not meet the required level of accuracy. Moreover a great amount of labour effort is necessary in order to reduce the time needed for carrying out the works. This is essential, especially if we consider that at the time of the surveying, the excavation works are postponed, thus the excavation productivity is reduced dramatically.
GeoAnalysis S.A., in the frame of a research programme funded by the Hellenic Ministry of Development, has developed a technique for the rapid and effective surveying of archaeological excavation sites. The technique combines image acquisition with the aid of a radio-controlled model helicopter, with digital photogrammetric procedures that generate the necessary for archaeologists map products.
The overall methodology provides rapidly the final products (Digital Terrain Models, rectified photos, vector drawings) soon after the photography is acquired. Those products will be in digital form and in three dimensions, therefore they could be possibly used as input in modelling software and produce also photorealistic models for presentations.
The developed methodology is also applicable in other fields where fast surveying with topographic accuracy is required, and furthermore where it is necessary to survey using a contact-free method i.e. the modelling of large building constructions, where panels of aluminium-glass are going to be fitted.

1.1 Basic stages of system development

This system is mainly based on the construction of a patented model helicopter used for specialised photogrammetric image acquisition, in order to obtain vertical photogrammetric images (analogue and/or digital), for the design of topographic plans or orthophotomaps of excavation sites etc. Furthermore, turning the camera by means of remote control it is possible to take photos from an angle, in order to survey details, building facades etc.
The radio-controlled model helicopter has the following features:

- Is powered by a reinforced motor, which is able to lift up to 5Kg; and with a full fuel tank can fly independently for more than 20 minutes at a maximum altitude of 500 meters above ground.
- Is equipped with a special aluminium base with a rotating horizontal axis, where the camera is mounted.

- The camera base has a special rubber suspension system to absorb vibrations.
- Is equipped with a camera rotation mechanism including a stepper micromotor, which is activated, by a special remote-controlled mechanism on the ground. The camera is able to take vertical images when it is completely loose; it can also be rotated from the ground turning up to 90 degrees, in order to photograph building facades etc. The camera is also equipped with an automated film propulsion mechanism at the back and the shoots will be taken by the same remote control.
- Is equipped with an electronic view observation system (viewfinder), which is mounted on the camera. This consists of a CCD camera and transmits through a UHF transmitter directly to a portable monitor on the ground.
- Trained operators carry out flights and shoots. The technician who handles the camera remote control is also responsible for the photogrammetric shoots. The model helicopter lands for refueling or for change of film, in case an analogue camera is used.

The development process of the system went though the following basic stages:

1. Model Assembling.
2. Remote-control Training.
3. Construction of a camera mount platform.
4. Aerial Photographs of Archaeological Sites.
5. Digital Photogrammetric Aerial Photography Processing and Production of End Products.

2 SELECTION AND ASSEMBLAGE OF MODEL HELICOPTER

Major objective for the selection of a radio-controlled model helicopter is the lifting of a camera or video camera, at a relatively low altitude, capable to acquire pictures for photogrammetric processing
Therefore, the criterion for the selection of the appropriate model has been the lifting ability of models studied, provided that the camera elevation system will be an extra load on the model.
After a thorough marketing research on the models that might meet the programme requirements, we have ended up buying a VARIO Benzin Trainer model, product of German technology.
The model that has been chosen is 1.46m in total length and 1.64m in central rotor diameter. Its total weight is just over 9Kg and its elevation power is approximately 5Kg.
The flight autonomy it provides with one full fuel tank lasts for about 20 minutes. However, that time is reduced with the addition of the camera load, provided that extra power is required in order to elevate this extra load.

Figure 1. The model in the first stage of assemblage

The remote-control device chosen for this model is a FUTABA FF8U Super, operating at a frequency of 35,200MHz with a PCM or FM signal set potential. The setting of the remote control has been chosen to be PCM. The model's piloting servomotors are all FUTABA S9204 type, except for the piloting motor of the back rotor, which is S9205 type. Furthermore, the model is equipped with a gyroscope to control the flight stability, which is a FUTABA, GY501 type.

Figure 2. Futaba Remote Control

The model's engine is a two-cycle Japanese ZENOAH Komatsu engine, G230PUH type, at 0.23cc, equipped with a special-type exhaust and a combustion regulator, which raises the engine power to 3.2Hp. The fuel required is gasoline super mixed at a 40:1 ratio with two-cycle engine oil.
The first testing flights of the constructed model took place at the old military airport of Kilkis. Figure 3 shows the model after the first flights. Meanwhile, the camera mount system was already under construction.

Figure 3. The model after the first flights.

2.1 Training on Remote Control

For the training on remote control, we have used Flight Simulator Programme 3 in 1 R/C Flight Simulator of CSM Intelligent Technology. The programme includes a parallel port connected to the model's remote-control device, and all actions required by the operator are identical to the ones required by the normal piloting of the model.
At this point, it must be pointed out that no mistakes are allowed during the operation of the remote control, since the slightest mistake can result in definitive loss of control and in crash of the helicopter. This can result in the destruction of several parts of the model, which are expensive to replace. Consequently, the time each operator needs to be trained on the simulator may be really valuable.

2.2 Manufacturing of camera mount platform

The most difficult project within the programme is the construction of the camera mount platform on the helicopter, which must be able to rotate, so that it may be possible to:

1. Take aerial photographs towards vertical facades at high altitudes, when access is impossible opposite the façade.

2. Take panorama aerial photographs (camera turn 45^0) to provide the general view of archaeological sites or buildings.
3. Take aerial photographs with the camera axis at a vertical position, in order to take stereo pairs of aerial photographs to reproduce 3-D models of the sites.

There are several factors that one must consider in such a construction. First of all, the primary prerequisite is to ensure a certain state that allows the centre of mass of all extra parts to be situated at the same vertical axis with the central axis, around which the central rotor of the helicopter rotates, regardless camera lens the orientation. Otherwise, the system will be unstable and there may be piloting failure or loss of the model's control during the rotation of the camera.

In order to install the camera mount system on the helicopter, the landing gears provided by the model's manufacturer are removed and replaced by larger ones made of aluminium 10mm. All connections are made with elastic dumpers to absorb vibrations.

Figure 4 shows the experimental layout of the camera mount in order to determine its centre of mass at a horizontal and vertical position of the lens axis. According to the above, this point must be situated at the same vertical position with the rotation axis of the helicopter's rotor. Then, the motors that move the camera and the motor that activates its shutter have been adjusted. All these motors are FUTABA S3001 type and the camera's remote control is FUTABA FF6 type, operating at a frequency of 35,060MHz at an FM setting to avoid possible interference by the camera's remote-control system with the corresponding system of the helicopter.

Finally, in order to join the camera system with the helicopter's chassis, according to the prototype, we have used elastic dumpers and silicone-rubber suspensions in order to achieve as large absorption of the rotor's vibrations as possible, and to avoid possible transfer to the camera mount system.

Figure 4. Experimantal arrangement of camera mount

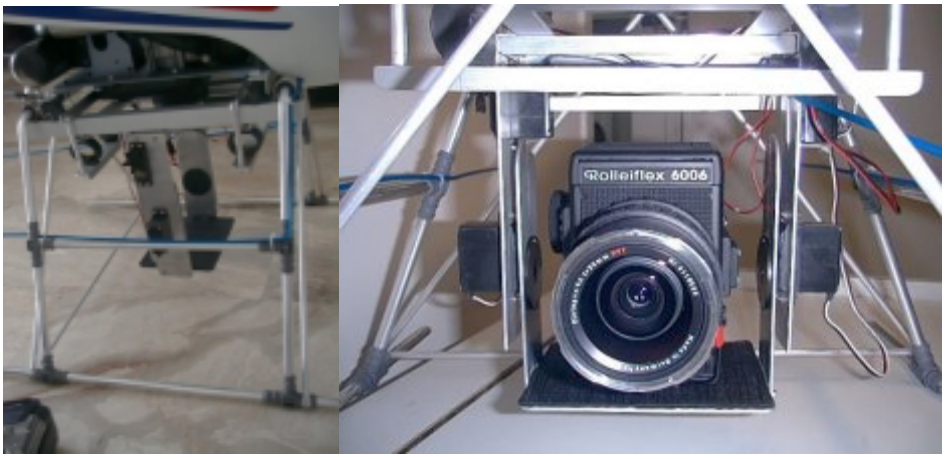

Figure 5. Final aluminium camera mount system

2.3 Image acquisition in archaeological sites

During the photogrammetric surveying of archaeological sites, the elements required for the photogrammetric processing are the following:

1. Overlapping photographs of the excavation site objects with an overlap of 60 and over, for stereoscopic (three-dimensional) photogrammetric processing, production of relief digital models and 3-D product respectively, or alternatively.
2. Overlapping photographs of an object with a slight overlap (less than 20%) for single image (2-D) photogrammetric processing (reduction) and 2-D photogrammetric product, respectively.
3. Photogrammetric checkpoints (photocontrol points).

Furthermore, other factors that must be taken into account are the following: the quality and the general features of the camera, the method of calculating the photostable points' coordinates and the geometry of shots with regard to the object. It is possible to calculate the distance of photography (range of photographs) from the desired accuracy,
The camera the model was designed for is a Rolleimetric 6006 medium-format camera, which is also equipped with a reseau at the back, in order to achieve a better performance in terms of photogrammetry.

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