Aerial Survey in Hamadab & Meroe region 2014

Republic of the Sudan

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Abstract: The first archaeological survey connected with the HMD-QSAP Project begun in September 2013 and was carried out between January 14th and March 3rd 2014. The survey comprises the first out of two planned archaeological survey-campaigns consisting of a relatively surface documentation related to archaeological remains of all subsumable periods in time up to modern or sub- recent date (WÖSS 2014). The project is founded by the Qatar Sudan Archaeological Project (QSAP). The project director is Dr. Pawel Wolf (DAI Berlin). The head of the survey team was Mag. Florian Wöss (DAI Berlin). In this article I present the final results of the aerial survey, like orthophotographs and image-based models by use of a low cost UAV system – a modified DJI Phantom 1.

Under the auspices of QSAP we planned an archaeological reconnaissance survey in the research area between the Wadi el-Hawad in the south and Meroe City in the north, including both banks of the Nile and parts of the desert and rocky terrains in the east (see WOLF et al. 2014).

For the aerial documentation selected sites throughout the survey region were flown. I used a DJI Phantom combined with a Canon S100 & A2500 camera to produce orthophotos and 3D Models of the landscape and archaeological remains. As of January 2014 I joined the survey of the Deutsches Archäologisches Institut (DAI) Orientabteilung, Berlin, of the Hamadab and Meroe region, Republic of Sudan. A poster documenting the results of this aerial survey was presented at the conference in Vienna. The results of this survey utilised different SfM programs to build the various models and photos. To achieve the best results several Canon cameras, using a KAP/UAV program, were employed. The survey project was innovative by being the first to test a DJI Phantom in a desert environment and actively manage incoming problems such as sand and high temperatures. As well as the results of this 3D modeling, the poster also highlighted the benefits and problems of using and operating DJI UAVs in a desert environment for the purposes of archaeological research.

Keywords: UAV, low cost, image based modeling, North Sudan, 3D Model, aerial photography, SfM.

Introduction

In summer 2011, the Royal City of Meroe and the surrounding area, including the pyramid cemeteries, became a UNESCO world heritage site. In November 2013 an archaeological project was started to survey the area to the south of the newly defined borders of the UNESCO site. The project begun by reviewing the corpus of known sites and features recorded by Friedrich Hinkel (HINKEL 1977) and details such as exact location and state of preservation of these sites were checked in the field. Drawings, photographs and overall descriptions of the sites, as well as of important features, were also undertaken. We further expanded Hinkel's corpus with the inclusion of a significant number of new sites which were also recorded in detail. This combined survey information was entered onto a custom built MS Access database connected with ArcGIS, which was capable of handling such a large volume of both qualitative and quantitative information on these sites, as well as photographs. As the survey area covers some 84 km², the database constitutes a powerful tool to aid and assess current and future research in the region.

The survey covered archaeological sites between the Wadi el-Hawad and Meroe City, comprising the western range of the mountain region and the desert eastwards towards the *jubal*, as well as present-day settlements surrounding the Nile floodplain (WÖSS et al. 2014).

This article focuses on the production of high resolution aerial photographs - using a simple, low cost, modified DJI Phantom in combination with two compact digital cameras - within the survey area, to create image-based models of selected important sites, and to supervise and manage the collation of all survey information on to the data base (see Fig. 1).

Fig. 1 – The DJI Phantom in action (Copyright: F. Wöss, 2014)

Classification of sites according to Hinkel

The survey used maps based on the survey grid originally established by Hinkel. This was combined with modern geo-referenced data provided by Nicole Salamanek of the Beuth Hochschule für Technik, Berlin, who was responsible for all mapping and ArcGIS tasks for the whole Hamadab project. To each new site, a number was assigned following the cataloging system of Hinkel, which was invented to map archaeological remains in Sudan. With the aid of tablet computers and specialized applications such as pdfMaps we could utilize these geo-referenced maps directly in the field during survey, which was a great advantage. Coordinates for all new sites and features were recorded using two Garmin GPS devices (GPS Map 60CSx & GPS Map 62). All aerial photographs and 3D models were also geo-referenced in this way.

Data management and survey methods

The collected data was entered onto a custom built MS Access database, coded by N. Salamanek, F.Wöss and the author (GR). VBA Scripts were employed to build the data management structure. It was intended that the linked tables and photographs should be presented in a software ergonomic fashion, to ease utilization of the database by future researchers. The database is linked to ArcGIS so that every waypoint is visible on the produced maps. In the future we intend to change the database system to a MySQL or JAVA based system, to enable connection to a Geo Server or other form of online geo-referenced presentation.

During survey we undertook detailed description of the sites and features on specially fabricated forms. These were digitalized and scanned and linked to the database.

The dating of these was mainly done with the help of finds collected from features and sites. But also the superstructures of the archaeological remains were analyzed with the help of type cards derived from Welsby D. (WELSBY 2005).

UAV – aerial photography and image based modeling

For the purposes of the survey, we used maps especially adapted from satellite images, which proved extremely useful for the locating and mapping of sites within complex landscapes.

However, satellite images present a number of problems, including logistical obstacles, such as the ability to access up to date images, as well as the nature of the images themselves, wherein shadows from aerial objects and clouds are projected onto the surface, obscuring surface information. Moreover, colour definition of satellite images are often far from accurate (BOSAK 2013).

In order to obtain high-resolution colour photographs we utilised a small UAV device. A preliminary literature review revealed little use of such devices in desert environments, so it was decided to that a low cost system should be incorporated so as to test the initial feasibility of their use in such an environment. Consequently, a DJI Phantom quadrocopter was identified as the most appropriate device for the purposes of the survey. During the January to March 2014 survey season we further modified the camera mounting, as well as some parts of the main system. For the 2015 season a GPS Tracker, FPV system, a three axis gimbal, double battery system, a LiPo safer and modified landing foots were also incorporated.

For the 2014 survey we fixed two different camera models on the UAV device, utilising either a Canon Powershot S100 or A2500. A program called CHDK was used to update the cameras firmware and a KAP/UAV plug in. This application is specifically programmed for returning high quality results in aerial photography. For the 2015 season a Canon Powershot S90 and A3300 were attached to the UAV. For video survey and FPV the Walkera iLook+ camera also proved to be a perfect addition to the device. To facilitate longer flight time stronger batteries were also added so that larger areas and in particular mountainous regions could be swiftly surveyed from the air. Finally, larger propellers were also added on the device for a better and more stable flight position (see Fig. 2).

Fig. 2 – The modified quadrocopter (Copyright: G. Raab, 2014)

Aerial photos – orthophotos

To avoid blurred photographs the cameras were fixed to the device by means of an anti-jelly plate. In producing the orthophotos a measured perpendicular angle was used. For the final processing of these images several different methods were tested, and a common JPG format and the cameras own RAW format was deemed sufficient (see VERHOEVEN 2010). The cameras were programmed to take both JPEG and RAW photographs every three seconds so as to ensure a 60% overlap in the survey images (see Fig. 3).

Fig. 3 – The "Suntemple", Hinkel Site Nr.: NE-36-O/3-J-250 (Copyright: G. Raab, 2014)

To ensure exactitude in geo-referencing and also not referenced photographs TIFFs Agisoft PhotoScan program was used, and for post-processing several analysis software tools and applications were also tested.

A GPS tracker is also now incorporated into the UAV so as to record the exact position of every photograph taken.

Conclusion and future tasks

Problems with low cost UAVs in the landscape of Sudan:

The most common source of problems with operating an UAV in a desert environment is related to heat, wind, sand and silt, and reflecting sunlight. Operating temperatures could sometimes be over 50°C, which occasionally had adverse effects on the energy efficiency of the devices LiPo batteries.

In regions of complex morphology, especially mountainous areas, problems with strong winds provide challenging even for experienced UAV pilots in avoid unexpected crashes. Proximity to large nearby iron objects such as cars or transport containers, as well as large geological formations including iron, were also fund to be somewhat disruptive.

Practical safety concerns obviously necessitated an avoidance of high energy power lines, and any contact with such obstacles usually shut down every WLAN device used of fixed to the UAV because of frequency disturbance.

Solutions for safe flights in desert regions:

In order to safely operate an UAV we suggest programming the device to fly in a diameter of a maximum 300m horizontal around the operator and a maximum height of 70m, to avoid losing contact with the device.

When using a low cost device, it is recommended that the original remote control is exchanged for a professional standard control. Usually the original remote included with a low cost device is poorly insulated against frequency distributions, which would inevitably effect the safety of its operation over long distances.

The Phantom UAV was tested to an outdoor temperature of 45°C and continued to work reasonably well but it was clear that this was the upper limit of the devices ability to operate accurately and efficiently, and therefore operating air temperatures above 50°C should be discouraged.

When faced with high wind speeds (30-40 kph) it is recommended to fly the UAV in manual mode. Occasionally in GPS mode the internal stabiliser required too much time to safely maintain the UAV in position, which would inevitably have an adverse effect on the quality of any photographs derived from such flight conditions.

Sand and dust are obvious problems when operating in a desert environment. To avoid too much silt permeating the inner structure of the UAV it is advised to weatherproof the photo case. If you are landing in the desert try to use a landing platform or “land in the hand”.

It is important to be able to maintain the devices flight capacity in the field during survey, so take as many additional LiPo batteries as you can reasonably carry with you. During the survey, we maintained between 10 and 15 batteries, as high temperatures in particular can render some batteries obsolete. It is also advised to utilise a battery charger with a fast loading option and health status proof.

Spares parts for the device that can safely be replaced in the field is also recommended, or a second identical model of the UAV being used.

Finally, it is advised to record details of every UAV flight in a specific 'drone diary'. It is also best never to fly alone so use a second person to act as a spotter during flights.

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