GeoResJ 3-4 (2014) 1–8

Contents lists available at ScienceDirect

GeoResJ

journal homepage: www.elsevier.com/locate/GRJ

Compact and inexpensive kite apparatus for geomorphological field aerial photography, with some remarks on operations

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ARTICLE INFO

Article history:
Received 2 October 2013
Revised 1 June 2014
Accepted 6 June 2014
Available online 12 July 2014

Keywords:
Kite
Aerial photography
Geomorphology
Sand dunes

ABSTRACT

Equipment for performing low-altitude aerial photography for geomorphological studies on 10–1000 m scales is described, with particular reference to study of sand dunes. An automatic digital camera is lofted by a parafoil kite: the arrangement costs around $400, collapses into a volume of ~2 l and can be deployed in a few minutes, making it convenient for field use when wind conditions (>4 m/s) permit. Some operational considerations are discussed and we demonstrate two scientific applications – change detection to show a dune at White Sands has not advanced in an 11-month interval and the generation of a digital elevation model of Bruneau Dune.

1. Introduction

An aerial perspective is often useful in geomorphological studies, either in its own right or as a bridge between the remote sensing view from orbit and that afforded from the ground. Beyond flying an observer in an aircraft in the classic mode of aerial photography, an array of platforms exist for so-called small-format aerial photography (reviewed in detail by Aber et al. [1]) wherein an imaging capability is deployed from the ground on-site.

Such approaches are facilitated by the ever-growing capabilities of lightweight digital cameras. Other technologies include solid-state gyroscopes that facilitate flight of slow-moving radio controlled vehicles such as quadcopters, and GPS guidance which allows autonomous survey flights by small airplanes. However, these techniques (and the use of balloons, which typically requires the conveyance of heavy helium cylinders to the field) all entail a certain amount of expense and complexity.

Kite aerial photography (KAP) has a rich history, notably from the dramatic view of the destruction of San Francisco by the 1906 earthquake. The field has experienced a renaissance with the availability of lightweight digital cameras, and a web search will reveal many examples. A wide range of systems can be used, from large kites suspending radio-controlled steerable platforms with video viewfinders used in an interactive manner, to simple timelapse devices. This paper focuses on the latter type, with specific application to the geomorphological study of sand dunes, for which kite images were used in a recent book [7]. Since sand dunes tend to be found in windy locations, kiteborne photography is particularly well-suited to this application, and modern parafoil kites (Fig. 1) can be readily packed into a small rucksack for convenient deployment in the field. More particularly, the relatively low cost, mass and volume, and quick deployment and retrieval, means that aerial photography can be attempted with little effort, and can be considered an opportunistic augmentation to other field activities, rather than needing to be a premeditated enterprise.

While aerial photos, or high resolution (<5 m) satellite imaging may be readily available for some locations (notably the continental USA), many desert areas worldwide do not have such coverage. Such data may in any case be years old. KAP with wide-angle megapixel cameras offers the ability to obtain resolution of about 1/1000 of the altitude: thus typical flights to ~10 to ~200 m altitude offer centimeter to decimeter resolutions, in geometries that can be near-vertical, oblique, or near-horizontal. For a range of applications, KAP may be more timely and/or more cost-effective than obtaining spaceborne or commercial aerial photography, and for other applications may provide resolution or view angles that are not otherwise available.

2. Apparatus

Some initial experiments were carried out with a small parafoil kite and a homebuilt timelapse camera using a simple timing circuit 'hotwired' via an optocoupler across the shutter switch of a

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http://dx.doi.org/10.1016/j.grj.2014.06.001
2214-2428/

Fig. 1. Experiments with an early kite camera variant – a homebuilt timer driving a keychain camera, at White Sands National Monument, New Mexico, USA. First author is at left, with Jim Zimbelman at right. Note the curved upper surface of the parafoil kite. Note also that the installation shown here has the camera too close to the kite to fly stably – 10 or meters would perform much better. Photo courtesy of Jason W. Barnes.

small keychain digital camera (see [5]) attached to a bar or small board suspended a couple of meters below the kite bridle attachment point. Reiche et al. [9] describe a similar arrangement for suspending meteorological instrumentation from a parafoil kite. Although a few good results have been obtained (Fig. 2), this approach was unsatisfactory in a number of ways, most particularly because the majority of frames were motion-smeared. This resulted primarily from the slow readout of the cheap detector in the 'keychain' cameras used (such small cameras lack a mechanical shutter), but also because initial experiments tended to attach the camera too close to the kite, leading to higher angular rates. Even taking hundreds of pictures in a flight, not infrequently it was found that no images were useable.

A dramatic improvement is obtained with a more modern camera, optimized for documenting fast-moving sports activities such as surfing and mountain-biking. Such cameras, the example being used here is the HERO GoPro2, have optics and detectors that permit short exposure times and thus much reduced susceptibility to blur. They are furthermore marketed with robust protective housings (see e.g. Fig. 3), and convenient controls to set image acquisition at regular intervals. The image format is large enough (e.g. 2840 $\times$ 2880 pixels) that images can be cropped substantially to show regions of interest with acceptable resolution.

The kite dynamics can also be improved with some care. In effect the camera suspension can be considered as a pendulum. A vital consideration, learned unfortunately by experience, is that the pendulum should have a long period to prevent coupling between the swinging camera and the kite dynamics which can in turn reinforce the swinging. This is avoided by the simple precaution of attaching the camera to the line about 10 m away or more from the kite. This effectively lengthens the swing period to a point where resonant interactions are reduced acceptably.

More elaborate KAP apparatus uses a Picavet suspension wherein a platform is suspended on 4 pulleys, through which a cord passes to attach at two locations on the kite string. This suspension allows the platform to maintain a constant horizontal orientation even when the suspension points move rapidly in space. Such an arrangement is important to avoid rapid scene motion in video, but is generally unnecessary for terrain photography and is somewhat prone to tangling. Simply passing a loop of cord through four holes in the camera platform (for which the plastic display mount for the GOPRO was used) is generally adequate to ensure a generally-horizontal orientation when wind turbulence is minimal. The system used by the author has a $\sim$1.5 m loop of cord, such that the suspension forms 2 legs of about 40 cm length (see Fig. 4).

The suspension cord is attached at two points onto the kite string – most conveniently after the kite has been launched. Remarkably, the weight of the camera and the tension on the line is enough to hold the system on the line even with only a couple of loops of the line around a rigid element such as a carabiner or swivel hook. These elements allow the rapid attachment and removal of the suspension from the line.

The camera mounting itself in this instance is simply the plastic support plate supplied with the camera, onto which the waterproof protective case is attached on a hinge which allows the tilt angle to be adjusted. The plastic plate was trimmed by $\sim$2 cm on 2 sides, and four holes drilled through which the suspension cord is threaded. More elaborate arrangements can be introduced: an automatic mechanism to scan the camera in azimuth increases observing efficiency substantially, although full radio-control pan-tilt mounts with video viewfinders can be obtained commercially. The latter arrangement is significantly more massive (and expensive) than that shown here, and also requires rather higher winds and/or a larger kite.

The distance between the suspension points determines the azimuthal stiffness of the mount. If a rigid mounting is desired (such that the camera platform always points downwind or upwind, along the kite string direction) then the mounts should be far apart (here, about 60 cm), with the suspension forming a right angle. Alternatively, mounting the suspension points close together allows the suspension to swing (or even wrap around) which may be desirable for a wider range of azimuths.

3. Operating considerations

General safety considerations pertaining to kites should be followed – e.g. do not fly near power lines, roads etc. and pay attention to applicable regulations (see [1]) Beyond the camera, kite and line, a few accessories have been found to be useful. First, protective (e.g. leather) gloves are all but essential, as severe abrasion of the hands will occur when winding the kite back in. With suitably close-fitting gloves, the camera can be operated and attached without their removal. A handheld anemometer may be useful in assessing wind conditions, although with practice the wind pressure felt on the face or wind noise can become an adequate guide.

The GoPro cameras have a variety of operating modes, from individual stills to high-speed movies. Most useful in this application is the timelapse setting, where still images at a cadence of under a second to minutes can be automatically acquired. The best cadence is a compromise between acquiring enough images to ensure the available views are obtained, while not oversampling (i.e. obtaining multiple near-identical images, which will fill the