An Innovative System for Low Cost Airborne Video Imaging

Paul Maxwell DARE
Spatial Scientific Technologies Pty. Ltd.
PO Box 520, Blackwood, SA 5051, AUSTRALIA
Ph: +61 405 141 647; Fax +618 8278 8067
paul@spatialscientific.com.au

Abstract: Airborne video imaging has been used for many years for various mapping applications worldwide. Experience has shown that it is a technology that is neither well-suited to spectral remote sensing (due to its poor spectral capabilities), nor is it well-suited to spatial remote sensing (due to its poor geometric properties). Even so, airborne video imaging has proved enormously popular for some very specific mapping applications. One such application is mapping of linear infrastructure features, such as roads, pipelines or powerlines. Any country, whether developing or developed, can benefit from mapping of its linear infrastructure assets. However, to derive full benefit from this type of mapping, the data collection and processing must be both cost-effective and efficient. This paper presents an innovative yet low cost methodology for acquiring airborne video data, based on the use of an aircraft known as a powered parachute (PPC). A PPC is a low cost, simple aircraft which can fly safely at low speeds and altitudes, but still provides an extremely stable platform for imaging sensors. Tests carried out in Australia have shown it to be an ideal platform for airborne video imaging of linear features. However, the choice of platform is only part of the system – the remaining component, which is no less important, is the software that is used to process the video data. Over the years many different algorithms have been developed for mosaicking video images into continuous scenes. This paper also presents a methodology for rectifying, processing, and analysing sequential video images. The resulting combination of platform, camera and software forms an ideal system for asset mapping, which can realistically be implemented in less developed countries.
Keywords: Airborne video; low cost platforms.

1. Introduction

Over the years, the term ‘airborne video’ has been used for many different types of airborne imaging technology. Historically, airborne video has referred to any airborne image data that did not come from film-based cameras, either small or large format, or digital line scanners. Thus early airborne video systems were based around analogue video cameras. However, as technology progressed, the term airborne video was also used to describe early small format digital frame cameras. Now that small format digital cameras (and large format ones as well to some extent) are ubiquitous, the term digital aerial photography is better used to describe image acquisition form these types of cameras. Consequently, the term airborne video now best describes imaging from a video camera, either analogue or digital. This paper is therefore concerned with only those sensors, and not the wider spectrum of digital airborne cameras.

Airborne video imaging has been used for remote sensing applications for many years. Early airborne video systems relied on analogue data, whereas more recent systems make use of digital video or even high definition video. Previous catalogued uses of airborne video are numerous, but include environmental mapping, natural resource management and asset mapping. Examples of environmental mapping where airborne video systems have been used include agricultural assessment [1], forest health mapping ([2], [3]) and coastal zone monitoring [4]. Linear asset mapping applications have also been described ([5], [6]).

The advantages of using airborne video for remote sensing applications are cost and simplicity. The disadvantages are that the data lacks the geometric quality of digital SLR cameras, as well as lacking the spectral quality of digital multispectral cameras. In the past, use of video was justified since it was probably the only true low cost sensor available. However, nowadays the wide availability of many advanced digital still cameras which are priced at the same level as digital video cameras means that the use of airborne video is much more difficult to justify. Consequently, airborne video should now only be used for niche applications where other sensors are just not suitable.

The keys to the successful use of any remote sensing system is choosing the correct sensor for the application, and using the appropriate platform. This is also true for airborne video. Modern airborne video is ideally suited to low budget applications where rapid data delivery is required, but where spectral and spatial quality is not paramount. Alternatively, airborne video can be a valuable source of spatial data when it is literally impossible to acquire any other data. In order to support these applications, the video sensor must be mounted on a flexible, low cost platform. This paper proposes the use of a powered parachute as a platform for the airborne video imaging system. This novel concept will likely to prove itself extremely valuable in certain niche applications, both in developing and developed nations.

The three components to the innovative imaging system described in this paper are:

- the imaging device – a video camera
- the aerial platform – a powered parachute
- software for data processing

Each of these components are described in the next three sections, followed by a description of how their integration can be used for a range of different mapping applications.

2. Video Imaging Devices

A range of cameras are available for airborne video imaging. They differ in terms of size, quality of image data and cost. The cheapest cameras, and those that offer the poorest quality data, are analogue video cameras. The reason for the poor quality of the data is because moving images in the video data are created by interlacing pairs of sequential image frames. With high frames rates it is not possible for the human eye to see the interlacing, but when the frame is frozen the interlacing effect is clear, especially if features within the images are moving (figure 1).

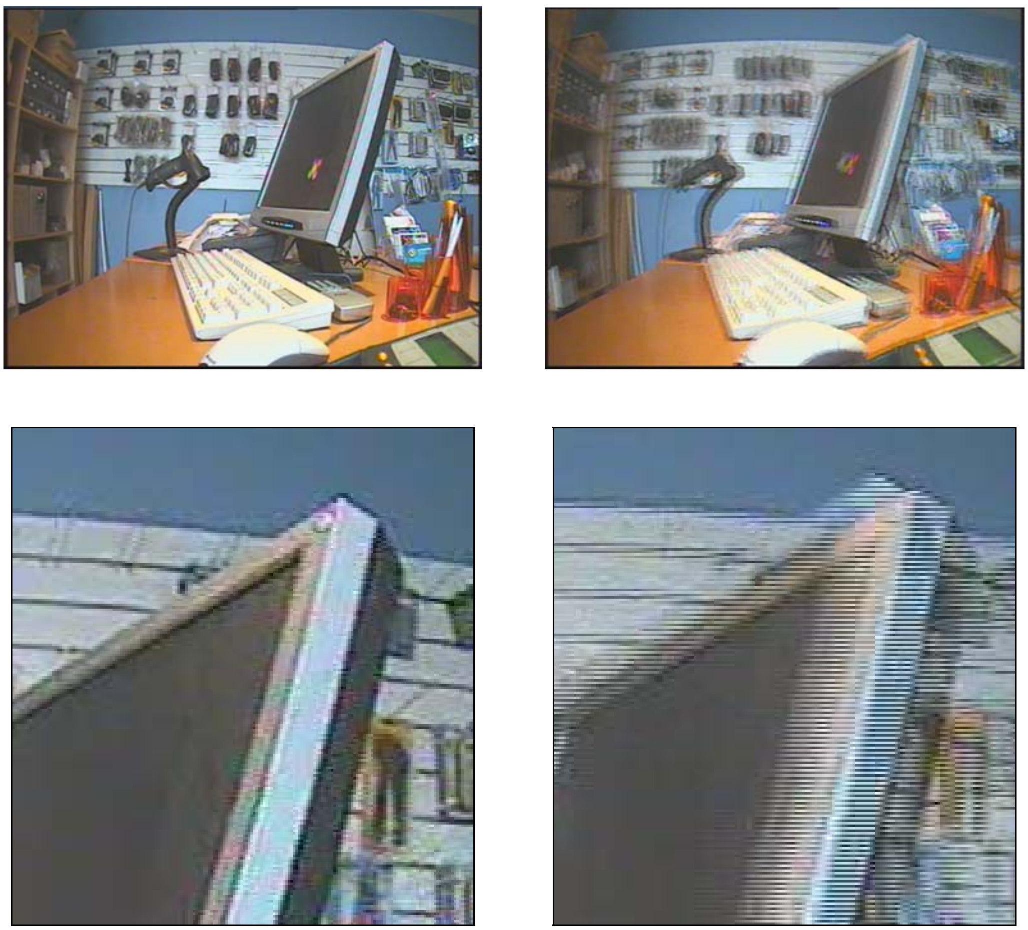

Fig. 1. Interlacing effects caused by moving features in analogue (interlaced) video imagery
(Top: full frame images; bottom: detail from full frame images).

Figure 1 shows the effects of interlacing. The images on the left are stationary, and therefore frames extracted from these images appear normal. However, when the camera is moved (the images on the right), features move in the images, and the interlacing becomes evident. It is clear that the frame is actually made up of two sequential frames that are interlaced together. Consequently, when analogue video cameras are used for mapping purposes, the effects of interlacing can often be problematic [7].

In recent years digital video camera technology has superseded its analogue counterpart. Analogue video cameras tend to be older, bulkier, and have less functionality. Consequently there are few compelling reasons to consider analogue video technology as a source of data. However, one strong reason for using analogue video cameras is that some modern cameras are available that are extremely small. These small video cameras, often known as lipstick cameras or bullet cameras, contain the lens and imaging sensor, but are reliant on a camera for recording the data. A typical lipstick video camera is the Sony XC-999 (figure 2). The dimensions of this camera are approximately 120 × 22 × 22 mm.

Fig. 2. Sony XC-999 lipstick video camera.

The compact size and light weight of lipstick video cameras means that they can be easily installed on a range of aerial platforms. There is no need to build a robust camera mounting system – these cameras can literally be attached to an aircraft using strong tape and cable ties. Obviously the low cost, ease and flexibility of the installation make cameras of like this extremely useful.

For most applications, but not necessarily all, it is necessary to extract individual frames from the video imagery for mapping purposes. To do this with analogue video imagery a video capture device must be used – this is a piece of hardware that links a computer to a video source. Video imagery can then be converted to a common digital file format, such as AVI or MPEG, from which frames can be extracted.

The next step up from analogue video is digital video. Digital video is currently the standard in video imaging technology, and offers many advantages over analogue video. In particular, digital video data can be captured in a non-interlaced format known as progressive scan. The problems of moving features showing interlaced artefacts in the imagery (illustrated in figure 1) are removed because each image is captured sequentially, and only one image is used to create a frame of data. Importantly, digital video imagery can easily be converted to a digital file format, such as AVI or MPEG, through the use of a Firewire (IEEE1394) link. This removes the need for a video capture device. Generally the data from digital video cameras is of much greater quality than that from analogue video cameras. Additionally, digital video cameras offer more functionality and flexibility of use compared to their analogue counterparts.

Recently the first consumer high definition (HD) video cameras have become available. Since mid-2005, Sony has been marketing a HD Handycam, the HDR-HC1 (figure 3).

Fig. 3. Sony HDR-HC1 consumer high definition Handycam.

HD video offers much better image quality through high resolution image capture. Images are recorded over 1080 scanning lines, as opposed to 720 scanning lines for standard definition (SD) PAL video. The aspect ratio of the image is 16:9, compared to 4:3 for SD video. This results in a much wider image, specifically designed for the latest generation of widescreen HD televisions. The implications for airborne video is that data can be collected at a higher resolution than is possible with SD.

As can be seen, there are many options for acquiring video imagery for mapping. The choice of imaging system should be determined by the application in question. Once the imaging system has been chosen, the platform on which that system will be mounted can be selected. As with the imaging system, the platform should be chosen according to the specific needs of the application. In many scenarios where airborne video is used, the ideal platform will be a small, low cost system. The next section of this paper describes perhaps one of the smallest airborne platforms, the powered parachutes.

3. The Powered Parachute – An Innovative Aerial Mapping Platform

The concept of using of small, lightweight aircraft for remote sensing is not new ([8], [9]). However, in the past the use of small aircraft has not been widespread due to limitations in imaging technology. Nowadays, however, good quality imaging technology has reduced in size and weight, such that it can now be installed into a small aircraft.

One of the smallest manned aircraft which can be used for remote sensing data acquisition is the powered parachute (figure 4). A powered parachute (PPC) is a two seat aircraft, powered by a single engine, and slung beneath a parachute canopy. The engine provides the thrust for forward motion, and the parachute canopy provides the lift for vertical motion. A PPC can take off in distances as small as 15m, can fly as high as 5000 feet, and can maintain speeds of up to 40 km/h. Importantly, the lifting capacity of a PPC is 200kg, which is more than sufficient for the pilot, a camera, a computer system etc. Furthermore, PPCs are extremely stable platforms, and can be flown after just a few hours of training.

Fig. 4. Powered parachute, on the ground and in flight.

Integrating a camera onto a PPC is a task that can be simply carried out by a suitably qualified engineer. Powering the camera, computer, GPS and any other instrumentation can be done from rechargeable dry cell batteries.

In summary, a PPC is the ideal platform for low cost mapping applications that do not cover a wide area. They are especially useful for applications where it is very difficult, or even impossible, to a light aircraft.

4. Software for Processing Airborne Video Imagery

Airborne video imagery can be used in two ways: either as a source of spatial data where sequential images are mosaicked together to form continuous image strips, or where the original moving images are used. Either way, software must be developed for processing and value-adding in order to create a useful spatial data product.

4.1 Software for processing discrete frames

In the past many different methodologies have been presented for processing sequential frames of video image data to create continuous image strips ([6], [5]). Some of these methods are more complicated than others, and some are more successful than others.

A simple methodology is presented here for mosaicking images together. An image matching algorithm automatically extracts tie points from the overlap area between two sequential images. Using those tie points, the pair of images are registered to each other using a conformal transformation function. That transformation function is then used to estimate the alignment of the next image in the sequence. In this way the search space for tie points between the second and third images is greatly reduced, hence speeding up the process of automatic image matching. This process is repeated for all of the images in the sequence.

It is important that a conformal transformation function is used in the mosaicking process since this reduces the degree which errors are propagated in the registration process. Higher order polynomial transformations functions propagate errors much more rapidly, even though they may initially give better registration results. Some typical image mosaics are shown in figure 5.

Fig. 5. Typical image mosaics from airborne video imagery

4.2 Software for utilising continuous image sequences (movies)

In addition to using airborne video data for creating spatial image mosaics, the movie data can also be extremely useful for applications such as asset mapping (pipelines, powerlines roads etc.). However, to derive full benefit from the data, it needs to be processed to add value. One way of adding value to the data is by annotating the movie with information such as data and time of acquisition, and latitude and longitude of the camera. As a part of this investigation into airborne video imaging, software has been developed by the author for this purpose, the result of which is shown in figure 6.

Fig. 6. Annotated video imagery

The images shown in figure 6 are three images that have been extracted from the processed movie file. All of the images in the movie file have been annotated with date of acquisition (1st June 2005 in this example), and latitude and longitude of the camera at the time of acquisition. Further information, such as type of camera used, time acquisition, flying height etc., can all be added as required. By spatially and temporally referencing the images in this way greatly increases their value to the end user, and makes them more accessible through a GIS.

In summary, software for processing airborne video data is essential to ensure that the end user can derive full value for the imagery. There is little available commercial off the shelf software for processing airborne video data, hence the reason that the software described here has been custom developed. The next section of this paper now describes how the three components of the proposed system, camera, platform and software, are brought together to create an innovative, low cost aerial mapping system.

5. Mapping from powered parachutes

5.1 Overview of video mapping from powered parachutes

So far this paper has described the three components essential for any aerial mapping system (the camera, the platform and the software) with an emphasis on low cost and flexible data acquisition. By combining a video imaging system with a powered parachute and custom developed software results in an aerial data acquisition system that is easy to build, cheap to fly, and can be used in some the of the most remote parts of the world. The specific advantages and disadvantages of airborne video acquisition from powered parachutes are listed in table 1.

Table 1. Advantages and disadvantages of mapping from a powered parachute

Advantages	**Disadvantages**
System is cheap to build (less than US$20,000)	Not suitable for mapping wide areas
Running costs are very low (less than US$25 per hour)	Low quality spectral information from video imagery
System can be used in remote areas	Geometric quality of video imagery is variable
Slow speed and low flying height means high resolution data	Limited to flying in good weather (wind less than 20km/h)
Technology is very simple – can be serviced and maintained cheaply	Software must be custom designed (commercial off the shelf software not widely available)
System can be taken to field site by small pick-up truck, or towed behind a car	
Rapid data delivery	

Although the proposed system does have some limitations, they are not all considered to be important. For example, the limitation of not being able to use the system for wide area mapping is somewhat irrelevant since that is not an application for which the system is designed. Additionally, the spectral and geometric limitations of video data well known, so video data should only be used as a data source when these limitations do not impact negatively on the application. The other disadvantages of this system (weather and software availability) cannot be avoided, however, and must be worked around.

5.2 Typical applications

The typical applications for which the proposed imaging system can be used are dictated by the attributes of the system. The spectral and geometric limitations of the video imagery makes it unsuitable for advanced remote sensing applications, such as vegetation health studies or topographic mapping. However it is useful for:

- Corridor mapping – mapping of linear infrastructure features, such as roads, railways, pipelines, and powerlines.
- Emergency management – rapid mapping of the spatial distribution of damage from disasters such as earthquakes or tsunamis.
- Archaeological mapping – an application where very high resolution data is useful, but precise radiometry and geometry are not essential.
- General mapping of inaccessible regions.

The most important of the above applications is probably the last one – the mapping of inaccessible regions. Places such as isolated islands or remote communities without airfields suffer from the fact that it is not possible to costeffectively map their land cover features. Satellite imaging is always an alternative, but its limitations means that it is not always the most appropriate source of data. In such cases, the proposed system offers a viable alternative.

In addition to the applications listed above, there are no doubt many other scenarios where the system can be usefully applied.

5.3 Implications for developing countries

An important potential use for the proposed imaging system in is developing countries. Previous studies have suggested that developing countries have a need for low cost, simple to operate systems that can be put in place very rapidly [10]. If this is the case, which it no doubt is in some developing countries, then the proposed system would be potentially very beneficial. Powered parachutes are ideal platforms for use in developing countries due to the simplicity of their construction and low maintenance requirements. They are typically powered by 58 horse power, 2 stroke engines, which can be maintained and serviced by any moderately qualified engineer. The challenge is now to prove the value of airborne video data acquired from powered parachutes, through some form of validation programme, to encourage organisations to take up this new technology.

6. Concluding remarks

This paper has discussed the merits of acquiring airborne video imagery from a powered parachute. The system is cheap, flexible and simple to implement and operate. It can be used for a variety of mapping tasks, and is particularly applicable to use in developing countries, where spatial data is required, but where sources of data are very limited. Although it suffers from some drawbacks, they are not significant, and do not negate it's potential effectiveness.

The first stages of development of this system have already been carried out. The platform has been tested for stability as an aerial mapping platform, and from the data collected it has been shown to be very suited to this type of work.

The next stage of development of the proposed system is to source funding from interested organisations who wish to support the validation phase of this project. Once validated there is nothing to stop the system being transferred to anyone who has a need for it.

7. References

[1] Everitt, J. H., Escobar, D. E., Villarreal, J. R., Noriega, J. R. and Davis, M. R., 1991. Airborne video systems for agricultural assessment. *Remote Sensing of the Environment* 35: 231-242.

[2] Dare, P. M., Zerger, A. and Pickett-Heaps, C. A., 2002. Comparative evaluation of Ikonos, airborne linescanner and oblique-looking video for mapping manna gum (*Eucalyptus viminalis*) health in South-Eastern Australia. *Asian Journal of Geoinformatics* 3(1): 63-69.

[3] Prost, C. J., Zerger, A. and Dare, P. M., 2005. A multilayer feed-forward neural network for automatic classification of Eucalyptus forests in airborne video imagery. *International Journal of Remote Sensing* 26(15): 3275-3293.

[4] Buckley, S. J., Mills, J. P., Clarke, P. J., Edwards, S. J., Pethick, J. and Mitchell, H. L., 2002. Synergy of GPS, photogrammetry and INSAR for coastal zone monitoring. *International Archives of Photogrammetry and Remote Sensing* 34(4).

[5] Um, J. S. and Wright, R., 1999. Video strip mosaicking: a two dimensional approach by image bridging. *International Journal of Remote Sensing*, 20(10): 2015-2032.

[6] Dare, P. M. and Fraser, C. S., 2001. Automatic mosaicking of airborne video images: an operational example of powerline mapping. *Geomatics Research Australasia*, 74: 11-24.

[7] Pickup, G., Chewings, V. H., and Pearce, G. (1995). Procedures for correcting high resolution airborne video imagery. *International Journal of Remote Sensing* 16(9): 1647-1662.

[8] Dare, P. M., 2005. The use of small environmental research aircraft (SERA's) for remote sensing applications. *International Journal of Geoinformatics*. Accepted for publication – in press.

[9] Graham, R. W., 1988. Small format aerial surveys from light and microlight aircraft. *Photogrammetric Record* 12(71): 561-573.

[10] Rokhmana, C. A., 2005. "Aerial Mapping by Consumer Camcorders." *GIM International*, 19(2): 40-43.