Compact Airborne Image Mapping System (CAIMS)

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ABSTRACT:

Airborne image mapping systems, to a large extent, remain the preserve of specialist aerial survey companies and research groups. This paper describes the current status of the CAIMS project, established in July 2006 at the National Centre of Geocomputation, National University of Ireland, Maynooth with their industrial partner; Compass Informatics, Dublin. It's chief objective is to develop a compact, less complex, mobile airborne mapping system.

Historically, aerial survey systems comprise technically complex and expensive image mapping systems. These high-end camera and navigation systems are usually installed in aircraft that have been specially adapted to carry out this activity. A dedicated full time team, including Survey Manager, Pilots and Observers are required to support this activity. Compounding the situation is the cost of advanced software modules and associated Data Processing specialists required to turn these data into useful georectified and orthorectified image products. Meanwhile, more advanced, less complex, reasonably priced imaging and navigation sensors continue to appear on the market. Allied to this trend are less complex, cheaper data processing modules enabling data to be collected and processed in a cost effective and timely manner.

The CAIMS project was setup to review current technology for compact, relatively in-expensive, mobile aerial image mapping systems. The chief research objective was to develop a complete system in terms of survey operation, data acquisition and processing. Some secondary objectives include: (i) the development of a compact acquisition system that could be installed in common light-aircraft, using a removable, fully licensed mounting system; and (ii) the development of in-flight survey management software tools and downstream pre-processing modules enabling rapid turnaround of georectified mosaics. No attempt is made to reduce the role of conventional image survey systems but rather it is to look at areas where this new technology could be used to complement existing survey work and, indeed, open up new sectors. Some examples of the latter include development of rapid mobile aerial mapping methodologies and route corridor surveys. The results of this work will help develop novel solutions for some age-old aerial survey problems and so enable a wider audience access to this rapidly evolving technology.

Background

Airborne remote sensing can trace its roots back to the late nineteenth century (Airborne Camera, 1969). More recently, aerial cameras systems have evolved from film-based to digital camera sensors (Kain et al, 2004). Aerial digital cameras can be classified based on their collection geometry (line or frame), sensor heads, multispectral capability, image format, data recording and associated navigation sensors (Cramer, 2004). Some of the higher-end aerial camera systems provide excellent data but complexity and associated costs still limit their use to a small specialist group using specially adapted aircraft. Examples of these higher-end cameras include ADS40 from Leica Geosystems (Leica 2007a) and Digital Sensor System (DSS) from Applanix (Applanix 2007). A number of digital aerial image mapping systems have been designed around commercially available small and medium format cameras including Kodak DCS 420 (Greer, 1997) and Canon EOS series (Sladojevic et al 2006). These systems still fail to address some of the issues which limit the wider employment of this technology. These issues centre around a core data acquisition system, ancillary platform modules and downstream processing. The core data acquisition system includes survey planning modules as well as triggering and recording modules. Ancillary platform modules include camera mount and power. Downstream processing deals with the steps required to turn images into useful georeferenced and orthocorrected products. Directly linked to these issues are complexity and cost. These need to be minimised in order to encourage wider use of this rapidly evolving technology for mobile mapping applications.

Compact Airborne Image Mapping System CAIMS

The system comprises a 12.8MP Canon EOS 5D digital camera capable of acquiring images 4368*2912 in size (Canon, 2005) connected to a General Dynamics XR-1 ruggedized laptop. This laptop has both MIL-810F and IP67 ratings and is ideally suited to operation in this mobile mapping environment where equipment is subject to vibration and temperature change as well as to continual movement in/out of aircraft (General Dynamics, 2007). Data acquisition software was written based on Canon's RC V8.4 SDK to acquire and store images (Canon, 2007). This software is capable of controlling image capture based on current aircraft position along a flight survey line or based on a fixed time interval. A maximum, sustained image capture rate of one frame per 2 seconds is possible with the current system. A GPS is also connected to the laptop.

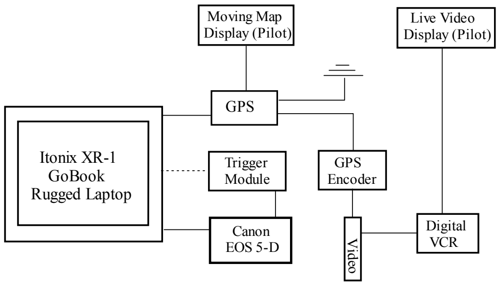

Figure 1. Schematic of data acquisition system

This allows a GPS position to be logged at time of image capture. These data are logged in a separate file. The GPS is also encoded onto live video stream and logged onto a digital VCR. Current GPS position and planned course is available on a yoke-mounted Garmin 96 (Garmin, 2007) display which has basic moving map capability. This is used to fly pre-planned routes as a series of way-points. The live video feed is displayed on a co-mounted monitor display. This enables the pilot to track linear features such as rivers and roads which may not be depicted in any great detail on conventional maps due to poor map revision.

Core Data Acquisition Module

Software modules were written using Microsoft .NET (C#) and VB for planning surveys, controlling acquisition and formatting data for downstream data processing. Canon's software development kit; RC V8.4 SDK was used to acquire and store images (Canon, 2007) and ESRI Mapobjects 2.1 (ESRI, 2007) was used for all spatial data handling.

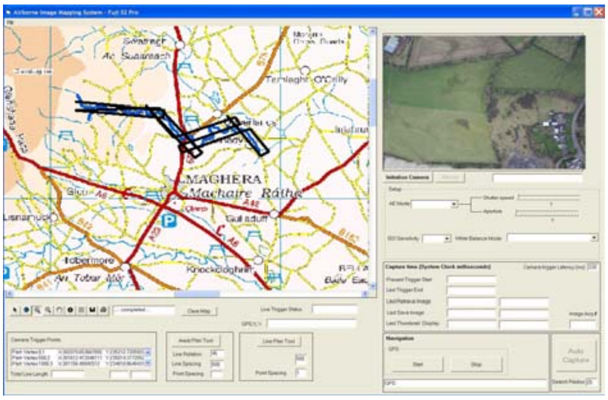

Figure 2. CAIMS software comprising survey planning, data acquisition and pre-processing modules

Survey planning module: This allows the user to choose either a block or linear feature survey. The former applies to features such as forest stands, agricultural fields and municipal buildings ie features with areal extents. The latter is applicable to roads, rivers, coast-lines - features that are linear in nature. A polygon tool is available for block survey planning and a simple line tool for linear survey planning. The user first traces the extent of the feature on the map display, enters planned flying height, focal length and amount of along-track and across-track overlap required. Preferred flight line orientation can be chosen for block flying. A 24mm lens was used so swath width was roughly 1.4 time flying height above ground level. Flight lines and associated camera trigger points are automatically calculated. These coordinates are then available for upload into a tracking GPS.

Data Acquisition: The position of the aircraft is plotted on a *moving map* during data acquisition. Any planned survey can be loaded and the operator can choose whether he/she acquires images based on calculated trigger points from survey planning or from a pre-set, fixed time interval. A tolerance can be set by the operator eg 50m so, that an image is acquired only if the aircraft comes to within 50m of the intended trigger point. A fixed time interval can be used if the base map data are unsuitable and the pilot is tracking features using live video display. GPS position is logged continuously against system time. Images are tagged with system time at the moment of capture. The track of the aircraft is plotted on the moving map display and this can be cleared at any point to reduce clutter.

Installation issues

Power Module: One important feature, sometimes overlooked, is power supply for all components. This is important when designing mobile mapping systems for airborne platforms. Operators are usually keen that little or no power is drawn from the light aircraft since this may invalidate operational guidelines (EASA 2007). The XR-1 laptop has one main battery and one backup supplying between 5.5hrs and 7hrs battery time (XR-1, 2007). All other components: camera; video; VCR; GPS encoder; monitor and GPS displays have their own power supply. In addition, a 12 VDC gel-cell power pack with multiple *cigarette lighter* outputs is also available. This together with a 300W NiKKAI inverter (Maplins 2007) provides primary power to all components except the laptop. All components have their own short term batteries installed in the event of primary source power failure.

Light aircraft camera mount: Aerial image mapping has, historically, been an activity reserved for a small group of highly skilled personnel. This is due to a combination of factors including the largely specialist nature of the aerial survey and the complexity of aerial image mapping systems. Installation of typical aerial image mapping systems requires rigorous certification for any modification to aircraft operating in a commercial capacity. Allied to all of this are the associated costs. Camera mounts can become a stumbling block since the aircraft usually requires some form of modification to the airframe. Some solutions involve cutting a hole in the fuselage; others entail fitting external enclosures. Both can be expensive in terms of engineering and certification. Suitable camera mount solutions that are relatively inexpensive and certified are a central factor in the wider roll-out of compact airborne image mapping systems, (McCarthy, 2006). The disadvantage of cutting holes in aircraft for camera mounting is that, not only is it expensive but also the aerial image mapping system is inextricably linked to that particular aircraft.

Figure 3. C-172 Light aircraft mount designed and constructed by NCG team, front view.

The complexity of aerial image mapping sensor technology has changed with the recent development of small and medium format digital SLR cameras. These cameras can be connected to compact laptop computers that control acquisition, tagging, compression and storage to hard disks. Smaller digital cameras no longer require specially engineered apertures cut into the floor or bulky external enclosures. External mounts, with a quick release mechanism, can now be a lot more compact and have the added advantage of allowing the user to use any aircraft of that type since the enclosure can be easily detached. Availability of camera mounts for aircraft has gradually improved over the last decade.

Some UK CAA mounts for light aircraft include baggage door mounts; AAN 25230_1995; AAN 20430_1987 as well as wing strut mounts AAN 27643_2003 (AAN, 2007). There are a number of examples of baggage door mounted cameras on USA's FAA register (FAA, 2007). One private agency received FAA field approval for a wing strut mounted camera (McCarthy 2006). This strut was used for both video camcorders and compact digital cameras.

Figure 4. Light aircraft mount designed and constructed by NCG team depicting camera cage

The CAIMS team elected to design a suitable camera mount to fit the wing strut of a Cessna-172 aircraft. This aircraft type was chosen since there are over 50,000 C-172 aircraft and Pilots worldwide (Kain, 2004). Also, Cessna design and build other high wing light aircraft (Cessna, 2007) so, this mount could easily be adapted to fit strut-chord dimensions with minimum engineering modifications. The mount is designed to enclose most industry standard digital cameras. An aperture at the bottom enables full view of the ground below the aircraft and can accommodate a digital SLR camera as well as a compact video camera. Cable holes on the top of the enclosure allow trigger, power and data cable group to link the external camera with the internal laptop, navigation and timing sensors. The mount, which can be swivel-mounted on either port or starboard wing, can be fitted by a non-specialist in a few minutes. It can also be placed at any location along the wing strut chord although minimal offsets between pilot and camera position are achieved at the lower end of wing strut. The aircraft mount is presently undergoing both FAA and EASA certification (FAA, 2007; EASA, 2007)l. It is likely that this development will help aerial mapping become more accessible to a wider audience.

Data Processing

Data Pre-processing: Data acquisition with this system can produce large quantities of data in a relatively short time. For example, two hours survey flying can produce over 3600 image files totalling 21GB in size together with associated navigation log files. Some of these data are redundant, however, or not of any great interest. Pre-processing data enables useful imagery together with associated navigation details to be separated and stored in a structured fashion. The track flown can be compared with the planned survey flight lines to check quality and completeness of the survey. Along track and across track stereoscopic coverage can be set so that only imagery matching the parameters are extracted and saved for further processing. This results in a structured dataset which helps speed up georectification or orthocorrection during the main processing stage. A software module has been written to enable the operator to perform these steps and output a range of control file formats. These are usually required by georeferencing or orthorcorrection applications and comprise essential information on such items as images names, locations, nominal GPS image centre, camera model etc. Planned and flown flight lines, together with thumbnails, enable rapid review by operator before the main processing.

Georeferencing and orthocorrection: Many photogrammetric software tools are available for processing digital aerial images. These include Leica Photogrammetry Suite from Leica Geosystems (Leica 2007b), Geomatica from PCI (PCI 2007), Inpho (Inpho 2007) and BAe's Socket Set (BAe, 2007). Other systems, perhaps less well known, include EnsoMosaic (Enso, 2007) and PhotoMOD (Photomod, 2007). Processing data remains a relatively cumbersome task for small to medium digital camera format cameras. Factors that affect smooth processing include choice of camera and lens, variable terrain availability of quality navigation onboard the aircraft as well as lack of quality GCPs. All of these data processing systems are currently undergoing testing using aerial imagery collected by CAIMS .

Results

Testing of the system began February 2007. So far, over 1500km of data has been collected over linear and areal features for River habitat studies and Noise Modelling along road corridors. The whole system fits into a 35 litre rucksack and can be fitted to the aircraft in less than five minutes. CAIMS is designed to operate for 5 hours, matching the maximum endurance of the current Cessna-172.

Figure 5. Mosaic test output from Leica's LPS (ERDNDIA)

CAIMS has been tested in varying external temperatures of between -5°C and +15 °C. Over 80% overlap along tracks and 50% across track overlap has been achieved at a flying height of 1000m AGL using 24mm lens with corresponding resolutions of between 10cm and 20cm. Operators with little or no knowledge of mapping or surveying have used the system to plan surveys, acquire data and then pre-process data for final orthocorrection. They have found the system robust and easy to use. Choosing the optimal photogrammetric data processing route is the main focus of current work since this will ensure a smooth and efficient work flow from survey planning right through to data delivery. It is clear though that direct georeferencing techniques (Toth et al, 1998; Sun, 2006; Light 2001; Mostafa et al, 2000) on board the aircraft will help speed up downstream processing.

Conclusions

CAIMS has been designed as a compact, modular, easy to use, inexpensive, mobile image mapping solution. The entire acquisition system can be installed in less than five minutes and operate for up to five hours. Survey planning, data acquisition and data pre-processing software modules have been written and tested. These modules have improved work flow from survey-planning right through to data pre-processing. Aircraft camera mounting solutions have been identified as one of the issues hampering wider use of mobile, airborne image data acquisition. One mount design is presently undergoing certification. Data processing using photogrammetry software for compact airborne imaging systems remains relatively cumbersome although direct georeferencing offers faster downstream processing. It is likely that CAIMS will be modified in the short term to incorporate a more comprehensive navigation sensor system.

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