LOW COST IMAGE MAPPING FOR GIS USING A REMOTELY CONTROLLED MODEL AEROPLANE

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ABSTRACT: Mapping from small scale remotely piloted vehicles (RPVs) is not a new concept. The idea is so appealing in terms of its apparent simplicity and cost effectiveness, that numerous attempts have been made with varying degrees of success. However, to date, a commercially viable solution seems to have eluded us. It is true that military and police operations are carried out using RPVs but the criteria for mapping purposes differs somewhat from those used for surveillance operations.
This paper discusses an experiment in which an attempt was made to circumvent the stability problems associated with small RPVs by using a continuous imaging device (a video camera) which would enable a subsequent selection of suitable images (frames) regardless of the turbulence encountered during the flight. It was anticipated that some of these images may be geometrically marginal and only suitable for processing using digital photogrammetric techniques. This technology now exists on personal computer platforms which leads us to believe that the commercial viability of mapping limited areas using small scale RPVs will soon become a reality.

1. INTRODUCTION

From time to time, an idea or concept emerges and disappears only to resurface at a later date. This may be due to the fact that problems which are difficult to solve, render the idea inoperable for the technology of the time.

As technology advances, some of the previous difficulties are easily overcome and the opportunity for a new approach presents itself.

We think that technology has now advanced to the stage where it is worth revisiting an old idea i.e. aerial photography from miniature airborne platforms.

This paper looks at the possibility of harnessing, in a cost effective manner, existing products to develop a working system of data acquisition. This method would have numerous applications for a myriad of surveying related tasks and if successful, could considerably reduce the cost of data acquisition.

Military and police surveillance operations have driven the development of GPS, avionics and telemetric systems to an operational level. It would seem that an adaption of these systems for mapping purposes would be relatively straight forward. Let us examine the problems associated with miniature airborne platforms.

2. PLATFORM STABILITY

Small platforms are very prone to weather conditions, particularly wind. Gusty conditions play havoc with the attitude of the aircraft causing high angles of tip and tilt and rotation.

Line of sight control from an operator on the ground is very difficult because at altitudes even as low as 300ft, the airborne unit becomes difficult to see clearly and therefore to correct for change in position and attitude.

3. PLATFORM POSITIONING

The simple RC (Radio Controlled) platform has line of sight communications. Lose the communication and you lose aircraft and payload. Positioning is a matter of skilful judgment by the ground pilot and is consequently subject to gross errors. Altitude estimation is equally difficult so that the *XYZ* coordinates of the camera station have a low level of reliability.

Usual aerial mapping techniques involve an aircraft flying at constant elevation on a series of parallel 'runs' taking a series of still photographs with typical forward overlap of 60% and side lap of 25%.

To achieve this with a miniature platform would require a complete solution to the stability and positioning problems. We do not, as yet, know whether this can be done in practice, but it looks promising given the new technologies of avionics and GPS.

Miniature avionics units are readily available to the model aircraft hobbyist. These units are available within a range of sophistication depending on price. At one end of the scale is the autopilot with a height lock which automatically engages should line of sight communications be interrupted. The model will cruise to a preset altitude and will circle slowly until retrieved or until it runs out of fuel. This type of system can be purchased locally for around AUD$2,500.

At the sophisticated end of the scale, surveillance RPVs (remotely piloted vehicles) carry an integrated system comprising an avionics unit for RPV control and stability in three dimensions, a GPS (Global Positioning System) unit for navigation and position fixing and a telemetry unit for real-time links to a ground station. Using equipment such as this, the photo mission takes on the precision and flight planning characteristics of a full-scale operation. Way points can be pre-set and RPV movements monitored from the ground station on a video display. Changes can be made in real time to any pre-set parameters. A full system of this type costs approximately AUD$40,000. With this latter equipment it would seem that stability and RPV positioning problems have been largely solved enabling us to concentrate on image capturing.

Our experiment relied entirely on digital photogrammetry, not as a solution to the platform stability problem, but in an attempt to circumvent the platform stability problem. The positioning problem was approached indirectly as well. Rather than trying to control the RPV's position precisely we decided to continuously record images and then select appropriate frames subsequently. This meant a normal 25 frames per second video camera could be used. This approach meant that our equipment requirements for the photo operation amounted to just three items: An Aerial Platform, a Video Camera and a Pilot. We were very fortunate to enlist the services of Jim Oliver as a provider of an RPV and also a pilot, and Joe Van der Maat of the AudioVisual Section of QUT for the video camera. Without the excellent cooperation of these two people this experiment would not have left the ground.

The RPV used was in fact a model aircraft, that is a quarter-scale Cessna L-19/0-1, commonly called a "Bird Dog", with a wing span of 108 inches, a wing area of 1450sq inches. Jim's willingness to cut a hole in the bottom of his model and to modify the cabin area to accommodate the camera is due to his generosity and inquisitive nature and we thank him immensely. The model was powered by a 38cc petrol engine (for reliability), the camera was a hand-held CamCorder.

4. PROBLEMS ENCOUNTERED ON FLIGHT

As anticipated wind-gusts were the major factor influencing the stability and positioning of the aircraft. Notwithstanding the early morning take-off time, there was sufficient air turbulence to cause yawing rotation, tip and tilt of an extreme nature with respect to normal aerial photography. Another major image defect was due to vibration from the petrol engine. The camera had been heavily padded and suspended in foam and bubble-wrap for two reasons: one, was to eliminate vibration; and secondly, to protect it in the event of a mishap. The specially procured engine mounts were also meant to eliminate vibration. Video cameras seem to be especially sensitive to vibration and in this case the situation was exacerbated by the vertical attitude of the camera.

Solutions to the positioning and stability of the RVP already exist in the form of miniature avionics units discussed previously. Vibration problems might be eliminated if the lens was remote from the recording tape, such as a CCD (charged coupled device) Camera linked by telemetry to a ground recorder. Depending on funding these hardware systems will be trialled in future experiments.

5. DESCRIPTION OF THE TECHNIQUE

The technique is based on using digital imagery at all stages of the mapping process. Normally, film is used either for data acquisition or for the production of the final map. Using digital techniques leaves control of the process with the user.

The first step is to acquire video imagery using a remotely controlled platform, which in our case was a remote controlled model aeroplane. The video camera was mounted in the aeroplane and directed vertically downwards. The camera was switched on before the flight and after the flight the camera was used in play-back mode to check that adequate coverage had been obtained.

The second step is to select a pair of images from the tape which have suitable stereoscopic overlap and to process these images through a digital photogrammetric system to produce an orthophoto. The images are acquired from the tape and transferred to a computer file using frame grabber technology.

The final step is to take the orthophoto file generated by the digital photogrammetric software and produce a hardcopy output, which for this project was a laser jet printer.

6. ORTHOPHOTO PRODUCTION

An orthophoto is a photograph which has been corrected for the effects of aeroplane tilt and terrain variation.

A stereoscopic model is formed from the stereoscopic images by the photogrammetric software. This process establishes the tilts of the aeroplane at the times of exposure. Once the stereoscopic model is established a digital elevation model (DEM) is generated by the photogrammetric software. The software uses automatic correlation techniques to match corresponding points on the imagery and to calculate individual point heights.

The established tilts of the aeroplane together with the digital elevation model of the terrain are combined by the software to produce an accurate orthophoto by correcting for the effects of tilt and relief displacement.

7. RESTRICTIONS WITH VIDEO IMAGERY

There are a number of limitations, restrictions or special considerations which apply when using video imagery for mapping purposes.

Firstly, the elements of inner orientation of the camera, such as focal length, geometric lens distortion and position of the principal point are either unknown or unstable. These elements can be determined by calibration but in this technique any discrepancies are largely compensated for by the adopted procedure.

Probably the most severe restriction is the limited resolution and coverage which can be obtained using a video camera. For example, the small format and small focal length of a typical video camera means that some 500 video images are required to cover the same area at the same scale as a standard aerial survey photograph. Accordingly, at this point in time, the technique is most suited to project work, and is not at all suited to large mapping projects.

One of the difficulties of using remotely controlled aeroplanes is in determining their exact location and altitude at any time. Both influence the coverage which is obtained. This is somewhat offset by the video imagery itself which can be acquired continuously over a considerable length of time.

Video images can realistically only be processed using digital photogrammetric systems. In the past this was a severe restriction because such systems were either expensive or not readily available. However, this is changing and systems are becoming more affordable and more available.

The technological evolution can only continue to work in favour of video imagery.

8. PROJECT DESCRIPTION

The technique was tested at a site in Tingalpa in Brisbane.

As previously described, an onboard video tape acquired continuous imagery over the test site. Overlapping images were selected and written to file. These image files were saved in standard TIF format and were used in the processing stage.

Processing with the digital photogrammetric software followed a standard procedure. First the individual images were registered so that the image measuring system was referenced to the centre of the image.

A number of control and check points were coordinated in the field. Some of the points were used to control the photogrammetric model while others were used for checking. The control points were identified in the images and labelled with their allocated numbers.

The stereo model was formed and oriented to control. Although one is able to view the model stereoscopically, this was not required for the procedure and accordingly was not done. The purpose of the stereo model formation is to organise and orient the geometry for DEM generation.

The DEM was generated by the software using an auto-correlation technique. That is, the software matches corresponding points in each of the two images by identifying like patches in the images. A match leads to the generation of a height point. The process continues systematically until the model is covered by a grid of height points, which of course is the DEM.

There was a minor problem in that the correlation algorithm in the digital photogrammetric system used was not very sophisticated. Occasionally it would become "lost" in areas of similar image appearance such as reasonably extensive areas of uniform grass coverage. Points in these difficult areas did not contribute to the model.

The orthophoto was produced. A grid and title block were added and then the orthophoto was printed out on an HP Laser Jet printer.

The test orthophoto map is shown below.

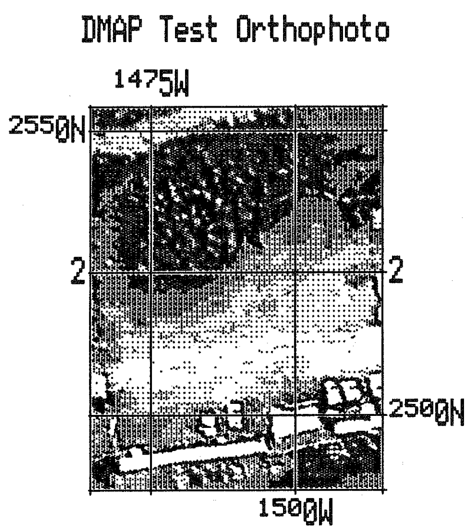

Fig. 1 Test Orthophoto Map

9. PROJECT RESULTS

The results were very pleasing in that we had produced an orthophoto from video imagery using a personal computer digital photogrammetric system.

The resolution of the image was a limiting factor. An estimate of the accuracy achieved was about ±1m on the ground or 4 pixels on the image.

The imagery was effected by troublesome vibration as well as irregular motion of the flight path. The vibration most certainly affected the level of accuracy achieved.

The procedure for producing the orthophoto was straight forward although the correlation algorithm was sometimes limiting.

10. FUTURE DIRECTIONS

There are three main steps to be taken in order to improve and refine the technique.

Firstly, geometric restitution can be improved by applying accepted techniques such as camera calibration or adopting a procedure which minimises the need to calibrate.

Secondly, software with a more sophisticated correlation algorithm needs to be used to improve the reliability of DEM generation.

Thirdly, and perhaps most importantly, platform stability and positioning needs to be improved substantially in order to make the technique more efficient. This can be achieved by using a purpose built RPV controlled by commercially available avionics components previously described.

11. CONCLUSIONS

The project has shown that orthophotos can be produced from video imagery acquired from a remotely controlled aeroplane and using personal computer based software.

It is clear that the future direction is in the adoption and use of avionics components.

The low cost of the technique and its components would seem to indicate that possible applications such as project mapping for subdivision design, map revision, mapping for urban planning, environmental monitoring and GIS mapping are limitless.

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