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Validation of a simple one person method for structural mapping using Sirovision

A simple, one-person digital photogrammetric method is described for mapping highwall structure using Sirovision software, without the need for detailed survey support. Comparative data are presented from the stand alone method and an alternative standard method supported by site based differential GPS positioning of camera locations. The results from the two methods are, for practical purposes, identical.

INTRODUCTION

Various laser and digital camera based photogrammetry systems are used in the Bowen Basin for geological mapping. Suppliers have often focussed on the spatial accuracy and precision of their systems. However, in many situations it is the speed of delivery of structural data and the ability for an operator to work completely independently in collecting orientated geological data of adequate accuracy that is of greater importance than locating the geological structures in 3D space with centimetre precision.

Sirovision enables a user to carry out structural mapping using survey controls provided by handheld GPS positioning of one reference camera position and taking an initial reference photograph in which the camera is set to be flat and level. No additional ground control points are needed. Thereafter, additional 3D models can be created by taking hand held stereo pair photographs that are aligned to the reference images. All that is needed for the hand held photographs is that a suitable baseline distance has been paced out between the camera locations so as to support 3D image creation and there is sufficient image overlap to create the 3D images.

Because of the convenience of the method and the speed with which results can be obtained it has been dubbed Stand Alone Sirovision.

This note describes the method and presents data obtained from recent mapping carried out using the stand alone method and a conventional method in which the camera locations or ground control points were defined using a site based differential GPS.

METHOD

When carrying out photogrammetric mapping of highwalls, there are various methods of providing georeferencing controls in the images to achieve sufficient spatial and geometric accuracy in the final 3D models. These methods generally require a minimum of three surveyed control points within each image that forms part of a stereo pair. This will often require access to toes and crests of highwalls and survey support.

This note describes a technique that is available in Sirovision (2010) which allows a single person, using fully portable equipment, to quickly photograph and create 3D models of a highwall. The method is demonstrated to produce results that are well within the range of error that would be expected from traditional mapping methods or that would be required for structural analysis.

The equipment that is required for this method is:

- a digital SLR camera and fixed focal length lens: a Nikon D300 with an f = 24 mm lens were used in the work reported here,
- a sturdy tripod and head to capture the reference image: a Manfrotto model 074B tripod and model 405 head were used,
- a custom levelling base plate,
- a simple hand held GPS: a Garmin Etrex Summit GPS was used,
- a handheld compass: a Suunto compass was used,
- a laser range finder to measure the distance to the highwall: a Bushnell Yardage Pro Sport 450 model was used,
- a tape measure.

All of these items can be easily carried by one person.

The stand alone method involves creating one or more reference 3D models and then, through a process of software based image matching, daisy chaining additional 3D models aligned to the reference model(s). The additional models are based on stereo pair photographs that can be taken by hand. The only constraint is that there must be sufficient overlap and an appropriate baseline separation between each pair of photographs to create a 3D image from each stereo pair.

Field Procedure

An initial reference stereo pair of photographs is acquired. The first, conventionally the left, photograph is taken using a camera that is level in both elevation and tilt. Figure 1 shows a camera mounted on a custom plate that incorporates two spirit levels to achieve maximum levelling accuracy. Reliance on circular bubble levels as typically used on tripods and off-the-shelf levelling heads will introduce 1° to 3° inaccuracy which renders the stand alone method unusable.

Figure 1: Camera mounted on custom levelling plate

The photographs do not need to be taken perpendicular to the highwall. If the initial left hand photograph does not include the area of interest, then the line of sight of the camera can be elevated and a second photograph taken that does include the area of interest. An overlap of at least 30% in the two 3D images is required so that the software can accurately georeference the positions of all of the pixels in the second 3D image.

The position of the camera where the first image of the reference pair is acquired is measured using a handheld GPS typically with a positional accuracy in the horizontal plane of ±5m based on satellite availability. Experience shows that the actual accuracy often is better than the value indicated by the GPS. Care is required to ensure that when recording eastings and northings or transferring them to other programs that the coordinate reference datum is known.

The direction of the camera is measured by taking a compass reading of the direction of the optical axis (the line of sight) of the camera. This is a critical measurement for application of the stand alone method and must be made with the best accuracy possible. Compass readings may need to be corrected for local magnetic declination. As a rule of thumb, in the Bowen Basin region this will usually mean adding between 5 and 12 degrees to the magnetic reading to obtain a reading relative to grid north.

The right hand image of the reference pair can be taken with a hand held camera but it is preferable to use a tripod. The distance between the left and right camera locations should be between $^1/_6$ and $^1/_9$ of the distance to the highwall as measured using the range finder. The distance between the two camera locations should be measured as accurately as possible and is best measured using a tape measure, properly tensioned. Using a tripod when taking the right hand image makes this measurement easier.

Subsequent stereo pairs of photographs can be taken by hand. Each pair should overlap with the previous pair by 30% to 40%. As with the reference stereo pair, the baseline separation should be between $^1/_6$ and $^1/_9$ of the distance to the highwall. It is sufficient to pace out the baseline.

In the work reported here the time required to take the reference photographs including all necessary measurements was 15 minutes. The time needed to take the additional 12 pairs of hand held photographs to cover 750 linear metres of highwall was an additional 20 minutes.

DATA PROCESSING

The field data was processed using the Sirovision version 4.1 software. A detailed description of the process is beyond the scope of this note. The methods used are described in detail in the Sirovision manual (CSIRO, 2010a).

Using field data always involves some overheads in data transfer and management but, including downloading the images from the camera, the first two 3D models, suitable for geological mapping were produced within 40 minutes of returning to the office. The complete, 750m long georeferenced 3D mosaic ready for structural mapping using the Sirojoint component of Sirovision was completed within 2 hours of creating the reference 3D image.

The data processing could have been carried out in the field within a similar period using a current, mid-level notebook computer.

RESULTS

Standard GPS versus differential GPS

To undertake the comparison reported here the camera position of the camera for the first image of the reference pair was obtained using a hand held GPS receiver and a differential GPS receiver. The results from each method used are shown in Table 1. The easting and northing values show only small differences that are less than the 'accuracy' indicated by the hand held GPS receiver. The elevation values are quite different. This arose because the particular hand held GPS used in this case calculates elevation from barometric pressure, and was not calibrated to a known height datum before deployment. However, errors in elevation have no impact on the calculated geometry of geological structures.

Table 1: Comparison of hand held and differential GPS location results for left hand reference camera

Method	Stand alone (m)	Differential (m)	Difference (m)
Easting	~605	~603.295	1.705
Northing	~749	~749.879	0.879
Elevation	379	433.543	54.543

Distance measurement from differential GPS versus tape measure

The distance between the left and right camera positions of the reference image pair was measured using the differential GPS and a fibreglass tape measure.

Table 2 shows the difference in the measurements of the baseline between the two camera locations used to take the photographs of the reference image pair.

Table 2: Comparison of measured distances using a tape measure and differential GPS

Method	Tape (m)	Differential GPS (m)	Difference (m)
Distance	15.35	15.38	0.03

Normally the tape measurement would be expected to show the greater distance as tapes sag. Tape stretch is one explanation for the observed difference, an error in the differential GPS measurement is another. Nevertheless, the apparent error is less than 0.2%. Such an error would have a negligible impact on the calculated dimensions of geological structures and does not affect the calculation of the orientation of structures.

Coordinate measurements from differential GPS versus Sirovision

Although not required, a second set of reference photographs was taken, approximately 157m NE from the first reference. The two camera positions were located using the differential GPS. Their positions were also calculated using Sirovision on the basis of the hand held measurements that were made when establishing the initial reference model. The results for the left hand camera position of reference set 2 are shown in Table 3.

The results show that there is a drift in the horizontal positional data as the distance from the reference model increases. The cause of this is inaccuracy in the compass measurement of the direction in which the initial left hand reference image was taken.

There are two ways to treat this error. The first is if there is a feature of known orientation then all the models can be transformed to align with the known feature. The second is to establish reference models every 100 to 200 m, as previously described, and to use them to pin the models created with the photographs taken with the hand held camera.

Table 3: Calculated and measured coordinates for reference position 2, left hand camera

	Sirovision	Diff GPS	Difference
E(m)	~733.382	~722.746	10.636
N(m)	~871.310	~853.019	18.291
El(m)	431.001	430.859	0.142

No significant drift was observed in the elevation values. This is further evidence that the drift is due to inaccuracy in the initial reference model set up rather than any fundamental defect in the method.

Highwall Orientation

The highwall bearing and batter angle were measured on the reference model using the Sirojoint component of Sirovision (CSIRO, 2010b). The results were compared with the latest pit survey and mine design and the results are shown in Table 4.

The results are identical.

Table 4: Comparison of highwall bearing and batter angle obtained from Sirojoint and the mine survey

Method	Siro joint	Mine Survey	Difference
Bearing (°)	049	049	0
Batter angle (°)	70	70 (design)	0

Structural Measurements

Two prominent geological structures, shown in Figure 2, were measured for orientation. Three methods were used: Sirojoint based on a 3D model created using the stand alone method, a 3D model created using differential GPS generated data, and the estimate of one of the authors (JVS) based on his site observations and database built up over a number of years. The results are shown in Table 5.

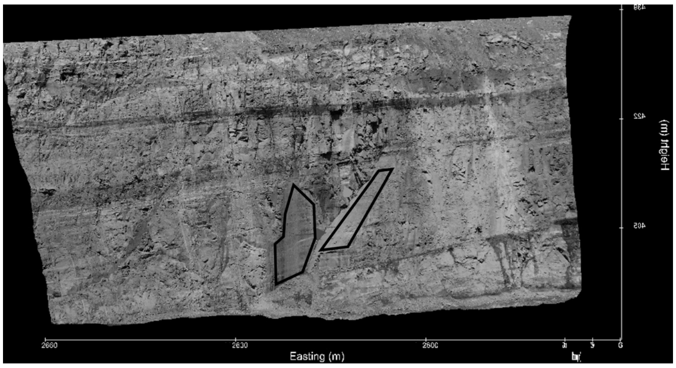

Figure 2: A 3D model of a section of the 45 m high highwall showing the two structures referred to in the text

Table 5: Orientation of selected geological structures using 3 different methods

Structure	Sirovision Stand alone	Sirovision Diff GPS	JVS
J1 D/DDN	87/293	86/294	82/283
J2 D/DDN	48/021	45/025	49/020
Intersection Plunge/Trend	46/021	45/020	42/009

D/DDN = dip/dip direction

The structural measurement results show that there is little practical difference in the calculated orientations for planes that were selected regardless of whether the survey data for the Sirovision models came from hand held tools or the differential GPS. It is also remarkable to note how close the field estimates of the orientations of the structures are to the Sirovision values. This is despite observing the required stand off from the highwall and the difficulties of measuring structural orientations from various viewing points.

It is recognised that the comparisons of location accuracies and structural orientations presented here are for a very small data set. However, they are typical of the results that the authors have obtained from using the stand alone method. It is expected that future work will demonstrate for larger data sets that the accuracy and repeatability obtained using the stand alone method is comparable to that obtainable by traditional face mapping techniques under field conditions.

CONCLUSIONS

The results of the work presented in this note demonstrate that a 750m long, 45m high highwall can be photographed in about an hour and all of the models processed within 3 hours ready for structural geological interpretation. This can be done by a single operator using hand held tools.

The accuracy of the orientations obtained using the hand held tools is comparable to results obtained when a differential GPS is used to establish camera positions. It is judged that the accuracy is well within what can be obtained in the field using tape and compass, particularly given exclusion zone and access restrictions that are mandatory in Australian open cut coal mines. The work reported provides validation of a rapid method for measuring structure where the spatial position of the structures is not critical enough to require the accuracy of a differential GPS unit. The orientation and spacing of structures can be obtained by the stand alone method with the accuracy required to undertake meaningful geotechnical analysis of the structures.

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REFERENCES

CSIRO, 2010a: Siro3D Sirovision 3D Imaging Mapping System Manual Version 4.1.

CSIRO, 2010b: Sirojoint Sirovision structural mapping and analysis system – User manual Version 4.1, CSIRO.

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