

Hunter Valley Photogrammetry Project

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Abstract

We attempted to map coal mine outcrops from four mines in the Hunter Valley, New South Wales, Australia, using Sirovision photogrammetry software. We took oriented digital photos of 12 high wall outcrops, from which we produced six 3D digital models. We were not able to verify the validity of these models, and we suggest adding functionality to Sirovision for estimating position errors.

Introduction and research questions

Mine exposures and road-cuts can serve as excellent sources of geological and structural data. By nature, they form fresh outcrops that are being enlarged over time, allowing for 3D structural reconstructions. These valuable sources of data are often inaccessible, however, due to safety regulations that forbid direct contact with the outcrops. With photogrammetry, 3D orientations of a rock face can be determined from a safe distance.

Photogrammetry is a generic name for the creation of 3D representations based on 2D images. The technique mimics the human ability to use overlapping 2D images from each eye to infer the third dimension (Fig. 1). The human brain correlates the overlapping parts of the images obtained from both eyes and uses the distance and differences between the images to gain understanding of the 3D shape of the object.

Sirovision is photogrammetry software from the CSIRO that creates 3D digital models from two or more georeferenced images (images that are oriented in physical space). The geometries of objects can be improved by adding additional information such as the lines of view of the camera, ground control points that are linked to an absolute reference grid, or measurements of distances between elements of the model or its anchors (Fig. 1). Sirovision uses an algorithm that forms a per-pixel correlation between the overlapping parts of two images of an outcrop. The best match between the images will use the absolute and the perspective differences (distortion) in order to estimate the geometric properties of the outcrops and form a digital model of it. This digital model can be georeferenced to an absolute reference grid and scaled to its real dimensions. After a digital 3D model is constructed

and georeferenced, measurements of planes and lineaments can be made. The process enables one to make measurements of dangerous or inaccessible outcrops using a camera, GPS, and the software package, replacing the conventional geologic compass that requires direct physical contact with the outcrop.

This report describes the use of Sirovision for investigating geological structures exposed in coal mines in the Hunter Valley. The project included software training, practical experiments, 10 days of fieldwork in various coal mines, construction of digital 3D models, mapping and measuring of different deformation features exposed in mine high-walls, and, finally, structural analyses.

Software training was done at UQ and CSIRO facilities under the guidance and supervision of Prof Joan Esterle of UQ and George Poropat and Phil Soole of CSIRO. It involved a wide review of the principals of the software and step-by-step instructions for construction of a model and extraction of measurements from it. During the preparation, a field exercise was conducted at Kangaroo Point in Brisbane, and all necessary gear was purchased, including a digital SLR camera (Nikon D70), two fixed focal length lenses (50 and 28 mm), a built-in GPS, and a tripod. Custom calibration files for the UQ camera and lenses were produced by CSIRO and were used during subsequent photogrammetry.

Images were collected during 10 days of fieldwork (two 5 day journeys) in the Hunter Valley. The overarching questions we tried to address were:

What are the different deformation features in the Permian stratigraphic sequence of the Hunter Valley? What is their relative timing, and how do they vary spatially?

Answers to these questions have both scientific and practical importance. To address these questions, we planned to: (A) construct 3D digital models of each outcrop, (B) map deformation features observed in each model, (C) correlate different observations from different models, and (D) construct a relative time line for the deformation features and discuss their relationship with Permian and Mesozoic tectonic events, in particular the formation of the New England Oroclines. This final step was to be achieved by using crosscutting relationships and fold-tests to determine the relative timing of joints, folds, and faults.

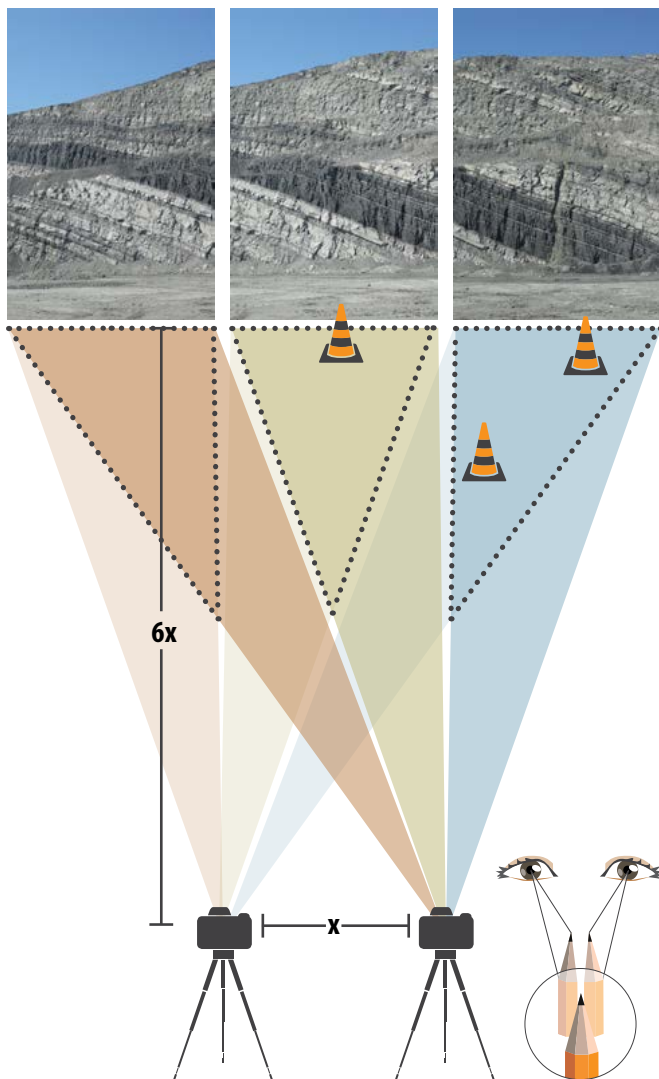


Figure 1: Illustration of photogrammetry principles and Sirovision. The human eye enables true 3D triangulation at distances of only a meter or two. Geometries of more distant objects are interpreted from clues such as shade, perspective and the viewer's previous knowledge. Photogrammetry software such as Sirovision mimics and extends the precise stereoscopic capabilities of the human eyes to distances of hundreds of meters. Sirovision uses pairs of images that are spaced at roughly 1/6 of the distance to the outcrop to create 3D digital models. The models are georeferenced by recording camera and control point locations in the field (marked as cones). These positions are measured using either mine surveying equipment or simple handheld GPS.

Technical information

We visited the Rixs Creek, Mt Owen, Glendell, and Integra mines (Fig. 2). From the four coal mines, twelve high-wall locations were photographed for construction of independent 3D digital models (see digital appendix A). The stratigraphic nomenclature from each mine was documented in order to correlate stratigraphy between mines.

Each outcrop was photographed from a minimum of two locations in order to pair the images and create a 3D model of the overlapping area. The paired images were converted from RAW format to tiffs and imported to the Sirovision project library. We started the project using Sirovision version 4, and upgraded to version 5 as it was released (the Sirovision terminology used in this report is for version 5). Task files for the matching procedure were created for each pair, and matching was done with manual monitoring of the outcome for each pair. After the matching was completed, 3D images were created as 3D tiff format images (presented as sjt files). These 3D images were then aligned and matched with each other to form one coherent 3D model of the entire outcrop. Some of the pairings were unsuccessful, and some of the final models had unrealistic geometries. The successful models were then mapped, and bedding planes and deformation features were measured in order to form a regional correlation, timeline, and to conduct structural analyses.

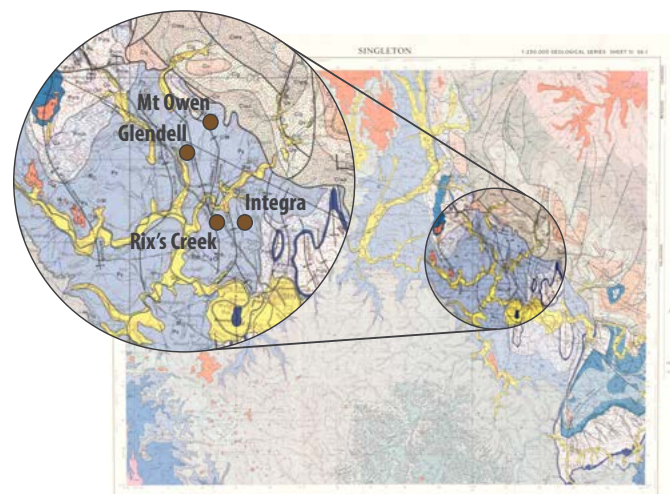


Figure 2: The sampling sites in the Hunter Valley, NSW, Australia (map after: Rasmus, P.L., Rose, D.M. and Rose, G., 1969. Singleton 1:250 000 Geological Map Sheet SI/56-01. Geological Survey of New South Wales, Sydney).

Outcome and conclusions

Out of the twelve sites, only six models were built (see digital appendix A). Two of the missing six were not completed due to inadequate orientation information and lack of overlapping control points, which caused instability of the 3D interpolation of the model. The other four models resulted in Sirovision error messages or produced distorted 3D planes that did not resemble the real outcrop.

Out of the six working models, problems such as space between aligned images and 'floating' images (Fig. 3 or see digital appendix A, Glendell 1) raised the need for a validation scheme for the output measurements. The software can evaluate the quality of matching, but it lacks an evaluation for the end result digital model or the measurements that were taken from its surfaces. The absence of a calculated accumulated error application in the package was raised after rendering several models that appeared to be good but did not look like the original outcrop.

The end result of the project was six fully functional and measurable 3D digital models from four sites (three from Rix's Creek and one of each from the other mines). We have mapped deformation features from some of the models and have preliminary structural analyses for joints in the different outcrops, but the inconsistency and lack of georeferencing validation led us to stop at that and not attempt to form a regional correlation.

We suggest addition of a validation application to the software package. Such an application can be based on redundancy of additional constraints (i.e. lines of view, ground control points, or measurements

of distances between elements of the model or its anchors). These controls are used for georeferencing the model, but they can also be used as independent internal validation points if not used for the construction of the model. The coordinates of a ground control point, for example, can be inserted to the model algorithm and be used to form the model. Such coordinates can also be extracted from a georeferenced model. Provided they were not used in construction of the model, a comparison between the coordinates of the point in the model and its independent coordinates measured in the field can serve as empirical validation for the absolute error of the model. In order for this proposed scheme to be operational for 3D error, a minimum of three independent measurements from different sites in the model must be taken for 3D stability of the error estimation. An additional aspect that must be imbedded in the cumulative error calculation is the accuracy of the GPS (differential GPS would best suit this purpose). This suggested process does not necessarily require three additional independent measurements. 3D stability of the test can be achieved by embedding the above error application scheme in the production of the model. Given one additional constraint, the model can be separately calculated several times with different ground control points extracted from each calculation, and functioning as a test point (see Fig. 4 for illustrated example). Then a general calculation can be plotted using all control points. The general calculation will have a smaller error of the largest one of the previous calculated models. This way the final outcome can be presented with the maximum independent error calculation for its results.

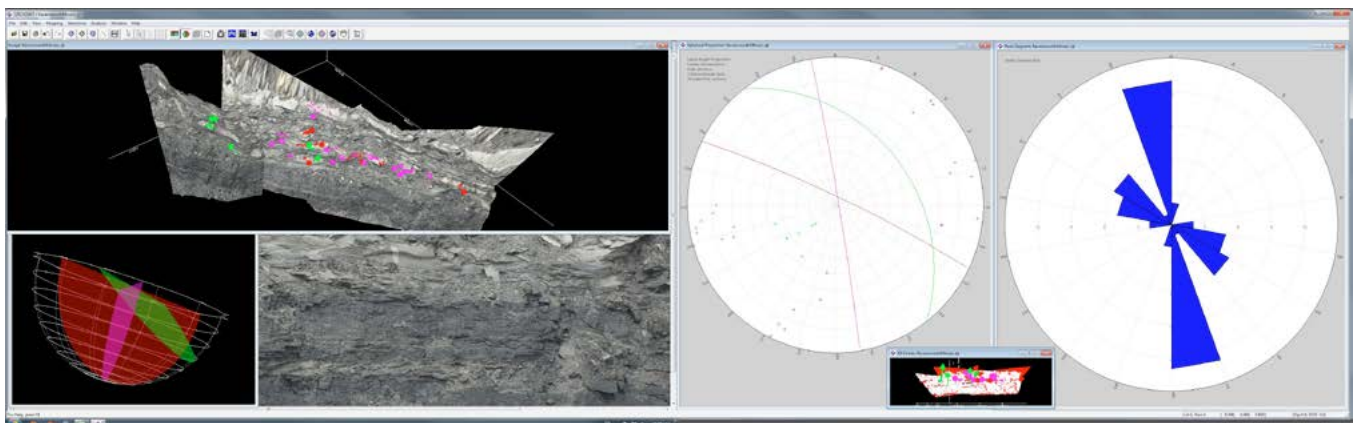


Figure 3: Sirovision screenshot showing the toolbar, a 3D model (top left) and measurements that are simultaneously projected on a stereogram and rose diagram (on the right). Under the model (bottom left) is a 3D illustration of calculated means of three different measurement orientations, as well as a frontal view of the digital model without the measurements. Note that one of the 3D images (on the left) is parallel to the rest and is not fully aligned with the rest of the model. Such an error might not influence the stereographic projection but does indicate potential errors in the model.

The above application is a logical suggestion that can be programmed and merged with the software package in several different ways. We think the addition of such a function will expand the possible uses of the software and improve its output and overall accuracy. We understand the computing resources that are required for such validation scheme are larger than what is currently used for construction of a model, but it may still be within the capability of standard high-end personal computers and normal workstations.

In conclusion, there are numerous potential uses of Sirovision, both for industry and academia. This relatively simple and inexpensive software enables quick and efficient collection of data in the field. We recommend that a quantified validation application should be added in order to establish the accuracy of the results.

Acknowledgments

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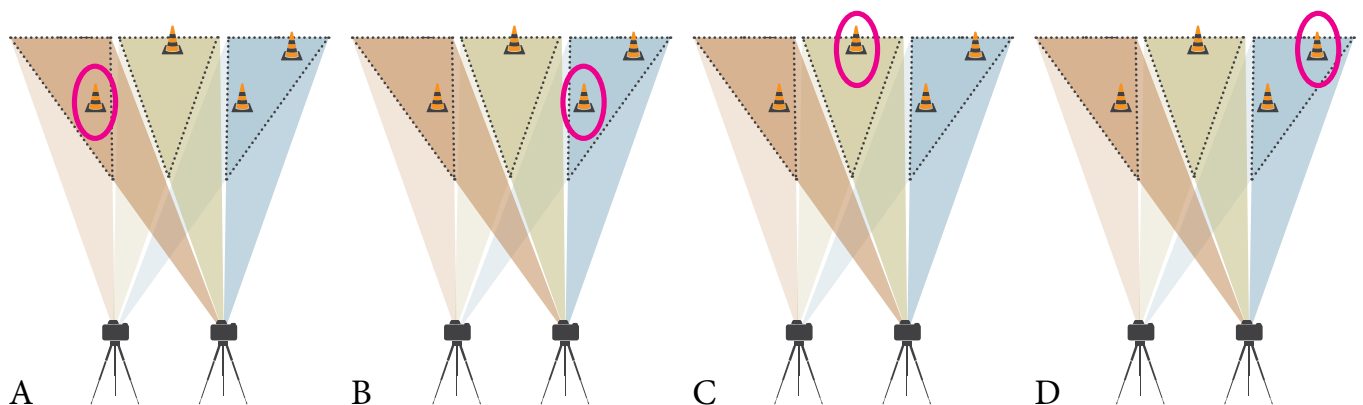


Figure 4: An illustrated suggestion for determining accumulated errors in the 3D models and derived measurements. For clarity, we present a simplified example of adding a ground control point to test its calculated coordinates in the model. The same result could be achieved by adding measurements of distances or bearings, or adding an additional camera site. With the addition of one (fourth) ground control point to a modeling site, the model can be constructed several times (A, B, C, and D), excluding different control points from each one (marked with a pink ellipse), and using it as a validation for comparison of its coordinates with its calculated location in the model. This will result in empirical estimates of error for each setting (calculated error $A_{(x, y, z)}$, calculated error $B_{(x, y, z)}$ and so on). The calculated final model is constructed using all control points, and will have higher accuracy than the calculated test model with the largest error. This will result in a maximum X, Y and Z error that can be assigned to the final model or each one of the measurements that were made from it.