A New Elevation Mapping Paradigm: high definition stereo satellite elevation mapping using limited ground control

Gerry Mitchell, Professional Geoscientist (BC), Professional Geophysicist (Alberta)
President, PhotoSat, www.photosat.ca
Email: gerry@photosat.ca

Necessity is the mother of invention. A unique method of processing stereo satellite photos, independent from the ground survey control, was developed not because the advantages of this approach were initially identified, but instead because the majority of PhotoSat's first stereo satellite elevation mapping projects had no accurately surveyed ground control.

Conventional stereo photo elevation mapping begins by identifying numerous ground survey control points on the stereo photos. The east, north and elevation coordinates of these points are then applied to the many location points in the photos. The elevation data is processed using the combination of the stereo photos and the ground survey points.

During the 2003 to 2008 resource boom, Vancouver based mining exploration companies worked many advanced exploration and development projects in remote parts of the world. These projects required accurate, high resolution elevation maps for development plans, feasibility studies and resource and reserve estimates. Many of these projects, particularly at their early stages, had no or very poor quality ground survey data.

Mapping for these early projects were carried out using 1m stereo satellite photos. With many of these projects, the initial elevation mapping relied exclusively on the geometric accuracy of the stereo satellite photos. When survey data became available at a later phase of the project, a linear shift was applied to the satellite elevation mapping to fit the mapping to the newly available ground survey data. The remote nature of the projects and lack of control required a new elevation mapping paradigm, which would allow elevation mapping from stereo satellite without the use of survey ground control.

The new stereo satellite elevation paradigm:

Stereo satellite photos are initially processed for elevations with no reference to the ground survey data. On completion of the satellite elevation processing, the satellite elevations are compared to the ground survey data **-** if there is ground survey data. If accurate ground survey data exists, a linear shift in east, north and elevation is applied to the stereo satellite elevation mapping to match the coordinates of the most important or most clearly defined ground survey point.

The remaining survey points are then evaluated as checkpoints. The elevations and horizontal coordinates of the remaining survey points are compared to the elevations and horizontal coordinates of stereo satellite mapping. If the elevations of the remaining ground control points and the stereo satellite mapping agree to within a meter, the project moves forward to the next step; formatting and delivery.

If the elevations of any of the ground control points mismatch by more than a meter in elevation, the stereo satellite elevations are matched to the most consistent set of ground survey points and a report of probable survey errors is sent to the client for review. A solution is discussed with the client before proceeding with delivery.

Survey errors:

Early stereo elevation mapping projects offered an opportunity to learn about the inherent absolute and relative accuracy of the high resolution stereo satellite photos. Time after time, the stereo elevation mapping identified errors in the survey data, which was often provided well after the stereo elevation mapping had been completed and delivered.

In 2004, survey coordinates for one hundred drill hole collars were provided for a project in a mountainous area of Mexico. The survey data showed an apparent error of up to 30 meters in PhotoSat's satellite elevation mapping. On examination of the drill hole coordinate elevation data, it was discovered that sixty of the drill hole elevations were within 2m of the stereo satellite elevations. The other forty drill hole elevations varied between 26.5m and 30.5m above the stereo satellite elevations. In this area of Mexico there is a 28.5m difference in the elevations measured above sea level (the orthometric height) and elevations measured above the Clarke 1866 ellipsoid (the ellipsoidal height).

It was then discovered that one of the contract surveyors had reported orthometric elevations while the other had reported ellipsoidal elevations, creating an offset of 28.5m between the two sets of survey data. Since the drill hole data was about to be used in a resource and resource estimate, the discovery of this inconsistency, and the subsequent correction of the data prior to the engineering study, saved the company a significant amount of time, money and frustration.

On another project in 2005, stereo elevation mapping identified a mismatch of 30m between elevations at a proposed mine site and the elevations at a proposed processing plant and tailings disposal site 25 km away. Over the 25 kilometer distance between the mine site and the plant site, the elevation differences between the ground survey data and the stereo satellite mapping smoothly varied from 0 to 30m. Subsequent checking, by a different contract surveyor, revealed a 30m elevation survey error, resulting from an inconsistency in the elevation reference. The 30m error had apparently been smoothly distributed over the 25 km distance, between the mine site and the plant site by the original surveyor.

On a third early project, it was curious that all of the survey points that were on access roads matched the stereo elevation mapping to within 2m while other survey points with no road access mismatched the stereo satellite elevations by up to 15m. Subsequent resurveying of all of the survey points remote from the roads confirmed the accuracy of the stereo satellite elevation mapping for all points away from the road.

There was some suspicion that the remote survey points, which were often on steep hill sides or hill tops, were measured with a low cost hand held hiker's GPS unit rather than with the more precise, but much bulkier and heavier, engineering quality GPS unit that was used to survey the points with road access.

Proof of accuracy:

In October 2008, Sunridge Gold Ltd. of Vancouver provided PhotoSat with 45,000 accurately surveyed points distributed over an area 15km by 50km in Eritrea. These surveyed elevations were part a large study measuring the intensity of the earth's gravitational field over this portion of Eritrea.

Elevation data acquired for mineral exploration gravity surveys are probably the very best elevation data for measuring the accuracy of any type of remote elevation mapping. Under some geological conditions large metallic metal deposits can be discovered by precise surveys of the gravitational field. Dense, buried, metallic mineral deposits exert a greater gravitational attraction than do areas of non-metallic rock. Mineral exploration gravity surveys typically cover large areas and require precise elevation mapping.

In order to map the gravitational field with enough precision to detect a buried metal deposit, there must be an accurately measured elevation for each survey point used for a gravitational field measurement. Elevation survey data in gravity surveys are subjected to very high levels of quality control. Elevation errors of as little as 20cm can seriously compromise the usability of the gravity survey data. Isolated elevation errors manifest as spikes in the otherwise smoothly varying maps of the gravitational field providing an additional check against elevation survey blunders in the gravity survey data. Such spikes would thus demand resurveying.

The 45,000 stations from the Eritrea gravity survey were surveyed by MWH Geophysics of Kelowna, British Columbia using Magellan GPS units operating in Real Time Kinematic (RTK) mode. These surveying instruments measure ground location points with better than 2cm accuracy. 12,715 of these survey points lay within the area of a stereo satellite elevation mapping project conducted by PhotoSat for Sunridge Gold.

Following the stereo satellite elevation processing, a linear shift was applied to the resulting stereo elevation mapping to match one of six surveyed ground control points provided by Sunridge Gold. The elevations of two of the other ground control points matched the stereo satellite elevations to within a few centimeters. The elevations of the remaining three surveyed ground points were different from the stereo satellite elevations by over three meters due to a survey blunder.

An accuracy of 48.3cm RMSE was calculated for the stereo satellite elevation mapping, using the 10,081 surveyed checkpoints that were on slopes less than twenty percent grade[1]. The accuracy of the stereo satellite elevation data on the slopes greater than twenty percent grade, determined by 2,634 surveyed elevation points, is 76.4cm RMSE.

This result clearly shows that, with a single accurately surveyed ground control point, the elevations for an area of hundreds of square kilometers can be accurately mapped with stereo satellite photos.

[1]The Guidelines for Digital Elevation Data (2004), recommend using areas with slopes less than twenty percent grade to determine elevation accuracy.

References:

United States, National Digital Elevation Program, Guidelines for Digital Elevation Data, Version 1.0 (Washington: 2004) 27.