Rapid and Low Cost Digital Elevation Model (DEM) Production of the Guinsaugon Southern Leyte Landslide Area Using Close Range Terrestrial Photogrammetry

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Key words: photogrammetry, DEM, digital elevation model, close range terrestrial photogrammetry, mapping, Guinsaugon Landslide, Disaster Mapping

SUMMARY

A rapid and low cost means of producing a digital surface elevation (DEM) map of a severe landslide area is described in this paper. This method is suitable for the quick capture and assessment of dynamically changing terrain data scenarios such as disaster-stricken or potential risk areas and in the rapid production of topographic maps of these type of areas. It uses an unconventional means of remotely measuring surface elevations using identified features between corresponding stereopair photographs taken from the ground level. Also called close range photogrammetry, it is typically used in the fields of architecture, archeology, and industrial applications where the camera and subject distance is within only a few meters. We applied this method successfully in the production of a surface model and subsequent topographic map of the large landslide area in Barangay Guinsaugon, St. Bernard Province of Southern Leyte which occurred February 2006. Actual time spent in the field for data gathering was only half a day to accomplish the work.

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1. BACKGROUND

In the early morning of February 17, 2006 in the Philippines, a massive mudslide buried the small village of Guinsaugon in the town of Saint Bernard, Southern Leyte. The landslide caused widespread damage and loss of life. The official death toll stood at 1,126 dead.

The deadly landslide followed a ten-day period of heavy and continuous rains and a minor earthquake of 2.6 in the Richter scale.

Many scientific and engineering studies have been done and some are still underway to assess and determine the factors that contributed to this disaster. Many of the studies required the determination of pre and post landslide geophysical information. In addition, the landslide area is constantly changing due to constant movement of the eroding slopes.

Up till now, there has been no actual topographic survey or mapping of the landslide area. The site consists mostly of steep slopes and slippery rock faces especially at the upper half leading to the ridge lines at the top where the rim of the landslide portion is found. Most of the difficulty in mapping this type of terrain can be attributed to several factors namely:

- Difficult terrain consisting mostly of large rocks and loose debris especially along the main riverbed and made inaccessible during the rainy season;
- Persistent and low lying cloud cover at the top and constantly emerging fog along the upper slopes;
- Steep earth and rock slopes which are constantly eroding;
- Potential for flashfloods even during light rain showers.

One of the engineering studies required a topographic survey map of the area at a limited budget. GeoAnalytika was approached to produce the map since there were no other interested parties. Preferred contour interval for the topographic map was 5 meters at a scale of 1: 5000.

Photo Courtesy Getty Images

2. THE PROJECT AREA

The following scenarios were encountered during the site visit:

Persistent fog and cloud cover

Steep and Near Vertical Slopes

High sloping (> 60 deg) rock faces

Potential flashfloods

Loose stone and mud surfaces constantly eroding

3. PROPOSED SOLUTIONS

What was needed is a method that can produce the required map quickly, at low cost and that will not place the survey crew at risk.

3.1 Conventional Solutions

The most popular and conventional methods employed locally for topographic mapping entail either executing a topographic survey or vertical aerial photography.

Conventional topographic surveys require occupation of most or all of the areas for measurements using an EDM (Electronic Distance Measuring) instrument. Clearly, this is next to impossible considering the prevailing field and terrain conditions. This method is very time consuming and costly in terms of manpower and resources.

Aerial Photography is another popular solution for the production of topographic maps of medium resolution. Using fixed wing aircraft, the process involves the capture of stereo photography at high altitude. However, persistent cloud cover and intermittent fog conditions make it very difficult to acquire good stereo coverage at any time of the day. This was observed even during the summer season when the survey team visited the area. This makes logistics and planning for an aerial mission difficult and can make it expensive with failed fly-overs. With rotary wing aircraft, stereo photography is much more challenging and can also be dangerous if not properly executed.

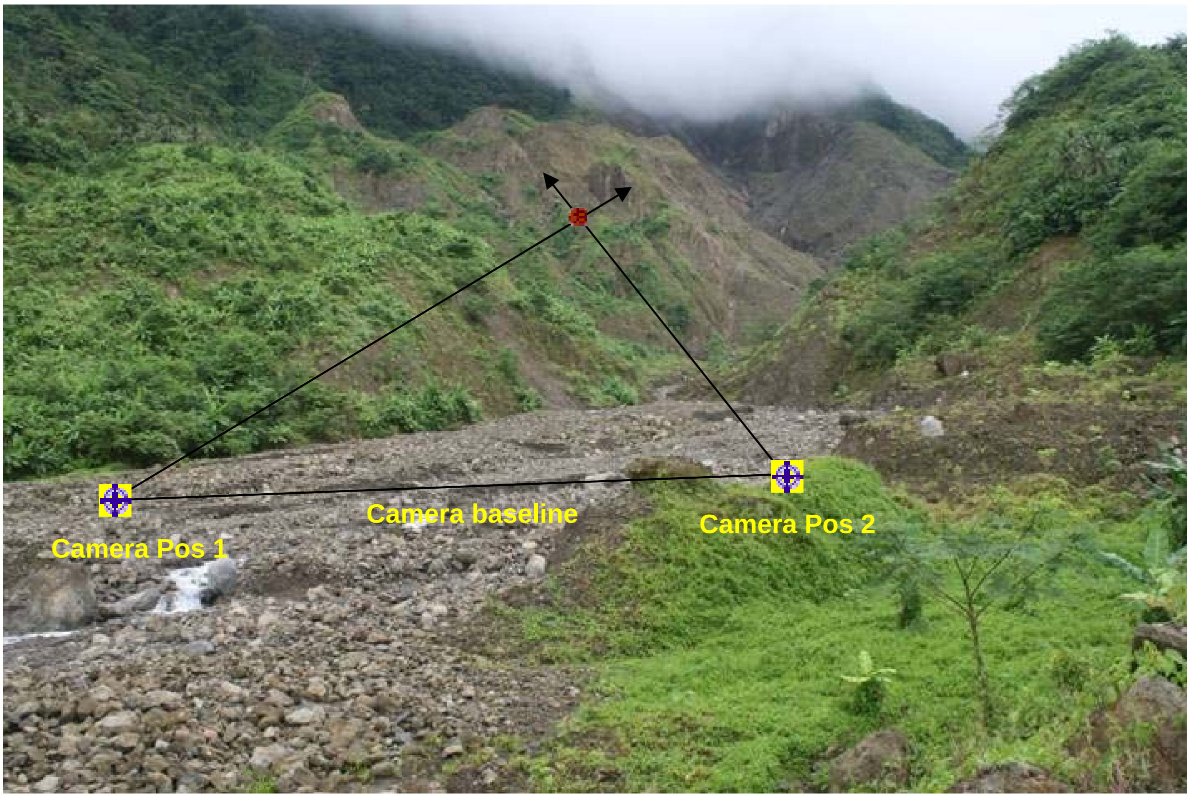
In view of this, current solutions are not feasible (or possible) and can become very expensive; we need to look at alternative solutions.

3.2 An Alternative Solution

Given the mapping requirements, an alternative solution is Terrestrial Photogrammetry using Close Range Photogrammetry methods. This method uses ground based photography, i.e. photographs are taken close to the ground as opposed to high altitude photography. Photographs are still taken of a common area from two separate locations and all areas to be mapped have to be photographed in stereo. The principles of close range photogrammetry is still the same as vertical high altitude stereo photogrammetry with parallax measurements of two overlapping and stereoscopically visible points on both photographs. In addition, the base-to-object distance ratio dictates the scale and accuracy of the resulting map.

In order to calculate the positions of objects and points on the overlapping region on both photos, the system must reconstruct the position and orientation of the stereo photos as seen by the camera and reconstruct the orientation of the camera and its line-of-sight to the photographs. Subsequent collinearity equations of the camera are constructed in 3-D space and the intersection point of the two viewpoint lines.

This process requires the definition of 6 independent quantities of position and orientation (rotation). To compute these quantities at least three (3) control (reference) points are required whose accurate positions (x,y,z) are known or measured beforehand (e.g through usual surveying and/or GPS measurements). These are usually points on the ground which can very easily and accurately be identified on the overlapping portion of the stereo photos. More control points are better resulting in redundancy while requiring a more complex least squares solution. In addition, these extra points can also serve as check points during map accuracy validation.



Advantages for Close Range Terrestrial Photogrammetry are:

- Prosumer" DSLR digital cameras (non-metric) can be used. There is no need for expensive photogrammetric cameras.
- Ground based stereo photography does not require high altitude aircraft platform.
- Less time is consumed in the field; therefore, there is less danger to survey crew in such environments.
- The cost is lower in terms of manpower and resources required compared to other methods.

Disadvantages for Close Range Terrestrial Photogrammetry are:

- Camera calibration is required to determine lens parameters such as radial distortions, vignetting, chromatic aberrations, etc. Another requirement is to determine the actual camera photo center (i.e. similar to IO) coordinates.
- It is more complex to set-up on the field. Camera positions need to be carefully located so as to provide stereoscopic coverage.

- This requires more skill and experience in photography, such as correct camera exposure settings to enable high quality photos to be acquired.
- It also requires careful survey planning and execution to collect 3-D reference points in the overlap areas among the stereo photos.

The current challenges that were faced during the survey execution at that time was that this method has never been done before in the Philippines (or we have never encountered such a process being done locally). So if the process is successful, this would be a pioneering effort.

4. SYSTEM DESCRIPTION

4.1 Camera System

The camera we used is the Canon DSLR Model 400D Semi-Professional Camera with 10.2 megapixel resolution. The lens is an Image Stabilized (IS) zoom lens with 18-55 mm focal lengths. The lens system was also equipped with Haze, UV and polarizing filters.

Camera calibration was achieved using a separate camera calibration software which corrected the images individually before being passed on to the photogrammetric software.

Camera calibration and image lens distortion correction is important to enable the highest possible accuracy to be derived from the image measurements. Camera calibration determines the (internal) camera characteristics such as actual focal length during shooting and exact image photo center (principal point). This method is similar to the camera calibration procedures for metric cameras used in more expensive systems.

The system we used separately corrects the individual images for camera system distortions before photogrammetric processing. This entails single pass batch processing for all the collected photographs.

4.2 Photogrammetric System

To calculate accurately the camera parameters during photography, our system requires only two (stereo) photos. Required reference points are reduced to minimum of three(3), which must be precisely measured on the ground using conventional

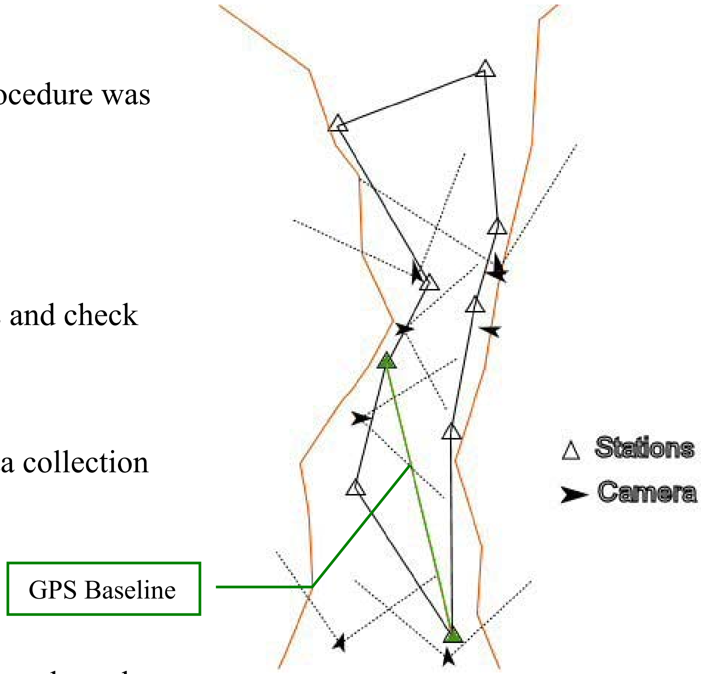
Stereo Pair and Common Points for Digitization methods such as a survey traverse or GPS point positioning. Extra points can be used to compute error estimates of the stereo processing and give probable errors of mapping especially of object points that have larger base-to-object ratios.

Since scale becomes smaller as the base-to-object distance increases, we need to measure very precisely the reference points on the ground (to the nearest cm.) since the accuracy of the measurements of far away objects will depend greatly on the these reference points.

5. MAPPING PROCEDURE

The following surveying and mapping procedure was followed:

- Establishment of GPS Baseline
- Selection of camera locations and photography
- Selection of good reference points and check points
- Conduct of survey traverse
- Photo Correction
- Photogrammetric processing – data collection and digitization
- Quality Control
- Map Production



A GPS baseline was established to be used as the reference baseline for the survey traverse. An Electronic Total Station (ETS) instrument would be used to establish the ground coordinates control stations to be used as reference stations where the photo control coordinates will be measured. Reference and check points must be carefully selected so they are within the overlap areas of the stereo photos and be visible both on the ground and in the photos. Another important aspect during stereo photography is to ensure that hidden areas are reduced or eliminated through sufficient overlap and photo coverage.

The 3-D coordinates of these reference points and check points are then subsequently measured on the ground using the ETS.

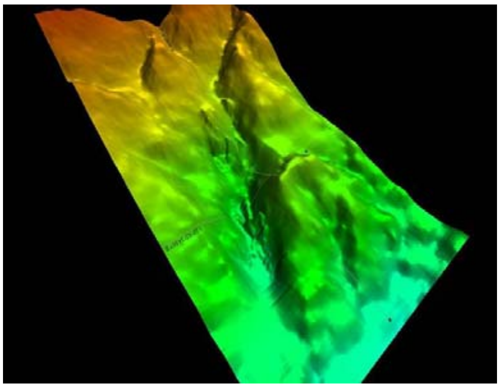
The most tedious portion of the process is the digitization of common points from the stereo photographs. These can be done by tagging the common points in the individual photos or by viewing stereoscopically. It is important that the stereo photographs be image enhanced to enable the digitizer to visually select the common points correctly.

By carefully monitoring the RMSE for individual points, points with excessive errors are rejected. This process of quality control ensured that the topographic mapping standard for accuracy at the selected scale is maintained throughout the area.

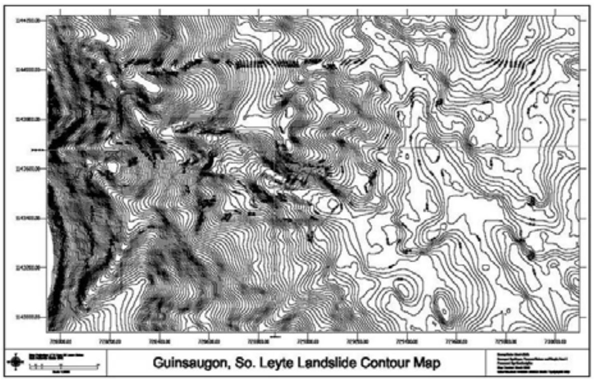
Typical field set-up for the survey crew

6. RESULTS AND CONCLUSION

Based on this project, we conclude that Close Range Terrestrial Photogrammetry can be a cost-effective solution for topographic mapping of landslide and similarly configured areas. For this project, the actual time spent to capture the stereo photography and set up the necessary GPS and field survey was only one(1) day thereby reducing risk to the field survey crew and lowering field operation costs. Given the proper training and system resources, this process can be done quickly, efficiently and safely in the field. This method can also achieve mapping at high (cm. to decimeter) accuracy depending on the mapping requirements by adjusting and controlling the base-to-object distance ratio.



Resulting Digital Elevation Model



Final Topographic Map

6. POTENTIAL APPLICATIONS

- Disaster Mapping and Monitoring- Pre and Post Mapping
- Risk Assessment
- Preservation Applications
- Floodplain Mapping
- Large Structure Mapping and 3D Model Reconstruction
- Mining and Mine Mapping
- Dumpsite Mapping and Volume Extraction
- Road Stability/Subsidence Monitoring and Assessment
- Building Deflection and Foundation Monitoring
- Crack Detections
- Bridge Deformations
- Wall Deformations

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