GIS incorporation of Structure-from-Motion (SfM) models utilizing disaster response related imagery

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The Rissa, Norway Landslide of 1978

The Oso, Washington, (USA) landslide one year after the March 22th, 2014 landslide

An aerial photograph of the Oso, Washington landslide showing the path of the slide and the Stillaguamish River.

1. Introduction

Structure-from-motion (SfM) photographic alignment and related photosynth technologies create 3D objects using photographs from multiple perspectives. These technologies can utilize images from single or multiple sources or cameras, and allow for the quick creation of proportionally accurate models.

Models can then be used for geographic decision making (e.g. can a truck of size x drive down road of width z?) or to identify where there are data gaps not apparent from the initial imagery. Because of the ease of creation, SfM technology is finding its way into the disaster response toolkit.

A 3D post-earthquake SfM model of Katmandu was posted on the Internet by National Geographic on April 30th, five days after the 7.8 magnitude earthquake hit Nepal on April 25th, 2015.

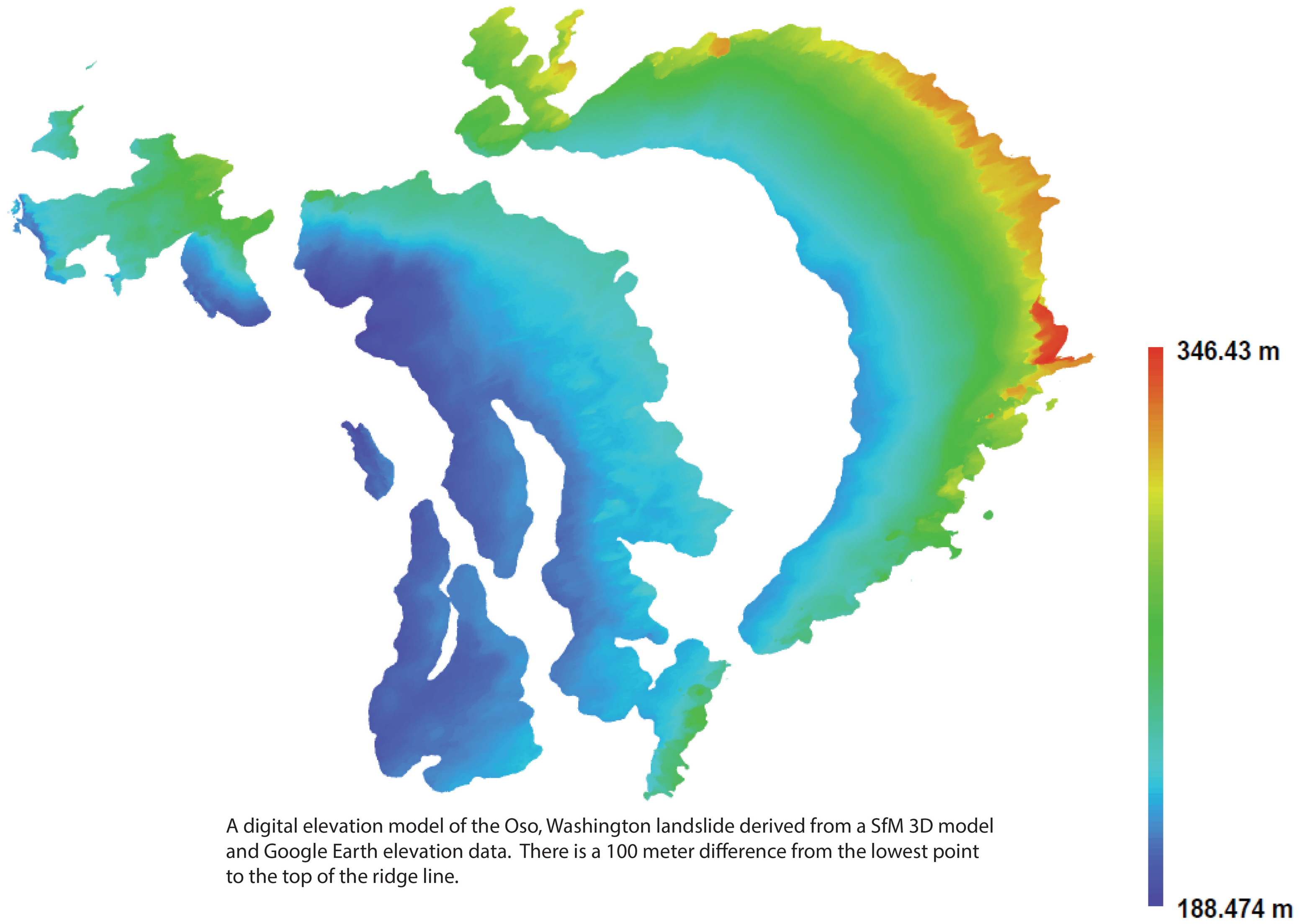
In this analysis I reviewed the time and data management concerns of building a model. The model was based on the March 22th, 2014 landslide in the Oso, Washington community, a recent large landslide in the northwest area of the United States. During the slide, eight million cubic meters of clay slid, encompassing a village below the slope and killing 43 people. This slide was very similar to the Rissa, Norway landslide of 1978.

2. Model Building

In this analysis I used Agisoft Photoscan 1.0.4. to create a 3D model of the Oso landslide. Images were collected from several online sources and from my visit to the site of the landslide. In total, I collected 187 images and tried aligning all and various subsets using the software. In the end, I found that the 73 images I took created the most comprehensive model. These images were taken over the course of 38 minutes at the landslide site.

The computer used run the software was a Dell 64 bit Optiplex 980 computer with an Intel i5 CPU 659 @3.20 GHz (lower than recommended) with 12 GB memory. The images were aligned using the "low alignment" parameter of the software without pair selection. After alignment, a dense point cloud was generated also using the lowest setting. Finally, a mesh was made from the dense point cloud with polygon count of up to 2,000,000 faces. The final model had 1,337,722 faces.

The 73 images were taken using a Sony ICLE-7 camera with a 24 Mp resolution at various focal lengths ranging from wide angle to telephoto. The full 187 image set required 1.96 Gb of storage space.



A digital elevation model of the Oso, Washington landslide derived from a SfM 3D model and Google Earth elevation data. There is a 100 meter difference from the lowest point to the top of the ridge line.

3. GIS - ArcScene / Google Earth

Google Earth and ArcScene are two common examples of geographic information systems that can deal with georeferenced spatial data in three dimensions. Google Earth switches into 3D mode as a person zooms into an area at a particular extent while ArcScene is the 3D component software to ArcGIS.

Using either a KML/KMZ file or a GeoTiff (a georeferenced image) either GIS can place the created model in the appropriate 3D space on a map or digital globe.

Conclusions

In this project it was easy to create a digital elevation model of a multi-hectare 8.000.000 M3 landslide given a very short period (< 40 min) to take photographs from limited access points.

The model build (multi-hour) easily revealed important data gaps and provided a model that could be georeferenced on a map and used during an emergency response.

ISO19115 standards cover most of the metadata issues regarding SfM models.

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4. Discussion

Models

Power of Model – Using Structure-from-Motion is extremely powerful and 3D models have multiple benefits:

- In the matter of minutes, with a UAV or a hand-held camera, images from disparate sources can be aligned to create a 3D model of a specific area.
- Models can be easily printed on a 3D printer
- Models can readily show data gaps that would not likely be noticed in 2D imagery
- Model size is much smaller than the set of images needed to make it
- Models can be georeferenced
- Models can be exported as georeferenced 3D mesh files and imported into ArcScene or Google Earth
- Models provide ways to accurately measure lengths, widths, and volumes
- Models provide an overview of an area and allow the viewer to look at a landscape from multiple perspectives

Data Management

There are many data management issues concerning photo-alignment.

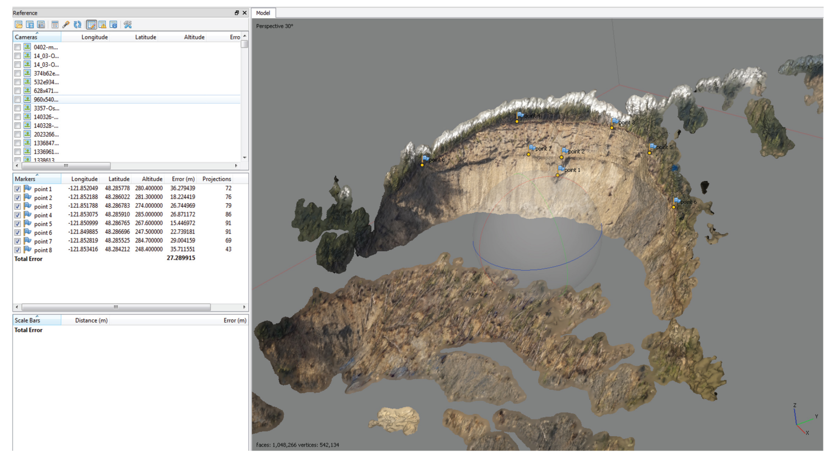
- In many cases, image and camera metadata are contained within the EXIF portion of a data image.
- Image use, permission, ownership and source should be recorded.
- Camera GPS information can be utilized and is almost universally WGS 1984
- Photo-alignment model file size, spatial resolution (alignment quality & number of mesh faces) and any use restrictions should be recorded
- Remaining spatial data concerns are likely covered by FDGC and ISO190115 spatial metadata requirements.

Copyright Issues

U.S. copyright laws allow for use of copyrighted images if the end result is a transformed object. Using photo-alignment to recreate a scale model of copyrighted object would not meet this criterion. However, use of a copyrighted 2D image as one in a set of images used to create a 3d model would be a transformative use of the 2D image. The author believes that this transformation is legal under current law.

GIS

Both ArcScene and Google Earth, but particularly ArcScene allow the user to look at models in-situ on topography from any angle. Since these models are proportionally constricted and are georeferenced, accurate measurement can be made from the models in regards to other topographic features.



The Photoscan produced 3D model of the landslide showing georeferenced points and the data gaps attributed to the low topographic position of the Stillaguamish River. Data gaps are related to the position of the cameras used to create the object.

Camera Calibration

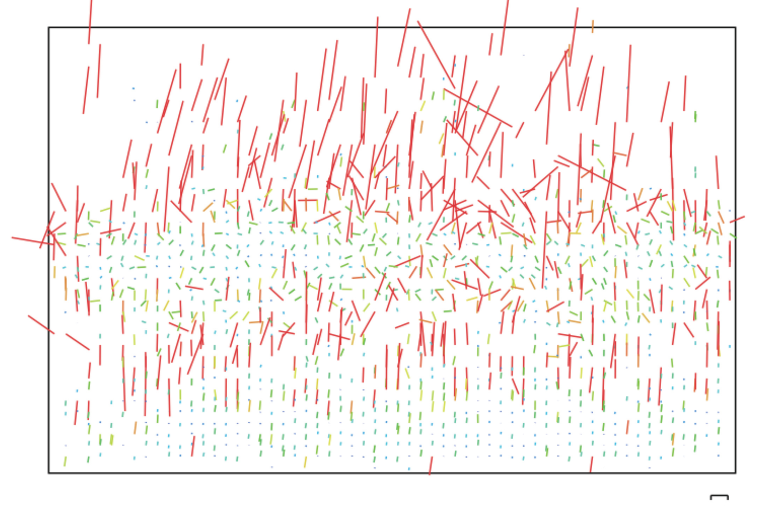
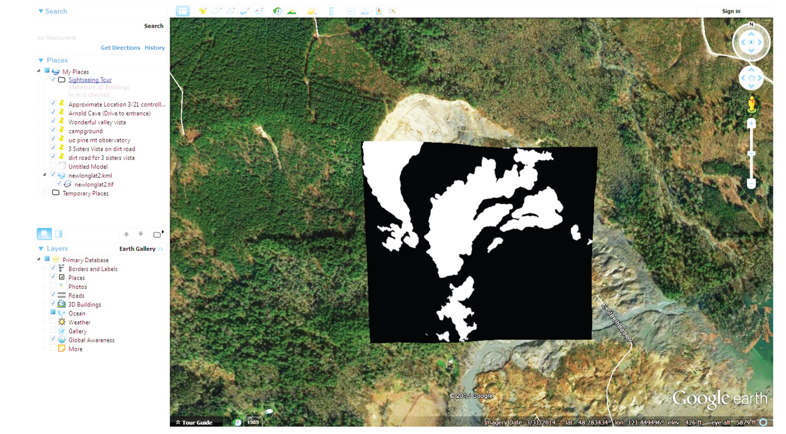


Image residuals for ILCE-7 (28 mm).

ILCE-7 (28 mm)

Type:	Frame	K1:	-0.0266056
Fx:	4842.67	K2:	0.0884417
Fy:	4842.67	K3:	-0.0783754
Cx:	2992.18	K4:	0
Cy:	2002.82	P1:	0
Skew:	0	P2:	0

Plot of calculated data errors from a subset (wide angle) of the 73 images use in creating the 3D model of the Oso landslide



Automatic placement in Google Earth of a KMZ file representing the 3D model of the Oso landslide based on the georeferenced 3D model