Generation of A Digital Surface Model For A Small Area Using Close Range Photogrammetry (CRP)

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Generation of A Digital Surface Model For A Small Area Using
Close Range Photogrammetry (CRP)

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Introduction

• A DSM is a digital representation of a surface.
• A digital surface is represented either by TINs or regular grids (pixels).
Introduction...

- Uses of DSMs

- Video games
- Crime scene
- Borrow pit mining
- Medicine
- Topographic maps
- Construction site excavation
- Archaeology
Introduction....

- **Photogrammetry Defined**

- Simply, measuring from photographs

\[
x_a = x_0 - f \left[ \frac{m_{11}(X_A - X_L) + m_{12}(Y_A - Y_L) + m_{13}(Z_A - Z_L)}{m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L)} \right]
\]

\[
y_a = y_0 - f \left[ \frac{m_{21}(X_A - X_L) + m_{22}(Y_A - Y_L) + m_{23}(Z_A - Z_L)}{m_{31}(X_A - X_L) + m_{32}(Y_A - Y_L) + m_{33}(Z_A - Z_L)} \right]
\]

Collinearity condition equations

Where:

- \(x_a, y_a\): Image coordinates of point (A).
- \(m_{11}, ..., m_{33}\): Rotation matrix elements.
- \(x_0, y_0\): Principal point coordinates.
- \(X_A, Y_A, Z_A\): Object coordinates of point (A).
- \(X_L, Y_L, Z_L\): Object coordinates of exposure station.
Objectives

- Demonstrating the procedure of DSM generation by close range photogrammetry.
- Assessing the accuracy of the result for two cases:
  - Using initial camera parameters from Exchangeable image file format (EXIF).
  - Using optimized self-calibrated camera parameters.
- Enumerating the potential use of the DSMs.
- Compare C.R. photogrammetry to other alternatives for DSM generation.
Materials and Methods

- Materials

  Total Station:
  Model: Leica TC407
  Angular Precision: ±7"
  Distance Precision (IR): ±(2mm+2PPM)
  Measurement speed: 2.4 seconds/point

  Digital Camera
  Camera model: Canon EOS 70D
  Resolution: 20 MP (5472×3648)
  Physical pixel size: 4 microns
  Focal length used: 18mm

  Signalized control points
  Size: A4
  Pattern: B&W rectangles

  Software Applications
  Agisoft PhotoScan®
  ArcGIS®
  Surfer®
Methods....
Field Work

Overview of the study area
East of Almanshya bridge

Collection of 3D Coordinates by Total station (8 min)
Capturing Images
72 images (15 min)
Distribution of Control Points
10 points
### Methods.... Photogrammetric Processing

1: 72 Images uploaded to PhotoScan

2: Automatic Identification of distinctive points

3: Digital image matching (Tie Points)

4: Solution of the Collinearity model

\[
x_a = x_0 - \frac{m_{12}(Y_4 - Y_L) + m_{13}(Z_4 - Z_L)}{m_{31} (X_4 - X_L) + m_{32} (Y_4 - Y_L) + m_{33} (Z_4 - Z_L)}
\]

\[
y_a = y_0 - \frac{m_{21}(Y_4 - Y_L) + m_{22}(Z_4 - Z_L)}{m_{31} (X_4 - X_L) + m_{32} (Y_4 - Y_L) + m_{33} (Z_4 - Z_L)}
\]
Methods....
Photogrammetric Processing....

5: 10 Control points identified on images  
(7 control, 3 Check)

6: Check the accuracy of the Collinearity model

7: Using EXIF Camera Parameters
- Initial focal length (18mm)
- Initial principal point
- No distortion parameters

8: Using Optimized Self-Calibrated Camera Parameters
- Self-Calibrated focal length (18.8mm)
- Calibrated principal point
- Radial distortion parameters (k’s)
- Tangential distortion parameters (P’s)

Locations of control points
Methods
Photogrammetric Processing

9: Generation of dense point clouds

10: Generation of a mesh

11: Export DSM and Orthophoto

Data Manipulation

12: ArcGIS and Surfer
   - Volume calculations
   - Contour maps
   - Orthophoto
   - Cross sections
   - 3D Scenery
Results

- **Precision of the Model**

<table>
<thead>
<tr>
<th>Standard Deviation of Control Points (EXIF Parameters)</th>
<th>Standard Deviation of Control Points (Calibrated Parameters)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>X(m)</strong></td>
<td><strong>Y(m)</strong></td>
</tr>
<tr>
<td>0.088</td>
<td>0.123</td>
</tr>
<tr>
<td><strong>RMS of Check Points (EXIF Parameters)</strong></td>
<td><strong>RMS of Check Points (Calibrated Parameters)</strong></td>
</tr>
<tr>
<td><strong>X(m)</strong></td>
<td><strong>Y(m)</strong></td>
</tr>
<tr>
<td>0.360</td>
<td>0.781</td>
</tr>
</tbody>
</table>
Results...

- **Dense Point Clouds**
  - 11.7 million points were created
  - Outliers (mismatch + unwanted features) have to be removed
Results....

- The mesh (TIN)

- From the dense point clouds, More than 2 million faces (triangles) were generated to represent the surface

Generated mesh
Results....

- Data Manipulation (ArcGIS)
  - The DSM and the orthophoto were imported into ArcGIS.

Contour map overlaid on an Orthophoto of 1cm resolution (ArcGIS)
Results....
- Data Manipulation (ArcGIS)

3D Scene of the contour lines draped over the DSM (ArcGIS)
Results....

- Data Manipulation (Surfer)

- The DSM imported into Surfer and used for contouring and to draw a cross section through A-A.
Results....

- **Data Manipulation (Surfer)**

  - The DSM was used in Surfer to calculate the planar area and the volume of the hilly terrain above the lowest contour.

- The results was:
  - 974 sq. m.
  - 1174 cubic m.
Results....

- **Data Manipulation (Surfer)**

- DSMs are also useful for visualization of locations of cut and fill.

- **Reference height 8.5m**

  - Positive Volume [Cut]: 191.2 Cu. M.
  - Negative Volume [Fill]: 198.7 Cu. M.
  - Positive Planar Area [Cut]: 300.8 Sq. M.
  - Negative Planar Area [Fill]: 282.2 Sq. M.
Results....

- **Time and cost**

- The field work time needed to collect the same amount of point clouds (11.7 Million points).

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Pt/sec</th>
<th>Time</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Station (Reflectorless)</td>
<td>4 Pt/sec</td>
<td>34 Days</td>
<td>13,000 $</td>
</tr>
<tr>
<td>Digital Camera</td>
<td></td>
<td>15 min.</td>
<td>500 $</td>
</tr>
<tr>
<td>Terrestrial laser scanner</td>
<td>200,000 Pt/sec</td>
<td>1 min.</td>
<td>100,000 $</td>
</tr>
</tbody>
</table>
Conclusions and Recommendations

- Self-Calibration highly improves the accuracy of the photogrammetric model.
- An accuracy of 7mm, 17mm and 29 mm total RMS for X, Y and Z respectively was obtained for the check points and 16mm, 19mm and 21mm for control points.
- The closeness of the values of the two sets, points out that the internal accuracy of the model is an indication of external accuracy and thus the need for check points can be downgraded.
To accurately represent the surface, the point clouds’ outliers should be removed before the DSM is generated.

Numerous products and uses can be obtained from a DSM.

Close range photogrammetry outperforms the classical surveying methods, especially when it comes to the time needed for field measurements and the density of generated point clouds.

Close range photogrammetry directly competes with terrestrial laser scanners.