Georeferencing oblique landscape photos to evaluate century-scale changes in the structure of Rocky Mountain and foothills landscapes

Wheeler Irrigation Survey, 1895

Higgs, 2009

Chris Stockdale - PhD Candidate

Committee
Ellen Macdonald - supervisor
Mike Flannigan
Eric Higgs

April 25, 2014
Banff AB
Mountain Cartography Workshop
Planning for the future without knowledge of the past is inherently riskier than the alternative.

“We are more likely to use the present to attempt to reconstruct the past, than we are to use the past to understand the present and guide the future.”

- Stephen Pyne
From: Swetnam et al. 1999. Applied Historical Ecology: Using the past to manage for the future
From: Swetnam et al. 1999. Applied Historical Ecology: Using the past to manage for the future
Remote Sensing
A more complete view

1939 – southern Alberta
Canada-wide aerial photography

1930  1949  1980  2010

1954

2004
Remote Sensing

- 1870
- 1885
- MLP
- 1930
- 1939 – southern Alberta
- 1949
- Canada-wide aerial photography
- 1980
- 2010

Wheeler 1895

Higgs, 2009
Remote Sensing
A more complete view

Requirements?
• Photographs taken at nadir
• Every pixel = same area*
• Lots of software tools available

Wheeler 1895

Higgs, 2009
Rubbersheeting

Can’t interpret vegetation after georeferencing
From: C. Bozzini, M. Conedera, P. Krebs 2012. A New Monoplotting Tool to Extract Georeferenced Vector Data and Orthorectified Raster Data from Oblique Non-Metric Photographs. *International Journal of Heritage in the Digital Era*
original document
a cropping of the original document with the shared frame in which vegetation categories were plotted and traced out

orthogonal view
vegetation categories placed upon a current topographic map and intersected with the shared viewshed

old photo perspective
vegetation categories inside the shared frame projected into the perspective of the 1933 photo

new photo (2012)

number of plotted features: 16
<table>
<thead>
<tr>
<th>Idx</th>
<th>Name</th>
<th>Dem</th>
<th>Photo position</th>
<th>World position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0.07</td>
<td>(nan, nan)</td>
<td>(651570.00, 5644332.00, 2317.63)</td>
</tr>
<tr>
<td>✔</td>
<td>1</td>
<td>0.07</td>
<td>(1248.30, 552.48)</td>
<td>(650583.51, 5641850.11, 1638.13)</td>
</tr>
<tr>
<td>✔</td>
<td>2</td>
<td>0.16</td>
<td>(1388.54, 1419.52)</td>
<td>(650083.60, 5640868.04, 1962.53)</td>
</tr>
<tr>
<td>✔</td>
<td>3</td>
<td>0.06</td>
<td>(1845.41, 1437.18)</td>
<td>(649231.77, 5640615.05, 2049.28)</td>
</tr>
<tr>
<td>✔</td>
<td>4</td>
<td>0.05</td>
<td>(2533.47, 776.45)</td>
<td>(649872.35, 5641937.47, 1656.13)</td>
</tr>
<tr>
<td>✔</td>
<td>5</td>
<td>0.22</td>
<td>(3768.46, 865.64)</td>
<td>(650207.40, 5643131.22, 1936.41)</td>
</tr>
<tr>
<td>✔</td>
<td>6</td>
<td>0.06</td>
<td>(4200.36, 1415.39)</td>
<td>(646848.32, 5640848.13, 1748.46)</td>
</tr>
<tr>
<td>✔</td>
<td>7</td>
<td>0.24</td>
<td>(4399.37, 1704.12)</td>
<td>(645626.07, 5640272.66, 2025.80)</td>
</tr>
<tr>
<td>✔</td>
<td>8</td>
<td>0.17</td>
<td>(4494.49, 1093.31)</td>
<td>(648966.26, 5642632.43, 1827.57)</td>
</tr>
<tr>
<td>✔</td>
<td>9</td>
<td>0.02</td>
<td>(5574.62, 1496.13)</td>
<td>(644641.60, 5641366.31, 1765.78)</td>
</tr>
<tr>
<td>✔</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ACCURACY TEST
1. 8 images used
2. 21 control points established in each image
3. 6 Anchor Points used to georeference the image
4. Remaining 15 control points (TEST points) are georeferenced in Monoplotting tool
5. Locations compared to Control Point
ACCURACY TEST

1. 8 images used
2. 21 control points established in each image
3. 6 Anchor Points used to georeference the image
4. Remaining 15 control points (TEST points) are georeferenced in Monoplotting tool
5. Locations compared to Control Point

<table>
<thead>
<tr>
<th>Image</th>
<th>Vector Error (m)</th>
<th>Displacement Error (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.9</td>
<td>1.7</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>0.74</td>
</tr>
<tr>
<td>4</td>
<td>47.3</td>
<td>26.6</td>
</tr>
<tr>
<td>5</td>
<td>11.8</td>
<td>1.9</td>
</tr>
<tr>
<td>6</td>
<td>19</td>
<td>3.1</td>
</tr>
<tr>
<td>7</td>
<td>9.4</td>
<td>4.5</td>
</tr>
<tr>
<td>8</td>
<td>6.7</td>
<td>1.8</td>
</tr>
<tr>
<td>9</td>
<td>10.8</td>
<td>7.9</td>
</tr>
<tr>
<td>Total</td>
<td>14.6</td>
<td>2.95</td>
</tr>
</tbody>
</table>
How do we use this to analyse landscape change?

1. Polygon based approach
2. Raster based approach
3. Hybrid polygon/raster
Polygons

Classify vegetation in plots in Monoplotting Tool

NOTE: Oblique view, MLP image
Polygons

Export spatially referenced objects to ArcGIS (or other GIS)

NOTE: Orthogonal view in GIS
NOTE: Orthogonal view in GIS overlain on Orthophoto of same time as MLP image
Rasters
Ortho image of same region
Rasters

Viewshed Analysis of image showing what part of landscape is visible in photograph
Rasters

Insert spatially referenced grid in Visible landscape

30m grid
Export spatially referenced grid to Monoplotting tool for classification of 2009 image
Rasters

1899 image with grid
Table 1: Vegetation Transition Matrix

<table>
<thead>
<tr>
<th>Initial</th>
<th>Final</th>
<th>Grass</th>
<th>Shrub</th>
<th>Decid.</th>
<th>Mixed</th>
<th>Conifer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
<td>-4</td>
<td></td>
</tr>
<tr>
<td>Shrub</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
<td></td>
</tr>
<tr>
<td>Deciduous</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>-1</td>
<td></td>
</tr>
<tr>
<td>Conifer</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
Table 1: Vegetation Transition Matrix

<table>
<thead>
<tr>
<th>Initial</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>Shrub</td>
</tr>
<tr>
<td>Grass</td>
<td>0</td>
</tr>
<tr>
<td>Shrub</td>
<td>1</td>
</tr>
<tr>
<td>Deciduous</td>
<td>2</td>
</tr>
<tr>
<td>Mixed</td>
<td>3</td>
</tr>
<tr>
<td>Conifer</td>
<td>4</td>
</tr>
</tbody>
</table>

Figure 1: Raster “change” surface
Put plots on landscape
Is 1913 more variable than 2009?
  Patch sizes, edge to interior, # of patches, fractal dimension, contagion, TPSA
Has the leading tree species of the forest changed?
  Where? Is this to more or less advanced successional species?

Is the forest more dense (stem density) in 2009 than 1913?
  Where is this observed? What were the original conditions?
Is the age class distribution of the forest older and more homogenous?
Primary Funding Sources

Natural Sciences and Engineering Research Council of Canada
www.nserc-crcsn.gc.ca

Additional Funding Sources

Alberta Innovates Technology Futures

In-Kind Support

Mountain Legacy

The Canadian Rockies 1861 to the Present

Swiss Federal Institute for Forest, Snow and Landscape Research WSL
• Bridgland 1912-1913
• Wheeler 1895-1899
• Total 1462 Image pairs
Choose area with extensive view coverage

5 km viewshed from all photos