Detecting coastal change in UAV Multi-View Stereopsis (UAV-MVS) point clouds

Dr Steve Harwin
TerraLuma UAV Research Group
Surveying and Spatial Science
School of Land and Food
University of Tasmania

UAS4RS – Brisbane 17-18 February, 2016
My PhD Research

• Detailed change mapping: using low altitude drone photography for monitoring landform change

• Case study: Fine scale coastal erosion monitoring

• The aim of my PhD (and publications*) was to rigorously assess the accuracy of the UAV-MVS survey technique to better understand the scale of change that can be detected

• The research evaluated survey design considerations (camera network design, camera calibration, and ground control density and distribution) through photogrammetric simulation and carefully planned experiments

• How precisely can we cost effectively survey and monitor landform change?


Data capture at key moments

- Gradual changes may be event driven or an indicator of subtle long term trends
- Traditional photogrammetry and satellite data may not provide the resolution we need to discern what is driving the changes
Study Site: Pittwater Estuary, Tasmania
The Study Site
The UAV and Camera

2nd Generation OktoKopter
2 kg payload
6-10 min flights

Canon 550D
Sony a5100
Typical UAV-MVS Survey

- Layout 10-20 GCP targets and survey them
  - usually with RTK DGPS, but in this case we used a Total Station prism and staff
- Plan nadir and oblique flights based on target terrain features
- Fly at between 20-50 m (AGL) for 5-10 minutes per flight depending on resolution and coverage requirements
  - in this case we flew at an average height of 20-25 m (AGL)
- Capture an image every 1 second in a flight
  - in this case we captured over 250 images in two flights, 172 of which were chosen for 3D reconstruction
- Generate 3D point cloud, ortho-mosaic and surface model using MVS
  - in this case Agisoft PhotoScan was used and the GCPs were manually located for model georeferencing
The Camera Network and Point Cloud
Reliably mapping the spatial extent and rate of change relies on comparable datasets of sufficient accuracy and temporal resolution to discern the what, when and why of that change.
Accuracy Assessment

- Precise Total Station survey to a std. dev. of <2 mm (1\(\sigma\)):
  - 13 Ground Control Points (GCPs)
  - 34 Validation Points (VPs)

- To compare Total Station GCPs to RTK DGPS GCPs:
  - The GCPs were degraded using a random Gaussian generator to introduce an error equivalent to typical RTK DGPS (1\(\sigma\) = 22 mm)

- Two flight plans were compared:
  - Only nadir images
  - Nadir and oblique images

- The surveyed VPs were compared to their positions in each derived 3D point cloud:
  - 34 VPs within the broader study area
Accuracy Assessment

<table>
<thead>
<tr>
<th>GCP Survey (Oblique Y/N)</th>
<th>RMSE$_{xy}$ (mm)</th>
<th>RMSE$_{z}$ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Station (N)</td>
<td>1.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Total Station (Y)</td>
<td>1.3</td>
<td>5.9</td>
</tr>
<tr>
<td>RTK DGPS (N)</td>
<td>10.3</td>
<td>16.6</td>
</tr>
<tr>
<td>RTK DGPS (Y)</td>
<td>7.0</td>
<td>11.9</td>
</tr>
</tbody>
</table>
Oblique imagery

With Oblique
(Y,Z offset (m) = (1.0,0.5))

No Oblique
(Y,Z offset (m) = (0.5,0.25))
2012 versus 2013
2012 versus 2013
2012 versus 2013
Profile 1 – 2012 vs 2013
Shoreline change – Scarp edge

Legend
- Green line: 2010 Scarp Edge
- Red line: 2012 Scarp Edge
- Blue line: 2013 Scarp Edge

2010-2012: 210 mm
2010-2013: 420 mm
Shoreline change – Vegetation edge

Legend
- 2010 Vegetation Edge
- 2012 Vegetation Edge
- 2013 Vegetation Edge

2010-2013: 210 mm
Key findings

• 3D point clouds with **1–6 points per cm\(^2\)** are produced for a flying height of \(\sim\)20–25 m above terrain

• UAV-MVS point cloud accuracy for natural terrain:
  – **< 5–6 mm** using precise control \((\sigma = 1–2 \text{ mm})\)
  – **10–11 mm** using differential GPS control \((\sigma = 22 \text{ mm})\)

• **70–80\% overlap nadir** photography supplemented with **oblique photography** focussed on complex portions of the terrain provides the most accurate and complete 3D reconstructions (of this coastal shoreline)

• The UAV-MVS technique allows **centimetre scale monitoring** of coastal erosion

• **Scarp edge** extracted from 3D terrain is a more reliable proxy for shoreline than vegetation edge (at this coastal site)
Acknowledgements

• Dr Arko Lucieer for his guidance and general advice
• Dr Jon Osborn for his advice and guidance in developing the photogrammetry experiments
• Darren Turner for piloting the UAV
• Matt Dell for advice on PhotoScan workflow and settings

Thank you
CASA Regulations for RPA

• The Rules:
  – Fly in line of sight and in daylight only (unless you have special permission).
  – Maximum flying height is 120m (400 feet).
  – The RPA is not allowed to fly within 30m of vehicles, buildings or people in public places.
  – You are not allowed to fly over populated areas or within 5.5km of an airfield.
  – To fly an RPA of any size for commercial reward, you need a UAV controller's certificate (soon to be known as a remote pilots license) and an unmanned operators certificate (UOC) for your business.

• Further information:
  Phone: 131 757

Shoreline retreat from aerial photography

Roches_1957 1957 shoreline (vegetation limit)
Roches_1975 1975 shoreline (vegetation limit)
Roches_1977 1977 shoreline (vegetation limit)
Roches_1986 1986 shoreline (vegetation limit)
Roches_1987 1987 shoreline (vegetation limit)
Roches_1997 1997 shoreline (vegetation limit)
Roches_2002 2002 shoreline (vegetation limit)
Roches_2007 2007 shoreline (vegetation limit)
Roches_2011_15thJuly_MGA

Data point transect