The potential uses of UAV-based remote sensing in the Great Lakes

Ben Vander Jagt
Doug Alsdorf
Satellite Hydrology and Remote Sensing
The Ohio State University

Great Lakes Workshop Series on Remote Sensing of Water Quality 2014
Cleveland, OH
Outline

✓ Introduction
✓ State of the Art
✓ Platform Configuration
  ❖ OSU test platform
✓ Research Topics thus far
  ❖ Sensors, Integration, and Accuracy
  ❖ Photogrammetry and Lidar
  ❖ 3D modeling, River Widths, Snow
✓ Great Lakes Applications (for water quality)
  ❖ Limitations and Future Solutions
✓ Conclusions and time for questions
Background

✓ Long before I was much of a scientist*, I was a fisherman
Introduction

- Small UAVs are fast replacing traditional platforms in applications including mapping, tracking, and emergency response.

- **Benefits vs traditional platforms**
  - Decreased upfront and operating costs
  - High resolution and high accuracy data
  - DDD – Dull, Dirty, Dangerous

- **Current Research Applications**
  - Landslide monitoring, Forestry, Geophysical Exploration, Water Resources, Change Detection
  - Water Quality?
Octocopter made by small “boutique” manufacturer in Michigan

Sensors include the following:
- Novatel OEM 615 Dual Frequency GNSS receiver (RTK)
- Antcom GNSS antenna
- Microstrain 3DGM Inertial Measurement Unit (IMU)
- Nikon D800 camera
- Autopilot and control software
- Velodyne Lidar (in the works)

Onboard computer to log/process the data (FitPC)
Images are typically taken at regular intervals as platforms move through the object space, based on matching relative changes in orientation and 3D object space information can be derived.

Using the collinearity equations and the 2D SIFT features, the object space can be reconstructed and the metric 3D measurements can be made.
Concepts – Collinearity Equations

- Relates projective image space to 3D object space
- Can be linearized and integrated into bundle adjustment
  - optimal

\[
\begin{bmatrix}
    x_{im} \\
    y_{im}
\end{bmatrix} =
\begin{bmatrix}
    x_o + \frac{r_{11}(X_A)}{r_{13}(X_A)} X_0 + r_{21}(Y_A) Y_0 + r_{31}(Z) Z_0 \\
    \frac{r_{12}(X_A)}{r_{13}(X_A)} X_0 + r_{22}(Y_A) Y_0 + r_{32}(Z) Z_0
\end{bmatrix}
\]

\[
\begin{bmatrix}
    y_o + \frac{r_{12}(X_A)}{r_{13}(X_A)} X_0 + r_{22}(Y_A) Y_0 + r_{32}(Z) Z_0 \\
    \frac{r_{13}(X_A)}{r_{13}(X_A)} X_0 + r_{23}(Y_A) Y_0 + r_{33}(Z) Z_0
\end{bmatrix}
\]
We assume scene to be static, UAS generates the stereo disparity.

- Problem: River is moving 😊
- Solution: Look at rivers edge
- Problem: Lots of vegetation at rivers edge
- Solution: Use Lidar
Accuracy (not precision!)

✓ Objective: How accurately can you resolve 3D information obtained from UAVs?

✓ Oftentimes, accuracy is what matters, as opposed to pretty pictures.

<table>
<thead>
<tr>
<th>Lidar</th>
<th>Indirect BA (truth)</th>
<th>Direct BA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.047 m</td>
<td>0.05 m</td>
<td>~0.05 m</td>
</tr>
<tr>
<td>0.056 m</td>
<td>0.041 m</td>
<td>~0.05 m</td>
</tr>
<tr>
<td>0.123 m</td>
<td>0.052 m</td>
<td>0.19 m</td>
</tr>
</tbody>
</table>
**Can we measure snow depth?**

- **Problem:** Snow is homogeneous in the visible spectrum (its white)
- **Solution:** Lower altitudes and high res imagery provide more texture

**Other remote sensing techniques fail in deeper snow**

- accuracy remains the same regardless of depth
Great Lakes Applications

- Thermal Discharge
  - High resolution data provides much better assessment on the magnitude of discharge by utility corporations.

- Ag/Sediment Discharge
  - Lake Erie algae blooms
    - Cyanobacteria
  - Individualized watershed sources
  - Inland lake blooms
    - Buckeye Lake
    - Grand Lake St. Marys
    - Etc.

- Currents/Lake Circulation
- Sediment Plumes
- Data Assimilation
- Whatever needs high resolution data will work well!

Credit: MERIS/NASA; processed by NOAA (probably George)
Data Assimilation

- More information is always better!

- Great Lakes DA
  - Model
    - NOAA GLCF
  - Observations
    - satellite
    - airborne
    - low altitude UAS
  - States/Outcome
    - predicted thermal plume
Current Limitations

- With small, electric platforms, battery life is an issue.
  - great for smaller scale work, not Great Lakes (yet)
    - e.g. a river outlet plume
  - payload weight has inverse relationship with flight times

- Sensor integration can be a problem (often requires custom payload solutions)

- FAA has yet to implement regulations pertaining to UAV operations
  - As of now, research/industrial users need a certificate of authorization to UAV research.
  - Takes ~6-8 months to obtain (if successful)
Current and Future Solutions

Hardware

✓ Solar Powered
  ❖ No refueling required
  ❖ Facebook/Titan Aerospace
✓ Increased Battery Life
✓ Decreased sensor cost

Software

✓ Cloud computing
  ❖ don’t bog down your work machine processing data
  ❖ One integrated software solution
    • GPS
    • Mapping
    • Navigation, etc
Any Questions?

Let's make this obsolete!