Infrastructure Monitoring: Sensing for Change Detection, Volume Estimation, and Proactive Remediation

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Project Goals

- sUAV platforms and trajectory optimization
- Quantify improved computer vision with sensor telemetry
- Determine accuracies that can be achieved with sUAV-mounted hybrid sensing and analysis
  - Electro-optical
  - LiDAR
  - Thermal Imaging
  - μSAR
Objectives and Tasks

**Year 1 (current year):**

- Computer vision expertise with addition of Dr. Ryan Farrell
- Use a controlled test environment for quantifying accuracy
- Assess accuracy of computer vision for detecting/measuring displacements in the controlled environment
  - sUAV flight optimization for computer vision models in the field

**Year 2:**

- Develop field test sites for evaluating displacements in a pipeline, a soil slope/embankment, an asphalt/concrete pavement, and a rock fall
- Assess accuracy of computer vision for detecting/measuring field displacements
- Compare and combine multiple sensing data sources
Ryan Farrell

- Recently joined the Computer Science Dept. at BYU
- Research Areas: Computer Vision, Object Recognition, Tracking
UAS – an “Unknown Aerial System”
Building Models (SfM)

Images: CC - jdegenhardt, Bob Snyder, Jacques van Nierkerk, Kyle Wagaman, (Flickr)
Building Models (SfM)

- SfM traditionally requires comparison of all pair of images (500K comparisons for 1K imgs)

Telemetry sensors (IMU, GPS, Altimeter) enable:
- Real-time camera location and orientation
  - This greatly constrains the image matching
- Option of adaptive or dynamic image collection

Image: CC - carfull (Flickr)
LiDAR and Computer Vision

• LiDAR and Imagery are complimentary

• LiDAR will allow:
  • better quantification of accuracy for computer vision models
  • better and more useful models by combining these modalities

• We are in the process of acquiring LiDAR and multi-spectral sensors

Illustration: Michael Goesele et al., 2007
Image Collection Optimization

Camera Path Optimization Workflow

- Elevation Data
- Rough 3D Model
- Optimize Flight Path
- Refine Model
- Collect Images
- Final 3D Model

C-UAS
Image Collection Optimization

- Multicopter Platform
- Genetic Algorithm
- Calculate optimal camera positions for 3D reconstruction
Volume Estimation

Lab Study: Box

Actual Volume: 1,256 cm$^3$
Model Volume: 1,267 cm$^3$
**Error:** 0.81%

Surface Measurement
**RMSE:** 0.56 mm
Joe’s Valley – Dam Inspection

- Quantification of Model Accuracy

Fly-over image of Joe’s Valley Reservoir Dam

Computer vision model of Joe’s Valley Reservoir Dam
Platform Selection for Accuracy

- Improvement of 7% with quadcopter vs. flying wing
  - Distance measurements
  - Pending: quantify surface feature accuracy for displacement detection
Progress Summary

• Current Progress
  – Quantification of accuracy of volume estimation
  – Improvement of 7% with quadcopter vs. flying wing
  – Scalable computing on Amazon EC2
  – Field testing on earthen levee spillway

• Planned Progress
  – Enhanced accuracy with LiDAR Velodyne
  – Integrated telemetry for enhanced SfM
  – Selection of field test site for pipeline monitoring