Optimized Infrastructure Monitoring

3D Modeling in Complex Environments

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**Project Overview**

**Optimized Infrastructure Monitoring**

Since 2013...
- Maximize model resolution
- Evaluate workflow impacts
- Optimize flight path
- Collect field data
- Simulate anomaly detection
- Model long linear infrastructure

Present...
- Model complex environments
Italy Earthquake Modeling

Link to Italy Model: http://prismweb.groups.et.byu.net/PL/App/#%2F/
Intelligent Multiscale Targeted Monitoring

debris blocking road  
medium interest area

failed retaining wall  
high interest area

intermediate foliage  
low interest area

damaged houses with unknown structural integrity  
high interest area
Optimized Flight Planning Validation

**Simulated Flights - 2015**

Grid Flight
Accuracy: 10 cm

Optimized Flight
Accuracy: 3.8 cm

**Physical Flights - 2016**

Grid Flight
Accuracy: 14 cm

Optimized Flight
Accuracy: 8.4 cm

+62%
+40%

With Pictures from DJI Phantom 4.
Close Up Flights

- Initially created holes
  - Bad input elevation data effects multiplied by close flights
  - Minor problems with algorithm view angles

- Solutions
  - Add a dome to the initial elevation data
  - View angles fixed
North Salt Lake Landslide

• Largest optimized flight yet!
  – 600x400 ft
• Fixed hole problem
• Initial elevation model pre-dated landslide
  – Mitigated with an added mound on the initial model to add dimension
• Future Work:
  – Change detection
  – Iterative model refinement study
St. Louis Levee

• Large and small UAVs
• Heavy lift platform and DSLR camera (piloted)
• Optimized path (fully automated)
Future Work: Change Detection Study

- Intelligent multiscale targeted monitoring
- Repeated flights over 4-6 months
- Field validate with precise ground surveys
- Evaluate use of longer term static ground control
  - Simplifies repeated inspections

1.3 mile landslide in Sanpete, UT
Indoor Flights

• Millions of miles of pipeline and other enclosed long linear infrastructure
• No current method for navigating a UAV autonomously through an enclosed linear environment
Proof of Concept

Arducopter Software-in-the-loop Simulator:
Combined Photogrammetry & LiDAR

- Optimization done in Summer 2016
- Lab scale equipment
  - Flow controller
  - Pumps and meters
  - Pipes and tanks
- Varied surfaces
  - Shiny metallic surfaces
  - PVC Piping
Complex Structure from Motion
Online 3D Model Gallery

BYU PRISM 3D Model Gallery

2016 Central Italy Earthquakes

St Louis Levee

2016 Japan Earthquake

https://goo.gl/DrMsK9
Going Forward

• Complete thorough change detection field study
• Intelligent multiscale targeted monitoring
• Continue indoor long linear inspection work moving to 2D
  – Physical 1D test flight
• Simulated iterative model refinement study
Measurable 3D Models on Your Smartphone

• Task: Calculate the volume of the boulder

8.5m x 6m x 3.5m = 180m³
Hole Detection

90 m 11 m 4 m

3 inch diameter holes
Advantages of Flying Closer

• Small objects visible at closer range
• Increased model knowledge ensures no spot will be missed
• Maximize coverage for 2D change detection
• Smaller (safer and cheaper) UAV’s
  – Example: Japan Earthquake model
• Can see beneath objects
Test Case

• Lab scale equipment
  – Flow controller
  – Pumps and meters
  – Pipes and tanks

• Varied surfaces
  – Shiny metallic surfaces
  – PVC Piping
Initial Results
Complex Structure from Motion
General vs Modeled

• Two methods of optimization

• Unknown system/anomaly
  – Bubble method

• Known system/anomaly
  – New method with blocked cameras
Application Study 1

- Steinaker Dam – Vernal, UT
- Already have a good model
  - Want to match with a smaller system and camera
- Change detection application
  - Flown 2 years ago
- Verification of optimized flight paths
Application Study 2

• Highline Canal – Payson, UT
• Long linear application
• Some obstructions
  – Pipes
  – Bridges
  – Trees
• Modeling of detected anomalies
Application Study 3

- Most Complicated System
  - Significant amounts of blocking
- Pictures within the key targets
- Added difficulty from reflections
- Depth of view problems
- Explore alternate methods
  - 2D change detection
  - Object recognition
Workflow

1. Record Data
2. Stream Data
3. Develop Usable Cloud
4. LOAM Processing
Workflow (part 2)

Generate Mesh

Detect Corrosion

Optimize Flight Path

http://www.gettyimages.co.nz/detail/photo/pipes-royalty-free-image/179276723
Initial Conclusions

• Feasible picture locations successfully determined and optimized
• Optimized waypoints reduced pictures by 50% while improving coverage
• Model knowledge increased coverage by ___
• Lidar significantly more accurate for model creation
• Focus issues magnified when in close proximity