Remote Sensing from Unmanned Aircraft: Image processing workflows, classification, and terrain extraction

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tactical Fire RSAC meeting, Mar. 20, 2012, Sacramento, CA
UAS for vegetation mapping

- Increased interest in using UAS for natural resource remote sensing tasks
- Smaller, light weight sensors for small UAS
- Low operating costs, imagery with very high resolution, repeated deployment for change detection, vegetation health
- FAA: Integration of UAS in National Airspace by 2015
UAS Operations at the Jornada Experimental Range

- Objectives: development of operational UAS-based remote sensing program for ecological applications
- Operated 2 UAS since 2006
- Areas of interests:
  - Access to airspace
  - Image acquisition
  - Terrain extraction
  - Orthorectification
  - Mosaicking
  - Vegetation classifications
  - Geometric and classification accuracies
  - Operational workflows
UAS Missions

• New Mexico
  – In National Airspace under a COA
  – In restricted (military) airspace
• Idaho 2008: COA issued to USDA
• Arizona 2011: COA issued to USDA
• Team of 6
  • 2 private pilot license
  • Private pilot ground school
  • FAA Class II med. cert.
BAT 3 UAS
- 1.8 m wingspan, 10 kg weight
- Flight duration: 2-5 hours

Sensors
- Video camera
- Canon SD900 10 mp
- Tetracam MiniMCA, 6 narrow bands, blue to near infrared

Image acquisition
- 700 ft AGL
- 75% forward, 40% sidelap
- Data file: X,Y,Z, roll, pitch, heading

<table>
<thead>
<tr>
<th></th>
<th>Canon</th>
<th>Multispectral</th>
</tr>
</thead>
<tbody>
<tr>
<td>Footprint:</td>
<td>160m x 213m</td>
<td>145m x 182m</td>
</tr>
<tr>
<td>Spatial:</td>
<td>6 cm</td>
<td>13 cm</td>
</tr>
<tr>
<td>Spectral:</td>
<td>3 bands</td>
<td>6 bands</td>
</tr>
<tr>
<td>Radiometric:</td>
<td>8-bit</td>
<td>10-bit</td>
</tr>
</tbody>
</table>
Same flight multispectral and RGB orthomosaics

Jornada
Sept. 2, 2011
Orthorectification and Mosaicking

PreSync

- All UAV Images
  - Generate Autopano tie points
- Initial EO
  - Camera calibration parameters
  - DOQ 1 m
  - DEM 5 m

Initial Tie Point Alignment

Rigid Block Adjustment

Individual Image Adjustment

Realignment of Tie Points

Repeat Rigid Block Adjustment

Further alignment required?

Yes → Repeat Rigid Block Adjustment

No → Corrected EO and tie points with ground coordinates

LPS

- Final Mosaic
  - AutoSync
- Mosaic
  - Ortho Images
  - DEM extraction
  - Aerotriangulation
  - Automatic tie point generation (optional)

Orthorectification and Mosaicking
Accuracy of Orthorectified Mosaics

New Mexico
173 ha
257 images
Elevation diff: 14 m
Reference: dGPS points

Idaho
116 ha
156 images
Elevation diff: 113 m
Reference: UltraCam X image
Multispectral image processing workflow

Data download from camera

Raw to multipage tif conversion

Multipage tif splitting

8-bit to 10-bit conversion

Band-to-band registration

Band stacking

Radiometric calibration

Orthorectification and mosaicking

Image classification

Issues encountered:

- Proprietary file format incompatible with GIS/RS software
- Software cannot handle 10-bit data in tif format
- Poor band co-registration
- Strong vignetting

Field data collection

Field spectrometer data

Training/test samples
Radiometric calibration

- Obtain ASD reflectance for calibration targets and dominant vegetation/soil
- Empirical line method to derive coefficients to fit digital numbers to field measured reflectance spectra
Color balancing

Image dodging approach during mosacking process in Erdas

Strong vignetting
Vegetation Classifications

- Object-based image analysis workflow: eCognition
  - Feature extraction through image segmentation and classification
  - Develop approaches for large image files: transferable rule-base
  - Determine features suitable for imagery from low-cost digital cameras (I-H-S, shape, texture)
  - Use of decision trees to determine optimal features
  - Develop field sampling approaches suitable for very high resolution imagery
Owyhee uplands, Idaho
330 ha
403 images
7-9 cm GSD
Classification of mosaics
Idaho

- Based on applying process tree for plots
- Required tiling and ran 10-12 hrs
- Overall classification accuracy: 83% and 88%
### Multispectral classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Producers Acc. (%)</th>
<th>Users Acc. (%)</th>
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<tbody>
<tr>
<td>Tarbush</td>
<td>52</td>
<td>83</td>
</tr>
<tr>
<td>Broom snakeweed</td>
<td>72</td>
<td>73</td>
</tr>
<tr>
<td>Creosote</td>
<td>94</td>
<td>79</td>
</tr>
<tr>
<td>Bush muhly</td>
<td>79</td>
<td>72</td>
</tr>
<tr>
<td>Marioly</td>
<td>86</td>
<td>81</td>
</tr>
<tr>
<td>Mesquite</td>
<td>89</td>
<td>92</td>
</tr>
<tr>
<td>Sumac</td>
<td>49</td>
<td>96</td>
</tr>
<tr>
<td>Tobosa</td>
<td>93</td>
<td>98</td>
</tr>
<tr>
<td>Overall Acc. (%)</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td>Kappa</td>
<td>0.83</td>
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</tbody>
</table>

**Legend**

- Bare
- Sparse on bright soils
- Sparse on dark soils
- Shadow
- Mesquite
- Mariola
- Sumac
- Broom snakeweed
- Tobosa
- Creosote
- Tarbush
- Bush muhly

**Image**: 130m x 130m
Terrain Extraction from RGB

• Extraction of digital surface model (DSM)
• Sparse DSM at 0.5-1 m resolution
  – Erdas ATE
  – Represents general terrain
• Dense DSM based on 3-D point cloud at pixel level
  – Erdas eATE
  – Fusion of RGB values with elevation data
  – Deriving vegetation heights
• Data used to estimate parameters for hydrologic and erosion models
Orthomosaic (387 images) and 50-cm resolution DSM
Terrain extraction from UAS imagery

Watershed delineation

1 m resolution DSM
DSM validation

Elevation values derived from the DSM and from field measurements with survey grade dGPS

Hillslope profiles derived from the DSM and from field measurements with survey grade dGPS
Dense DSM based on 3D point cloud

Using Erdas eATE module
Fusion of terrain model, imagery, and vegetation classification
Summary

• Workflows for UAS image acquisition, orthorectification, mosaicking, classification
• Multispectral imagery allows for better species discrimination and change detection studies
• Terrain extraction and vegetation height estimations show promise
• UAS are viable platforms for obtaining quality remote sensing data at very high resolution
• Data use for land cover mapping, hydrologic assessment, phenology, archaeology
Ongoing and Future Research

• Multispectral imagery
  – Ongoing spectral ground and airborne measurements, change detection, vegetation indices

• Terrain extraction
  – Streamline processing of point clouds
  – Compare elevations and vegetation heights with field data

• Scale these approaches to larger areas
• Compare/upscale using WorldView-2 data
• Test other UAS sensors (thermal, lidar, hyperspectral)
BAT 4

13 ft wingspan
35 lb payload
150 W generator
Thank you!