My background

- BS in GIS
  - City government GIS experience
- MA in Geography
- PhD in GIScience
  - Dissertation focused on drones as aerial data collection tools
    - Applied to precision agriculture—viticulture
- Drone research (and instruction) continues as faculty member
Drones 101
What is a drone?

• Aircraft without onboard pilot
  • Remotely and/or autonomously controlled

• Colloquial term for…
  • UAS – unmanned aerial (or aircraft) system
  • sUAS – small unmanned aerial (or aircraft) system
  • UAV – unmanned aerial vehicle
  • RPA – remotely piloted aircraft

• System?
  • Aircraft, ground control station, and communications
What is a drone?

• UAS, drone = broad terms
  • Military vs. civilian

• High variation in…
  • Physical size
  • Flying ability (e.g., altitude, endurance, takeoff/landing, payload capacity)

• For GIS users, sUAS is most appropriate
  • ~55lbs or less
Why drones?

• Numerous applications
  • Realty, film, delivery, inspection, monitoring, emergency management, agriculture, GIS/mapping/surveying

• Benefits
  • Low-cost alternative
    • Compared to manned aircraft or satellite
  • Frequency of use (data collection)
  • Ease of use
  • High resolution/detail
  • Less human risk
Drones: public reception/response

Unmanned Aircraft in the National Parks

Background
There has been dramatic growth throughout the United States in the numbers and use of unmanned aircraft during recent years.

“Unmanned aircraft” is defined as a device that is used or intended to be used for flight in the air without the possibility of direct human intervention from within or on the device. This term includes all types of devices that meet this definition (e.g., model airplanes, quadcopters, drones) that are used for any purpose, including for recreation or commerce.
Drones: public reception/response

### Table 2: Public Support for Aerial Drone Usage in Different Areas

<table>
<thead>
<tr>
<th>Area of Drone Use</th>
<th>% Supporting Drone Use in...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Search and Rescue Operations in Remote Areas (e.g., finding missing/injured persons)</td>
<td>93%</td>
</tr>
<tr>
<td>Climatic/Geological Mapping (e.g., testing snow/water/vegetation levels)</td>
<td>87%</td>
</tr>
<tr>
<td>Military Operations (e.g., detection/tracking of military targets)</td>
<td>73%</td>
</tr>
<tr>
<td>Traffic Monitoring on Major Highway Routes (e.g., reporting back-ups and delays during rush hour)</td>
<td>71%</td>
</tr>
<tr>
<td>International Border Patrol (e.g., monitoring immigration activities)</td>
<td>68%</td>
</tr>
<tr>
<td>Journalists’ Reporting/Coverage of News Events (e.g., natural disasters, crime scenes, sport events)</td>
<td>56%</td>
</tr>
<tr>
<td>Detecting Criminal Activities in Open Public Places (e.g., street-level drug dealing)</td>
<td>48%</td>
</tr>
<tr>
<td>Crowd Monitoring at Large Public Events (e.g., sporting events, concerts)</td>
<td>43%</td>
</tr>
<tr>
<td>Delivery Services for Small Items (e.g., mail, books) to Private Residences</td>
<td>42%</td>
</tr>
</tbody>
</table>

Source: National surveys conducted June 1-5, 2014 (n = 636)

Source: Miethe et al. 2014
UAS Components

- Airframe
- Motors / Propellers
- Battery
- Servos
- IMU
- GNSS
- e.g., digital camera

Aircraft

- Internal Sensors
- Payload
- Remote Pilot
- Flight Control

Ground Control

UAS Components

Photo by: J. Jacob
Platforms

- Rotary-wing
  - Single or multi-rotor copters
  - Upward-mounted propeller(s)
  - Vertical takeoff and landing (VTOL)
Platforms

• Rotary-wing

  • Advantages
    • Maneuverability
    • Hover capability
    • Staging area needs minimal

  • Disadvantages
    • Flight time: most ~20 min
    • Limited coverage area (solved with multiple flights)
Platforms

• Fixed-wing
  • Stationary wing to generate lift
  • Forward-mounted propeller(s)
  • Most launched, some VTOL

SenseFly eBee

FireFLY6 PRO

Trimble UX5 Series

AggieAir Minion

Photo by: D. Lightfoot
Platforms

• Fixed-wing

  • Advantages
    • Flight time: most ~40-60 min
    • Coverage area

  • Disadvantages
    • Staging area needed (takeoff/landings)
      • Launch procedure: by hand, pneumatic, etc.
    • Continuous aircraft movement (e.g., can result in image blur)

Photo by: J. Jacob
Platforms

• Lighter-than-air
  • Blimps
  • Kites

• Other
  • Telescopic poles
  • Ground-based

• Issues
  • Casting shadows
  • Coverage area
Sensors

• Commonly used

(Un)altered point-and-shoot digital cameras

RedEdge® by MicaSense

Designed for UAS

Parrot Sequoia

RIEGL miniVUX-1 UAV (*Lidar)

Tetracam ADC-Lite

*Lidar
Unmanned Aircraft Operation

• Airspace integration dictated by civil aviation authorities
  • USA: Federal Aviation Administration (FAA)
    • “FAA regulations do not currently provide for the treatment of tribal airspace as a distinct classification in which special flight rules apply” [1]
  • Canada: Transport Canada
  • Mexico: Dirección General de Aeronáutica Civil

• Legal requirements
  • UAS, as aircraft, must comply with FAA regulations
    • Mainly operating in Class G airspace
<table>
<thead>
<tr>
<th>Pilot Requirements</th>
<th>Fly for Fun</th>
<th>Fly for Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>No pilot requirements</td>
<td>Must have Remote Pilot Airman Certificate</td>
<td>Must be 16 years old</td>
</tr>
<tr>
<td></td>
<td>Must pass TSA vetting</td>
<td>Must be 16 years old</td>
</tr>
<tr>
<td>Aircraft Requirements</td>
<td>Unless exclusively operated in compliance with Section 336 of Public Law 112-95 (Special Rule for Model Aircraft), the aircraft must be registered if over 0.55 lbs.</td>
<td>Must be less than 55 lbs.</td>
</tr>
<tr>
<td></td>
<td>Must be registered if over 0.55 lbs. (online)</td>
<td>Must be registered if over 0.55 lbs.</td>
</tr>
<tr>
<td></td>
<td>Must undergo pre-flight check to ensure UAS is in condition for safe operation</td>
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</tr>
<tr>
<td>Location Requirements</td>
<td>5 miles from airports without prior notification to airport and air traffic control</td>
<td>Class G airspace*</td>
</tr>
<tr>
<td></td>
<td>Unless exclusively operated in compliance with Section 336 of Public Law 112-95 (Special Rule for Model Aircraft), the aircraft must be registered if over 0.55 lbs.</td>
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<tr>
<td>Operating Rules</td>
<td>Must ALWAYS yield right of way to manned aircraft</td>
<td>Must keep the aircraft in sight (visual line-of-sight)*</td>
</tr>
<tr>
<td></td>
<td>Must keep the aircraft in sight (visual line-of-sight)</td>
<td>Must fly under 400 feet*</td>
</tr>
<tr>
<td></td>
<td>UAS must be under 55 lbs.</td>
<td>Must fly during the day*</td>
</tr>
<tr>
<td></td>
<td>Must follow community-based safety guidelines</td>
<td>Must fly at or below 100 mph*</td>
</tr>
<tr>
<td></td>
<td>Must notify airport and air traffic control tower before flying within 5 miles of an airport</td>
<td>Must yield right of way to manned aircraft*</td>
</tr>
<tr>
<td></td>
<td>Must keep the aircraft in sight (visual line-of-sight)*</td>
<td>Must NOT fly over people*</td>
</tr>
<tr>
<td></td>
<td>Must fly under 400 feet*</td>
<td>Must NOT fly from a moving vehicle*</td>
</tr>
<tr>
<td>Example Applications</td>
<td>Educational or recreational flying only</td>
<td>Flying for commercial use (e.g. providing aerial surveying or photography services)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flying incidental to a business (e.g. doing roof inspections or real estate photography)</td>
</tr>
<tr>
<td>Legal or Regulatory Basis</td>
<td>Public Law 112-95, Section 336 – Special Rule for Model Aircraft</td>
<td>Title 14 of the Code of Federal Regulation (14 CFR) Part 107</td>
</tr>
<tr>
<td></td>
<td>FAA Interpretation of the Special Rule for Model Aircraft</td>
<td>*Subject to waiver</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Source: FAA 2017</td>
</tr>
</tbody>
</table>
FAA – Part 107 [current rule]

• “Small UAS Rule”
  • Effective: 29 August 2016

• sUAS = 0.5-55 lbs
  • Must be registered

• Visual line-of-sight, daylight operations

• 400 ft or below in uncontrolled, Class G, airspace
  • Other airspace off limits without authorization

• UAS operators must obtain pilot certification
FAA – Part 107 [current rule]

• Remote Pilot Certificate
  • Minimum 16 years of age
  • Pass written test
  • Security clearance (TSA)

Waiver Application Instructions

Submit your application as soon as possible prior to your planned operation. The FAA encourages applicants to submit applications at least 90 days prior to the start of the proposed operation.
FAA – Other

• COA (Certificate of Waiver or Authorization)
  • “an authorization issued by the Air Traffic Organization to a public operator for a specific UA activity” [2]
  • Case by case mission approval

• Section 333 exemption
  • Provides blanket approval for aircraft/pilot
    • Some restrictions apply

*Both were primary means of approval pre-Part 107 (both still exist)*
Drone registration

• For all owners
  • Hobbyist or commercial

• Instituted in December 2015

• Retracted in May 2017
  • No longer legally required as hobbyist
Interpreting & Utilizing Drone Data
UAS for GIS

• Why?
  • Inexpensive
  • Flexible
  • Resolution
    • Spatial and temporal

• Data products
  • Point clouds (like raw lidar data)
  • Digital elevation models (DEMs)
  • Orthophotos

As dense as lidar collections
1 cm vs. 10 m

1 cm vs. 1 ft

Source: Jensen & Mathews 2016
UAS for GIS

• Most UAS are used to collect...
  • Imagery [can generate point clouds, DEMs, and orthos]
    • RGB
    • NIR

• Other data
  • Thermal
  • Lidar
  • Meteorological observations
Workflow

Data Capture

Operations/Mission Planning

Data Processing

Data Products

Images courtesy of CLOUD-MAP and the authors

Source: Mathews & Frazier 2017
Data Processing

- Software options
  - Agisoft PhotoScan
  - Pix4D
  - VisualSfM
  - DroneDeploy
  - Drone2Map for ArcGIS

*Desktop vs. cloud*
Data Collection

• Plan, plan, and plan again

• Aerial data
  • Considerations
    • Time of day/year (lighting, wind)
    • Camera angle: nadir, near-nadir, oblique
  • UAS flight plan
    • Extent, overlap (end and side; ~80% and ~60% suggested)
    • Apps make this fairly easy [DJI Ground Station, Mission Planner, etc.]

• Ground data
  • GPS, other

Source: Aber et al. 2010
Georeferencing

Aerial photo ≠ map
Known scale required

• Direct
  • Using image geotags
    • From camera or UAS GPS receiver

• Indirect
  • Capture on-ground data for rectification
  • Ground Control Points (GCPs)
    • GPS (survey-grade) distinct objects or set targets

• Combination of both

What about GPS accuracy?
Data Collection

• Issues
  • Brightness differences
    • Within images
    • Image-to-image
  • Shadow casting
  • Image blur
Practical Guidelines

• Aircraft
  • Consider: price, size of study area, staging area, ease of use

• Sensor
  • No wide-angle, fisheye lenses (i.e. GoPro)
  • High megapixel ≠ better end product

• Georeferencing
  • GCP targets can be simple, inexpensive
    • Paper plates, foamboard
Data Processing

• What is Structure from Motion (SfM)?
  • Computer vision algorithms to “link” together multiple images of differing perspectives
  • Photogrammetry 2.0?
  • Creates lidar-like 3D reconstruction of space
    • Civil engineering, planning, change analyses

*aka Structure from Motion-Multi-View Stereo (SfM-MVS)*

Sources: Snavely, Microsoft Photosynth
SfM-MVS

- Keypoint detection
- 3D reconstruction as point cloud

*SfM products are arbitrarily scaled, located*

*Georeferencing required*
SfM feature matching

Photos by: G. Donnell et al. 2017
Data Products

- Point clouds
  - Sparse and dense
  - LAS format with RGB
- Mesh (like a TIN)
  - Surface for visualization, analysis, 3D printing
- DEMs
  - Digital Terrain Model (DTM): bare Earth
  - Digital Surface Model (DSM): all ground features
- Orthophotos
Data Integration/Analysis in GIS

• Point clouds
  • Rasterized DEMs (after filtering)
    • Hydrological analyses
  • 3D structural assessment
    • e.g., buildings, vegetation

• Orthophotos
  • Planimetrics
  • Image classification
    • Change detection
Demo

PhotoScan

3D Modeling and Mapping
UAS for GIS

• The future is here
  • High spatial resolution
  • Repeatability
  • Low cost
  • Data quality
    • Comparable to lidar
• More research needed to improve, optimize process
Resources

• Academy of Model Aeronautics
• Association for Unmanned Vehicle Systems International
• FAA UAS Homepage
• Hardware (UAS, Sensors, etc.)
  • DJI, 3DR, AggieAir, TetraCam, MicaSense, Parrot Sequoia, CHDK
• Software/Processing
  • PhotoScan, Pix4D, ESRI Drone2Map, VisualSfM, DroneDeploy
• UAS at Oklahoma State
• UAS Overview in GIS&T Body of Knowledge
• USGS UAS Project Office

*Clickable links are provided to source of graphics used in presentation not owned by the author*
GIS – Drones 101 & Interpreting and Utilizing Drone Data

Thank You!

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Faculty Affiliate, Unmanned Systems Research Institute

Special thanks to the...

SOUTHERN PLAINS TRIBAL TECHNICAL ASSISTANCE PROGRAM CENTER

National Tribal Transportation Conference
September 28, 2017