Drone based Sensor Platforms

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Outline of this Talk

- What are drones?
- How do they fly?
- Components of a drone
- Applications of drones
- TCS drone platform
- Wildlife conservation
- Forestry
- Agriculture
What are Drones?

- **Unmanned Aerial Vehicle (UAV)**
  - Any aerial vehicle without a human on-board
  - Remotely controlled by a human operator OR
  - Controlled by onboard computers

- **UGV/AGV**
  - Unmanned/Autonomous Ground Vehicle

- **UUV/AUV**
  - Unmanned/Autonomous Underwater Vehicle
Types of Drones: Multirotor

- Vertical take-off and landing
- Fly slowly and hover
- Lower speed & endurance

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Types of Drones: Fixed Wing

- Higher speed & endurance
- Cannot fly slowly or hover
- Cannot take-off & land vertically
Types of Drones: Hybrid

- Vertical take-off & landing
- Higher speed & endurance
- More complex & expensive

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Types of Drones: Nano to Mega

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Four Forces of Flight

- Thrust: A force that moves aircraft forward
  - Needs to overcome drag (frictional force)
  - Produced by the engine
- Lift: A force that “lifts” the aircraft up
  - Needs to overcome weight
  - Created by airflow over wings
Six Degrees of Freedom

Three AXES: X, Y, and Z
Translation and Rotation

Center of Gravity (Origin)

Up
Roll
Right
Yaw
Forward
Pitch
Down
Left
Backward

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How does a Drone Fly?

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Components of a Drone - 1

- Frame
- Motor
- Speed Controller
- Propeller

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Components of a Drone - 2

- **Flight Controller**
- **Radio Transmitter**
- **Radio Receiver**
- **Battery**

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Components of a Drone - 3

- Telemetry Module
- Camera
- Video Transmitter
- Video Receiver

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Components of a Drone - 4

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Ground Control Station
Components of a Drone - 5

- Monitor vital stats of drone
- Battery voltage
- Current draw
- ESC temperature
- Pitch & roll values
- Radio signal strength
- GPS signal strength
- Altitude, speed, heading
- Distance to next waypoint
- Distance to home
Sensors in a Drone - 1

- Accelerometer
  - Measures acceleration in all 3 axis
- Gyroscope
  - Measure angular rate in all 3 axis
- Compass
  - Determines heading
- GPS
  - Determines position based on GPS/GLONASS satellites
- Power module
  - Power supply to flight controller
Sensors in a Drone - 2

- Optical flow
  - More accurate landing
- Obstacle avoidance
  - Sense & avoid
- ADS-B
  - Broadcasts your position
Flight Control Algorithms

- PID (Propotional Integral Derivative) control
  - Closed loop control to stabilize the drone
- Inertial navigation
- Extended Kalman Filtering
  - Fuses all available measurements
  - Better error rejection
  - Non-linear state prediction
- SLAM
  - Autonomous navigation in GPS denied environment
Flight Modes

- Four controllable DoFs
  - Forward/backward, left/right, up/down, yaw

- Acro mode
  - Used by racing professionals
  - Gives more control over the drone
  - Uses least number of sensors for control
  - Less stable but high performance

- Stabilize
  - Flight controller (FC) just stabilizes drone
  - User controls all 4 DoFs

- Altitude hold
  - FC controls up/down
  - User controls 3 DoFs
Flight Modes

- **Loiter (position hold or hover)**
  - FC controls all 4 DoF

- **Autonomous**
  - FC controls all 4 DoFs
  - Drone takes-off, reaches a preset altitude
  - Drone navigates through a set of GPS waypoints at set speed
  - Drone returns to the launch point, lands
Safety Features

- Redundant sensors
  - Accelerometers, gyros, compass and power supply
- Pre-flight and in-flight checks
  - Check all sensors and isolate faulty sensors and continue flight
  - Return to home or land in case of sensor failures
- Battery failsafe
  - Return to home in case of low battery voltage
- Radio failsafe
  - Return to home in case of radio signal loss
- GPS failsafe
  - Land in case of GPS signal loss
- Geo-fence
  - Return home if fence is breached
Typical Drone Specs

- Small drones (like DJI Phantom)
  - Weight: 1.5 kg
  - Range: 2-3 km
  - Speed: 40 to 80 kmph
  - Endurance: 20 min
  - Payload capacity: 300 gms

- Racing drones
  - Weight: 750 gm
  - Range: 2-3 km
  - Speed: 150 to 200 kmph
  - Endurance: 5 to 15 min
  - Payload capacity: 100 gms
Applications of Drones

Hobby Drones
- Fun & recreation
- Photography
- Racing

Commercial
- Surveillance
- Disaster response
- Agriculture
- Inspection
- Media
- Entertainment

Military
- Reconnaissance
- Attack

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Crop health analysis
- Estimation of nutrition & water levels
- Detection of pests & diseases
- Estimation of height, count, acreage & yield

Spraying fertilizers & pesticides

Soil analysis
Infrastructure Inspection

- Pipeline inspection
  - Cracks, leaks, corrosion
- Railway track inspection
  - Rails, sleepers, fishplates
  - Ballast, vegetation
- Wind turbine inspection
- Powerline inspection
- Rooftop inspection

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Other Uses

- Disaster response
- Assess damage
- Search & rescue
- Medical supplies delivery
- Blood, organs, first aid kits
- Package delivery

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TCS Research UAV

- Fully autonomous multi-rotor drone, designed and built in TCS
- Innovative electronics and structural health monitoring with multiple fail-safes
- Long range, high endurance and high payload capacity
- Configurable multi-payloads; multi-spectral, visual and thermal cameras
- Customizable range, payload and radio frequencies
- Suitable for multiple applications; wildlife conservation, forestry, agriculture, infrastructure inspection
Wildlife conservation
Kaziranga National Park
Drones in Forest Plantations
High Resolution Elevation Maps
3D Point Clouds and DSMs

- Key forest figures
  - Tree count and height
  - Area and volume estimation
Tree Count and Tree Height Spread

Tree Count Snapshot

Frequency Histogram – Tree Height
Estimating Crown Diameter

TCS Algorithm approach overview:

- The crown diameter estimation was performed through a process of continuous iterations of “fitting an ellipse” across the visible canopy of the target tree (*threshold of 1200 iterations were employed for the purpose*)
- The major axis of the ellipse for each tree was considered the diameter of associated crown.
Tree Species, Crown Diameter Results

Area 1 – 60 m

- Pine: 258, 8%
- Spruce: 1011, 34%
- Birch: 576, 13%
- Other: 1341, 45%

Area 1 - Pine
Tree Height v/s Tree Crown Diameter (in m)

Area 1 - Birch
Tree Height v/s Tree Crown Diameter (in m)

Area 1 - Spruce
Tree Height v/s Tree Crown Diameter (in m)
Species Recognition & Proximity Assessment

- Deep learning algorithm for tree species identification and common infrastructure detection
- Proximity assessment
Precision Agriculture
Drones for Precision Agriculture

Actionable insights delivered to farmers on handhelds

Cloud based data analysis for early detection of water and nutrient stress, and pest infestation

Multi-spectral data acquisition for crop health monitoring, soil mapping and irrigation

- Reduces water and fertilizer usage
- Increases farmer income
- Reduces pollution
Precision Agriculture Pilot Studies
Crop Health Analysis

- Multi-spectral and visual imagery acquisition using TCS drones
- Accurate crop health analysis using various crop health indices
- Early detection of nutrient deficiencies and other problems
- Advanced algorithms for species identification, population estimation and localization
Early Detection of Crop Health Problems

Nitrogen deficiency in paddy

Poor tillering in paddy

Productivity variations in paddy

Productivity variations in sugarcane
Disease and Pest Incidence in Tea

Diseased Bush Acreage = 6.1%

- No Plant Stress
- Disease Stress
- Soil

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Experience certainty.
Estimate of Tea Bush Acreage 1/2
Bush Acreage =79.18%
Newer Leaf Mass ~3%
Older Bushes ~17%