Development and Verification of a Three-Dimensional Wind Measurement Sensor Hosted on a Meteorologically Instrumented Small Multirotor UAS

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ABSTRACT

Small multirotor unmanned aerial systems (UAS) have great potential to effectively investigate the urban boundary layer. Their ability to launch and recover vertically in tight urban spaces, along with their ability to be precisely controlled, including hover, makes them an especially attractive investigation tool for obstacle laden environments. These aircraft characteristics are also conducive to obtaining measurements with both high spatial and temporal resolution. With the motivation to obtain high-resolution measurements, a small multirotor UAS was meteorologically instrumented with both thermodynamic and kinematic sensors. This work details the development and subsequent verification of two orthogonally mounted acoustic resonance ultrasonic anemometers that provide a 3-dimensional solution suitable for measurement of the mean wind and its fluctuating component (i.e. turbulence). Comparison of the geo and time-stamped wind speed and direction measurement was made against a surface mounted anemometer during both indoor and field testing. The system will be deployed in upcoming urban field campaigns in the summer of 2020 and beyond.

RESEARCH OBJECTIVES

Measuring wind velocity at discrete points with fine spatial resolution is challenging, especially in the vertical direction. The developed system can be hosted on a small multirotor UAS and undertake such measurements conveniently, cost effectively and with minimal infrastructure.

Acknowledgements and Contact

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3-D WIND MEASUREMENT

- ACOUSTIC RESONANCE TECHNOLOGY
  - Unbounded horizontal plane allows air to flow freely
  - Vertical plane bounded by an upper and lower reflector and negligible air flow
  - 2 sensors mounted orthogonally inform the measurement of a 3-D wind field

Figure 1. Pole mounted acoustic resonance anemometer by FT Technologies that is used to measure horizontal (u,v) wind components.

THERMODYNAMIC MEASUREMENTS

- RESISTOR TEMPERATURE DETECTOR
  - Range: -50 – 100 °C
  - Accuracy: +/-0.1 K
- CAPACITIVE HUMIDITY SENSOR
  - Range: 0 – 100% RH
  - Accuracy: +/-0.5% RH

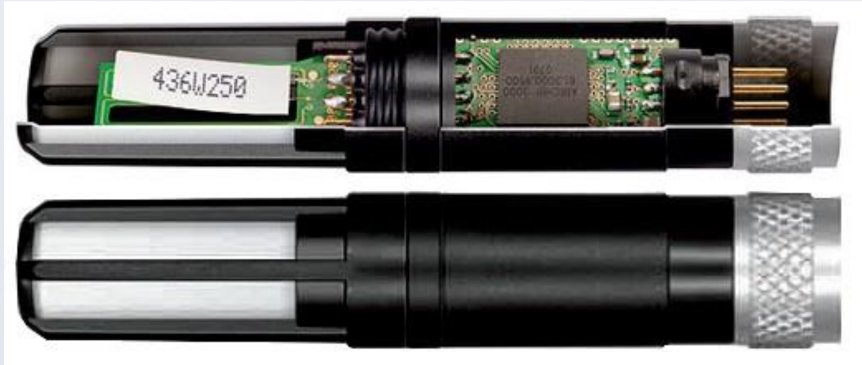


Figure 2. HygroClip HC2A-S for thermodynamic measurements and vertical flux calculations

MICROCONTROLLER AND INERTIAL MEASUREMENTS

- ARDUINO MEGA MICROCONTROLLER
  - Establish and control communication between all sensors using UART
  - Supply required voltage
- INERTIAL MEASUREMENT UNIT
  - Using the IMU onboard the Pixhawk flight controller
  - Output rate of 200 Hz
  - Used to transform wind measurements from aircraft to earth frame of reference and separate vehicular motion from wind velocity

Figure 3. Pixhawk flight controller, sensor suite microcontroller, and telemetry.

LiDAR

- LiDARUSA REVOLUTION 120
  - Allows construction of a 3D point cloud for characterizing the underlying surface-atmosphere interface
  - Maps more than 200 points per square meter

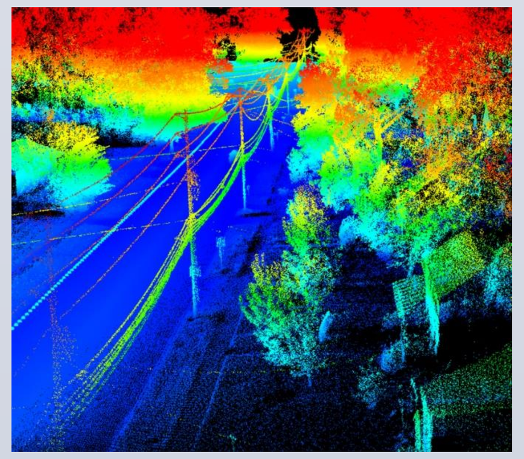
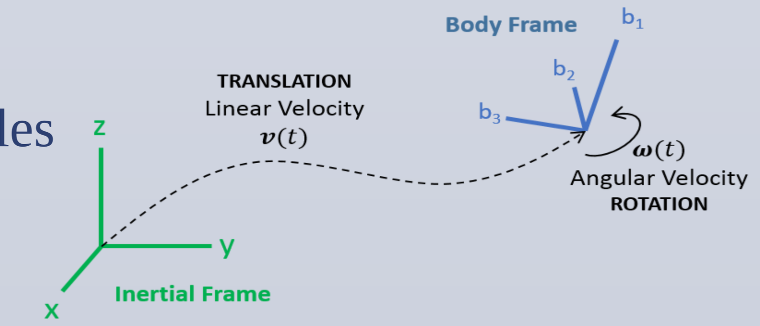


Figure 4. Sample output of a street and trees from a LiDARUSA Revolution 120

DATA REDUCTION

- Goal to make the sensor suite aircraft agnostic (no use of UA bus parameters)
  - Use ancillary IMU and GPS to produce Kalman filtered velocity; roll, pitch, yaw angles
- Wind velocity vector must be resolved from the wind sensor measurement signal
  - Transformation from the sensor to the body to the earth frame of reference



SYSTEM

- Hosted on a Tarot T-18 octocopter
- Anemometers mounted to two carbon fiber booms (52.8" and 55") that extend sensors 22.5" beyond the extent of the rotor flow field in order to sense the ambient atmosphere

Figure 5. Fully instrumented unmanned aircraft. microcontroller, power supply, data storage and telemetry are centrally located with all meteorological instruments mounted on booms: (a) on the ground; (b) in the air.

MOUNT DESIGN

- Modular, quick release clamps for anemometer boom permits for hot swapping instrumentation to change payload configuration in the field
- 1/8" layer of shock absorbing, vibration isolating/dampening material between sensor booms and landing gear to reduce vibrationally induced noise from rotors into wind speed data

Figure 6. Close up of quick release clamp used to attach anemometer boom to the landing gear. Also imaged: layer of vibration isolation material.

Figure 7. Close up of anemometer boom mount configuration on aircraft landing gear.

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