Meteo Sensors In the Sky ('METSIS')

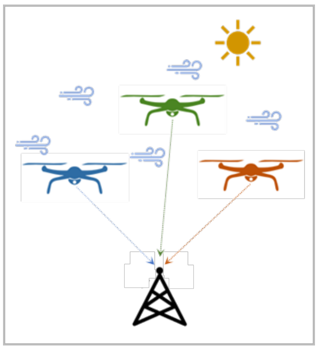
Executive summary

Background

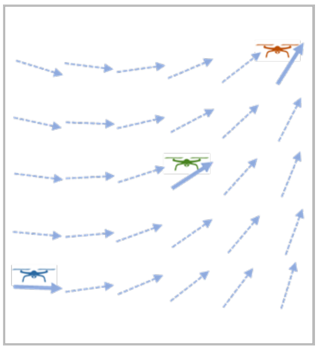
Because of their light-weight nature, drones can be vulnerable to wind. This is particularly the case at low altitudes where both wind speed and direction can change abruptly. However, at present, real-time and accurate knowledge of low altitude wind information is limited, especially in urban areas. This limitation makes it difficult to realize the numerous anticipated applications of drones in urban areas, such as aerial photography, mapping and package delivery. The U-space weather information service aims to address this issue by making the required weather, including wind data, available to drone operators.

The METSIS concept and its benefits

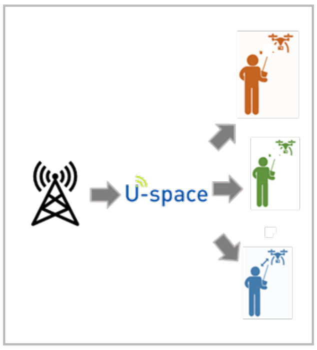
The Meteo Sensors In the Sky (METSIS) project proposes to test the use of drones as a wind sensor network for hyper-local wind now-casting in very low level airspaces (<500 ft). The METSIS concept consists of three steps; see Figure below. This project has investigated all three steps of the concept.



Step 1: Airborne drones measure instantaneous wind states and transmit data to a ground station



Step 2: Ground station uses the Meteo Particle Model (MPM) to estimate the wind field in real time. Here dashed arrows are MPM estimates and solid arrows are drone measurements



Step 3: The ground station communicates wind field data to drone operators via the U-space weather information service

The METSIS concept offers several technical and practical advantages. For drone operators, the METSIS approach has the potential to not only improve safety, but also improve flight efficiency as wind can significantly affect drone battery life and/or range. Additionally, in comparison to other approaches that make use of a dedicated measurement infrastructure such as LIDARs, the METSIS concept represents a relatively low-cost solution as the drones themselves provide the required wind measurements. This further strengthens the potential commercialization of the METSIS concept. Beyond drones, this approach for low-altitude wind measurement can also be applied to other areas of the aerospace industry, for instance for Shipboard Helicopter Operational Limitation (SHOL) analysis. Finally, METSIS has broader societal applications, e.g. safety of construction cranes, and as an additional input to national meteorological forecast systems.

Technical Contributions

This project resulted in the following main technical contributions:

- Wind tunnel testing of wind sensor: the accuracy of the ultrasonic wind sensor used in this project was analyzed in the NLR Anechoic Wind Tunnel.
- Meteo Particle Model extension: The MPM, which is used to estimate wind fields using drone observations, was extended to 3-dimensions.

- Development of the METSIS ground station: the ground station aggregates the data from all the drones (and wind sensors), logs the data, and uses the MPM to estimate wind fields.
- Real-time communication of wind data to a U-space Service Provider (USSP): The ground station also transmitted the MPM wind estimates in real-time to the AirHub Drone Operations Center.
- Drone-sensor configuration: four quadcopter drones were modified to mount the wind sensors onto the drones. This included modifications to the drone power supply and telemetry systems.
- Proof-of-concept flight-test experiment: A full day flight-test experiment using four drones was performed to study effects of obstacle-induced wind distortion, drone motion, measurement density, and measurement errors on the accuracy of the METSIS wind nowcasting system.

Conclusions

Based on the data collected during the flight-tests, the following main conclusions can be drawn:

- The flight-tests indicated that the METSIS concept is feasible in practice, i.e., that it is indeed possible to use drones as a weather sensor network for hyperlocal, low-altitude and real-time wind field estimations for U-space applications.
- When comparing the results of the experiment to the World Meteorology Organization (WMO) requirements for anemometers, the Meteo-Particle Model (MPM) showed satisfactory performance, especially during high wind speed scenarios. Therefore the MPM, which was originally developed for high altitude wind estimations for commercial aircraft, is considered suitable for low-altitude drone operations after the minor modifications made in this project.
- Answers to the main research questions of the METSIS project:
    - Effect of obstacles: static obstacles had a minor effect on overall accuracy at the distances at which drones are expected to operate from obstacles.
    - Effect of drone motion: given the low wind speeds during the experiment day, propeller induced flow had a strong negative effect on the measurements taken by the ultrasonic wind sensor during dynamic/motion scenarios. As such this research question remains inconclusive. This topic should be reconsidered in follow up research.
    - Effect of number of drones/measurement density: For the wind conditions observed during the experiment, the results indicate that a minimum of two drones are needed for the MPM to model changes in wind direction.
    - Effect of measurement error: no significant change in accuracy occurred when two different Gaussian noise models (with a standard deviation of 10% and 25% of the average wind speed during the experiment) were artificially added to measured data.
    - Communication of hyperlocal wind data to U-space Service Providers (USSPs): wind information can be transmitted in JSON format using HTTP POST. This proved to be a reliable means to communicate wind data to USSPs in real-time.

Recommendations for future research

Because of the promising results obtained from the flight-tests, it is highly recommended to continue this line of research as the implementation of the METSIS concept on a larger scale could result in a viable and low-cost system for hyperlocal wind nowcasts for the U-space weather information service. To this end, the following main recommendations are made to further develop this concept towards practical implementation:

- Repeat the experiment over multiple experiment days and consider more experiment scenarios to gain a more thorough understanding of system accuracy.
- Investigate methods to reduce the effect of propeller induced flow over the wind sensor during dynamic scenarios.
- Increase the scalability of the method by using indirect wind measurement techniques that do not require a dedicated wind sensor for each drone. If the wind sensor can be removed from the METSIS concept, the previous bullet point does not need to be considered for future research.
- Perform online optimization of MPM parameters to further increase accuracy.
- Future implementations should transmit wind data to USSPs in the GEOJSON data format (more widely used for weather data) via web-sockets (more scalable than HTTP Post).
- Demonstrate practical applications of hyperlocal weather information, including methods that drone operators can use to compute wind optimized routes to increase drone range/battery life.
- Explore the viability of the METSIS concept to other weather parameters such as temperature and air pressure.

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