Development of wind-aware piloting interfaces and dynamic quadrotor simulator with spatiotemporally-varying wind

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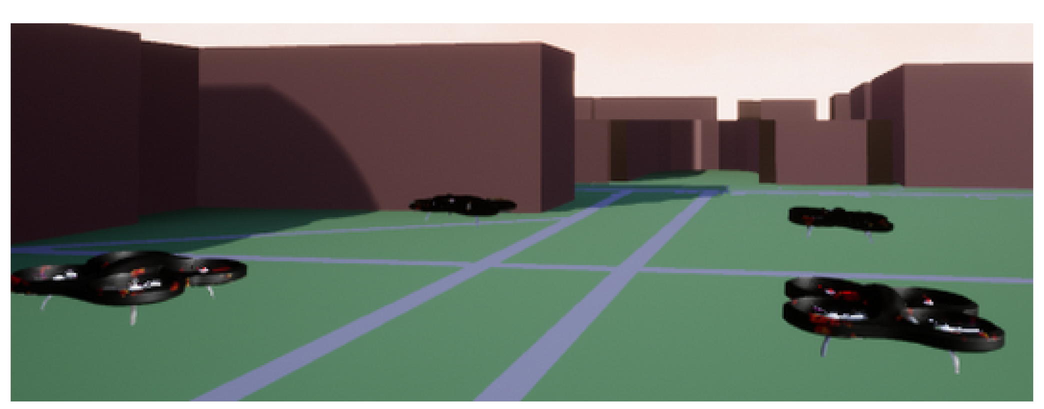
Introduction

As interest in low-altitude urban flight increases, there exists a need for high quality environmental feedback for pilots operating in dense environments [1]. Currently, pilots can rely only on natural perception, weather forecasting, and measurements from weather stations. Furthermore, there are no open-source human-in-the-loop (HIL) simulators allowing spatiotemporal wind. Our goals are two-fold:

- **Develop piloting interfaces** that succinctly relay wind conditions in familiar manners
- **Create a dynamic simulator** supporting 3D wind velocities varying in both place and time



1: Drones under varying winds in low-fidelity environment

Method

Piloting Interfaces

- Modify PX4 autopilot's Mavlink system to transmit estimated wind velocities
- Expand QGroundControl (QGC), an open-source ground control station, to display estimated wind velocities
- Develop wind-aware trajectory recommendation and preview system

Wind-Aware Simulator

- Use Microsoft AirSim simulator as basis
- Adapt existing work in spatiotemporal wind simulation [2]
- Introduce critical optimizations allowing for real-time simulation and HIL usage

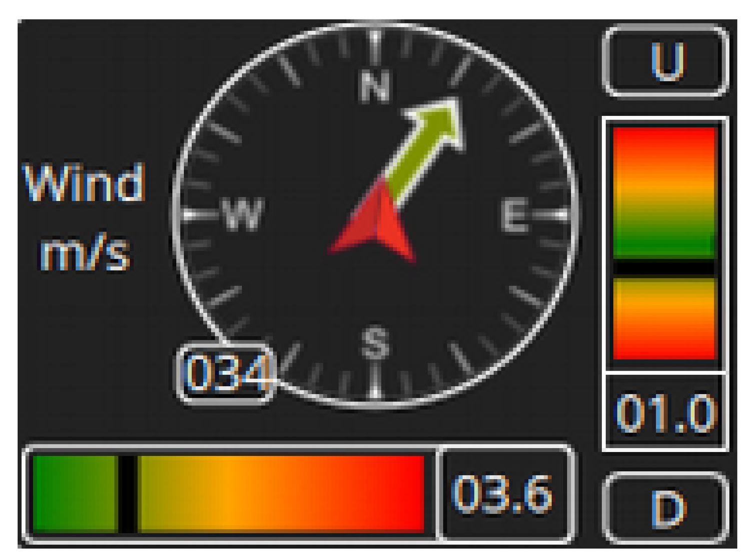
Interface Results

Wind Velocity Display

- Planar and vertical velocities separated
- Planar direction on compass, aircraft heading included for comparison
- Speeds shown on gradients, allowing quick reference
- Numerical magnitudes available alongside graphical indicator

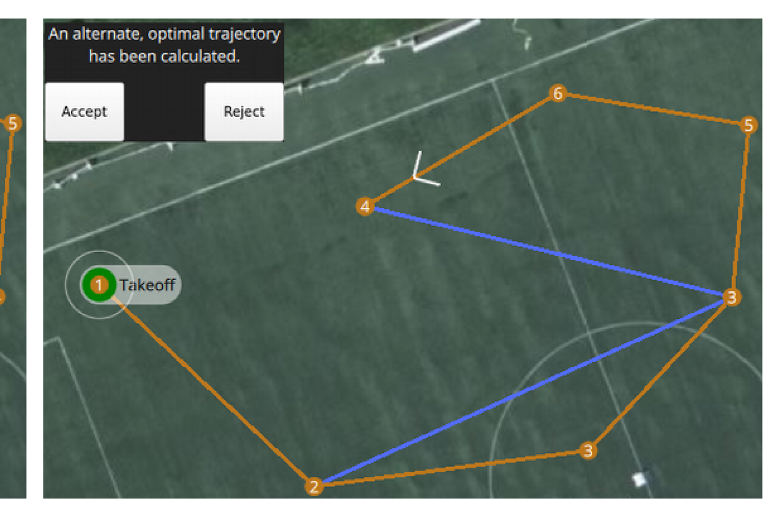
Trajectory Recommendation

- Recommendation and update implemented; *placeholder algorithm generates trajectory*
- Pilot previews new route, can accept or deny changes
- Modify new route afterwards if desired



2: Wind display with simulated velocity

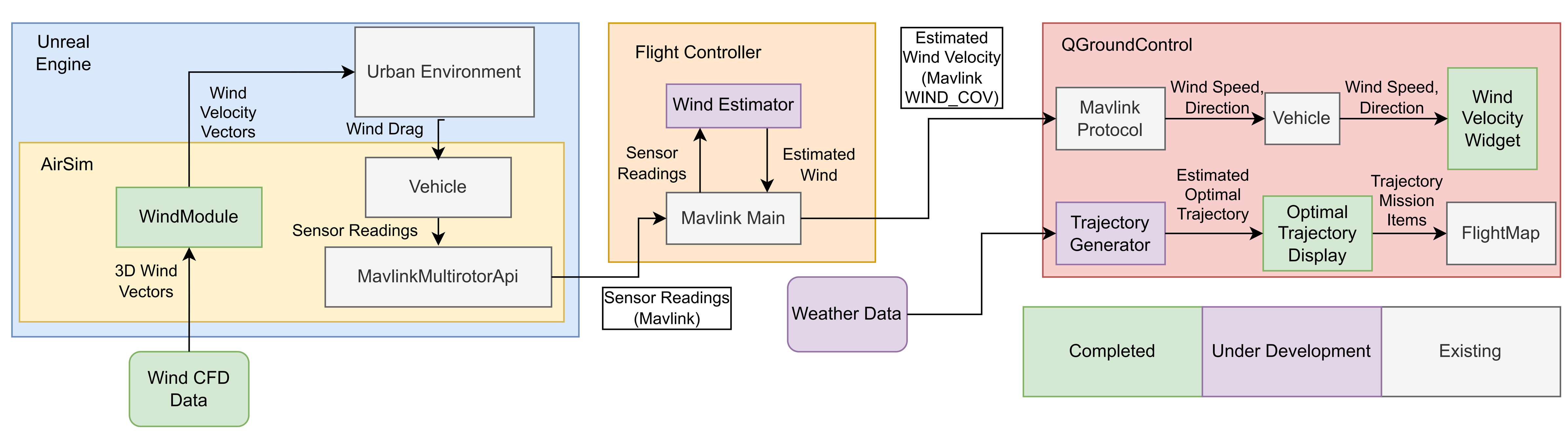
3: Pilot-generated trajectory



4: Recommended trajectory

Simulator Results

- Fluid simulation data provided by user in settings
- Local winds calculated directly from position; *high performance with minimal overhead*
- Parallel thread prepares upcoming data without impacting simulation
- Minimal changes to existing physics engine, previous functionality remains present



5: AirSim, Flight Controller, and QGC Information Flow

Conclusion

- Support for real-time drone simulations with spatiotemporally-varying wind
- Created prototype display for estimated local wind velocity
- Developed trajectory recommendation system

Future Work

- Quiver-plot style wind overlay in QGC
- Integrate optimal trajectory generation
- Display details for multiple simulated drones
- Create OSU campus simulation environment
- Test displays on physical drone

References

[1] Colleen Reiche, Adam P. Cohen, and Chris Fernando. An Initial Assessment of the Potential Weather Barriers of Urban Air Mobility. *IEEE Transactions on Intelligent Transportation Systems*, 22(9):6018–6027, September 2021.

[2] Fadri Furrer, Michael Burri, Markus Achtelik, and Roland Siegwart. *Robot Operating System (ROS): The Complete Reference (Volume 1)*, chapter RotorS—A Modular Gazebo MAV Simulator Framework, pages 595–625. Springer International Publishing, Cham, 2016.

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