Energy and Risk UAV Trajectory Optimisation

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Background

- Within the Solent region of the UK, thousands of medical items are moved between surgeries and hospitals on a daily basis.
- A fleet of vans is currently utilised to deliver these packages in a series of round-trips.
- There is scope to replace some of van deliveries with drone deliveries, if they are cost, time, risk and energy efficient.

Motivation

- Drones may have an advantage over vans as they are unconstrained by roads and traffic, which may allow them to reach their destination in a shorter timeframe (see Figure 1).
- However, these time savings are offset by limited range of batteries, higher travel risk and lower cargo capacity.
- If risk and energy can be minimised by choosing optimised trajectories, drones could prove to be a competitive logistics solution and could be integrated into the current solution.

Figure 1. Comparison between energy optimal van (purple line) and drone route (black line) linking two hospitals in the Solent region of the UK. Base map from OpenStreetMap.

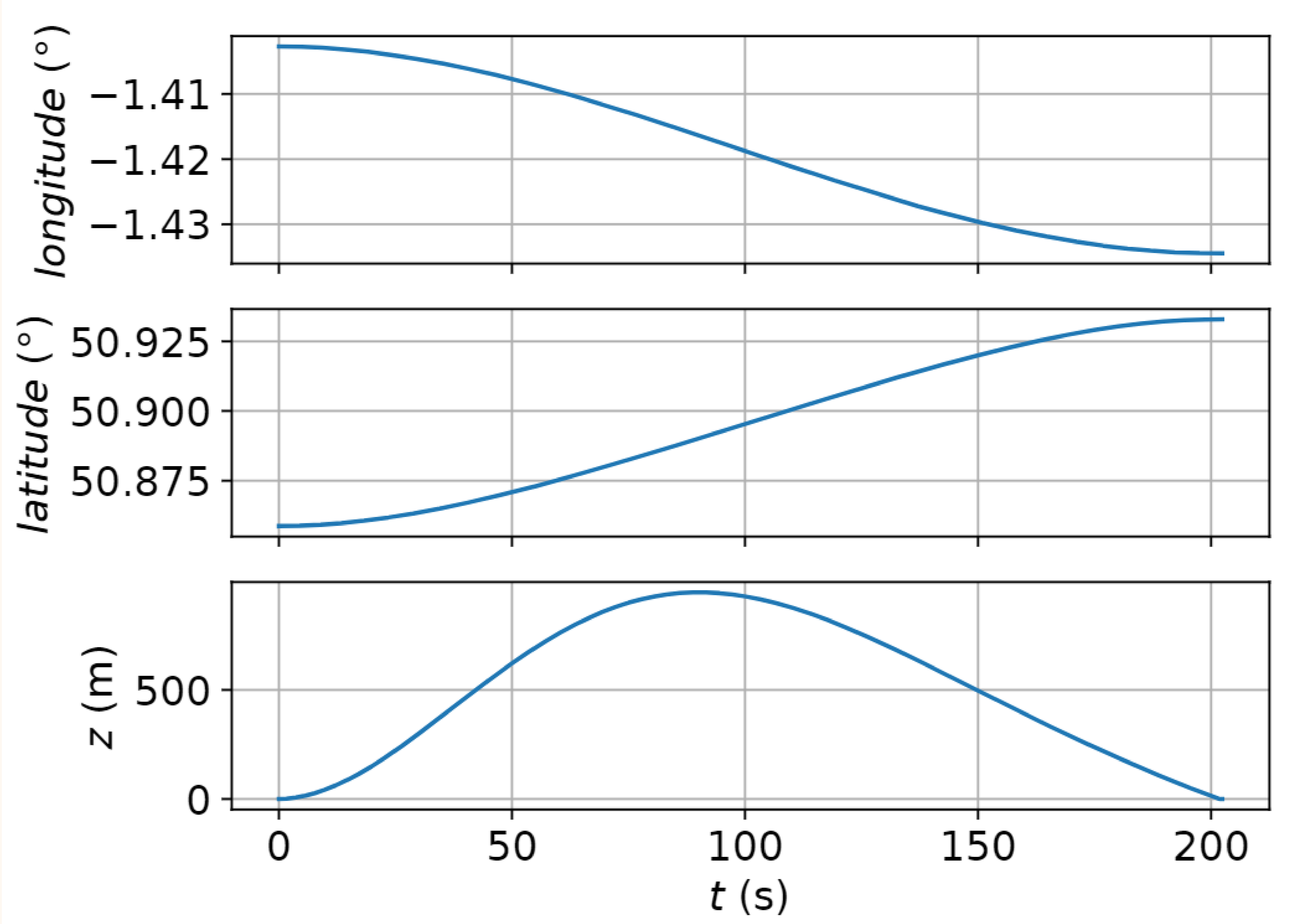

Figure 2. Change in latitude, longitude and altitude (z) over the course of a route between two hospitals in the Solent region of the UK.

Minimum Energy Drone Routing

- Energy optimal routes (see Figure 2) can be found by performing a minimum energy trajectory optimisation between two locations, where energy consumption, E, is minimised in an objective function:

$$\min_{\omega_i} \sum_{i=1}^{4} \int_{t_0}^{t_f} E(\omega_i(t))\ dt$$

$$s.t. \dot{\boldsymbol{X}} = f(\boldsymbol{X})$$

where f is the dynamics of the UAV.

- The State vector contains the quad-copters position (x, y, z), rotation (roll (ϕ), pitch (θ), yaw (θ)) and their rates of change:

$$\boldsymbol{X} = \left[x, y, z, \dot{x}, \dot{y}, \dot{z}, \phi, \theta, \psi, \dot{\phi}, \dot{\theta}, \dot{\psi}\right]^T$$

- The Control vector contains the angular velocity of its four rotors:

$$\boldsymbol{C} = [\omega_1, \omega_2, \omega_3, \omega_4]^T$$

Minimum Energy and Risk Drone Routing

- Risk can then be introduced into the objective function and given a weighting, α, to balance the importance of energy and risk:

$$\min_{\omega_i} ln(R(x, y, z)) + \alpha \sum_{i=1}^{4} \int_{t_0}^{t_f} E(\omega_i(t))dt$$

- Some iterative testing is then conducted to find a suitable weighting to match the problem and, once identified, risk and energy optimal routes can be found (see Figure 3).
- The weighting used can be flexible based on the use case as in some applications the safety of the flight may be critical, whereas in others the energy consumption may be the more important factor.

Future Work

- Improving the drag estimation, considering the effect of weather and wind on the UAV, as well as modelling different drone types (e.g., hybrid).

Figure 3. Example energy and risk optimal route between two hospitals in the Solent region of the UK. Base map from OpenStreetMap.

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