Toward Computing an Optimal Trajectory for an Environment-Oriented Unmanned Aerial Vehicle (UAV)

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Arctic observing systems need to be enhanced with improved remote sensing technologies and capabilities -- particularly mid-altitude remote sensing using air-borne platforms. Over the past decade a few but increasing number of researchers have begun using Unmanned Aerial Vehicles (UAVs) to expand and improve upon existing remote sensing capabilities in the Arctic. Typically UAVs tend to be designed for a specific task or area of operation and so Unmanned Aircraft Systems (UASs) are usually not easily customizable. The cyberinfrastructure project that will be presented recognizes the need to develop UASs that allow for customizable sensor packages, reliable communications between ground and aircraft, tools to optimize flight control, real time data processing, the ability to visually ascertaining the quantity of data while the UAV is air-borne, and the ability to launch and land safely in these remote regions. We present a prototype software system that allows for this customization. This software has enhanced communication between ground and the UAV, can synthesize near real time data acquired from sensors onboard, can log operation data during flights, can visually demonstrate the amount/quality of data for a sampling area.

The software has been designed to benefit an existing NSF Arctic Observing Network project that will focus on the remote sensing of landscape-scale vegetation structure and function. Our UAS includes a paraglider UAV that has a suite of sensors suitable for characterizing hyperspectral reflectance and other surface properties. This paraglider UAV allows is low and slow flying, has a limited range but a relatively large (ca. 13kg payload).
Sensors onboard relay operational flight data (airspeed, ground speed, latitude, longitude, pitch, yaw, roll, and video) as well a series of customizable sensor packages. Additional sensors can be added to an onboard laptop or a CR1000 data logger. This presentation will describe the development, use and customization of our UAS as well as the applicability of the UAS our arctic research sites.

Due to the limited flight time, it is important to make sure that the UAV follows an optimal trajectory -- in which it cover all the points from a given area within the smallest possible flight time -- i.e., at the smallest possible trajectory length. Under the usual assumptions that we cover a rectangular area and that each on-board sensor covers all the points with a given radius r, we describe the optimal trajectory -- parallel to and fro paths, with a special fin-like deviations close to the edge.

A more complex optimal trajectory is also developed for the situations in which we need to get a more spatially detailed picture of some sub-regions of interest (in which we should have a smaller value r) and it is sufficient to get a less detailed picture (with larger r) in other sub-regions.

We also describe the best ways to cover the trajectory in situations in which an UAV missed a spot -- due to excess wind or to an inexact control. In some cases, it is more efficient to immediately go back and revisit the missed area; in other cases, it is more efficient to revisit the missed area on the next leg of the trajectory. In case of a strong wind, the optimal idea is to switch the direction of the trajectory, so as to decrease the effect of the wind.