UAV Paper

Some Guys

***Abstract*— Jack to add...**

I. TECHNICAL APPROACH

A. Aircraft Platform

The aircraft development platform used in this work was designed and fabricated in-house at Lehigh University, and is shown at Figure 1. The planform is based upon an inverse Zimmerman design. It is made of two half ellipses, both having the same minor axis but the forward ellipse having a major axis that is three times that of the rear ellipse. A fixed fin was used in conjunction with two elevons. The design has very benign stall characteristics, is capable of operating safely in turbulent air, and can glide down steeply to land when required. Full stall landings at almost zero airspeed are easy with this aircraft.

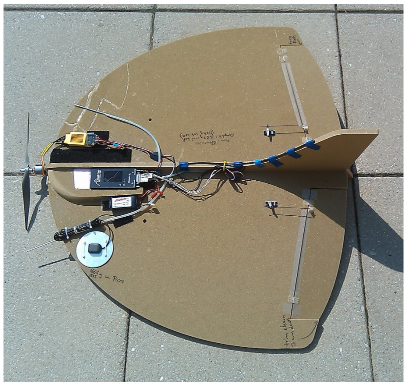

Fig. 1. Uglo 6 development platform used in this work. During testing, the aircraft was flown manually while telemetry data were logged via the on-board Piccolo SL autopilot system.

Other specific design requirements included being exceptionally sturdy, protecting the onboard data acquisition system, being easy to field repair, and easy to modify. The wing, fuselage and elevons were waterjet cut from 12.7 mm thick H80 Divinycell structural foam. A brushless outrunner electric motor and Lithium-Polymer batteries powered the aircraft. Two servos controlled the elevons. The center of mass was a few millimeters forward of the aerodynamic center as estimated by strip theory. The wing area is 0.609 m^2 and the mass 1.7 kg, giving a wing loading of 2.8 kg/m^2. The aircraft cruise speed is approximately 18 m/s ($C_L = 0.14$) but flies well at speeds below 10 m/s ($C_L > 0.45$). In its current configuration, flight time is on the order of 8 minutes. As aircraft go this one is not very efficient. However, it fulfills the design requirements very well.

B. Ground Truth Wind Velocity Estimation

As stated previously, one of the primary objectives of this work was to demonstrate real-time wind mapping with an actual aircraft. In order to characterize the performance of the proposed approach, "ground truth" data were needed. While these were readily available for simulated wind fields, estimating wind velocities in proximity to an actual aircraft during flight was significantly more challenging. To address this requirement, we employed a vision-based approach for ground truth wind field estimation.

During flight testing, brightly colored balloons containing an air-helium mixture were released serially from the ground so their trajectories would carry them in the vicinity of the aircraft flight path. The balloons were then tracked over time using what amounted to a wide baseline (*e.g.*, 50-70 meter) stereo vision system. To this end, a pair of Point Grey Chameleon 1280x960 video camera systems logged images at a rate of 2 Hz. Point correspondences between the two sets of camera images were then recovered manually for each balloon track during a post-processing phase. Using these correspondences in conjunction with a three-dimensional reconstruction approach based upon Hartley's method [1], the relative position and orientation of both camera systems, as well as the positions of the tracked balloons, were recovered to a scale factor. The scale factor was obtained by measuring the camera baseline. The balloon position estimates were then transformed to an earth-centered coordinate frame using GPS position estimates for the cameras, as well as measurements of camera azimuth and elevation from a compass and inclinometer, respectively. With the balloon positions known, their velocities – and as a consequence the Northing/Easting components of the wind field – were estimated using a finite difference approach vs. time with temporal smoothing to help mitigate high frequency noise.

To validate the efficacy of the vision-based approach, our initial experiments involved tracking a tethered ballooon rig carrying an EagleTree eLogger V4 with a 10 Hz WAAS enabled GPS module as payload [2]. The motivation was to use the logged GPS velocities for benchmarking the vision system's tracking performance. A total of 6 launches were conducted from different initial positions at standoff distances of $\approx 110 - 180$ meters from the camera systems. The balloon rig was released at ground level, and allowed to

C. Savtchenko is with the Computer Science and Engineering, Lehigh University, Bethlehem, PA, USA `cas210@lehigh.edu`

J. Spletzer is an Associate Professor of Computer Science and Engineering, Lehigh University, Bethlehem, PA, USA `spletzer@cse.lehigh.edu`

rise with minimal resistance while attached to a 125 meter long, 0.15 mm diameter tether. Each trial was considered completed once the end of the tether was reached. Results from these experiments showed that the mean absolute deviation between the two velocity estimates vs. time for all trials was 0.35 m/s (minimum 0.22 m/s, maximum 0.55 m/s). Results from a single launch are shown at Figure 2 (right). We should emphasize that these error levels represent the compounding of *both* the vision tracker and GPS velocity errors. These results indicate that the vision-based tracking system provides an effective means for estimating the wind velocity at standoff distances in excess of 200 meters.

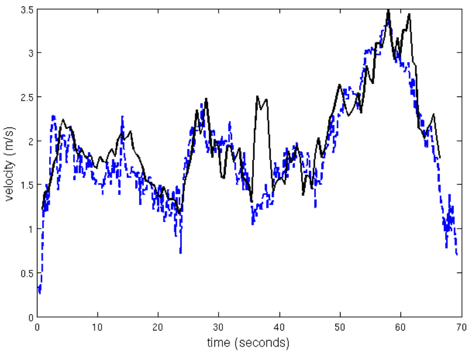

Fig. 2. Balloon velocity estimates vs. time for the vision system (solid black line) and GPS (dashed blue line). In this trial, the mean absolute deviation vs. time between the two approaches was 0.24 m/s.

II. ACKNOWLEDGMENTS

REFERENCES

[1] R. Hartley, “In defense of the eight-point algorithm,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 19, no. 6, pp. 580–593, June 1997.

[2] Eagle Tree Systems, *Instruction Manual for the Micro GPS Expander V4*, 1.3 edition, 2010.