Supplementary pilot observation

Before undertaking this simulation study, we conducted an informal pilot observation intended only to motivate the project, not to serve as validation data: a consumer multirotor (DJI Air 3) was filmed hovering indoors at low and high altitude using a Photron SA-X2 high-speed camera (1000 fps) with a Nikon 70–200 mm lens, and frame-by-frame pixel-coordinate tracking was used to compare positional dispersion at the two altitudes (Figs. 1 and 2). The low-altitude trial (left) exhibited tighter, more oscillatory positional excursions than the high-altitude trial (right). This observation provided qualitative motivation for investigating oscillatory motion during near-ground flight. However, the trial was uncontrolled in several respects relevant to interpretation, including a single trial per condition, indoor GPS-denied hovering, disabling of the downward rangefinder at low altitude to permit close approach, and the absence of a conversion from pixel coordinates to physical units. Consequently, the observation cannot establish GE as the cause of the measured motion differences and is not used to validate the aerodynamic model, simulation results, or quantitative conclusions of this study.



Figure 1: Pilot observation setup: high-speed camera and reference camera rig (left) and lighting configuration used to permit a high shutter speed at 1000 fps (right).

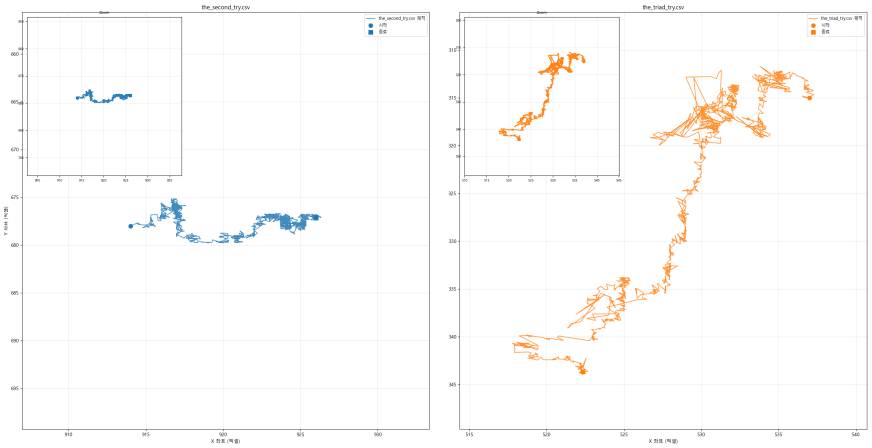

Figure 2: Pixel-coordinate hover trajectories from an informal pilot observation (1000 fps high-speed camera), low altitude (left, blue) vs. high altitude (right, orange). Shown only as qualitative motivation; see main text for caveats on interpretation.