3D Representation of UAV-obstacle Collision Risk under off-nominal conditions

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Safe operation of autonomous unmanned aerial vehicles (UAVs) in low-altitude airspace with beyond visual line-of-sight (BVLOS) flights demands robust risk monitoring of airspace as well as of people and property on ground. One of the safety critical factors for UAV flights is the risk of collision with static and dynamic obstacles in proximity to its flight path. This paper presents a detailed formulation of risk of obstacle collision incorporating the effects of off-nominal conditions introduced by component failures, degraded controllability and environmental disturbances such as wind gusts. The risk is represented in terms of a matrix with rows corresponding to the likelihood of occurrence of collision and columns representing severity of collision to the vehicle and surrounding structures. Risk likelihood is generated using a Bayesian Belief Network (BBN) that compiles knowledge from related Failure Modes and Effects Analysis (FMEAs) and Subject Matter Experts (SMEs) to determine the probability of collision based on on-board sensor measurements indicative of vehicle health and controllability. Risk severity is computed utilizing a point-mass 3D kinematic model of the vehicle in presence of wind. The proposed risk factor is demonstrated on real flight data from experimental flights of an octocopter at NASA Langley Research Center in presence of simulated obstacles and wind conditions. Effect of varying wind conditions, level of controllability and obstacle measurement noise on the risk factor is demonstrated. The proposed approach enables risk-informed decision making for timely mitigation of current and future unsafe events in autonomous systems.