Impact Angle Based Guidance Laws for Unmanned Aerial Vehicles

Abstract

There is a steep rise in the applications of UAVs in daily life, industry and military as well e.g. transportation, farming, surveying, surveillance, border patrolling, target localization and interception etc. In almost all of these applications path planning plays an important role to make the mission autonomous. For making the generated path flyable, constraints arising out of the dynamics of the vehicle should be taken into account at the time of path planning. Also, path length should be made optimal for time-critical missions. In many of the applications the environment may be cluttered with obstacles, so the problem of obstacle avoidance should also be addressed. This motivates us to address two different classes of problems: (1) time-optimal waypoint following in an obstacle-filled environment, and (2) time-optimal target interceptions considering constraints on impact angles as well as field-of-views (FOVs).

(1) In waypoint following problems the UAV is required to fly through a series of waypoints with specified orientations in three-dimensional (3D) space. These waypoints are either predefined or generated online based on the requirement of the mission. The orientation vectors at those waypoints are specified for a better utilization of on-board sensors. Using the concept of the optimal control theory the time-optimal path is first computed in an obstacle-free environment considering the bounds on the lateral acceleration. But in an obstacle-filled environment this time-optimal path may collide with obstacles. So, a strategy is proposed to switch to the next best path that does not collide with obstacles. Simulation results are presented to follow a series of waypoints in the presence of obstacles which are of different types and sizes to represent the real world scenarios. Then using a 6 DOF model of a UAV the proposed path is tracked with good accuracy to show the efficiency of the proposed algorithms.

(2) In target interception problems, guidance laws are designed to fulfill three main objectives as presented below.

i) The first problem proposes the time-optimal guidance law with impact angle constraints to intercept a nonstationary nonmaneuvering target in 3D space. The guidance law is based on the Proportional Navigation law and designed in such a way that the lateral acceleration bound is maintained throughout the mission. It has been shown that the presented scheme performs far better than the existing work in literature to achieve the same objective based on the Sliding Mode Control (SMC).

ii) The second problem discusses the stationary target interception with all possible desired impact angles considering the field-of-view (FOV) constraint of the on-board seeker making it feasible for practical applications. A three-stage Pure Proportional Navigation (3pPPN) law is proposed for attaining impact angle control over the entire angular range in two-dimensional (2D) plane, which is an extension of the two stage PPN guidance law existed in the literature. Then the problem is solved in 3D engagement scenarios and a four-stage PPN guidance law is proposed for achieving all possible impact angles. The proposed guidance law has also been compared with two different guidance laws with the same objectives: (a) two-plane-segregated two-planar-phase integrated guidance law and (b) recently published work for developing a nonlinear 3D guidance law. The outcome demonstrates a better performance of the proposed scheme.

iii) The third problem presents the nonstationary nonmaneuvering target interception with all possible desired impact angles in a two-dimensional (2D) aerial engagement scenario, where the target can move in any direction. The work also considers the FOV constraint for designing the guidance law so that the target is always visible while following the UAV trajectory, which makes it feasible for real world applications. The guidance law is based on the pure proportional navigation (PPN) and is capable of achieving any impact angle in the entire angular spectrum. The proposed guidance law is simulated to intercept a nonstationary nonmaneuvering target using a kinematic model of a UAV. A comparison with the related work existing in the literature has also been added to establish the efficacy of the present work.