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INTELLIGENT GUIDANCE ALGORITHMS FOR AUTONOMOUS UNMANNED INTERCEPTION SYSTEMS: SMART INFORMATION PROCESSING AND DECISION-MAKING

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Abstract. The paper addresses the problem of autonomous guidance for unmanned interceptor systems operating against highly maneuverable small aerial targets. A comparative analytical and numerical study of fundamental guidance laws Proportional Navigation (PN), Augmented Proportional Navigation (APN), Pursuit Navigation, and Linear Quadratic (LQ) optimal control - is conducted, with emphasis on their applicability under real physical constraints of small UAV platforms, including actuator inertia, limited available overload, and measurement noise. To overcome the limitations of classical methods, a combined adaptive guidance algorithm is proposed, integrating APN-based target acceleration compensation, Zero-Effort Miss (ZEM) trajectory prediction, and a nonlinear correction term justified through Lyapunov stability theory. The Lyapunov function approach, employing the squared line-of-sight angular rate, guarantees partial stability with respect to the guidance error variable across a wide range of initial conditions. A Kalman filter is incorporated into the guidance loop to provide reliable real-time estimates of target acceleration and time-to-go under high noise conditions. Three-degree-of-freedom numerical simulations confirm that the proposed algorithm achieves a miss distance of 0.1 m - a reduction of approximately 97 % compared to classical $\text{PN}(16.5$ m) and 97 % compared to APN (3.42 m) - while reducing average interception time by 12 % with only a moderate increase in computational cost. The results validate the effectiveness of combining nonlinear adaptive corrections with stochastic filtering for autonomous terminal guidance applications.

Keywords: adaptive guidance law; Kalman filter; Lyapunov stability; proportional navigation; UAV interception