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Title

Augmented Pursuit Guidance for Flight Trajectory Shaping

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Abstract

For long-range atmospheric flight vehicles such as long-range missiles and re-entry vehicles, trajectory shaping is essential to optimize the guidance performance specified for the mission. Various feedback guidance laws based on constant-speed and constant-altitude assumptions do not perform satisfactorily for long-range flights with significant speed and altitude changes. Although using the optimal guidance command history approximated by polynomials or neural networks is a practical option, it takes a lot of development time to account for various flight conditions. Real-time computational guidance based on convex programming, which has been extensively researched recently, has a high potential of practical application. Since most convexification procedures for non-convex trajectory optimization problems require linearization of the equations of motion, reliable trajectory initialization is essential for guaranteed convergence of convex programming approaches.

Pursuit Guidance (PG) is a simple guidance law that steers the vehicle's velocity vector laterally to the line-of-sight direction of the target. PG relies on the idea that the target can be intercepted if the lead angle (the angle between the velocity vector and the line of sight to the target) is reduced to zero. Although PG is not effective for precise homing guidance against moving targets [1], it is useful for long-range mid-course guidance since it can efficiently generates a feasible trajectory reaching the predicted impact point (PIP), which is usually assumed stationary. Furthermore, PG can be extended to improve some performance index or to control the terminal flight path angle. For convenience, PG with extensions is referred to as Augmented Pursuit Guidance (APG) in this paper.

APG proposed in this paper has two features: 1) lead-angle feedback with a time-varying bias, and 2) use of a pseudo-target flying to the same PIP. Trajectory shaping can be done easily since the true lead-angle history closely follows the lead-angle bias input. Furthermore, the optimal lead-angle history of a long-range air-to-air missile for the maximum terminal speed can be approximated by a linear function of the range to go, which reduces to zero at the terminal time. This observation implies that a suboptimal trajectory can be easily generated by using the linear approximation as the lead-angle bias input. Since the slope of the bias function is the only parameter to be determined, efficient trajectory initialization for more sophisticated trajectory optimization can be done very quickly. The concept of pseudo-target is useful for trajectory shaping when the terminal flight path angle is constrained. Similar concepts have been proposed in the previous studies [2] but it can be well combined with the use of lead-angle biasing to generate a suboptimal trajectory, which is close to the optimal one, for air-to-air engagement scenarios. This paper provides various numerical results showing the usefulness of APG for midcourse guidance of realistic long-range missile engagements.

References

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