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BIASED PURSUIT GUIDANCE LAW FOR REAR-SECTOR TARGET INTERCEPTION

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Abstract: *This paper presents a Biased Pursuit Guidance Law designed to enforce a terminal target approach from the rear-sector (tail-chase profile). By injecting a time-varying angle bias into the classical pursuit kinematic framework, the proposed guidance law systematically shapes the interceptor's trajectory during initial guidance phase.*

Keywords: *Numerical simulation, biased pursuit, guidance law, rear-sector, tail-chase, proportional navigation.*

1. INTRODUCTION

Classical Pure Pursuit (CPP) commands the interceptor's velocity vector to point directly at the target at all times. While geometrically simple, CPP lacks the trajectory-shaping capabilities needed for tactical operational constraints, such as avoiding forward-aspect defensive countermeasures or aligning an interceptor onboard sensor/payload with a specific quadrant of the target.

Proposed Biased Pursuit Guidance Law (BPGL) achieves rear-aspect target approach by injecting an intentional angular offset from the instantaneous line-of-sight (LOS), and it is used in midcourse phase.

Such an analysis was not found in [1] and [2].

2. ENGAGEMENT GEOMETRY

Consider a planar engagement geometry in an inertial coordinate frame, Fig.1, where:

• M denotes the Interceptor (Missile/UAV) with constant velocity magnitude V_M.
• T denotes the Target.

• R_{TM} denotes the relative range vector between M and T.
• Line-of-Sight (LOS) angle relative to the inertial baseline.

• γ_M denotes the flight-path angle of the interceptor.
• $\varepsilon = LOS - \gamma_M$ denotes the interceptor look-angle (lead angle).

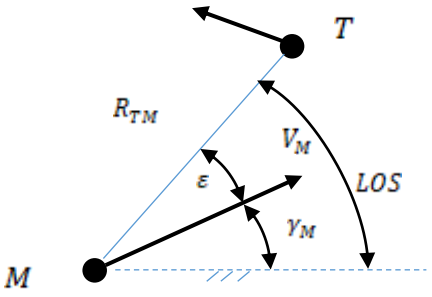


Figure 1. Engagement geometry

3. BIASED PURSUIT GUIDANCE LAW

The Biased Pursuit Guidance Law was defined in form of interceptor lateral acceleration demand by Eq.1, and it was used in first (initial) guidance phase.

$$a_N = Gain * (\varepsilon + Offset); \quad (1)$$

In the second (midcourse) guidance phase, starting when x coordinate of the interceptor approaches the x coordinate of the target to be less than threshold $x_{TM\ Threshold}$, the Offset term is omitted from Eq.1, and in that phase CPP was used to align the velocity vector of the interceptor toward the target position.

In the last (terminal) guidance phase starting when relative distance is less than $R_{TM\ Threshold}$, in order to minimise the miss distance even in case of the maneuvering target, the Proportional Navigation (PN) guidance law with navigation constant 3 was used, Eq.2.

$$a_N = 3 * Vc * \frac{d}{dt}(LOS) \quad (2)$$

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where the relative closing velocity is negative time derivative of the relative range, Eq.3.

$$V_C = -\frac{d}{dt}(R_{TM}) \quad (3)$$

NUMERICAL SIMULATION

Numerical simulation was done in horizontal plane by Fortran code [3] rewritten/translated to Matlab.

Initial value used in numerical simulation was: $Gain = 57.3$ (in order to obtain acceleration command of 1 m/s^2 for lead angle of 1°); $Offset = 50°$; $x_{TM\ Threshold} = 1000\ m$; $R_{TM\ Threshold} = 500\ m$.

The pseudo-code for guidance law is shown in (4)

$$\begin{aligned} &if\ (Rm1 < Rt1 - x_{TM_{Threshold}})\ then \\ &\quad Offset = 50 * Deg2Rad; \\ &else\ Offset = 0.0; \\ &a_N = Gain * (\varepsilon + Offset) \\ &if\ (Rtm < R_{TM_{Threshold}})\ then \\ &\quad a_N = 3 * Vc * dLOS\ \%terminal\ guidance \end{aligned} \quad (4)$$

Interceptor initial position was (x=0; y=0), $V_M = 100\ m/s$ toward the target initial position.
Target initial position was (range 10 km, deflection 2 km), $V_T = 50\ m/s$ ahead x-axe to the left.
Interceptor lateral acceleration was simulated as linear first-order system with time constant 0,5 s and limited to maximum value of 3 g.

4. RESULTS

Interceptor and target trajectories in horizontal plane was shown in Fig.1 for two values of $Offset$ (30° and 50°) and two values of $x_{TM_{Threshold}}$ (500 m and 1 km).

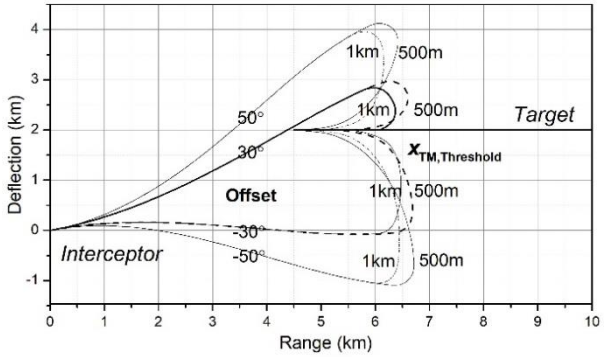


Figure 1. Interceptor and target trajectories in horizontal plane

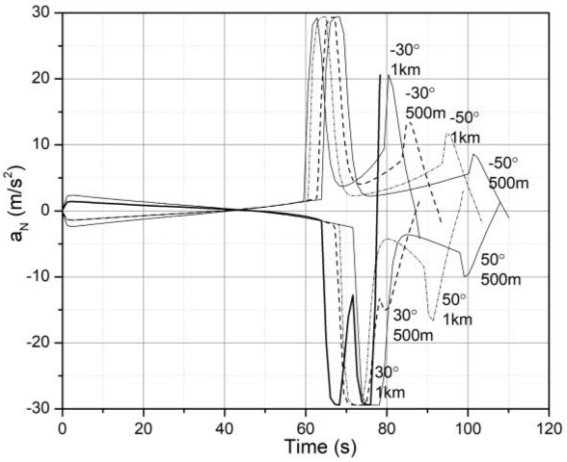


Figure 2. Corresponding missile lateral acceleration

In Fig.2 the corresponding missile lateral acceleration was shown. All terminal missile lateral acceleration values tends to zero, except for $Offset = 30°$ and $x_{TM\ Threshold} = 1\ km$ combination. That is the reason why in that case the final miss distance is significant (0,759 m), as shown in Table 1, Column 5.

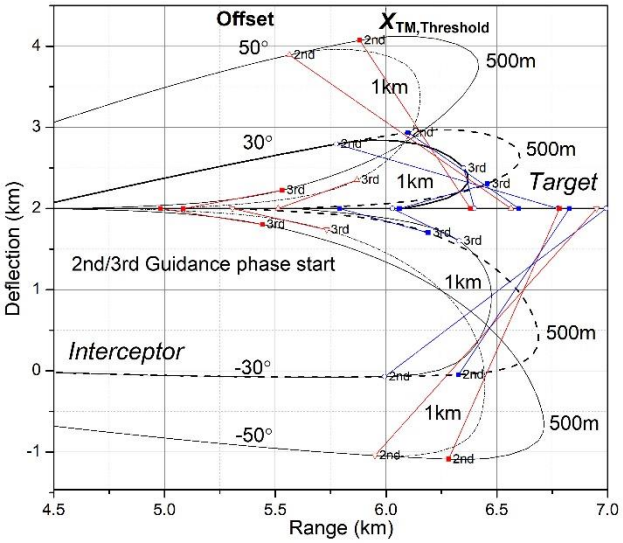


Figure 3. Switching guidance laws trajectory points

In Fig.3 all trajectory points are shown including switching points of different guidance laws (entering the 2-nd and 3-rd guidance phase). Instant corresponding positions of the interceptor and the target are marked and connected together.

One can see that only in case where $Offset = 30°$ and $x_{TM\ Threshold} = 1\ km$, when entering the final (3-rd) terminal guidance phase, the interceptor is still in front of the target (not in rear sector), resulting the larger miss distance.

Total time, energy and final miss distance was shown in Table 1 for all simulated parameter combinations.

Table 1. Total time, energy and final miss distance

Offset [°] (1)	$X_{TM\ threshold}$ [m] (2)	Total time [s] (3)	Total energy [g^2*s] (4)	Final miss [m] (5)
30	500	88,21	8180	0,003
30	1000	78,33	8869	0,759
-30	500	93,60	5126	0,001
-30	1000	88,08	5138	0,003
50	500	107,96	7036	0,001
50	1000	98,80	7097	0,003
-50	500	110,12	5421	0,0002
-50	1000	103,43	5346	0,002

One can see from Table 1 that inducing the larger Offset (Col.1) value results in larger Total time (Col.3). Opposite conclusion stands for $x_{TM\ Threshold}$ (Col.2) where the smaller total time was obtained when this parameter was enlarged.

In case of negative Offsets (Col.1) the Total energy (Col.4) used for guidance was smaller.

5. CONCLUSION

The Biased Pursuit Guidance Law offers an effective, elegant, low-complexity solution for enforcing rear-sector target interception.

By incorporating a bias to the target aspect angle, this guidance law enforces a curvilinear approach path that naturally loops behind the target and guarantees a tail-chase approach across a wide envelope of initial conditions.

This guidance law ensures optimal alignment for tracking systems and payloads. Because it requires minimal computational overhead it can be easily implemented.

Acknowledgement

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