

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

INTRODUCTION TO NAVIGATION AND GUIDANCE

AE 410/641 FALL 2020

Tutorial 3

ABHINAV SINHA and ROHIT NANAVATI



October 27, 2020

Objectives

- To familiarize yourselves with various terminologies used in the guidance literature.
 - Basic concepts of autonomous guidance in two-dimensions.
 - Concept of *unguided* versus *guided* vehicle engagement kinematics.
-

1. **Terminologies:** Pursuer, evader, line-of-sight, heading angle error, miss distance, time-to-go, relative velocity components, homing (endgame).
2. **Unguided vehicle:** Vehicle has no intelligence, follows some manual routine, probably human experience is involved
3. **Guided vehicle:** Vehicle is commanded via a computer, either installed on it or via telemetry.
4. **Kinematics of engagement:** Set of equations describing motions of the pursuer and the evader.

Consider the planar engagement geometry between a pursuer and an evader (both treated as point mass vehicles) as shown in **Figure 1**, whose kinematics, expressed in polar coordinates fixed to the pursuer's body, is governed by the set of nonlinear equations given by

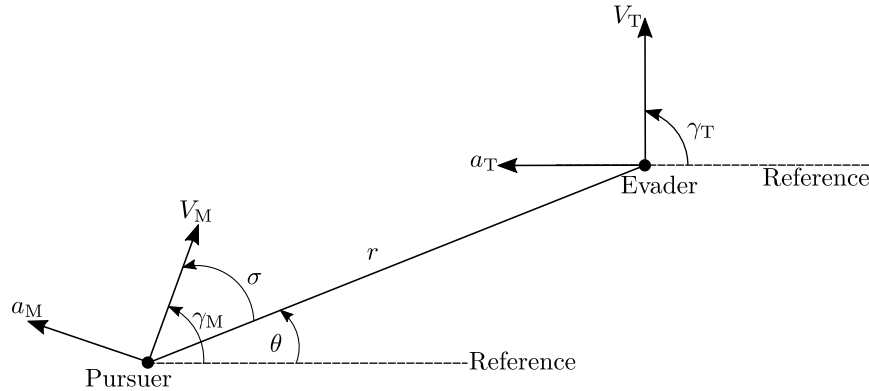


Figure 1: Pursuer-evader engagement geometry in a plane.

$$V_r = \dot{r} = V_T \cos(\gamma_T - \theta) - V_M \cos \sigma, \quad (1a)$$

$$V_\theta = r\dot{\theta} = V_T \sin(\gamma_T - \theta) - V_M \sin \sigma, \quad (1b)$$

$$\dot{\gamma}_M = \frac{a_M}{V_M}, \quad (1c)$$

$$\dot{\gamma}_T = \frac{a_T}{V_T}, \quad (1d)$$

$$\sigma = \gamma_M - \theta, \quad (1e)$$

where V_M , V_T denote the speed of the pursuer and the evader, respectively, while γ_M and γ_T are their respective flight path angles. The relative distance and the line-of-sight (LOS) between the adversaries are represented by r and θ , respectively, while the pursuer's look angle is denoted by σ . The components of relative velocities along and across the LOS are V_r and V_θ , respectively, while the lateral accelerations of the pursuer and the evader are a_M and a_T , respectively. Usually, it is reasonable to assume that speeds of the pursuer and the evader remain invariant during the course of engagement, and the adversaries have acceleration capabilities in lateral direction only.

Note that throughout our discussion, we shall stick to the viewpoint of the pursuer. That said, we study the problem of interception, however, the analogous problem of avoidance may also be studied in similar context.

Problem 1. Suppose $V_M = 400$ m/s, $V_T = 300$ m/s, $\gamma_M = 40^\circ$, and $\gamma_T = 30^\circ$. If the pursuer captures the evader successfully, what would be the value of LOS?

Problem 2. For $\theta = 0^\circ$, what would be the heading angle of the pursuer if the evader has a flight path angle of 90° . Assume $V_M = 500$ m/s, $V_T = 300$ m/s. What is the pursuer's the closing speed?

Problem 3. If the pursuer's flight path angle is given by the relation

$$\gamma_M = \theta + \cot^{-1} [\cot(\gamma_T - \theta) + \csc(\gamma_T - \theta)],$$

and it is certain that the evader is captured, then can you determine the closing speed?

Problem 4. A pursuer and a target are moving with speeds of 500 m/s and 250 m/s, respectively. If their look angles, σ and $\gamma_T - \theta$, are given as 150° and 90° , respectively, then check whether the pursuer is able to capture the target.

Problem 5. Does the condition, $\cos(\gamma_M - \theta) \sin(\gamma_T - \theta) = \cos(\gamma_T - \theta) \sin(\gamma_M - \theta)$, imply an interception of the evader?

Problem 6. Consider the planar engagement scenario in **Figure 1** where the pursuer is launched with a flight path angle, γ_M , while that of the evader (target) is γ_T . The relative separation, r , between them is 10 km with LOS angle, $\theta = 30^\circ$. The speed of the evader is half of the pursuer's speed, and is also equal to the closing velocity of the pursuer-evader engagement. Assume that the evader is non-maneuvering with its heading angle, given by $\gamma_T = 90^\circ$.

- (a) Obtain the possible pursuer's flight path angles with which it is launched, corresponding to above mentioned conditions.
- (b) Is interception guaranteed with above launch angles, if the pursuer is unguided?
- (c) Compute the possible heading angle errors corresponding to the above obtained pursuer launch angles.