About me

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- **Flight Mechanics**
- **Trajectory Optimization**
- **Bio-inspired Flight Techniques**
- **Guidance, Navigation, and Control**
- **Electric Aircraft**

Optimization Method & Optimal Guidance

Contents

AE8120

- **What is Guidance**
- **…**

Guidance, Navigation, and Control

1. Proportional **Navigation** → **Guidance** Method
2. Trajectory **Control** → **Guidance** Method

“Guidance in the aerospace context is the means by which a flight vehicle determines its needed changes in flight path to achieve vehicle mission objectives.”

Lu P., “What is Guidance?” Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

"The role of guidance is the determination of the vehicle-generated acceleration (magnitude and/or direction) history, and the instantaneous command in particular (for output to controls), to achieve a set of translation-maneuver targets subject to a set of (translation-maneuver) constraints."

Lu P., "What is Guidance?" Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

“(Guidance is) The process of determining a desired trajectory of an object and the change in object force vectors required to achieve it.”

Lu P., “What is Guidance?” Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

"A guidance system determines an aerospace vehicle's trajectory-control commands so that it follows a path from its current state to a target state, where "state" is defined by position and velocity coordinates."

Lu P., "What is Guidance?" Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

“Guidance is responsible for determining the desired vehicle attitude and propulsion system commands such that mission objectives are accomplished, while maintaining flight path and mission constraints.”

Lu P., “What is Guidance?” Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

“Guidance starts with the current position and velocity and determines the desired attitude (and sometimes throttle) for best getting to the target condition”.

”

Lu P., “What is Guidance?” Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

“Guidance selects the maneuvering sequence to get from the instantaneous state to a required state”

Lu P., “What is Guidance?” Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

“Guidance is the process of calculating the changes in position, velocity, attitude, and/or rotation rates of a moving object required to follow a certain trajectory and/or attitude profile based on information about the object’s state of motion.”

Lu P., “What is Guidance?” Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

“Guidance is about the determination of the maneuvering commands to steer the vehicle to fly a trajectory that satisfies the specified terminal/targeting condition as well as other pertinent constraints, and, if required, optimizes a defined performance.”

Lu P., “What is Guidance?” Journal of Guidance, Control, and Dynamics, Vol. 44, No. 7, 2021, pp. 1237–1238.

Keywords:

- Trajectory / Maneuvering
- Motion of Aircraft (Translational Dynamics)
- Select Commands
- Current State to Desired State
- Constraints

Note: Attitude is NOT irrelevant!

Note: Attitude is NOT irrelevant!

1. When flow angles (Angle of Attack) are part of the commands
2. Explicitly consider the attitude: 6 DoF
3. …

Typical guidance practice:

- Reference trajectory tracking
- Homing guidance (Missile)
- Online trajectory generation
- ...

Control:

- Forces and torques
- Attitude or flight condition
- Stability

Guidance

- Realize the maneuver
- Output to control
- Velocity and accelerations

Computational Guidance

Computational Guidance*:

- Relying on numerical algorithms
- Relying on onboard computation
- Model-based or data-based, no reference (necessarily) needed

*Lu, P., "Introducing Computational Guidance and Control," Journal of Guidance, Control, and Dynamics, Vol. 40, No. 2, 2017

Computational Guidance*:

- Relying on the computational power
- Optimization is a common means for computational guidance
- No reference != no initial input

Applied Mathematics

Typical guidance practice:

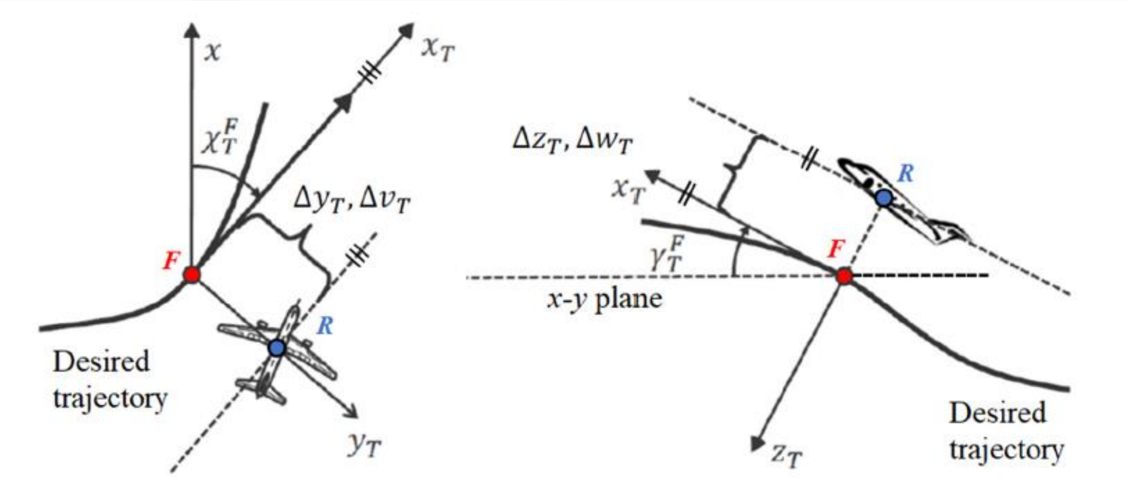
- Reference trajectory tracking
- Homing guidance (Missile)
- Online trajectory generation
- ...

⇒ The cutting-edges

Typical guidance practice: the cutting-edges

- Reference trajectory tracking:

- Design trajectory and controller jointly
- Ensuring stability
- Trade-off optimality

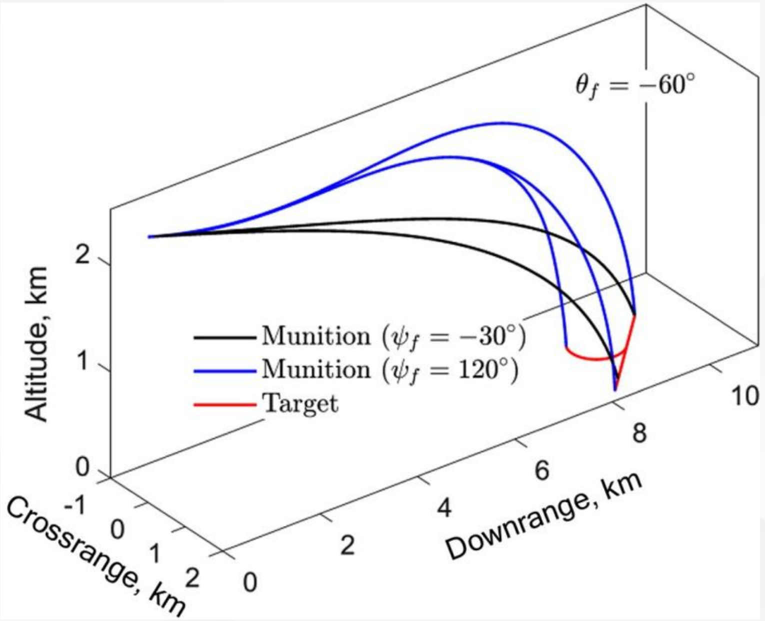


Piprek, P., Hong, H., & Holzapfel, F. (2022). Optimal Trajectory Design Accounting for Robust Stability of Path-following Controller. ***Journal of Guidance, Control, and Dynamics***, 45(8), 1385-1398.
Piprek, P., Hong, H.∗, & Holzapfel, F. (2022). Optimal trajectory design accounting for the stabilization of linear time-varying error dynamics. ***Chinese Journal of Aeronautics***, 35(7), 55-66.

Typical guidance practice: the cutting-edges

- Homing guidance (Missile)

  - Impact-time
  - Impact-angle
  - Impact-time and -angle
  - Field-of-view
  - 3D



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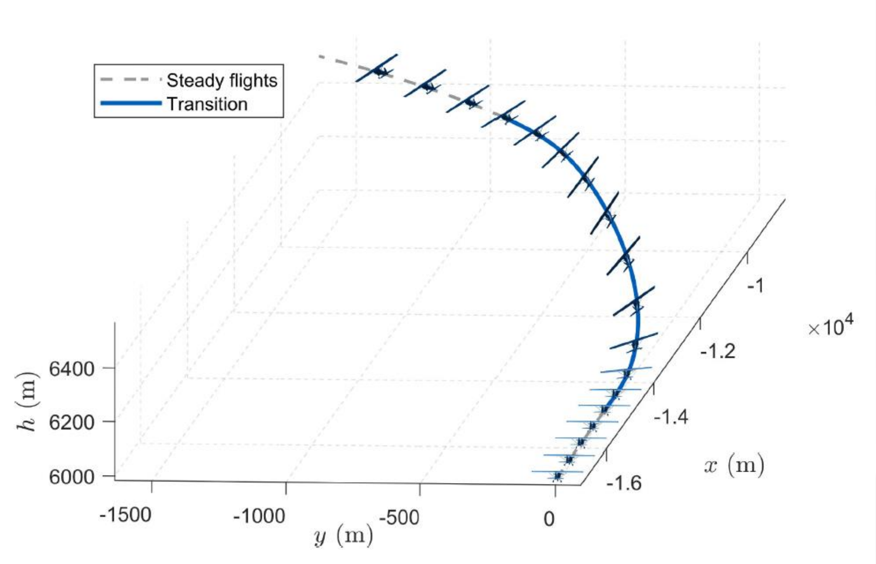
Typical guidance practice: the cutting-edges

- Online trajectory generation

  - Computationally efficient
  - Better (ideally, guaranteed) convergence
  - Constraints
  - Smoothness
  - …



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Hong, H., Piprek, P., Afonso, R.J.M., & Holzapfel, F. (2021). Trigonometric Series-Based Smooth Flight Trajectory Generation. ***IEEE Transactions on Aerospace and Electronic Systems***, 57(1), 721-728.

Homework

Tell me your understanding of “What is Guidance”

- Send to haichao.hong@sjtu.edu.cn
- Include “作业” and YOUR NAME in the subject line
- NO COPY PASTE