User Manual of the Simulation Framework for the Numerical Predictor-Corrector Guidance

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This document describes the simulation framework for the Numerical Predictor-Corrector Guidance (NPCG) implemented in the MATLAB programming environment.

1. Guidance logic consists of two parts.
    1) Numerical predictor-corrector algorithm based on Ref. [1]
        i. Longitudinal motion control algorithm.
        ii. Utilize a parameterized bank angle profile (linear shape).
        iii. Endpoint bank angle magnitude needs to be determined.
    2) Bank reversal algorithm based on Ref. [2]
        i. The predictive lateral guidance.
        ii. Utilize the bank angle solution from 1).
        iii. Damping ratio of the lateral motion needs to be determined.

2. Four atmospheric entry missions are given. Each problem formulation is given in a separated .m script.
    1) Mars robotic landing mission [3]
    2) Mars human landing mission [4-6]
    3) Apollo 10 lunar return mission [7-9]
    4) Hypersonic warhead, CAV-H [10-11]

3. There are THREE design parameters that affect the performance of the NPCG algorithm.
    1) GAP: guidance activation point where the NPCG starts to compute the bank angle command. No bank angle command at high altitude.
    2) sigma_f: endpoint bank angle magnitude in the linear bank profile of the NPCG algorithm.
    3) KBR: damping ratio in the predictive lateral guidance (bank reversal algorithm)

4. MATLAB scripts and functions
    1) Main_NPCG.m
        i. Main script that solves the four atmospheric entry problems using the NPCG and the predictive bank reversal algorithm.

2) ex_Mars_robotic
    i. Problem formulation for the Mars robotic entry problem.
3) ex_Mars_human
    i. Problem formulation for the Mars human entry problem.
4) ex_Earth_Apollo10
    i. Problem formulation for the Apollo 10 entry mission.
5) ex_Earth_CAVH
    i. Problem formulation for the CAV-H entry mission.
6) plotting.m
    i. Simulation results are plotted.
7) Aux_BR.m
    i. Bank reversal algorithm based on heading error (Tu et al., 2000).
8) Aux_BR_prdt.m
    i. Predictive bank reversal algorithm utilizing the linear bank angle profile which is calculated by the NPCG algorithm (Smith 2016).
9) Aux_dyn.m
    i. Unitless three-dimensional equations of motion of the entry vehicle. Numerical integration in time is executed.
10) Aux_dynE.m
    i. Unitless equations of motion of the entry vehicle. Only longitudinal motion is considered and numerical integration in unitless energy is executed.
11) Aux_dynE_3d.m
    i. Unitless three-dimensional equations of motion of the entry vehicle. Numerical integration in unitless energy is executed.
12) Aux_pci2pcr.m
    i. Coordinate transformation is executed from the planet-centered inertial frame (PCI) to the planet-centered rotating frame (PCR).
13) cal_airdens.m
    i. Simple air density model based on exponential function (Hicks 2009).
14) cal_delpsi.m

i. Heading angle error calculation that represents off direction of the entry vehicle's velocity toward a target.

15) cal_drdc.m
    i. calculation of downrange and crossrange using spherical trigonometric functions.
16) cal_QEGC
    i. Calculation of damping feedback term that eliminates phugoid oscillation in CAV-H example.
17) cal_sphdis.m
    i. Calculation of great-circle distance.
18) cal_z.m
    i. Range calculation based on the energy-based longitudinal entry dynamics.
19) cal_z_3d.m
    i. Range calculation based on the energy-based three-dimensional entry dynamics.

5. References

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