SSM
Scuola Superiore Meridionale

EMBRY-RIDDLE AERONAUTICAL UNIVERSITY

Analytical G&Cnets: AI-based strategies for a sustainable use of space

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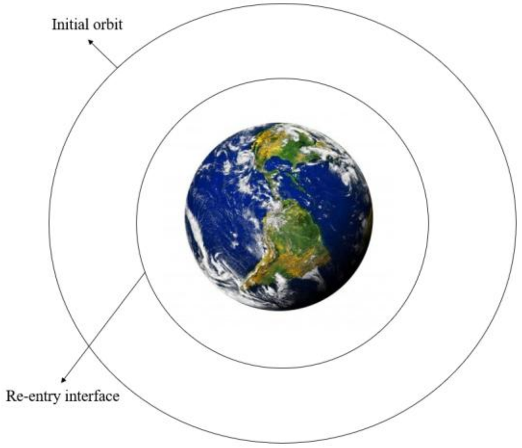
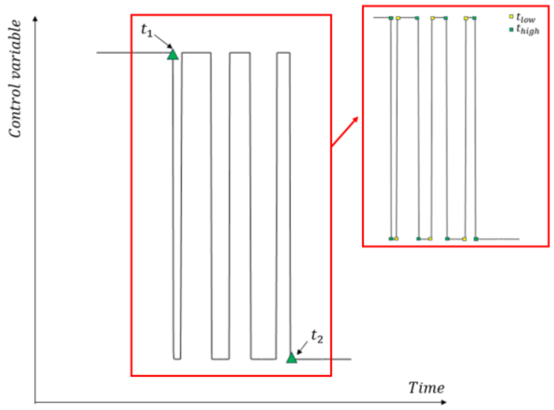
DRAG-BASED OPTIMAL TARGETED DE-ORBITING AND RE-ENTRY

First phase: De-Orbiting

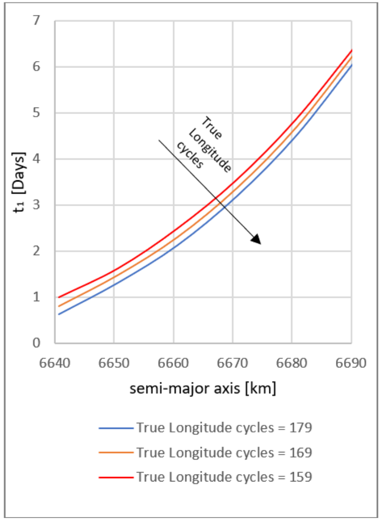


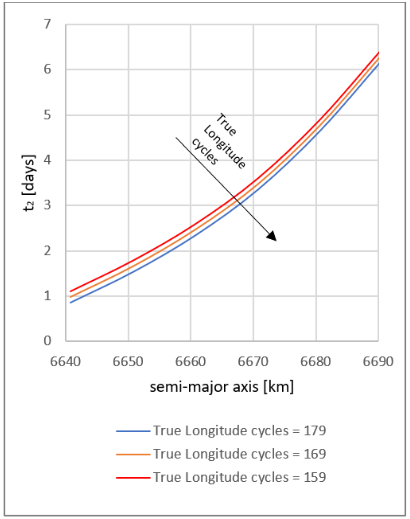


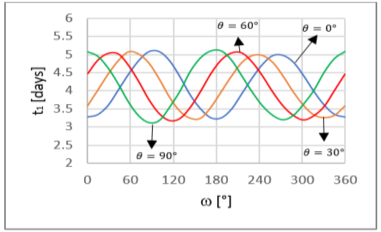
- Dynamics formulation in terms of the modified equinoctial orbital elements
- **Independent variable change** from time to true longitude to **manage the computational cost** and the **large time scale of the problem**.
- The altitude target is ensured thanks to an event constraint. The desired latitude and longitude are ensured applicating the algorithm in the next slides.

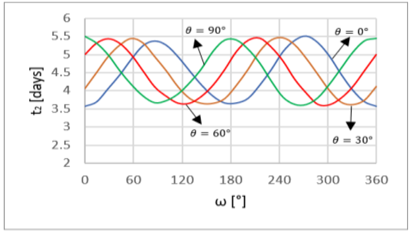
The optimal control solutions ensure the **desired de-orbit point** (in terms of longitude, latitude and altitude) **in the minimum time**. The computational time of few minutes does not make it suitable for real-time guidance generation on-board the satellite → AI-based approach

Determination of the optimal control parameters





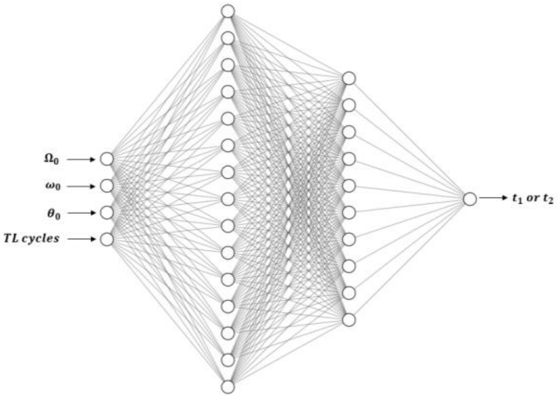




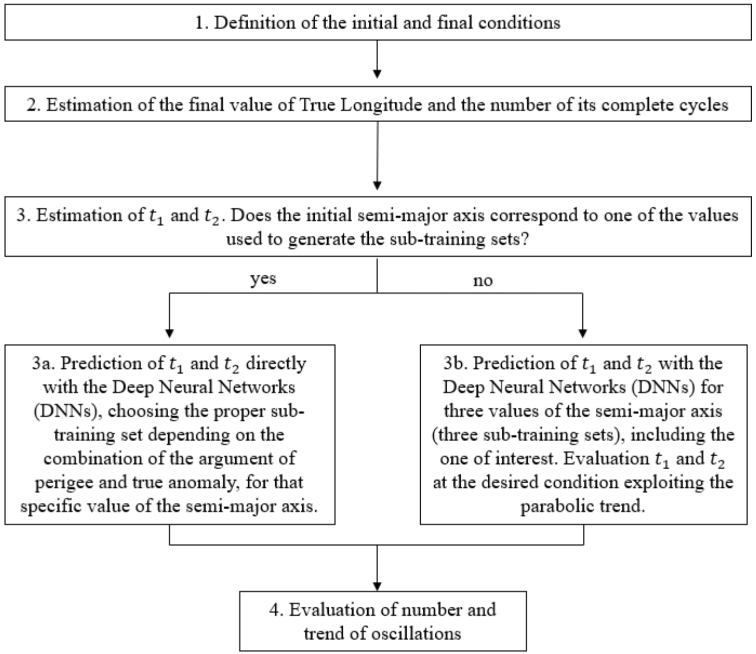
The number and time distribution of the oscillations → semi-empirical relations

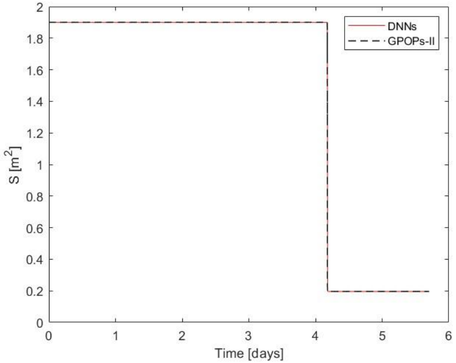
INPUT VARIABLES			
Ω_0	ω_0	θ_0	TL cycles
[0°; 360°]	[0°; 100°]	[0°; 100°]	Between minimum and maximum
[0°; 360°]	[0°; 100°]	[100°; 230°]	
[0°; 360°]	[0°; 100°]	[230°; 360°]	
[0°; 360°]	[100°; 230°]	[0°; 100°]	
[0°; 360°]	[100°; 230°]	[100°; 230°]	
[0°; 360°]	[100°; 230°]	[230°; 360°]	
[0°; 360°]	[230°; 360°]	[0°; 100°]	
[0°; 360°]	[230°; 360°]	[100°; 230°]	
[0°; 360°]	[230°; 360°]	[230°; 360°]	

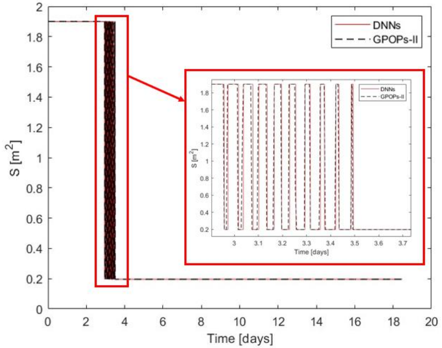
OUTPUT VARIABLES	
t_1	t_2

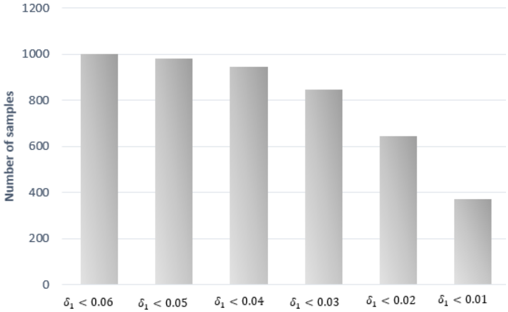


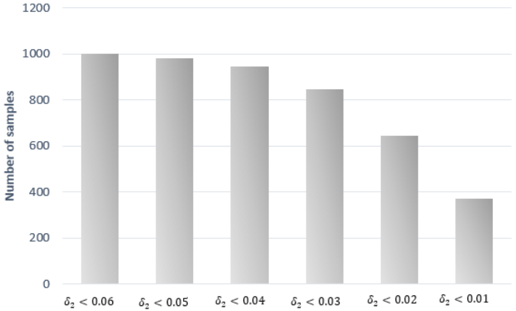
Guidance algorithm based on AI



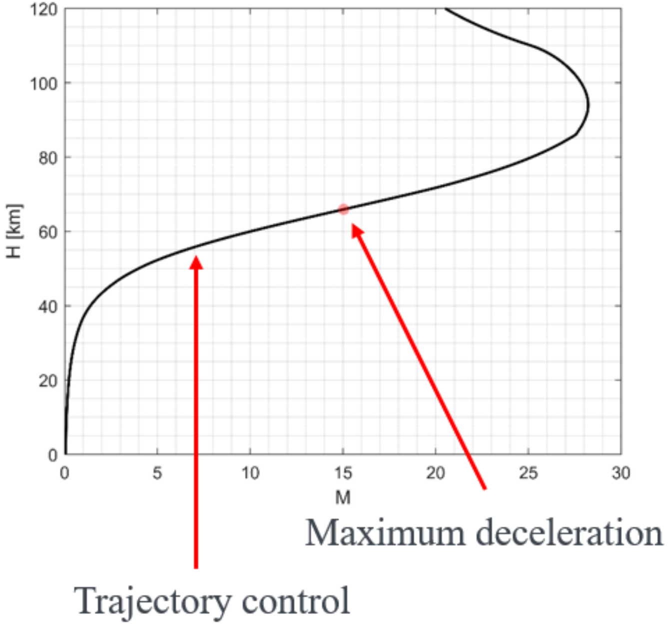


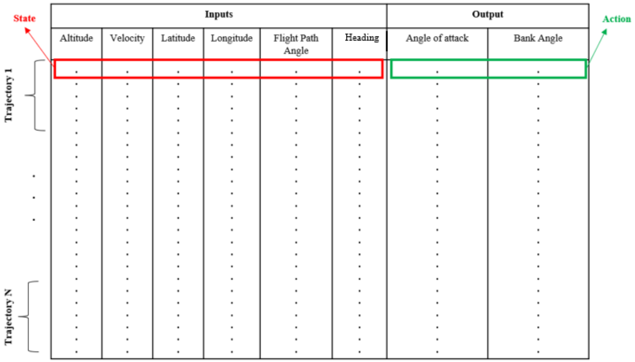


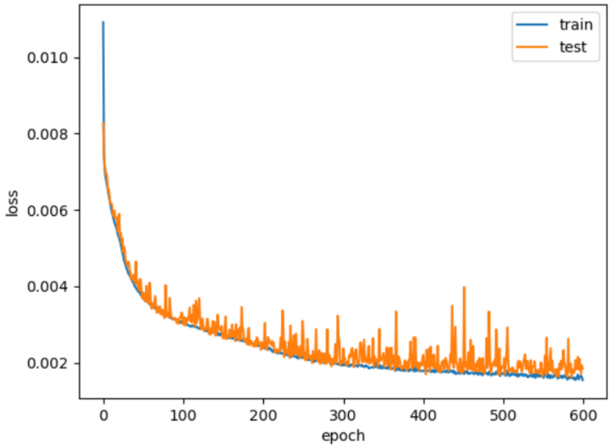




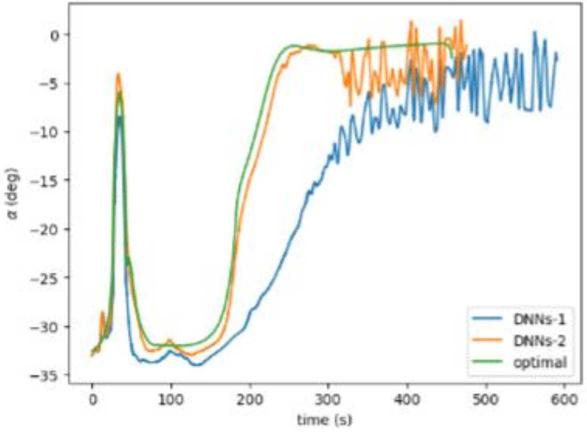
Second Phase: Re-Entry

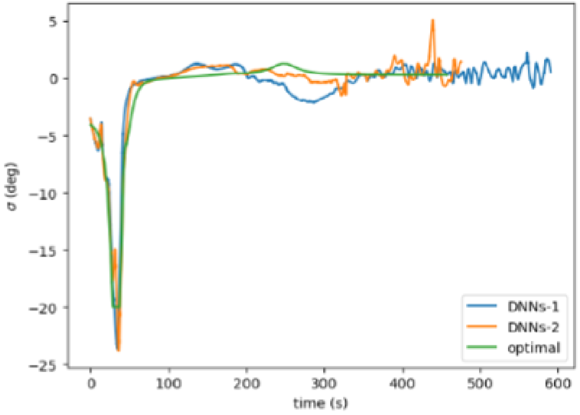




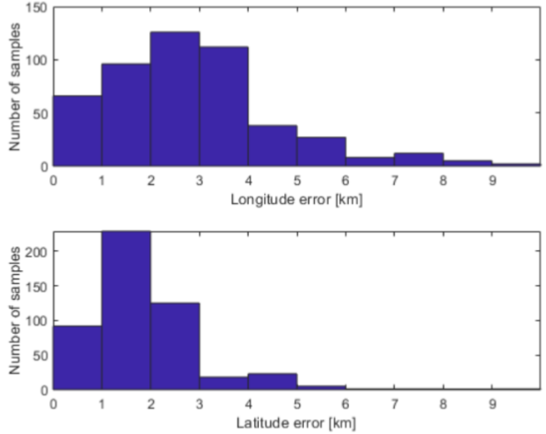


Performance in presence of perturbations

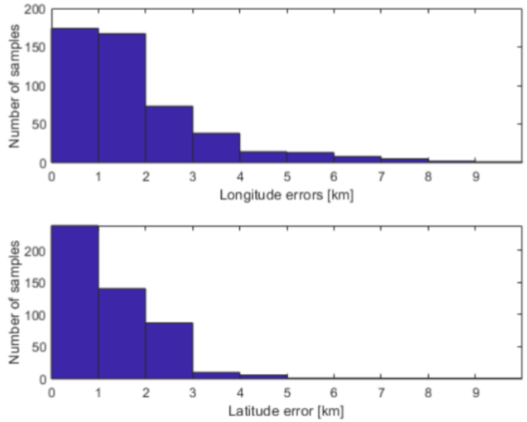




PERTURBATION LEVEL 1

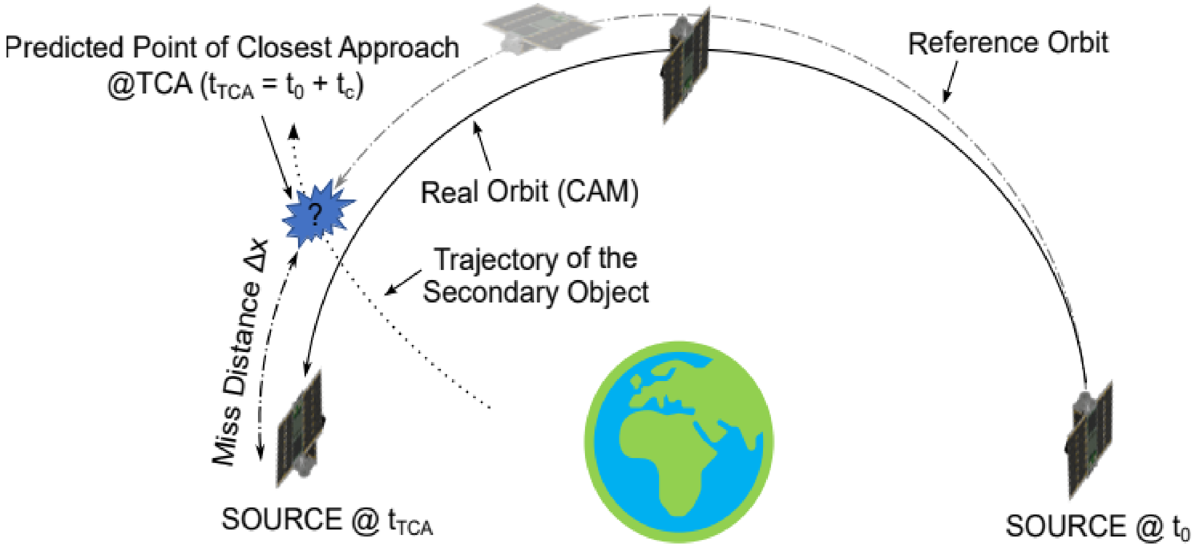


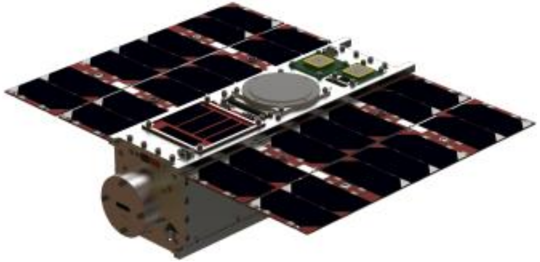
PERTURBATION LEVEL 2

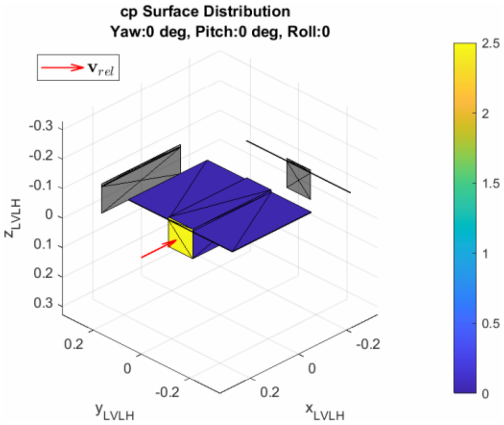


DRAG-BASED OPTIMAL COLLISION AVOIDANCE

Collision avoidance via aerodynamic drag







Feedback control based on AI

Approach based on DNNs

START

1. Reception of conjunction notice

2. Evaluation of the initial conditions
Assess the initial conditions from the conjunction notice to start the maneuver

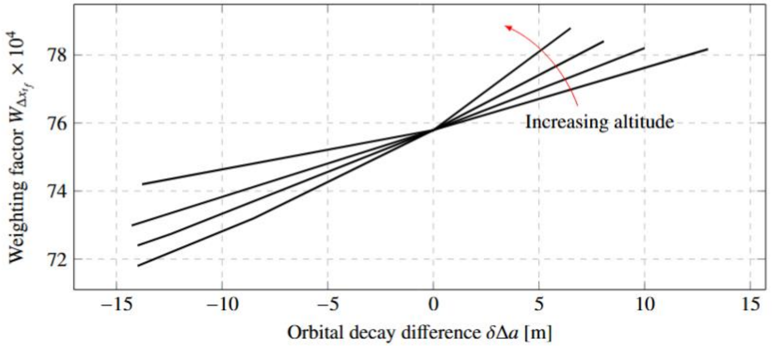
3. Define the control limits
Set minimum and maximum values of the angle of attack for the control problem

4. Predict the switching time with DNN
Use the DNN to predict the switching time, producing an initial optimal angle of attack profile based on the assumption of infinite rotation rate.

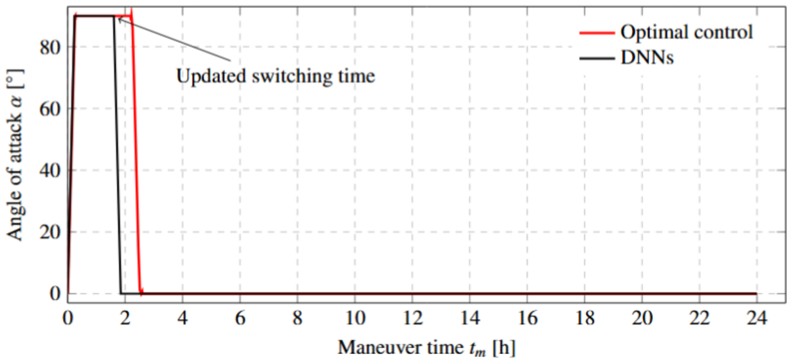
5. Apply Finite Rotation Rate
Adjust the predicted profile using a finite rotation rate, in line with satellite specifications, for greater realism.

END

Analytical update of the weighting factor

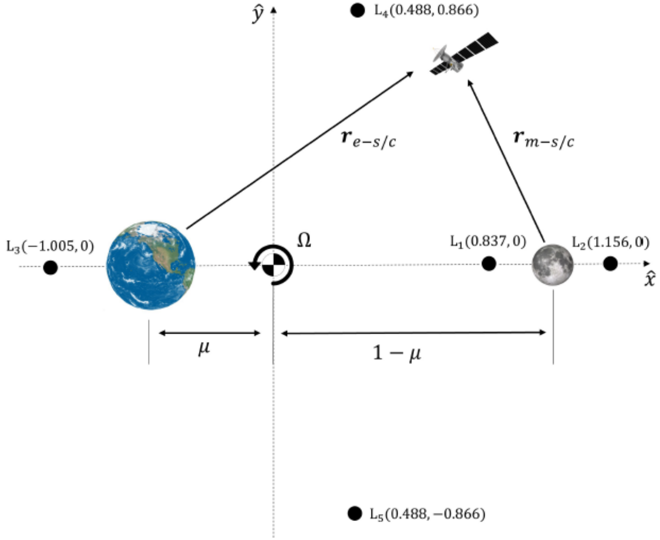


Control solution in perturbed environments preserving optimality

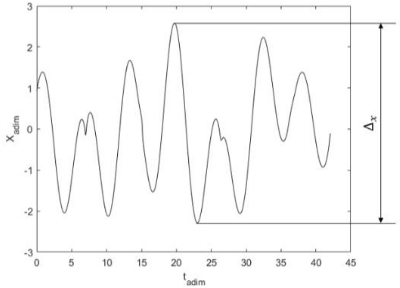


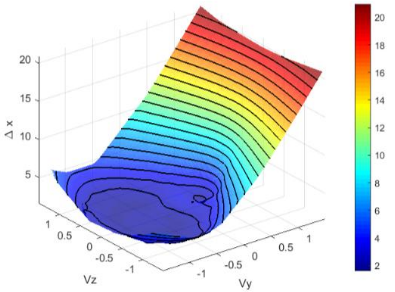
ORBIT STABILITY AND DETERMINATION IN CISLUNAR REGION

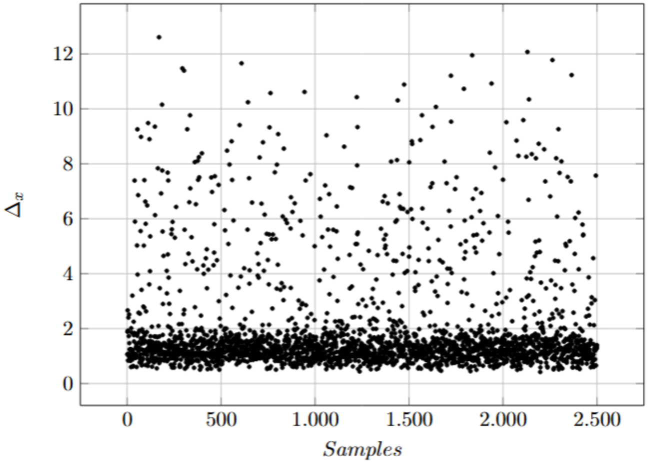
Orbit determination in the cislunar region



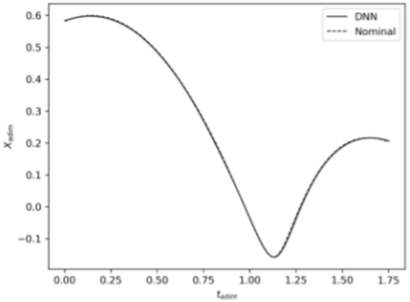
Parametric analysis to identify stable and feasible orbits



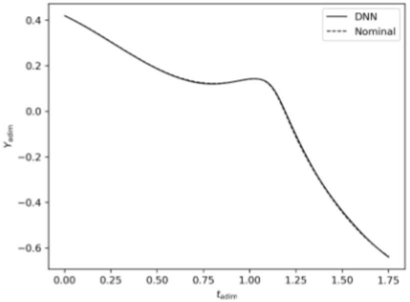




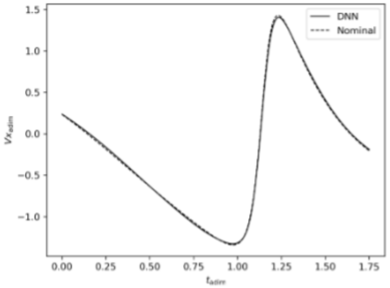
Example of predictions



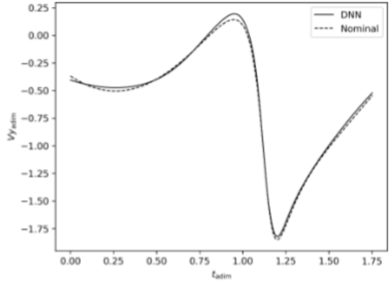
(a) x-component of position



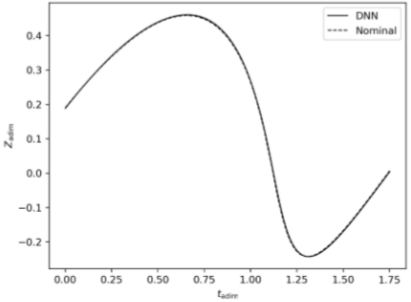
(b) y-component of position



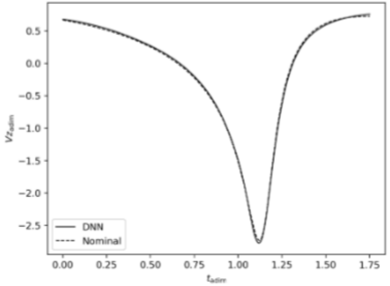
(a) x-component of velocity



(b) y-component of velocity



(c) z-component of position



(c) z-component of velocity

Advantages and Disadvantages

1. **Advantages:**
   - Reduced computational cost after trained, making them suitable for onboard use
   - High precision, ensuring quasi-optimal solutions
   - Adaptable for different scenarios
   - A sustainable use of space, optimizing the available resources
2. **Disadvantage:**
   - High computational cost for training
   - Numerical instabilities of the optimizers

Thank you for your attention

Questions?