Università degli Studi di Padova

Design and prototyping of a Guidance Navigation and Control system suitable for a lunar rover

Simone Fortuna - 38th Cycle

Supervisor: Prof. Marco Pertile

Co-supervisors: Andrea Merlo, Sebastiano Chiodini, Andrea Valmorbida

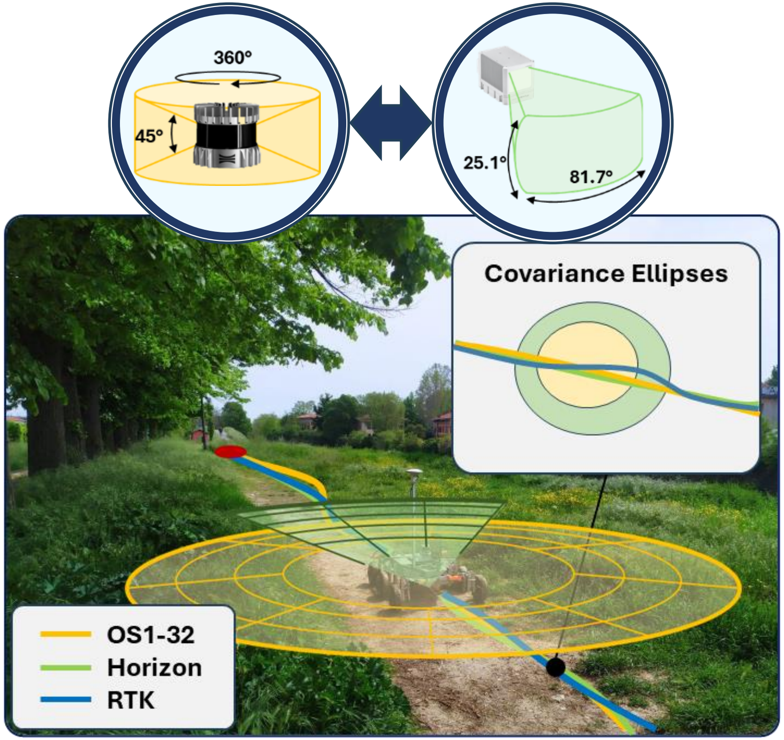
Admission to the 3rd year - 16/09/2024

Main activities

Main Activities *(Oct 2023 - Aug 2024)*

1. Enhancement of LiDARs comparison
2. Continuous Terrain Mapping for AutNav
3. Path Tracking and Maneuvering Strategies for Lunar Rovers

#1 LiDARs - Overview



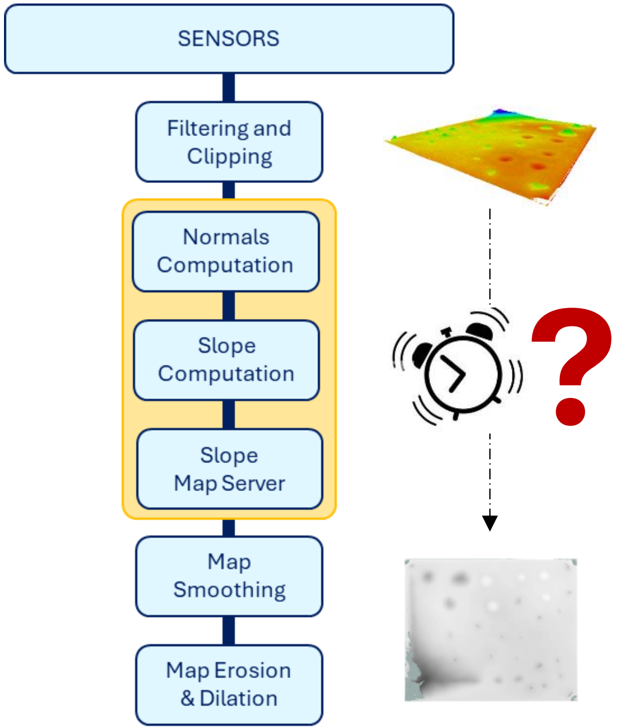
Ouster OS1 vs Livox Horizon

- Motorized Optomechanical vs MEMS Scanner
- SLAM Algorithm used: FAST LIO 2
- Comparison of metrological aspects:
  - ➢ Absolute Trajectory Error (ATE)
  - ➢ Map Quality
  - ➢ Uncertainty
  - ➢ **Computing Time**
  - ➢ **N° of tracked features**

#2 Mapping - Introduction

Continuous Terrain Mapping

- Traversability Maps: what information could be registered and what we chose?
  - Obstacles
  - Slopes
  - Roughness
  - Semantic terrain classification
- Objective: speed up real-time map construction by avoiding normals and using DEMs
- ROS 2 environment



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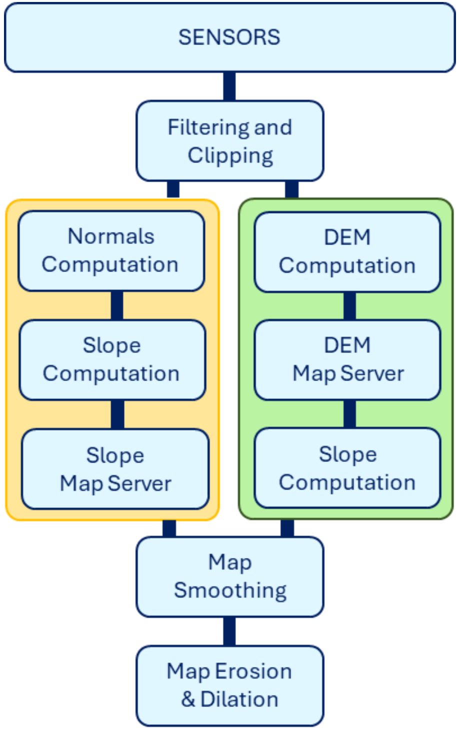
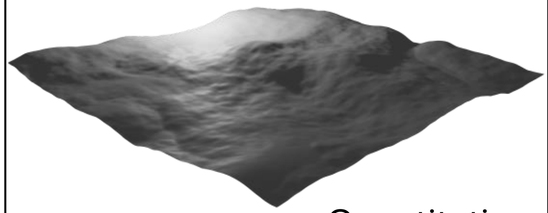


#2 Mapping – Comparison Methods

Comparison Methods

- **Static context, RoXY** - Starting from the point cloud of the entire real environment – no nav
- **Dynamic context, RoXY** - Navigating in the same outdoor environment
- **Static context, custom env** - Custom env to know real slopes and compute accuracy

Qualitative + Computing times



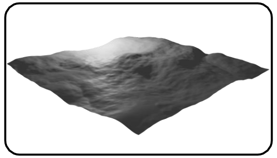
Quantitative

#2 Mapping – Results

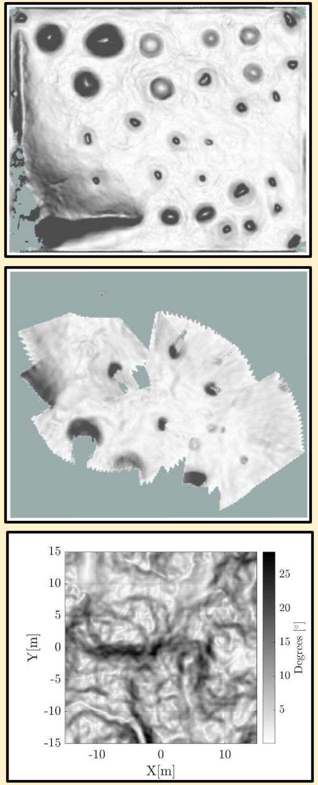
- Static context, ROXY

- Dynamic context, ROXY

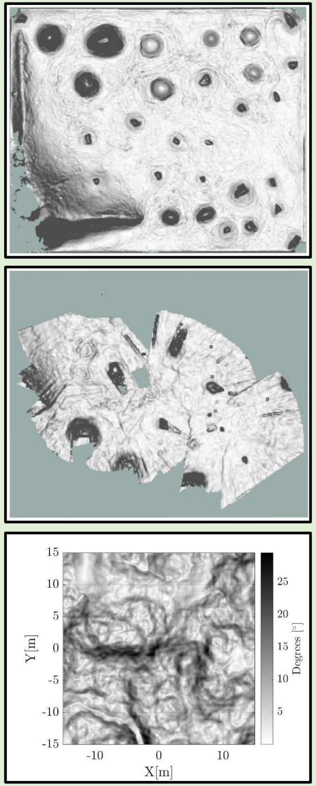
- Static context, custom env

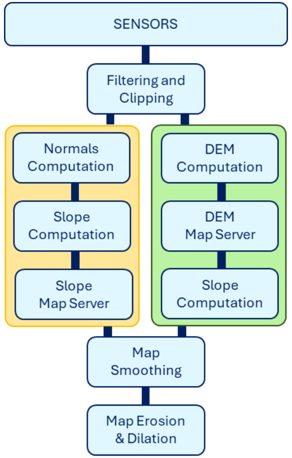


Normals



DEM



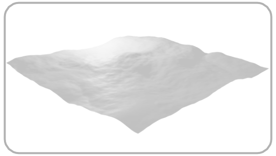


#2 Mapping – Results

- Static context, ROXY

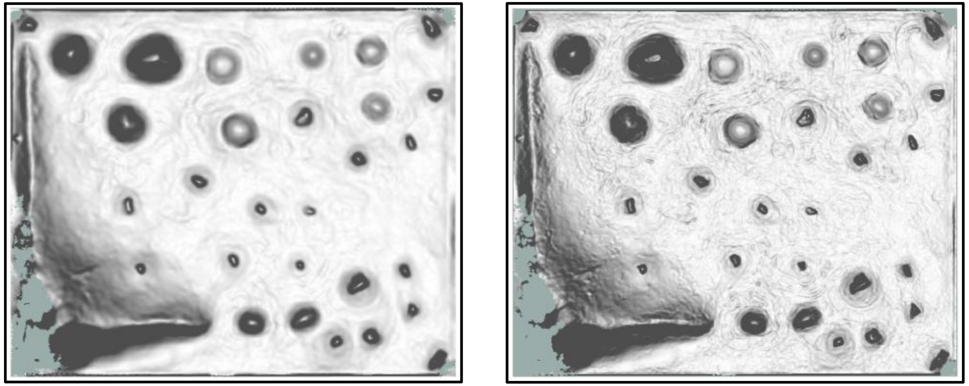
- Dynamic context, ROXY

- Static context, custom env



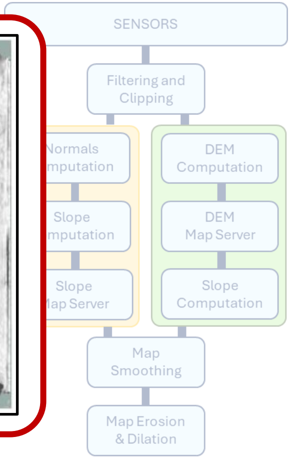
Normals

DEM



Normals Computation pipeline		Digital Elevation Model pipeline	
Normals computation (*)	$17468ms$ ($17373ms$)	DEM building (**)	$4335ms$ ($4245ms$)
Slope calculation	$209ms$	Slope calculation	$15ms$

(*,**) Times to compute rough normals or DEM, respectively.

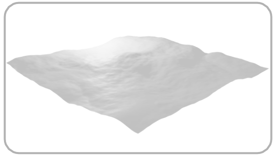


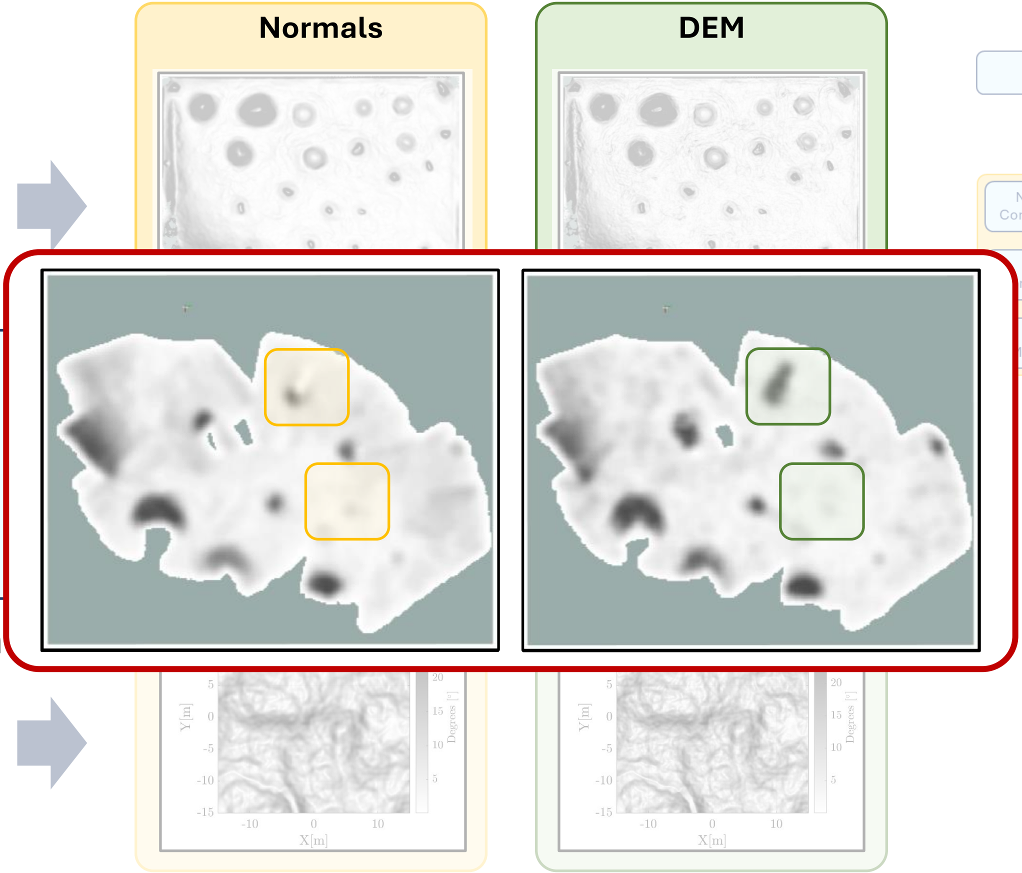
#2 Mapping – Results

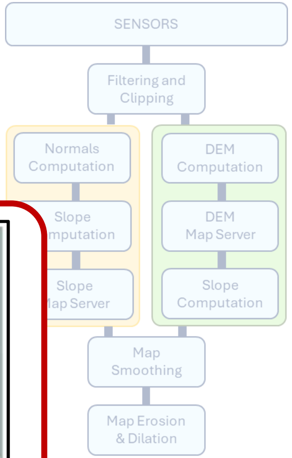
- Static context, ROXY

- **Dynamic context, ROXY**

- Static context, custom en







#2 Mapping – Results

- Static context, ROXY

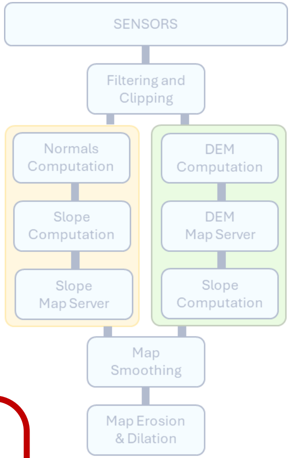
- Dynamic context, ROXY

Normals

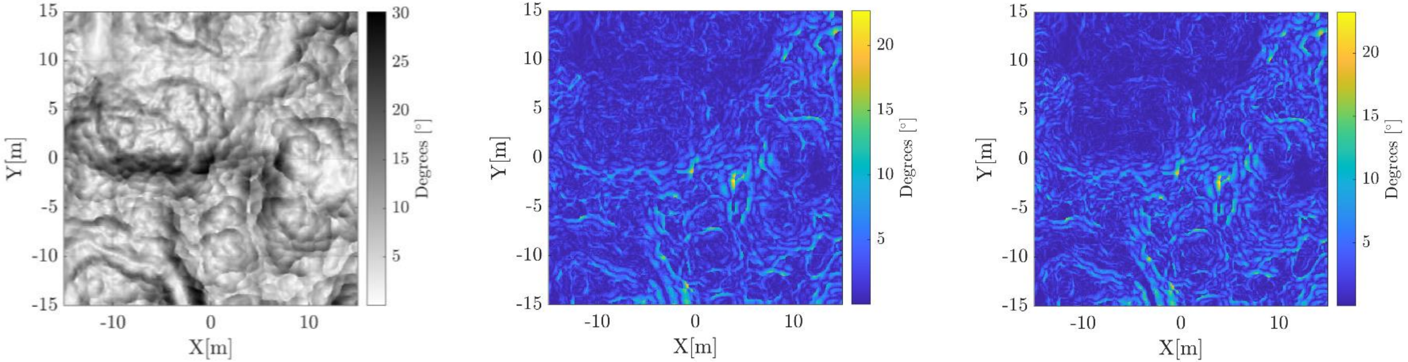
DEM

RMSE

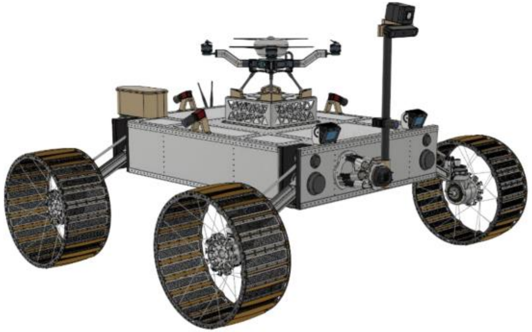
3.101° < 3.275°



Real Slopes

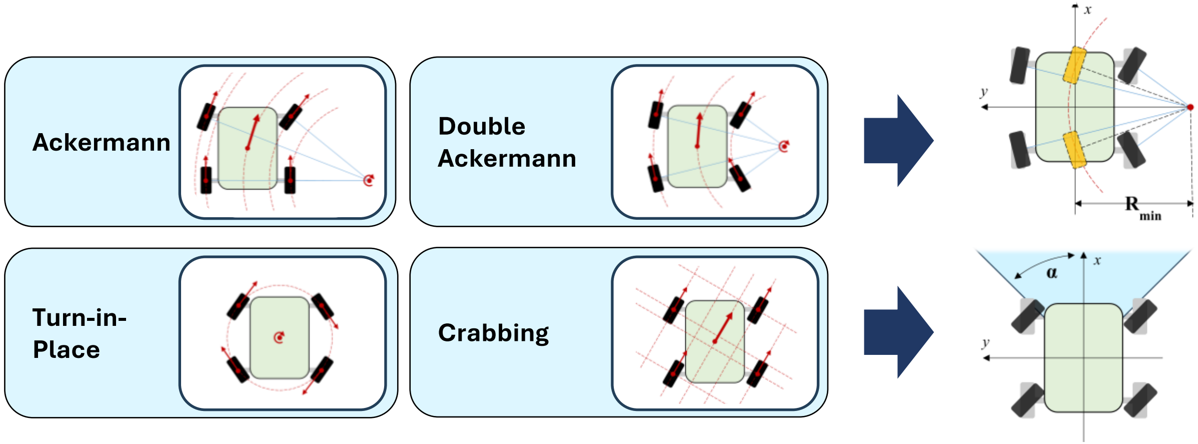


#3 Maneuvers - Introduction

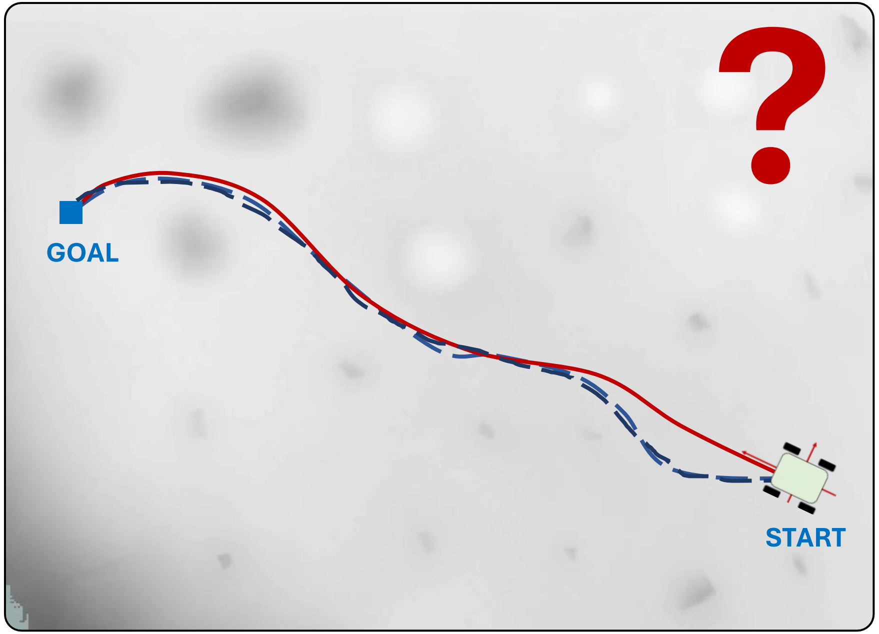


ULS platform constraints

- Non-holonomic
- No skid steering
- Set of loc modes
- Kinematic Limits

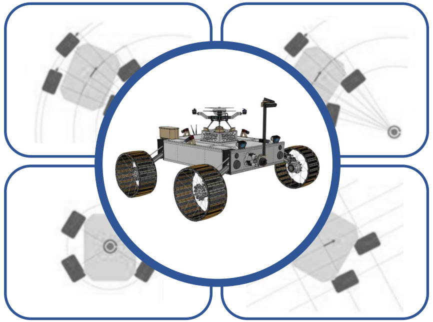


#3 Maneuvers – Nav2 stack and concerns



Concerns for ULS maneuvering

- Is the planned trajectory feasible?
- What locomotion mode must be chosen?
- What kind of controller must be used?

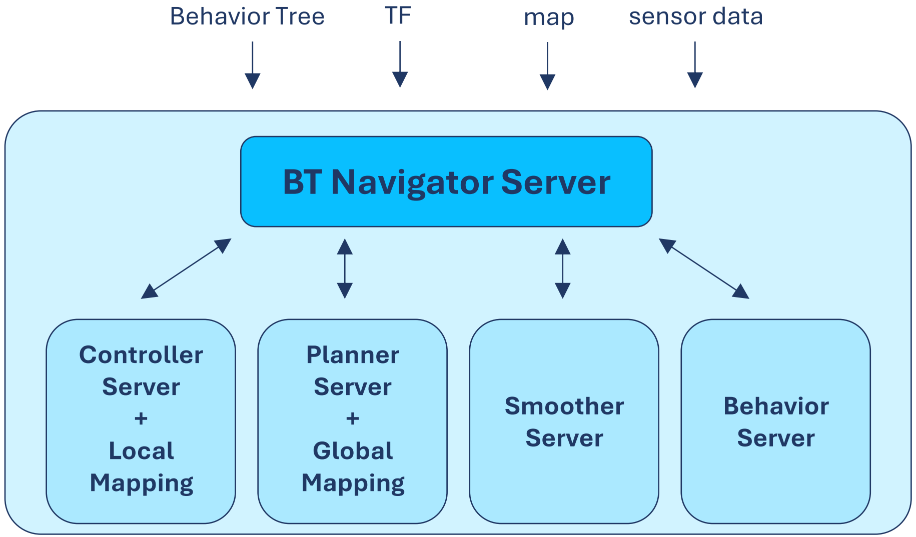


- *Non-holonomic*
- *No skid steering*
- *Kinematic limits*

#3 Maneuvers – Maneuver Server

Integrations and adjustments

- New Maneuver Server
  - ✓ *Modularity*
  - ✓ *Nav2 as-is*
  - ✓ *Simple Nav2 integration*
- Behavior Tree Integrations
- New controller for each locomotion mode



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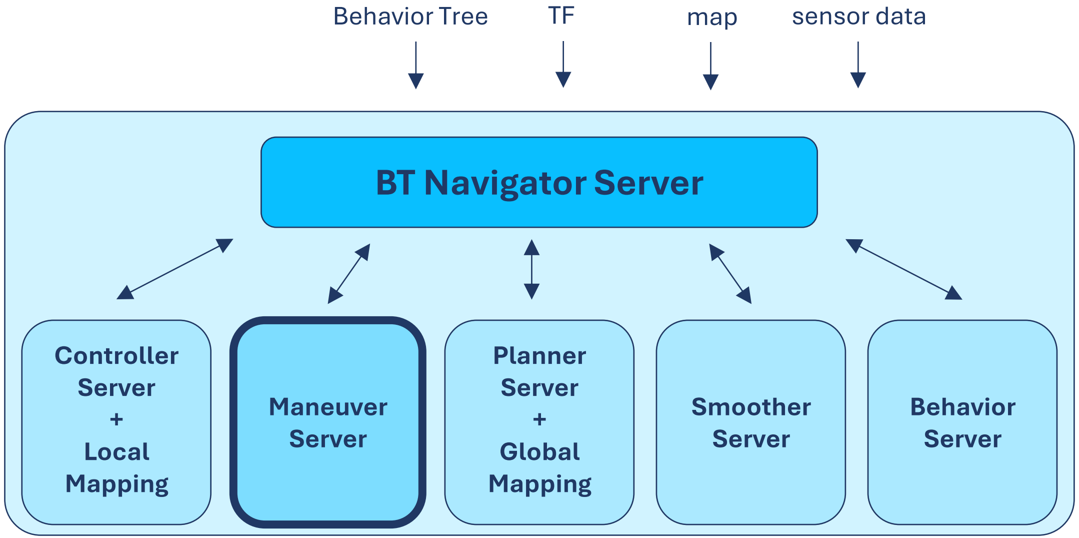
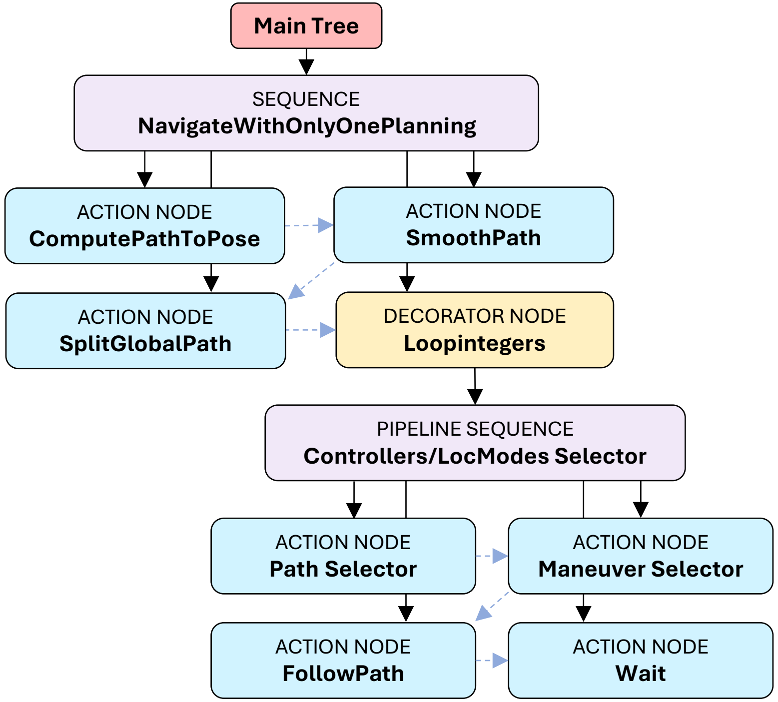
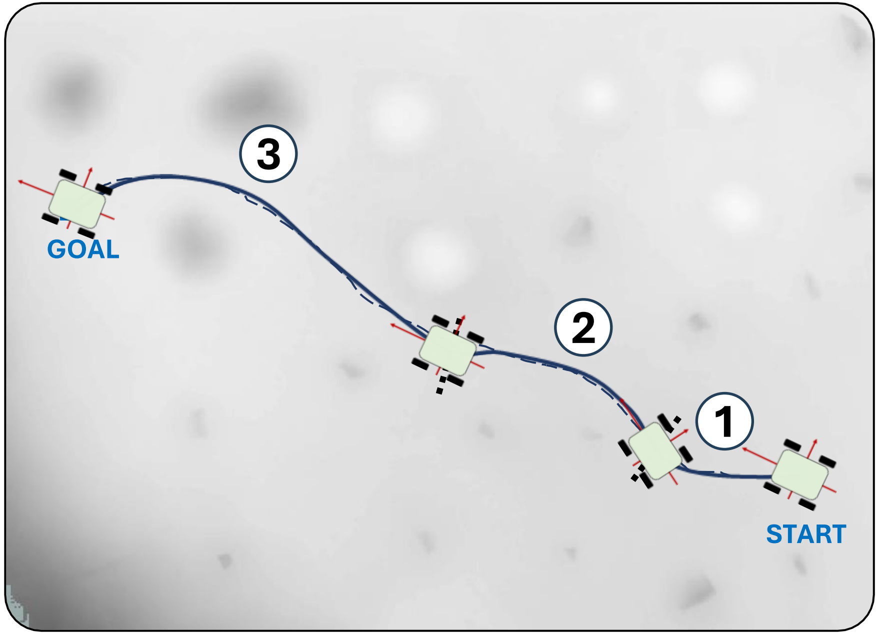


#3 Maneuvers – BT integration



No-Replanning BT configuration

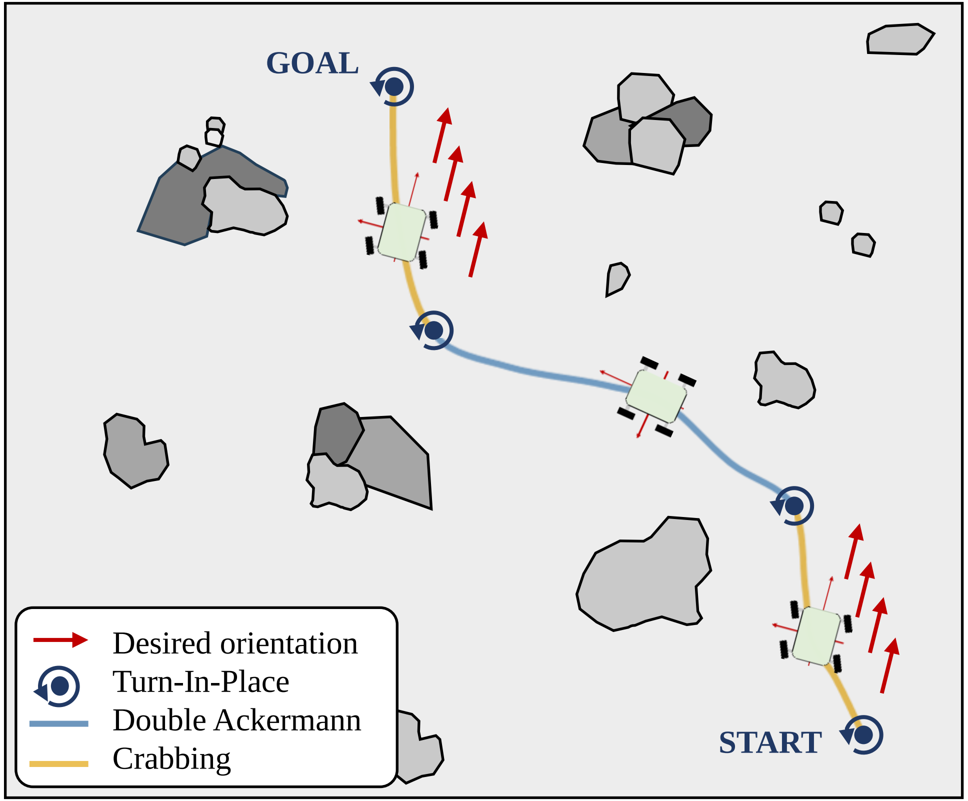


#3 Maneuvers – Path Splitting Logics

Path Splitting Logics

- Maximizing Crabbing
  - *Receive a direction*
  - *Translate while keeping a specific orientation*
  - *Turn-In-Place + Ackermann when not feasible*

- Ackermann + Turn-In-Place
  - *Find curvatures, split for* $R_{curv} < R_{min}$
  - ***1 Turn-in-Place*** *or* ***2 Turn-in-Place***



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➡ Ackermann + Turn-In-Place

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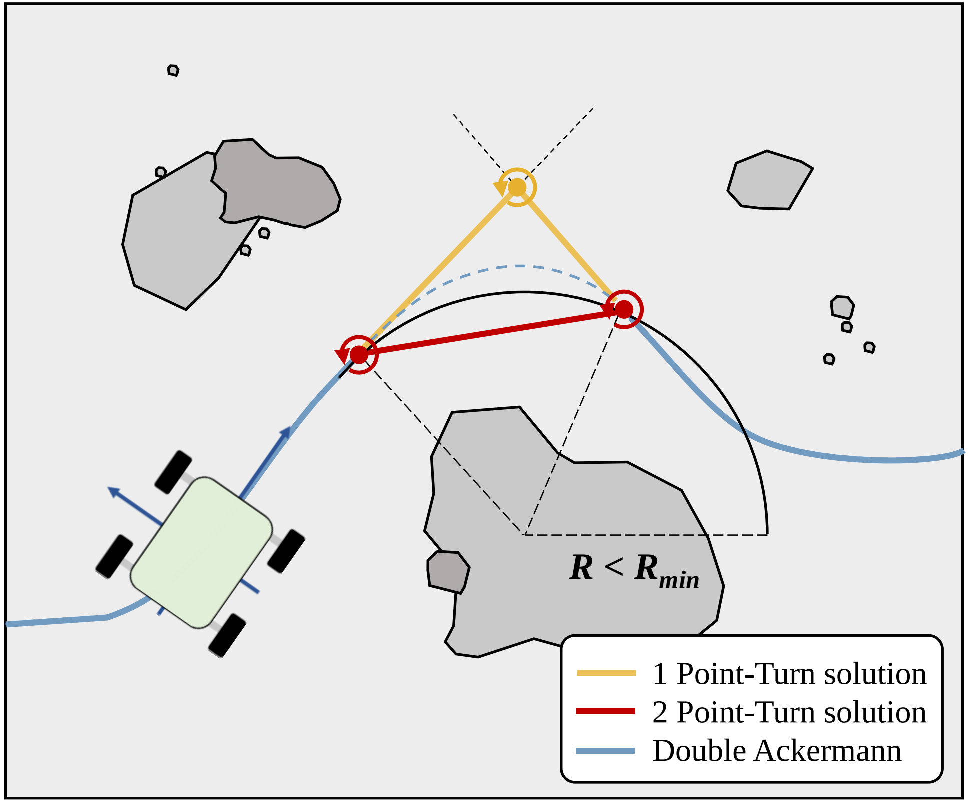

Timing

PHD STUDENT	**Fortuna Simone**	**DATE**	09/09/2024
PHD THESIS	**Design and prototyping of a Guidance Navigation and Control system suitable for a lunar rover**	**ADMISSION TO**	**Third year** in the Sciences, Technologies and Measurements for Space PhD Course

WBS NUMBER	TASK TITLE	% OF TASK COMPLETE
1	**Skills Acquisition and Literature Review**	
1.1	Study of Visual SLAM	**100%**
1.2	Acquiring skills in programming and ROS framework	**100%**
1.3	Navigation sensors and strategies review	**100%**
1.4	Rover GNC systems/architectures review	**80%**
2	**GNC system design and prototyping**	
2.1	Use cases and requirements definition for the lunar rover	**100%**
2.4	Design of GNC architecture and hardware implementation	**60%**
3	**Navigation SW and algorithms development**	
3.1	Definition of navigation/locomotion strategies	**80%**
3.2	Navigation SW and algorithms development	**70%**
4	**SW/HW tests and navigation strategies validation**	
4.1	Test campaign	**10%**
4.2	Test results analysis	**10%**
5	**Thesis writing and reports/articles redaction**	
5.1	Writing reports	**40%**
5.2	Article redaction	**50%**
5.3	PhD Thesis	**20%**

FIRST YEAR				SECOND YEAR				THIRD YEAR			
T1	T2	T3	T4	T1	T2	T3	T4	T1	T2	T3	T4
O N D	J F M	A M J	J A S	O N D	J F M	A M J	J A S	O N D	J F M	A M J	J A S

Thanks for the attention

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