ASTRA 2023
18 – 20 October 2023 | Leiden | The Netherlands

PerSim: Perception for Planetary Prospection and Internal Simulation

Raúl Domínguez[1], Mariela De Lucas Álvarez[1], **Siddhant Kadwe[1]**, Christoph Hertzberg[1], Siddhant Shete[1], Leon Cedric Danter[1], Marko Jankovik[1], Shubham Vyas[1], Jonas Eisenmenger[1], Pierre Willenbrock[1], André Felmet[1], Vikram Unnithan[2], and Frank Kirchner[13]

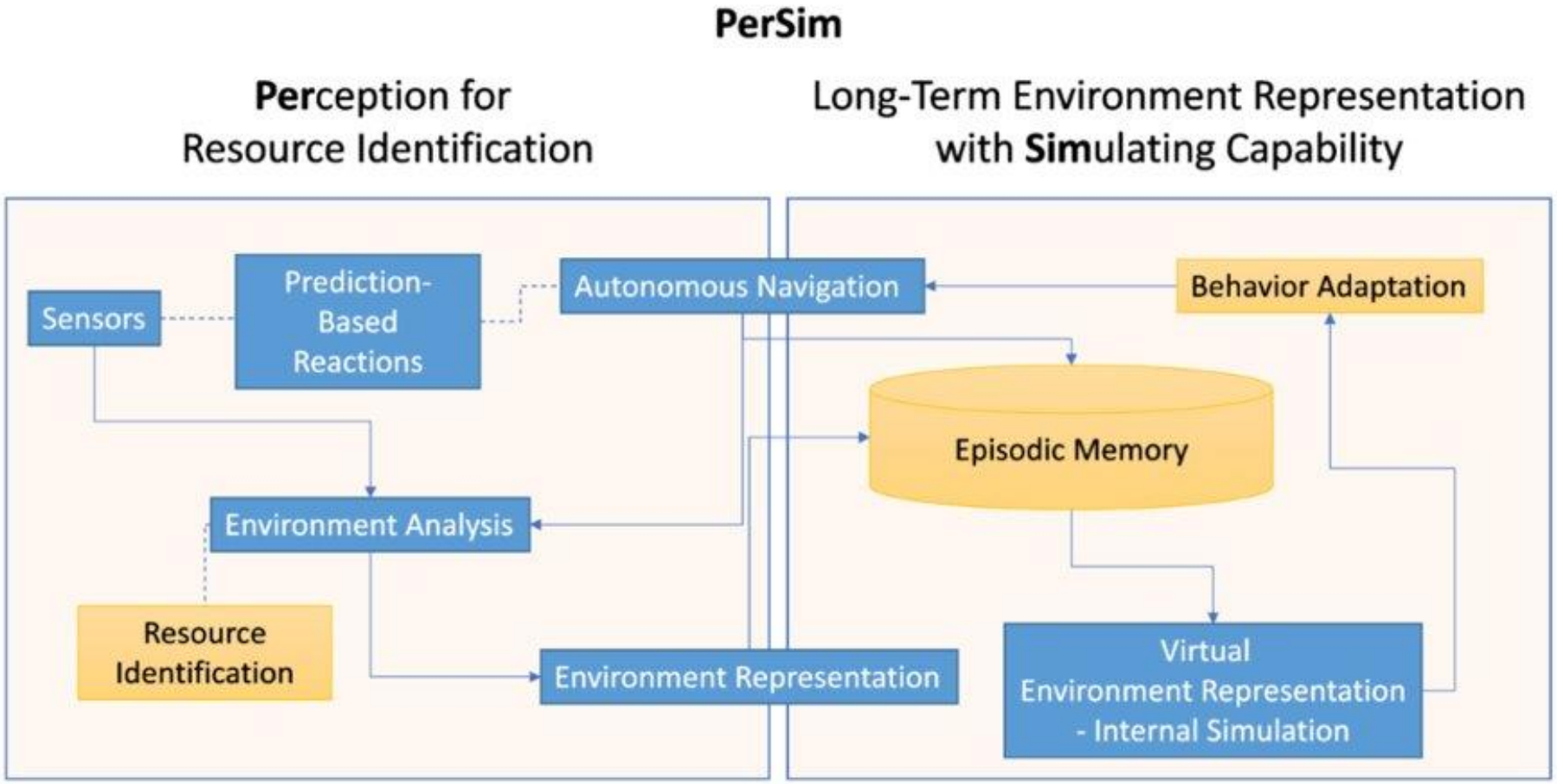
[1] German Research Center for Artificial Intelligence (DFKI)
[2] Geosciences School of Science, Constructor University
[3] Robotics Research Group, University of Bremen

Funded by:
Bundesministerium für Wirtschaft und Klimaschutz

Corresponding author: Mr. Raúl Domínguez, raul.dominguez@dfki.de

Table of Content

Introduction



Software

Architecture for long-term learning and environmental representation

Soft- & Hardware

Module for autonomous visual-based resource identification

Introduction

PERSIM

German Research Center for Artificial Intelligence

Resource identification

- Sampling of close-range data
- Design and development of sensor module
- Realistic representation of environment
  - Multi-Level surface map

Increase in degree of autonomy and reliability in navigation

- Control of rimless rovers
- Avoid hazards – tip over
- System agnostic
- Long term adaptive capabilities

Importance to testing

- Automated testing on servers
- Field tests

Table of Content

Architecture Design

Main exploration loop:

updates the visible area

Internal close-range rock analysis loop

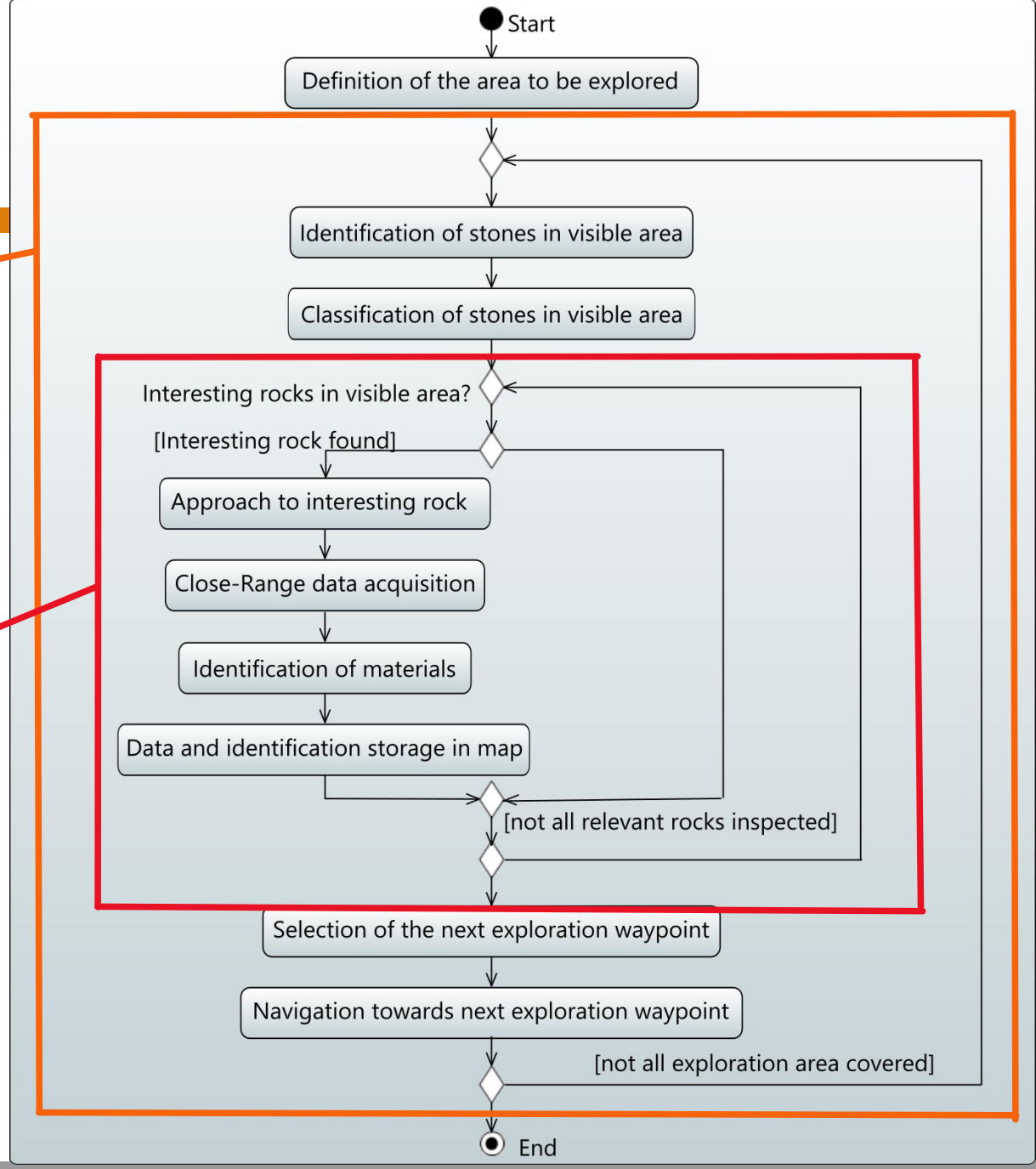


Table of Content

Resource Identification

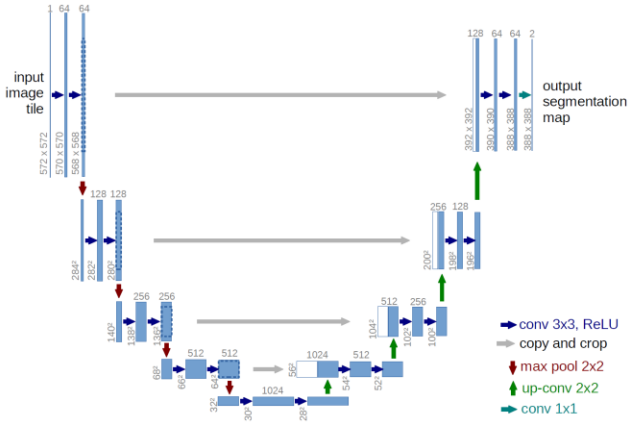
German Research Center for Artificial Intelligence

Rock Detection

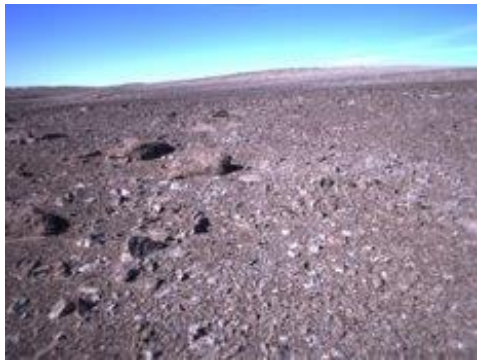
CNN based Rock Segmentation[1]

Testing Dataset – Devon Island Navigation Dataset[2]

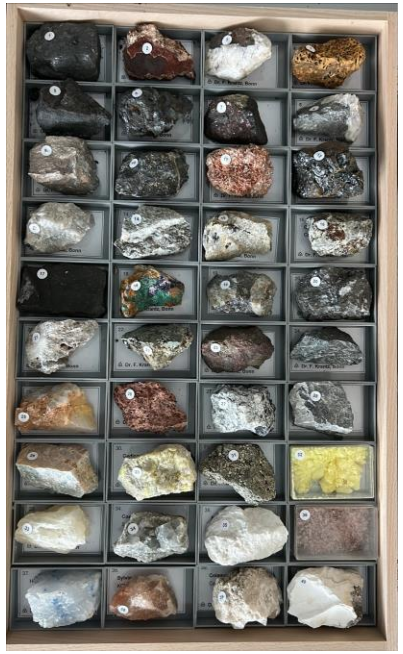
Attributes – Size, Texture, Shape



U-Net Architecture[1]



Sample image from Davon Island Dataset[2]

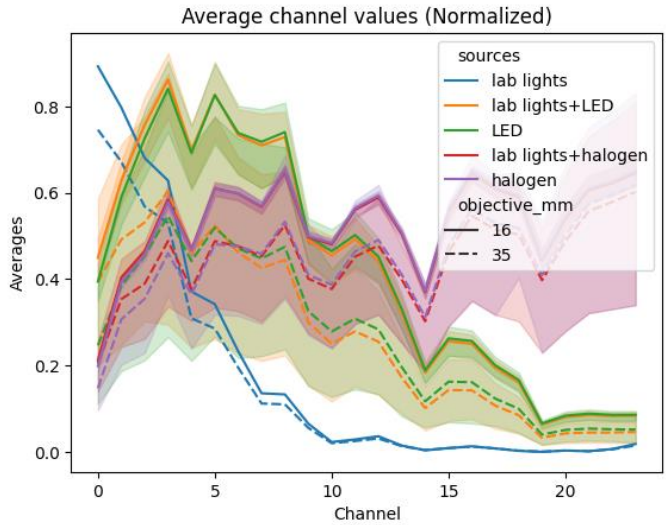


Hyperspectral Classification

Custom Dataset – Mineralogical samples

40 examples of igneous, sedimentary and metamorphic

Custom CNN based rock classification



1: https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/
2: http://asrl.utias.utoronto.ca/datasets/devon-island-rover-navigation/

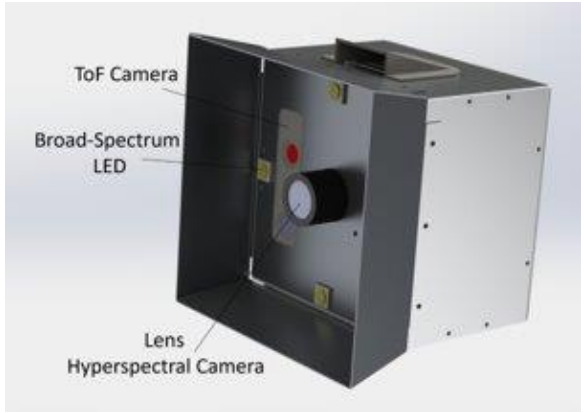
Resource Identification

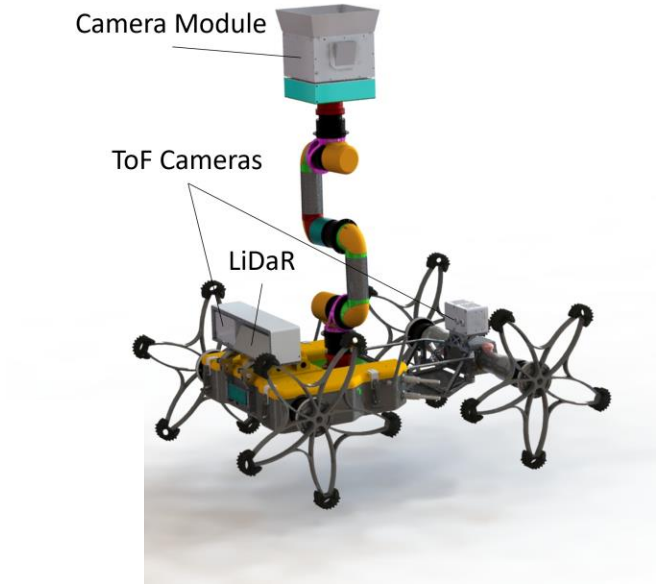
German Research Center for Artificial Intelligence

Sensors

Camera Module

- RGB + Time of Flight camera (Vzense DCam710)
- Hyperspectral Camera (Ximea SSM5x5)
- LED light source
- Sunshades
- Nvidia Jetson Xavier NX



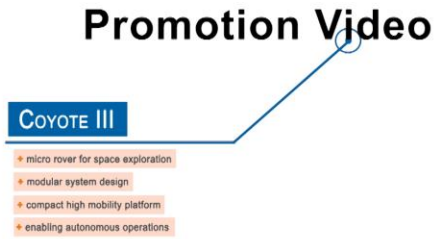


Deutsches Forschungszentrum für Künstliche Intelligenz GmbH

Solid State LiDAR (Velodyne Velarray M1600)

RGB + Time of Flight camera
(Vzense DCAM560C Pro)

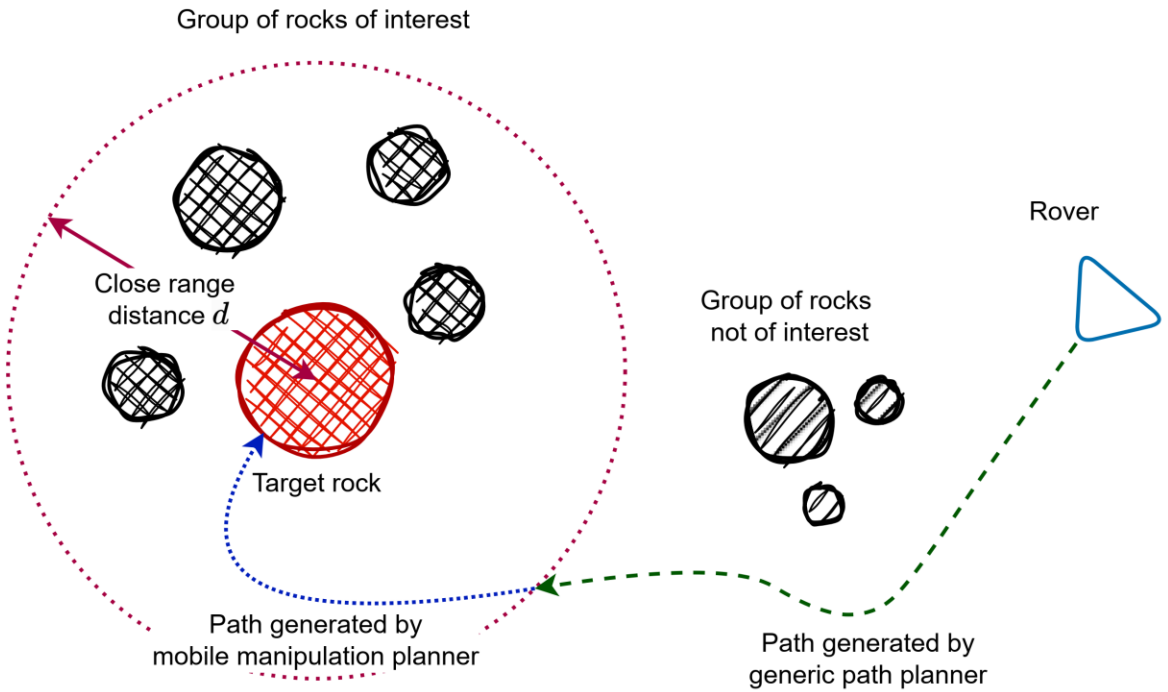
Electro-mechanical interface



Resource Identification

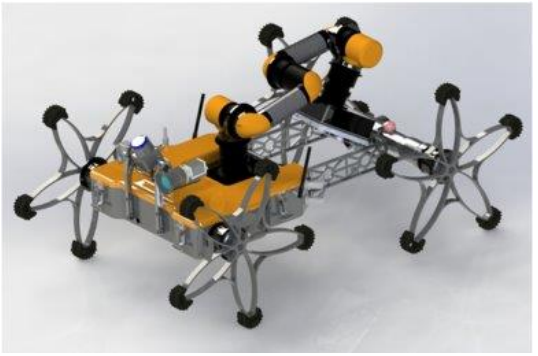
Autonomous Navigation:

- Environment representation
- Simultaneous Localization and Mapping (SLAM)



Mobile Manipulation:

- Coupled rover-base and arm movement
- Robot agnostic motion planner[3]
- Optimization based planner
- Self-collision detection ensured
- Robust and optimal



Rimless Wheels:

- Hybrid leg-wheel
- Better obstacle traversability
- Control improvements ongoing

3: https://github.com/spaceuma/ADE-Mobile_Manipulation

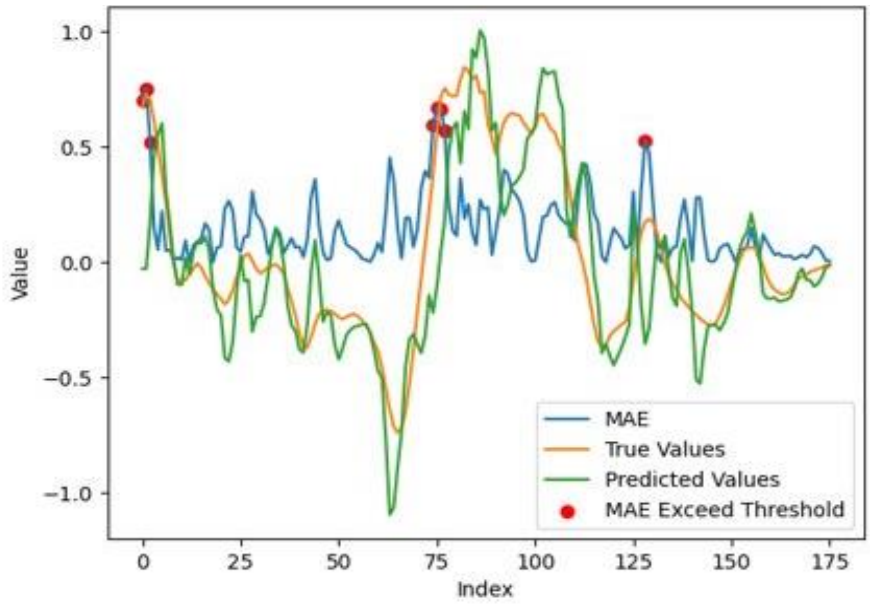
Resource Identification

Multifaceted framework prediction-based reaction:

Incipient tip over detection (ongoing/testing)

Anomalous motion detection (next)

Sensor error compensation (next)



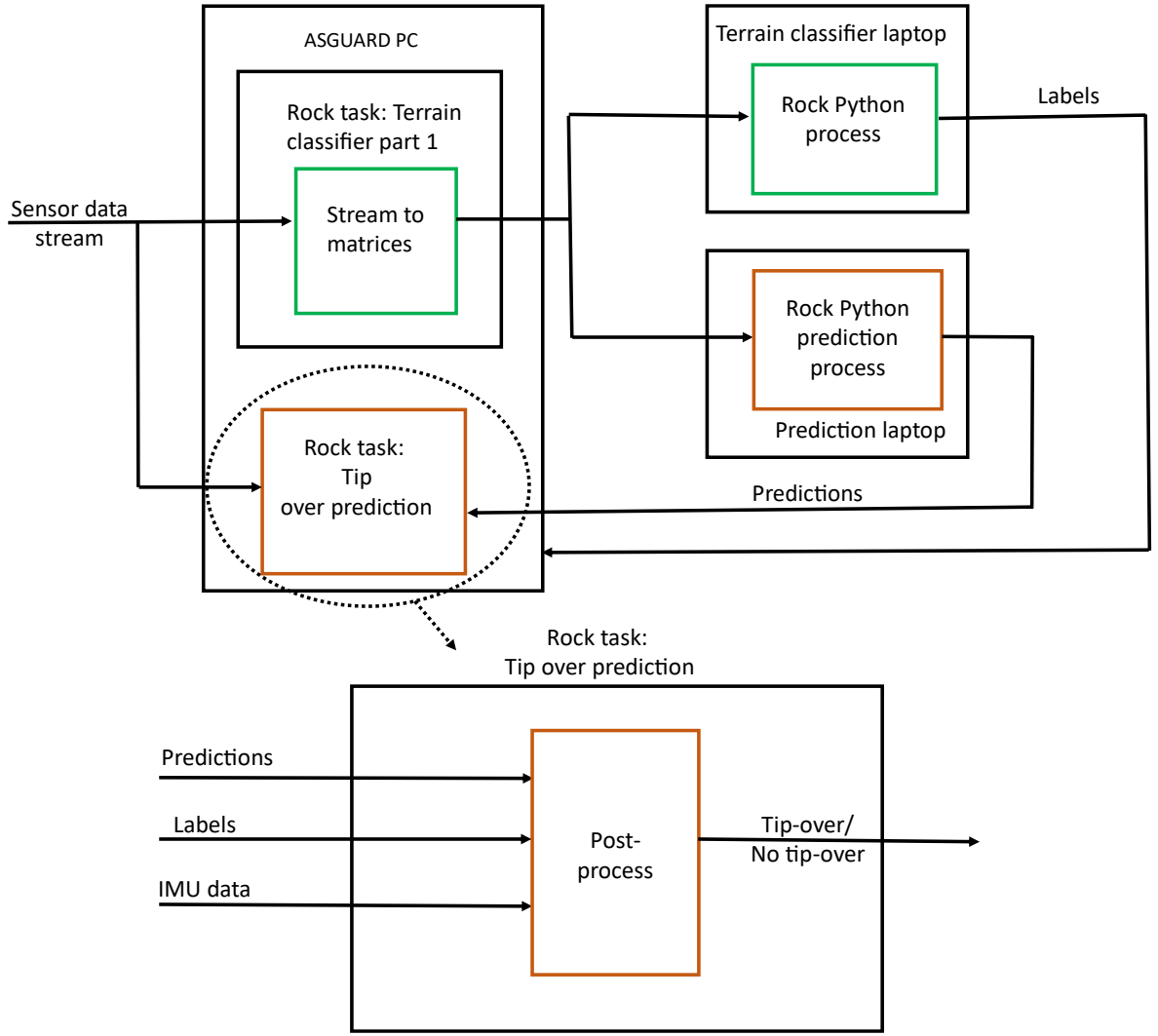
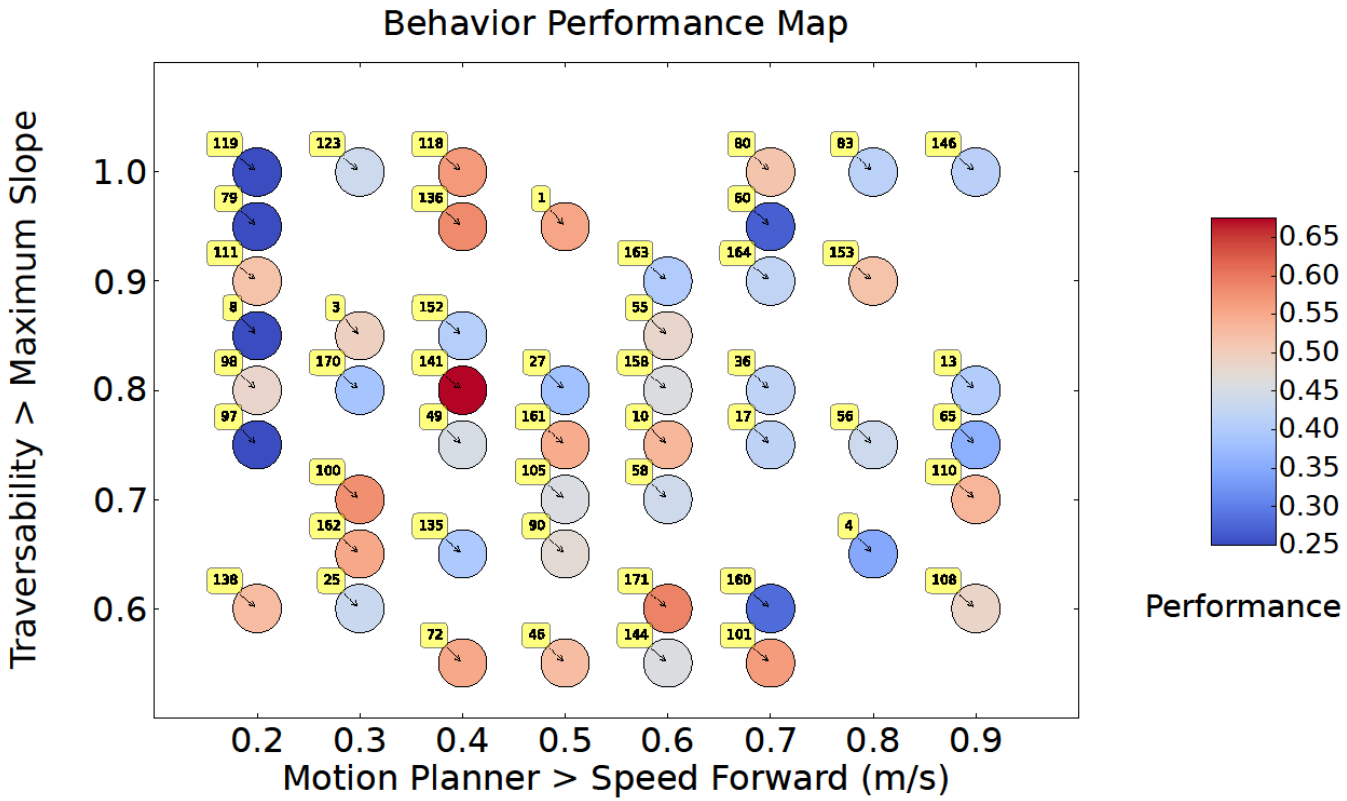


Table of Content

Long Term Navigation



Navigation behaviors

Automated **parameter value** search

Behavior Repertoire Bootstrap

Simulated evolutionary process
Behavior Performance Maps[4]

Gaussian Process Online

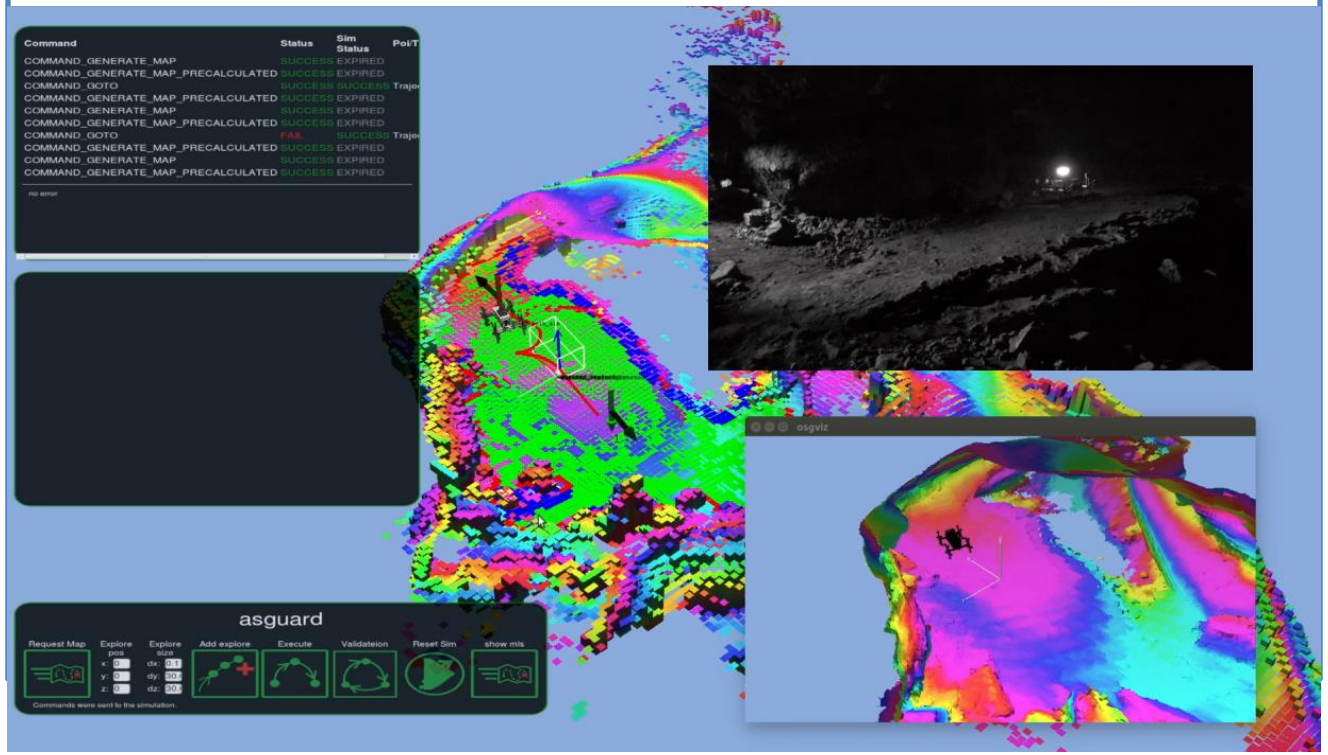
Stream Online Gaussian Process Regression[5]
Traverse performance computation

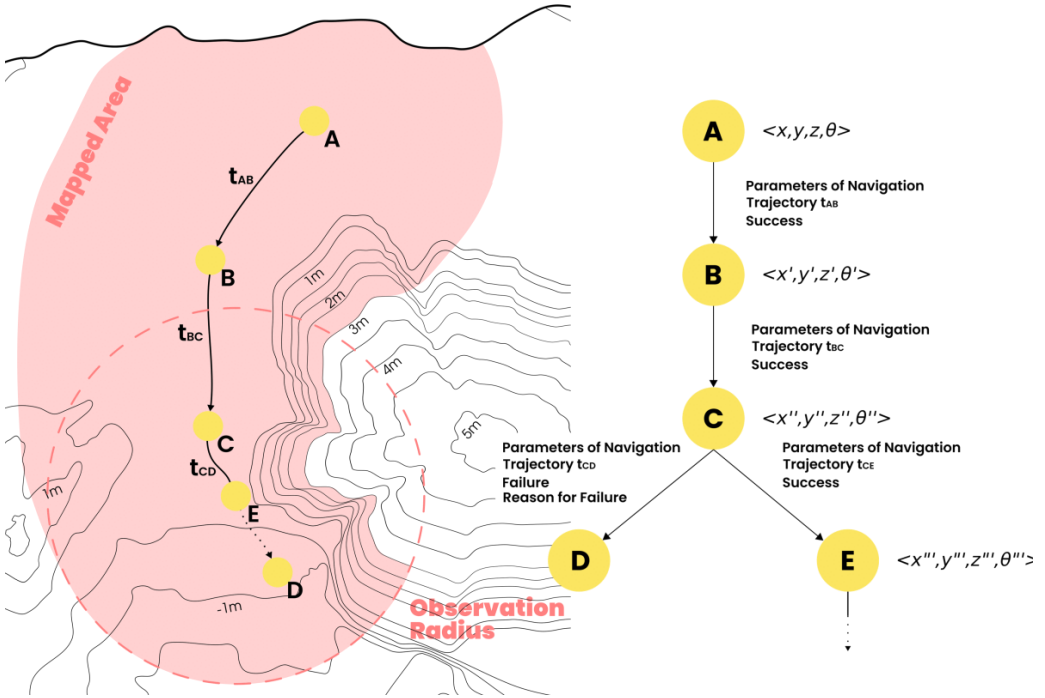
4: Cully, A., Clune, J., Tarapore, D., & Mouret, J.-B. 2015, Robots that can adapt like animals, Nature, 521, 503
5: Dettmann, A. 2021, Experience-based behavior adaptation of kinematically-complex robots, PhD thesis, Faculty 03: Mathematik/Informatik (FB03), University of Bremen

Long Term Navigation

Internal Simulation

- Generate environment simulations on board
- Decision making
- Analysis of the realism ongoing



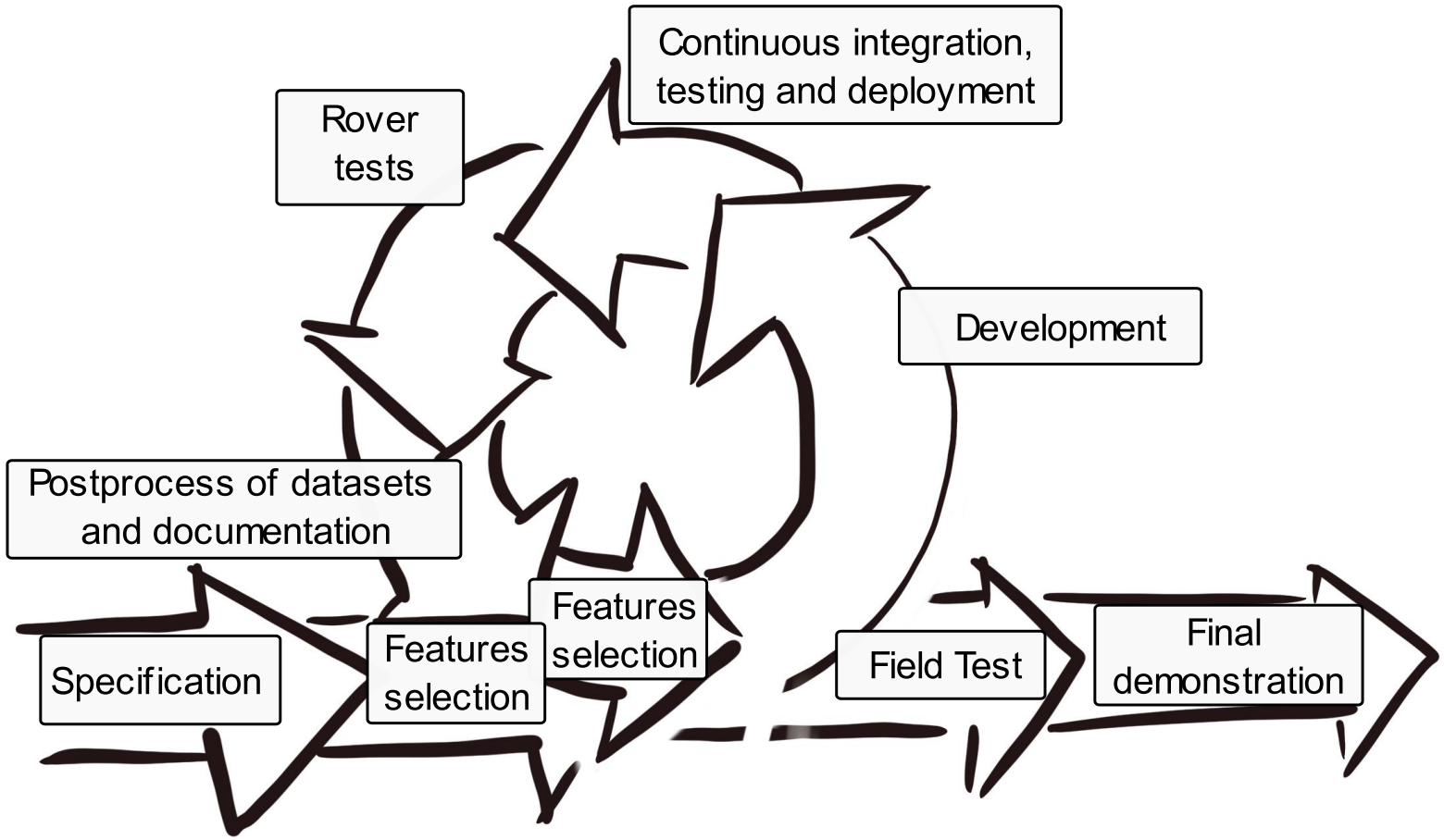


Episodic Memory

- Topological map
- Reuse of data product
- Avoidance of recurring errors

Table of Content

Software Development Methodology



Jenkins

GitLab

docker

Rock Core

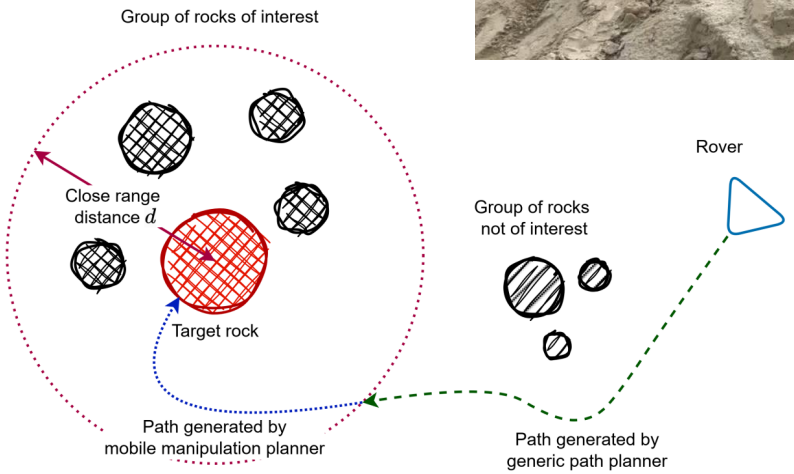
Table of Content

- Introduction
- Architecture Design
  - Resource Identification
  - Long term Navigation
- Software Development Methodology
- **Field Tests**
  - Bremen (Germany)
  - Vulcano Island (Italy)
- Outlook and Conclusion

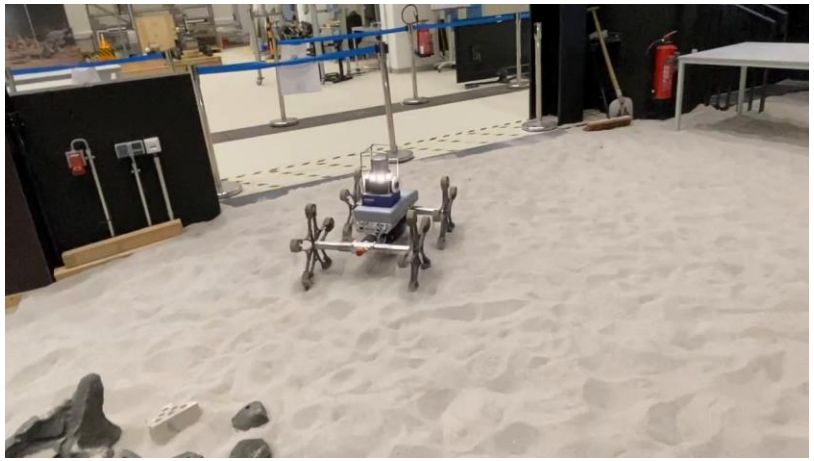
Field Test – Bremen

German Research Center for Artificial Intelligence

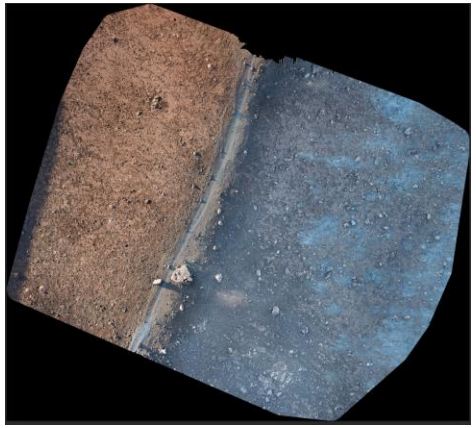
Navigation and Behavior Tree Test



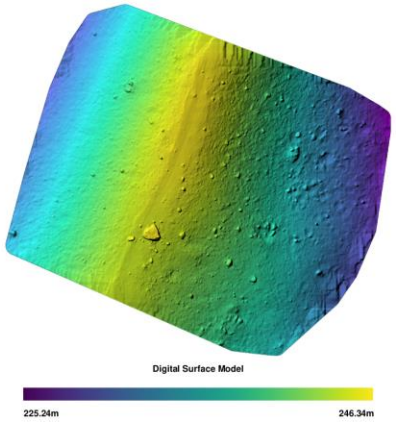
Terrain Classifier Test



Field Test – Vulcano Island



3D drone actual surface model



3D drone digital surface model

Participation in the 'Vulcano Summer School 2023'

Resource Identification

Gathered hyperspectral data to validate with lab analysis

SLAM

- Ground truth data -> Drones
- Rover driven manually

Autonomous navigation tests

Long term adaptation

Episodic memory logs

- Repeated navigation goal sequences
- 3 different locations

Table of Content

Outlook and Conclusion

PERSIM

German Research Center for Artificial Intelligence

Presented overview of architecture
- Long term navigation
- Autonomous prospecting

Agile approach

Field tests

Missing modules -> next field test

Thank you!

Siddhant Vivek Kadwe
Space Team, RIC, DFKI
Germany
siddhant.kadwe@dfki.de
+49 421 17845 4119

The PerSim project is funded by the Space Agency of the German Aerospace Center (DLR) with federal funds of the German Federal Ministry of Economic Affairs and Climate Action (BMWK) in accordance with the parliamentary resolution of the German Parliament, grants no. 50RA2124 and 50RA2036.

The International Vulcano Summer School was supported by the Helmholtz Association, project iFOODis (contract no. KA-HSC-06).