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GSTP ALPER

Absolute Localisation for Planetary Exploration Rovers

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ASTRA Conference

19/10/2023 - Loïc LE CABEC

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Scope of the project

Context

Objective

Roadmap

Current relative localisation performs well for short term traverses

Past and current Mars exploration missions have generally deployed a combination of various rover localisation techniques to produce the most accurate rover pose estimates possible with the resources available.

However, relative localisation is prone to

- Drift during long traverses
- Initial pose accuracy

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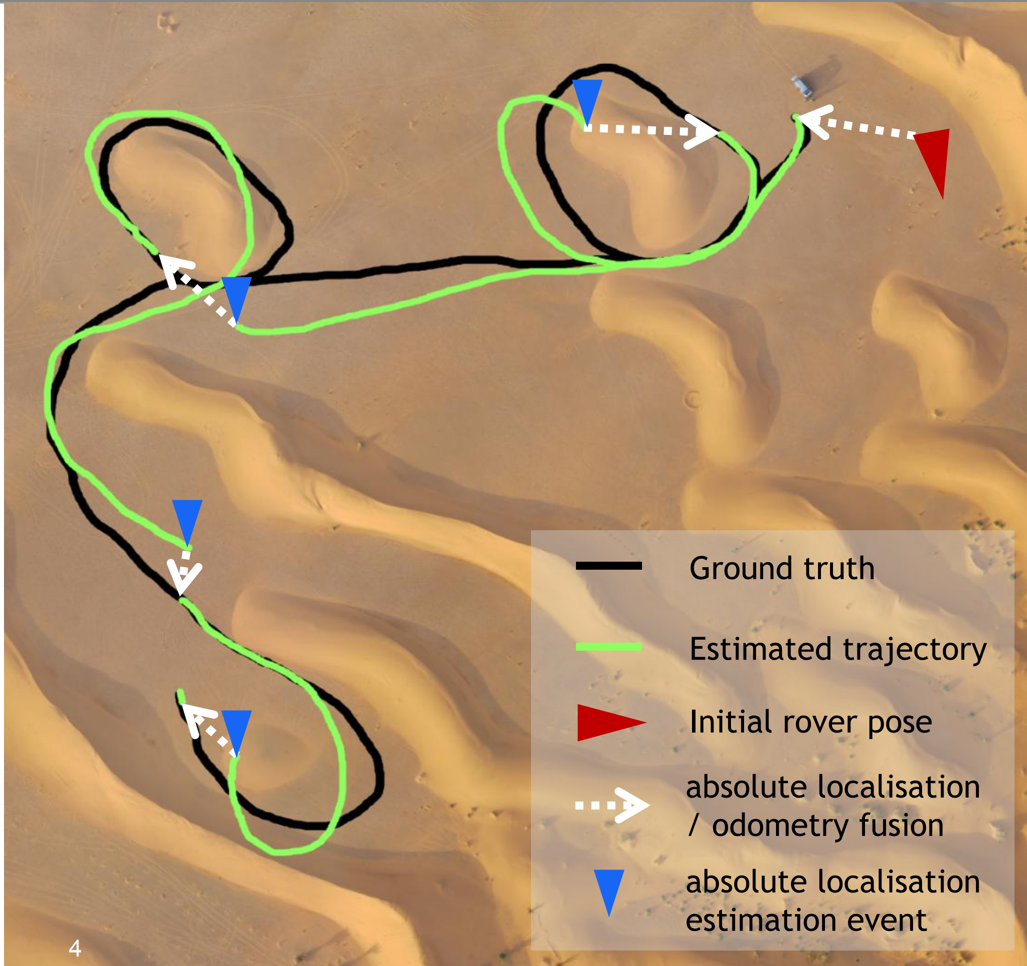
Provide absolute localisation algorithms able to run on-board autonomously

A complementary approach needs to be provided to ensure localisation accuracy and stability over time, regardless of the travelled distance.

Provide an absolute localisation algorithm:
- Runs autonomously on-board
- Provides localisation fixes along the traverse
- Uses representative data (ExoMars, HiRISE type)
- High maturity level
- Well defined operating domain



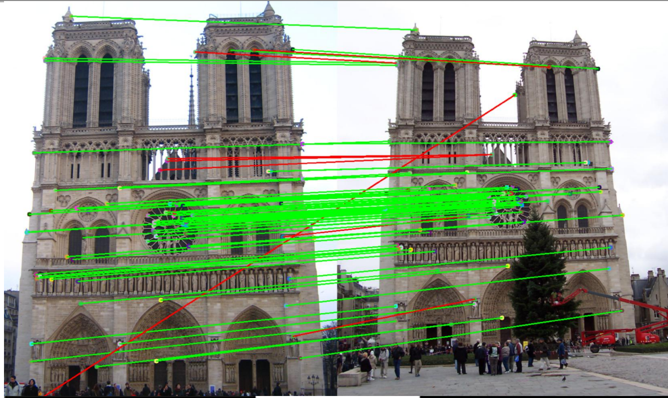
Cross-view localization with important view point difference

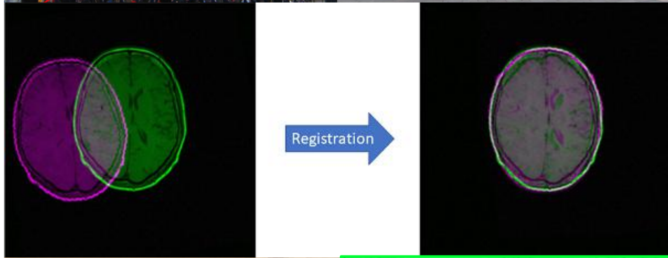
Localize rover acquisitions in orbital orthoimage. Challenges:

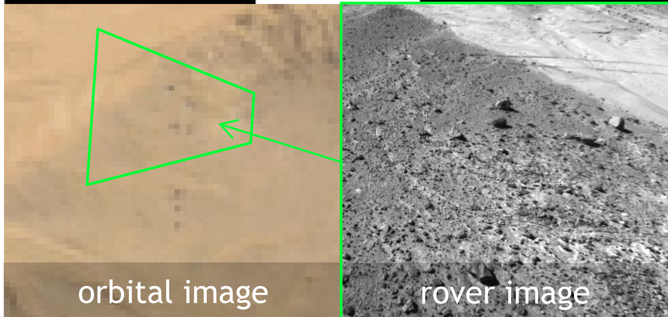
- Low orbital resolution: 25cm/px
- Limited rover field of view
- Illumination differences
- Different perspective

Failure of traditional computer vision methods

- Feature matching (ex: SIFT)
- Image registration







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No single universal localisation method consistently excels across all planetary exploration scenarios

TPT	CM	DICOR
Robust operator assisted absolute localisation	Autonomous feature based absolute localisation	Autonomous image matching based absolute localisation
All terrain types initial pose, short traverses	*Terrains with rocks long traverses*	*Terrains with discriminative texture long traverses*

01/12/2021 — 17/10/2023

DEFINE	PROTOTYPE	IMPLEMENT	EVALUATE
requirements/state of the art	*design/improve*	*C Library/Code quality*	*Field tests/Monte Carlo campaign*

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Technical achievements

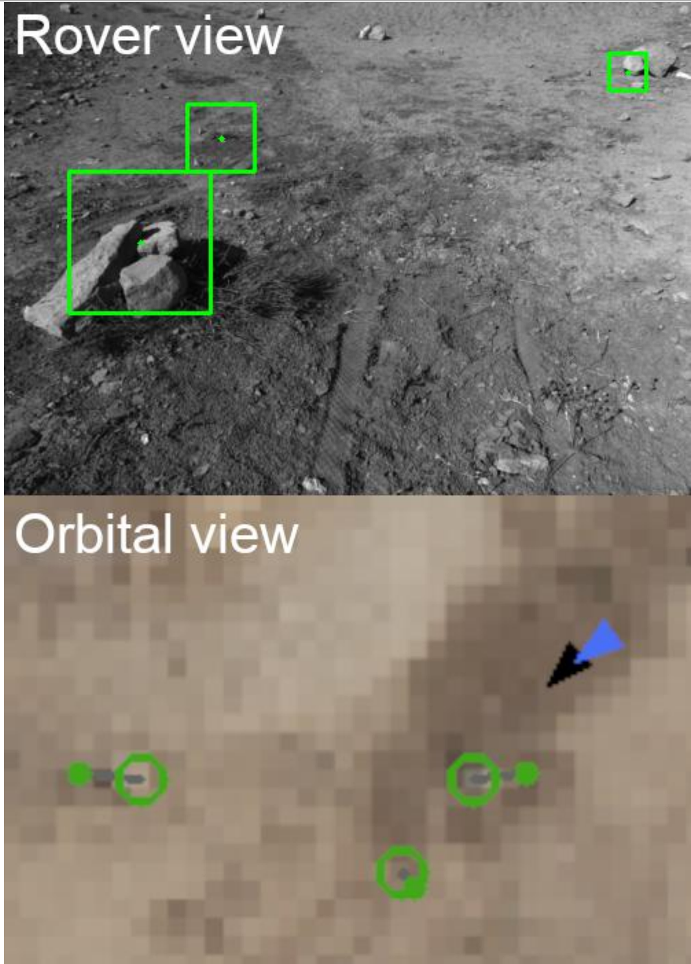
TPT: Tie Point Tracking

CM: Constellation Matching

DICOR: Dense Image Co-Registration

TPT: Operator assisted robust cross-view absolute localisation for short traverses

- The operator selects tie-points
  - Visual features in rover images
  - Corresponding landmarks in orbital images
- The rover estimates its absolute pose
  - Accurate first estimation
  - Minimize errors between tie-points
  - Track visual features on successive rover images



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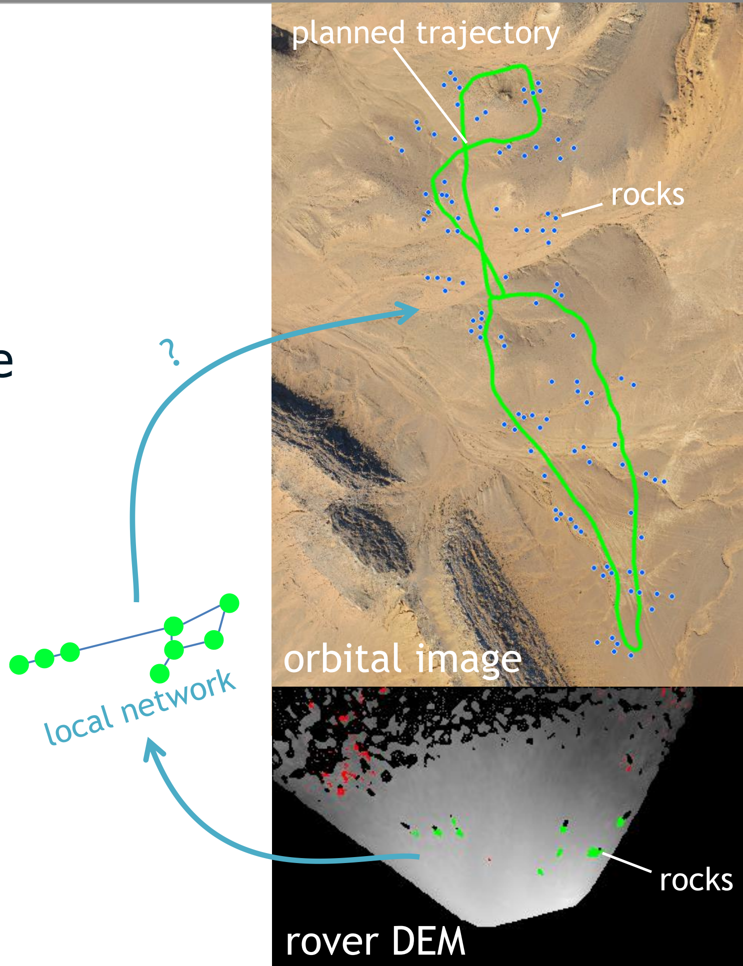
CM: Autonomous feature based cross-view absolute localisation for long traverses

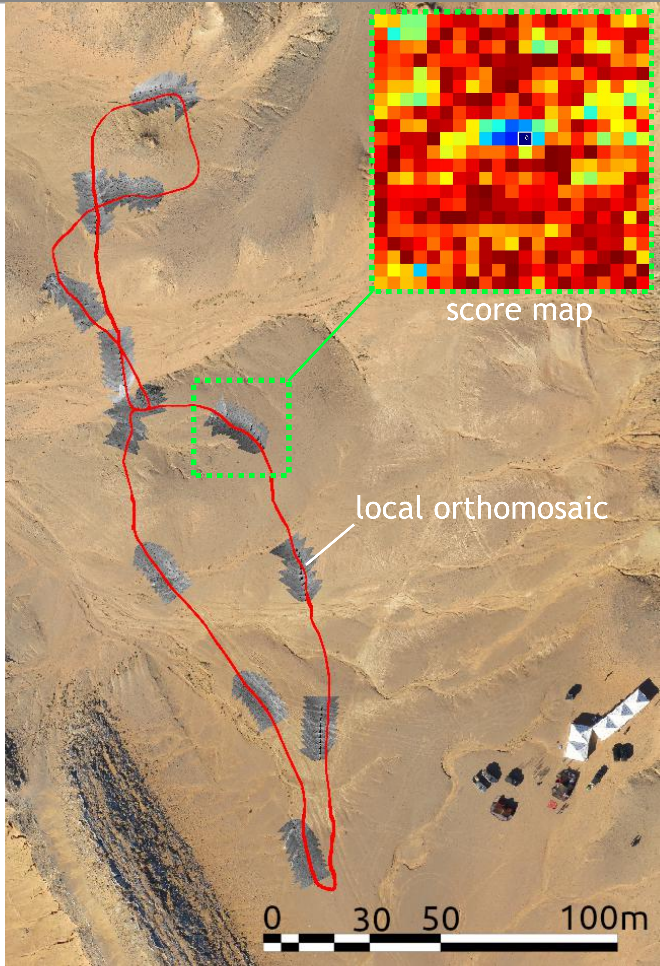
- The operator selects rocks on orbital image
  - Once before the traverse

- The rover estimates its absolute pose
  - Extract rocks in rover DEM
  - Update a local landmark network
  - Match local and orbital landmark networks
    - Constellation matching approach



DICOR: Autonomous image based cross-view absolute localisation for long traverses

- No operator intervention needed
- The rover estimates its absolute pose
  - Orthorectifies acquisitions
  - Assembles local orthomosaic
  - Matches local orthomosaic with orbital image
    - Template matching
    - ZNCC sample based score function
    - Pyramidal approach



Testing approach

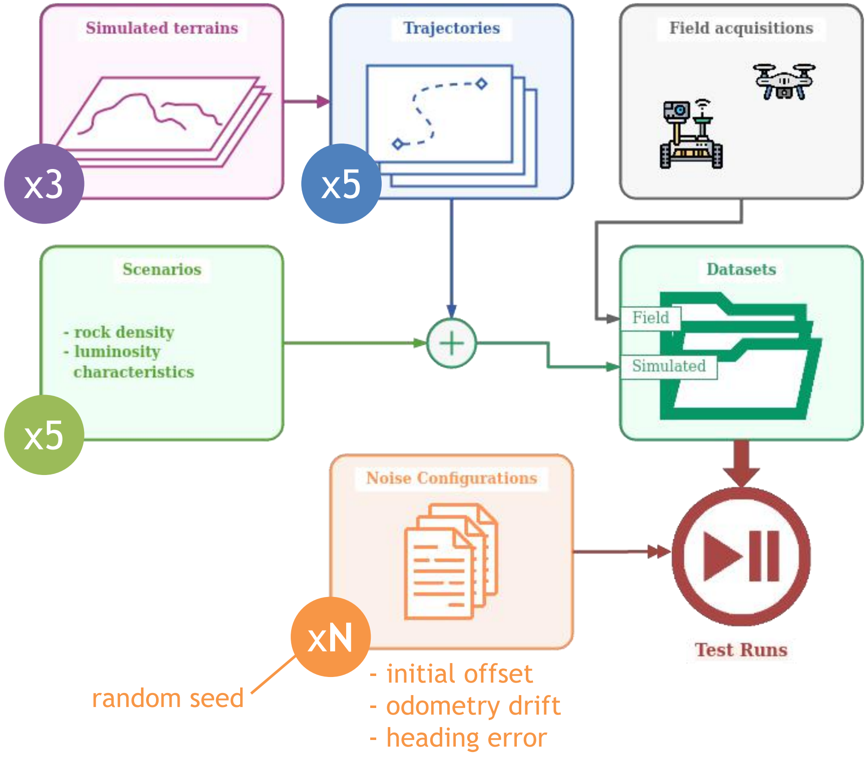
Test Categories

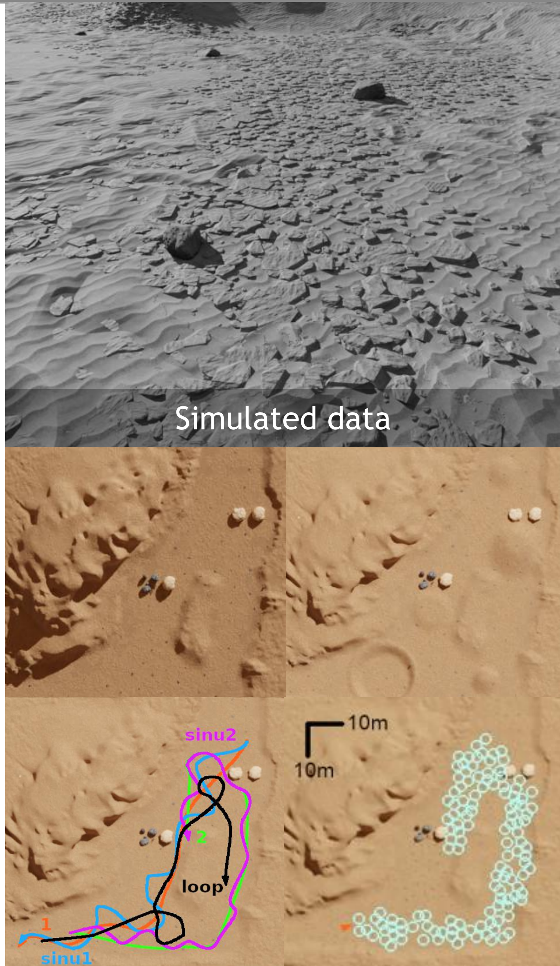
Approach

Test categories

- Functional tests
  - All core functions
  - Automatized non regression tests
- Benchmark tests
  - Computation time on LEON4
  - Memory consumption
- Monte-Carlo campaign
  - Statistical performance analysis
  - Characterize operating domain
- Field tests
  - Bardenas Reales Desert, Spain
  - Final live demonstration

Campaign approach





Results

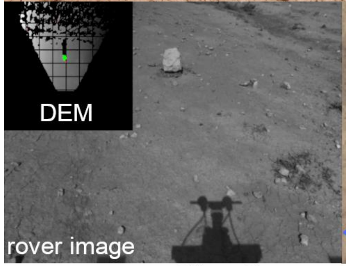
Field tests

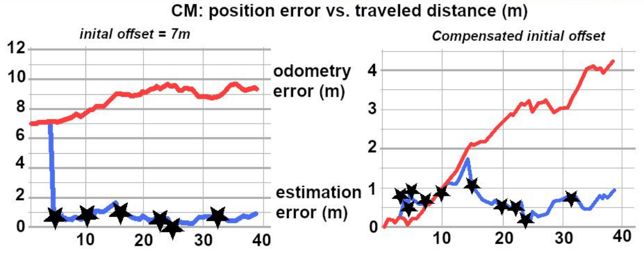
Monte-Carlo campaign

Field tests

- Gathered data
  - 9 trajectories in 3 zones (~15-30m)
  - 19 datasets with various:
    - Illumination conditions
    - Relief
    - Rock distribution

- Live demonstration results
  - Success on demonstration trajectories:
    - Max. estimation error = 1.25m
    - Robust to stereo-calibration noise, vibrations, etc.
    - Estimations every ~6m
  - Limitations:
    - DICOR: sensible to illumination conditions
    - TPT: limited range (~10m)





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Monte Carlo campaign

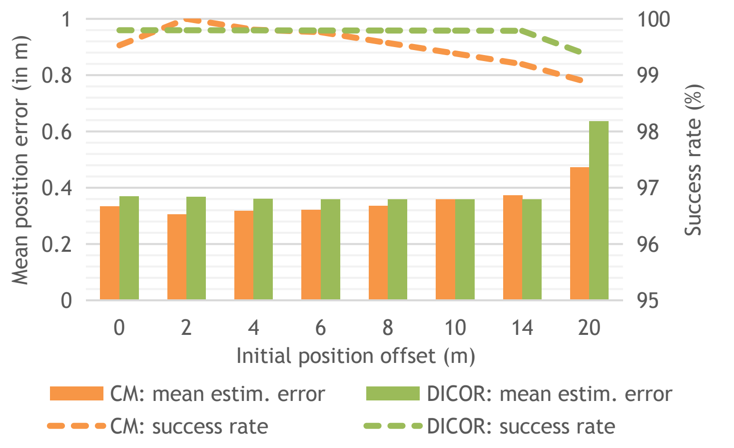
TPT: Reliable first estimation

- First estimation: success rate > 95%
- Good tracking on all terrain
- Sort range: estimation possible for ~20m

CM & DICOR: Reliable absolute pose estimation

- Success rate > 99% for all initial offsets tested (up to 20m)
- Robust to noise on input data
- Frequent estimations (~every 20m)
- Consistent results on real datasets
- Complementary operating domain

Noise robustness



Terrain characteristics

	nominal	relief	low rock density	sun inclination differences
DICOR	99.8%	98.0%	98.6%	94.8%
CM	99.5%	99.4%	88.6%	98.3%

Success rate vs. terrain type

initial offset < 10m - loc error between acq. < 10cm

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Conclusion

Achievements

Successful completion of an ambitious project

- Successful live demonstration in the Bardenas Reales
  - Smooth demonstration
  - Seamless integration on robotic plateform
  - Robust to real data noise
- 3 complementary localisation methods developed
  - C library developed, high coding standards
  - Characterized through Monte Carlo campaign
  - Good pose estimation accuracy
  - Robust to noise and terrain conditions

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