

AI4SE prospects at the European Space Agency

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09/10/2024

Driving the future of space AI through European innovation



Vision

ESA is a trusted partner for Member States, driving the growth of the European AI ecosystem through innovative technology and fostering the expansion of the space economy, by expanding the use of space data and achieving resource efficiency

Key AI domains

Mission design and engineering

Leverage AI technologies for a **smarter design and development** of space missions, and **boost S/C on-board intelligence**.

Mission operations

Improve **operational efficiency and enhance spacecraft autonomy**.

Insights from mission data

Generate socio-economic value by applying AI to extract **insights and knowledge** from data generated by space missions.

Agency efficiency and effectiveness

Leverage AI to **provide assistance, automate processes and routine tasks, and facilitate collaboration and knowledge sharing** across the organization.

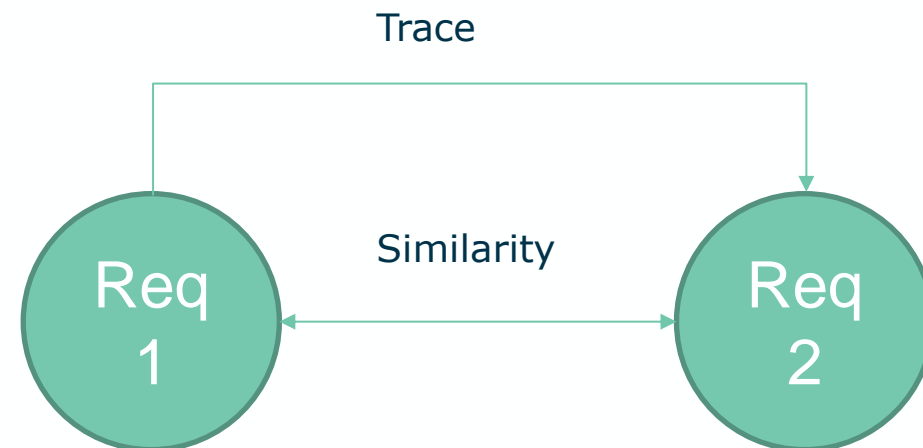


Design: requirement flow-down

Similarity analysis between requirements:
SentenceBERT model to compute embeddings + cosine similarity

Traceability:

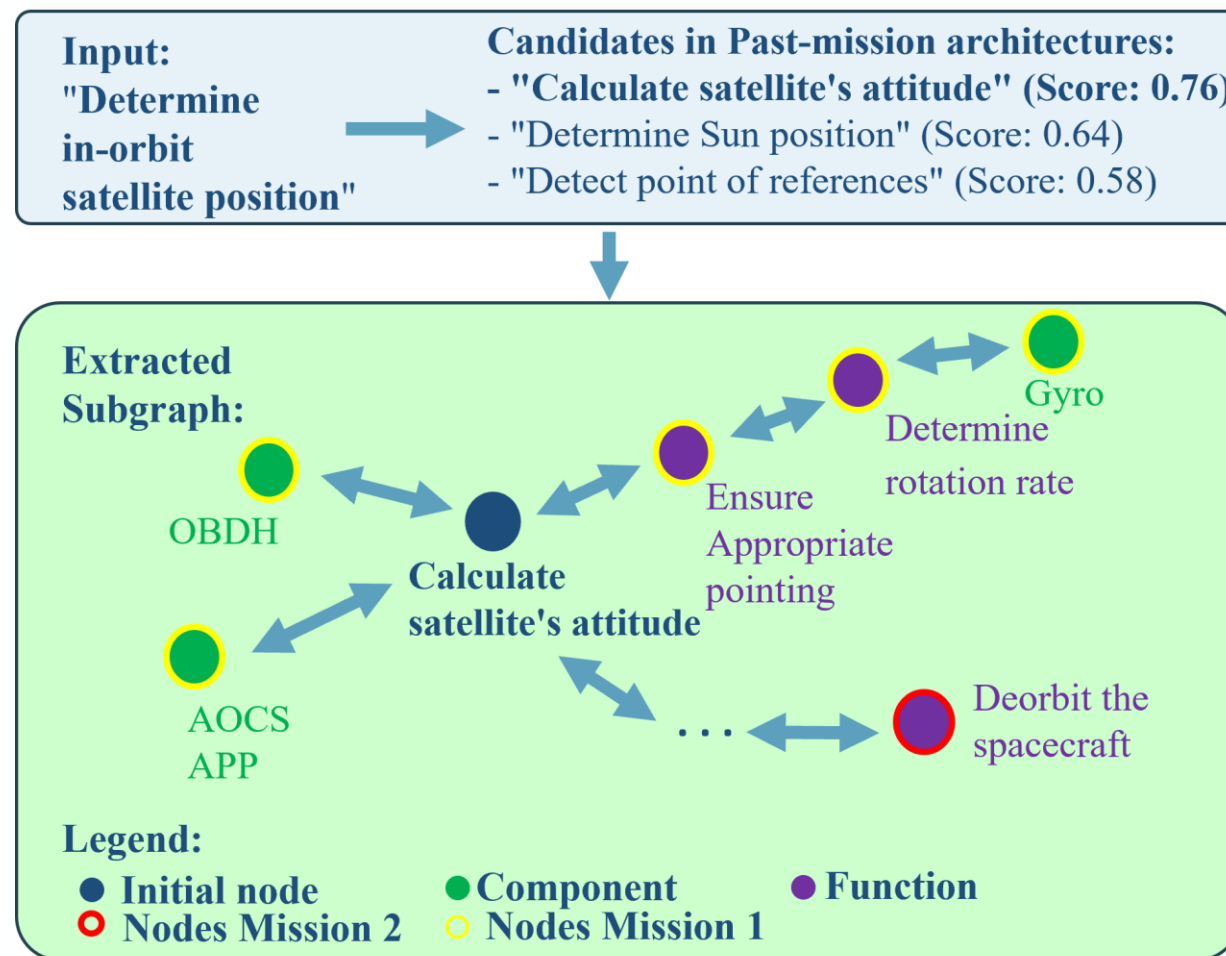
- Create balanced labelled dataset of positive and negative examples
- Train a BERT-like model on the binary classification problem



Design: system architecture

Build Knowledge Graph with past design

Find semantically most similar element node in Knowledge Graph through cosine similarity of same type



Design: Consistency requirements-architecture

- Based on a requirement, we extract a relevant part of the design space from the graph database
- Use a Large Language Model (LLM) as a reasoning engine to verify the model

GE

You have the following context :

The mass of the battery is 23kg with a 20% margin
 The capacity of the battery is 20kWh
 The mass of the PCDU is 50kg

Is this context consistent with the requirement : The mass of the battery shall be less than 25kg ?

In the study we use an on premise LLM and not ChatGPT for confidentiality reasons !

GPT

Based on the given context, the mass of the battery is stated as 23kg with a 20% margin. To determine if this context is consistent with the requirement that the mass of the battery shall be less than 25kg, we need to calculate the maximum allowable mass of the battery considering the margin.

The margin is 20% of the battery mass, which is calculated as $20/100 * 23\text{kg} = 4.6\text{kg}$.

Adding the margin to the battery mass gives us the maximum allowable mass:

$23\text{kg} + 4.6\text{kg} = 27.6\text{kg}$

Since the maximum allowable mass of the battery is 27.6kg, which is greater than 25kg, the given context is inconsistent with the requirement that the mass of the battery shall be less than 25kg.

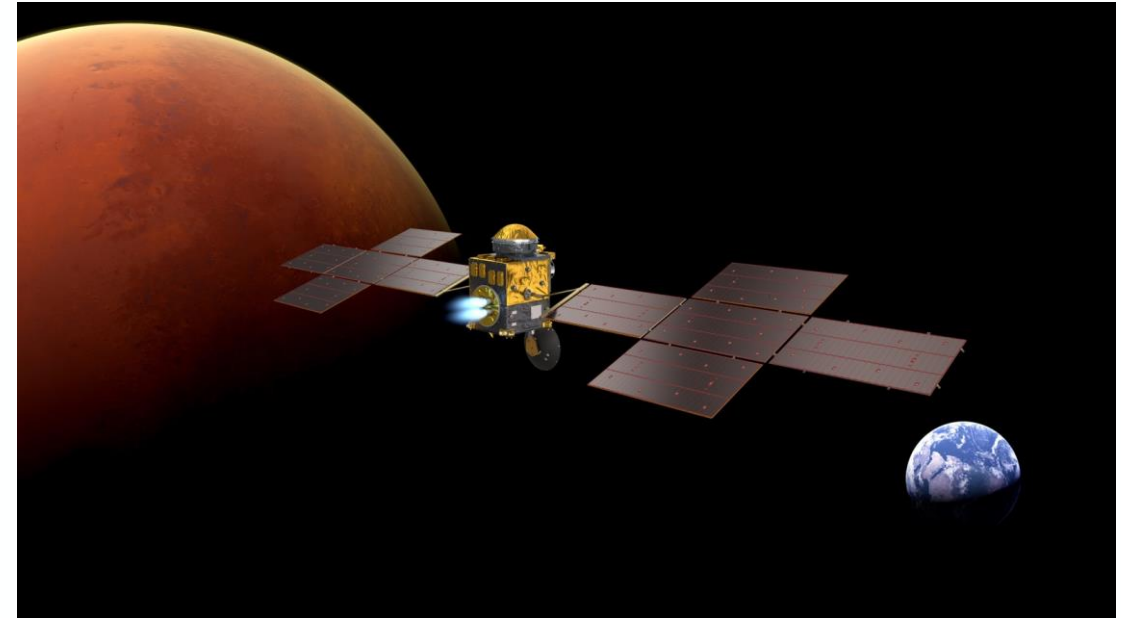
AI for OnBoard Autonomy - FDIR

AI can be of great help to support on-board decisions to trade-off alternative scenarios, their feasibility and limitation in terms of resources, constraints, or performance.

Areas of application include:

- early anomaly detection
- anomaly investigation
- dependency analysis

An AI based on-board FDIR solution can adapt to different and unforeseen scenarios and minimise need for ground support



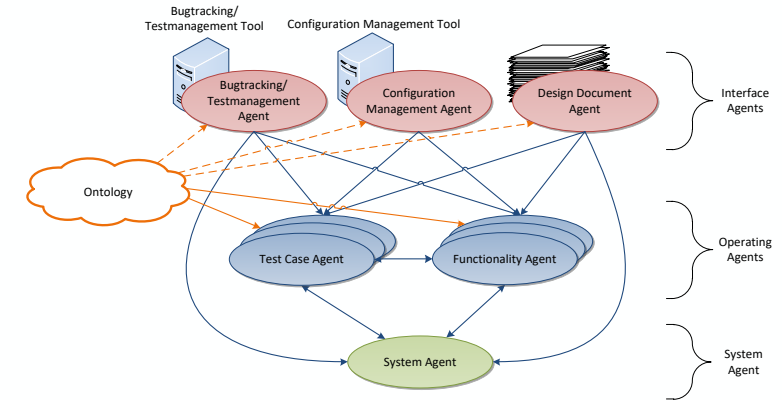
AI for V&V

AI to support the process of V&V for complex systems

- Bringing **intelligence**, **autonomy** and **automation** to the **Testing and Verification Process** (e.g. test sequence optimization, Analysis and interpretation of test data, Identification of critical areas to be tested, generation of test cases failure diagnosis).

V&V of AI systems

- Main challenge: potentially self-modifying systems, control surfaces which are non-linear and not fully described → stability, verification logic, sensitivity?



MASTV focusing on SW engineering (Multi-Agent System in support of Testing and Verification)

Test Space	Coverage Quality Matrix	Quality Matrix	Prioritization Result
Functionality	Functionality	Reliability	Efficiency
Detumble mode	0.5	0.55	0.0
Fine-pointing mode	0.4	0.7	0.1
Slew rate	0.3	0.43	0.6
Pointing accuracy	0.1	0.2	0.7
Pointing stability	0.5	0.1	1.0
Off-loading mode	0.3	0.3	0.5
Safe mode	0.8	0.7	0.4
Mode switching by teleco...	0.8	0.1	0.4
Equipment status in telem...	0.1	0.5	0.0
Performance parameters l...	0.9	0.7	0.6
Interface to system databa...	0.1	0.4	0.1
Matlab as run environment	0.8	0.5	0.5
Attitude control sensor mo...	0.1	0.1	0.4
Attitude control actuator m...	0.4	0.8	0.4
Dynamics modelling	0.8	1.0	1.0

Resulting Quality Matrix indicating good/bad quality for different S/W characteristics

AI for Mission Operations

Automated Operations

- Mission Control Automation beyond LEO
- Mission Planning
- Automated Mission Control

Operations for Tele-robotics, Autonomous and Crewed Systems

- Operations with Autonomous S/C and data Selection/Classification
- Human and Robotic hazard prediction
- Decision Support Assistant Agents for Astronauts and Ground Operators

