AI-Aided-XR: AI aided Augmented/Virtual Reality applications and VR aided Machine Learning

Robert Field, **Steven Kay (skay@gmv.com)**, David Miraut Andrés, Marcos Fernandez, Oleksandr Naronin, Jesús Gimeno Sancho, Raúl Rodríguez Juárez, Evridiki V. Ntagiou

AR/VR For Space Programmes Workshop 2023
ESTEC, Netherlands

Contents

- Introduction & Concept
- AI & XR Design Methodology
- Use Case Analysis & Selection
- AI-Aided-XR Framework Architecture
- Software Prototype Overview
- Conclusions

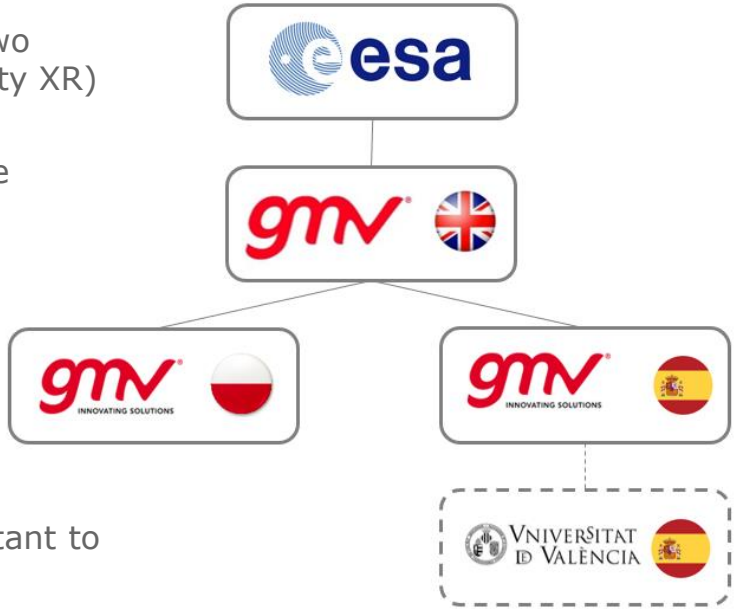
Introduction

AI-Aided-XR: AI Aided VR/AR Applications and VR Aided ML

ESA AO/1-11249/22/D/AH

Objectives of the study:

- Identification of the use cases where the interaction of the two technologies of Artificial Intelligence (AI) and Extended Reality XR) shall be beneficial for the space domain
- Demonstration of the benefits via implementation of software prototypes, where:
  - AI Serves XR
  - XR Serves AI



The AI-Aided-XR Project Team is formed by:

- GMV-UK acting as prime contractor
- GMV-Poland acting as sub-contractor
- GMV-SES acting as sub-contractor
- University of Valencia, ARTEC group, acting as expert consultant to GMV-SES

AI & XR Design Methodology

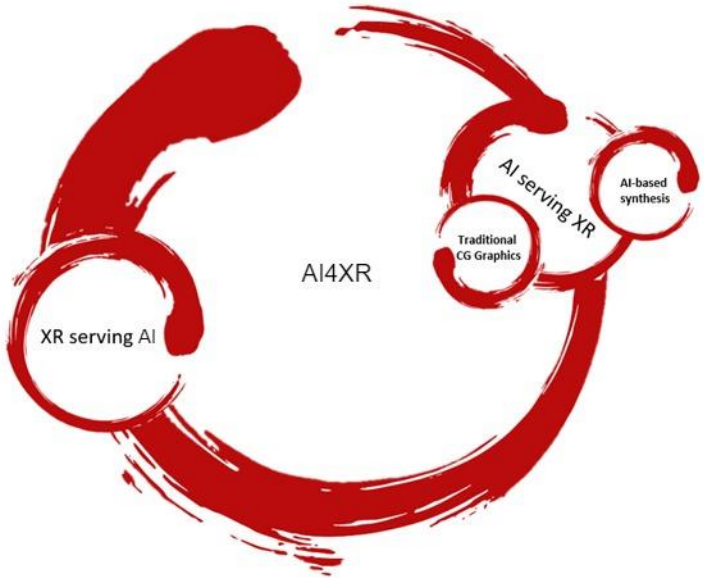
Cyclical relationship between AI-based synthesis and XR serving AI

Highly customizable XR environment through user input and parameters

Two parallel use cases: XR serving AI, and AI serving XR

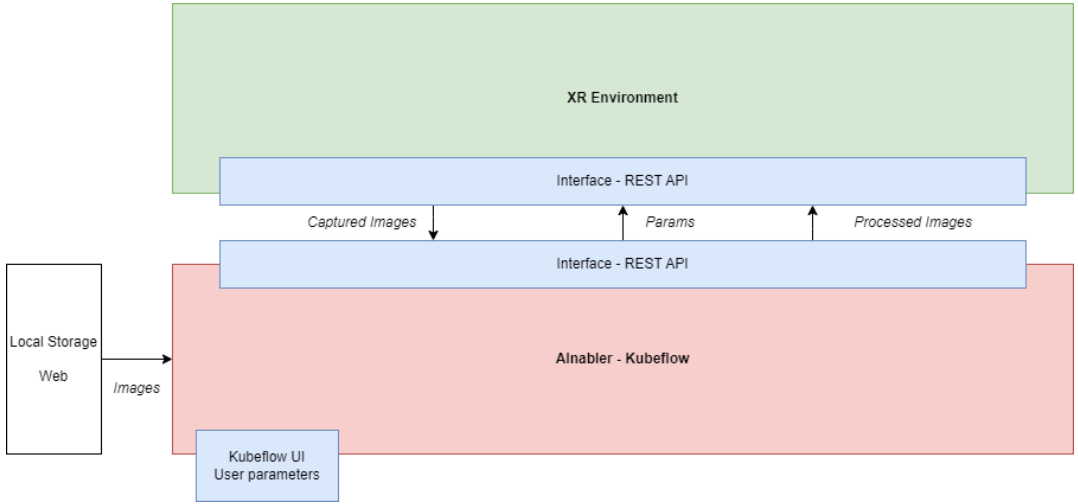
In the case where XR is serving AI, we expect some data to be generated and then consumed by the AI

In the case where AI is serving XR, we expect some AI to be informing the XR or providing some kind of service



AI-Aided-XR Framework Architecture

- **Architecture is based on two main components:**
  - XR Environment
  - AI Platform → ESA AInabler
- **Communication managed by a REST API**
- **The user primarily interacts with the AI Platform, but access is available to XR environment also**
- **Captured images in the XR environment are sent to the AI Platform for processing**



AI Platform based on ESA AInabler

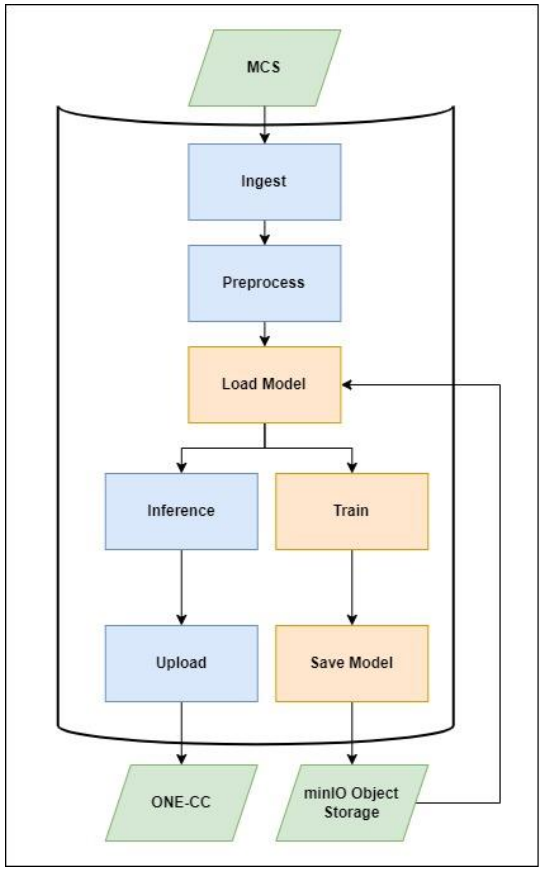
Platform-as-a-Service (PaaS) infrastructure hosted by ESOC, established by the ESA 'AI4Ops' activity

Based on Kubeflow, AInabler is an Open-Source MLOps platform for Kubernetes-based container orchestration

Kubeflow Pipelines approach selected for ML workflow modelling, providing:

- End-to-End orchestration
- Easy experimentation
- Easy reuse

Individual operations/algorithmic steps modelled as tasks, connected in a graph.



Use Case Analysis

Two branches of use cases studied

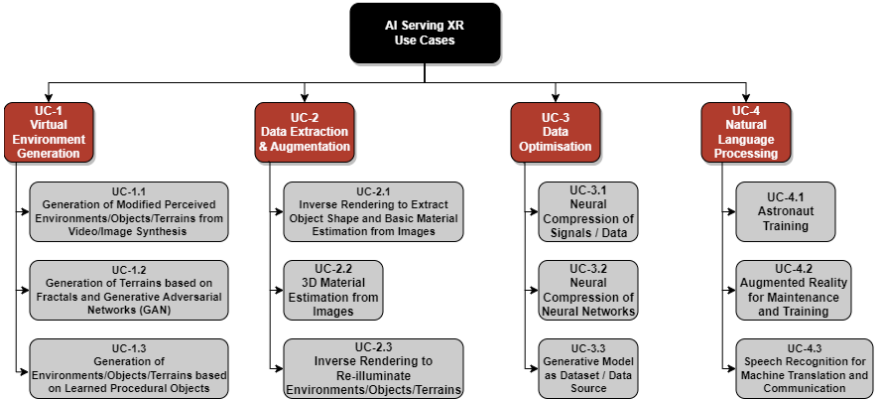
AI-XR

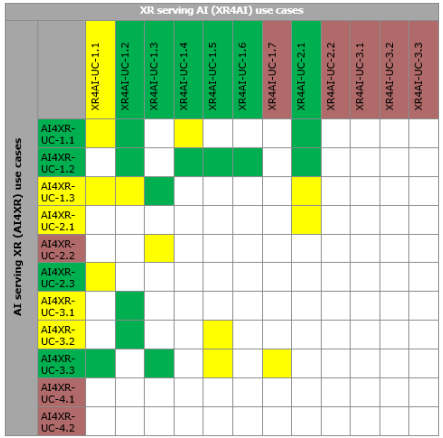
- Virtual Environment Generation
- Data Extraction & Augmentation
- Data Optimisation
- Natural Language Processing

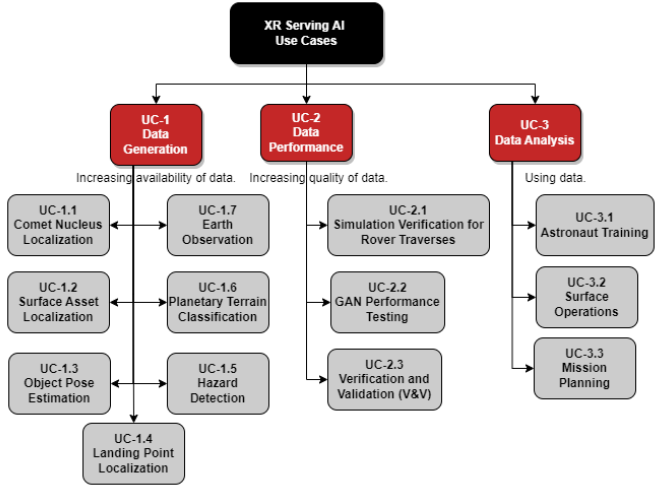
XR-AI

- Data Generation
- Data Performance
- Data Analysis

A similarity table helped the team visualise the cyclicity of use cases







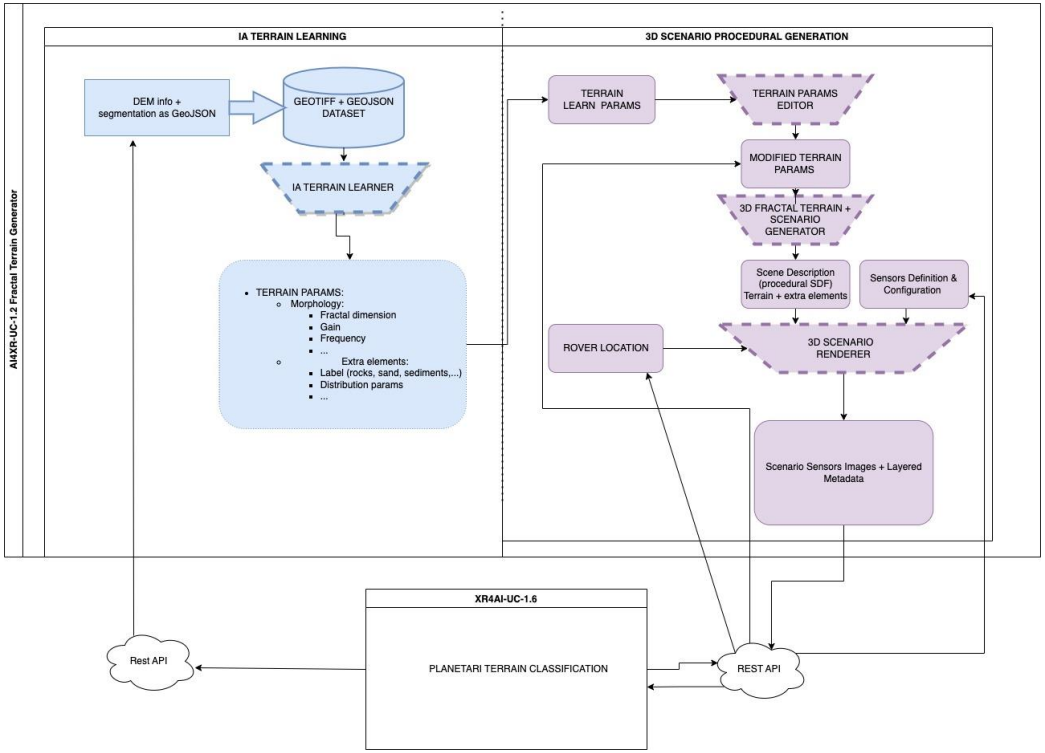
AI-Aided-XR: AI aided Augmented/Virtual Reality applications and VR aided Machine Learning

SW Prototype 1: AI Serving XR

Generation of Terrains based on Fractals

This prototype consists of two main components:

- **AI Terrain Learning** – where a terrain learner will generate the terrain characteristics based on a dataset sent from the AI platform (*for example, a scene with dense clusters of rocks)*
- **3D Scenario Procedural Generation** – where the learned parameters are passed through a fractal terrain generator and the scene is rendered with configurable camera models

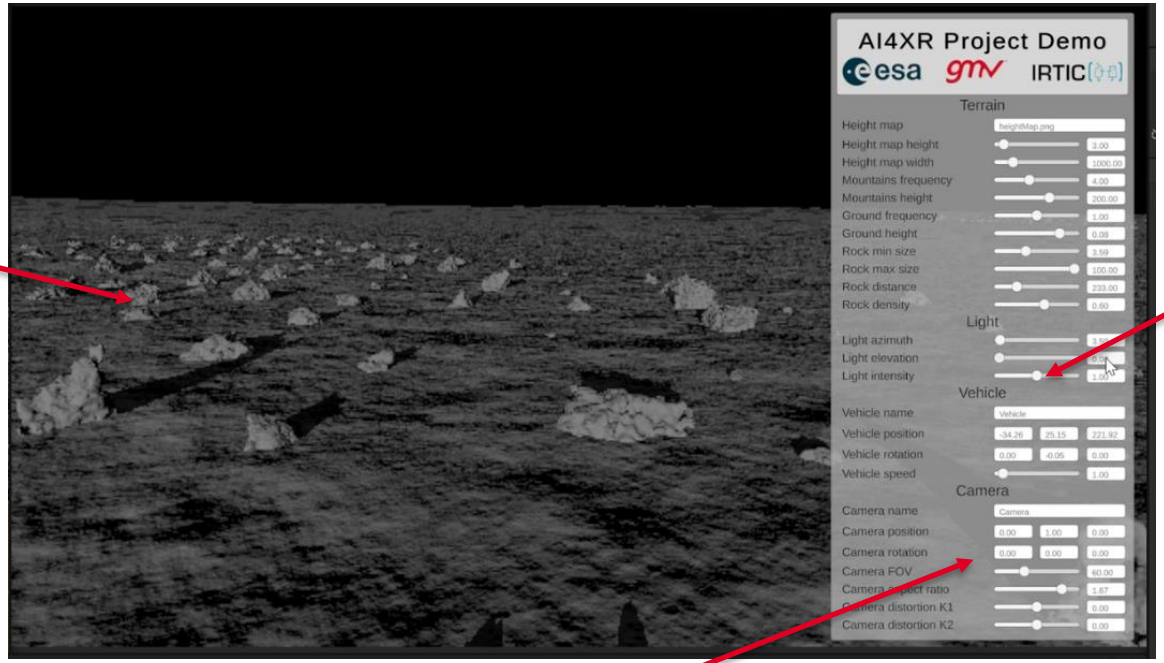


Generated synthetic data (images, depth data, labels) are then returned to the AI platform for ML training

SW Prototype 1: AI Serving XR

Generation of Terrains based on Fractals

Rock density, size, distances are all learned from the AI learner step



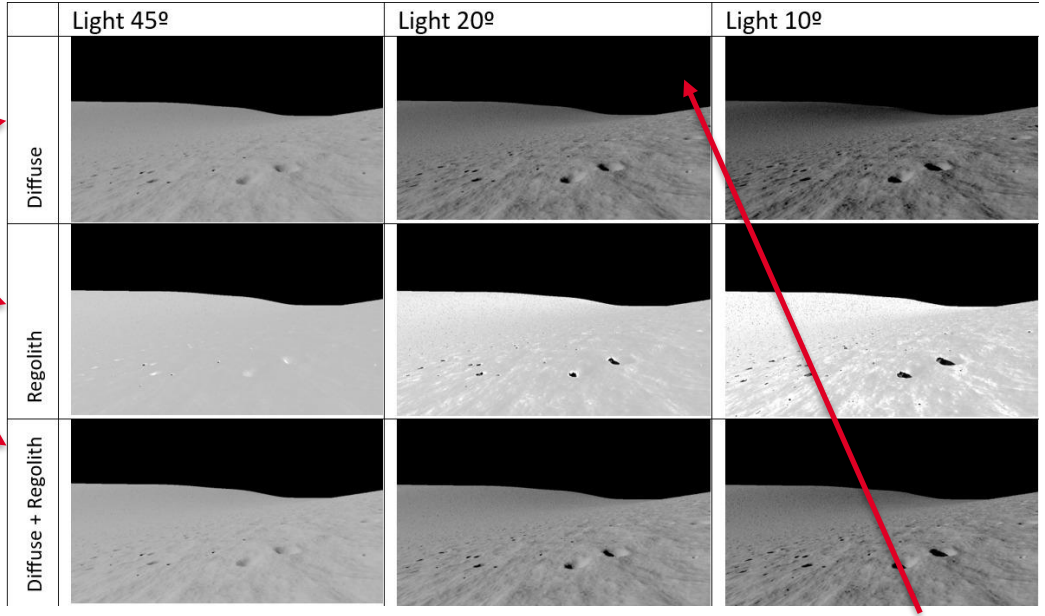
Terrain params configurator component allows users to fine-tune specific terrain features

Parameters set by the user in the AI environment from Kubeflow

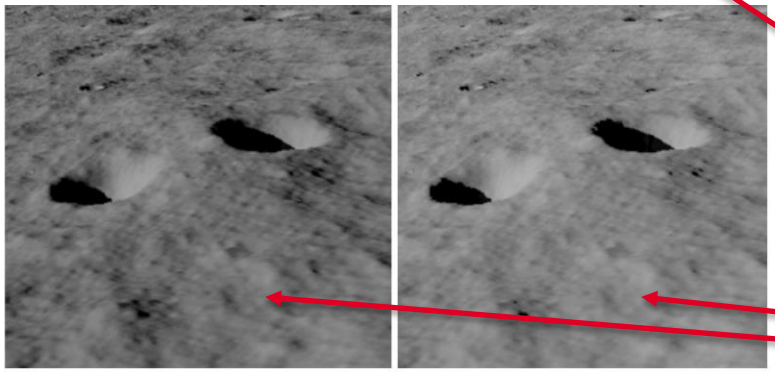
SW Prototype 1: AI Serving XR

Generation of Terrains based on Fractals

Example:
Controlling both diffusion and regolith parameters



In combination with light angles



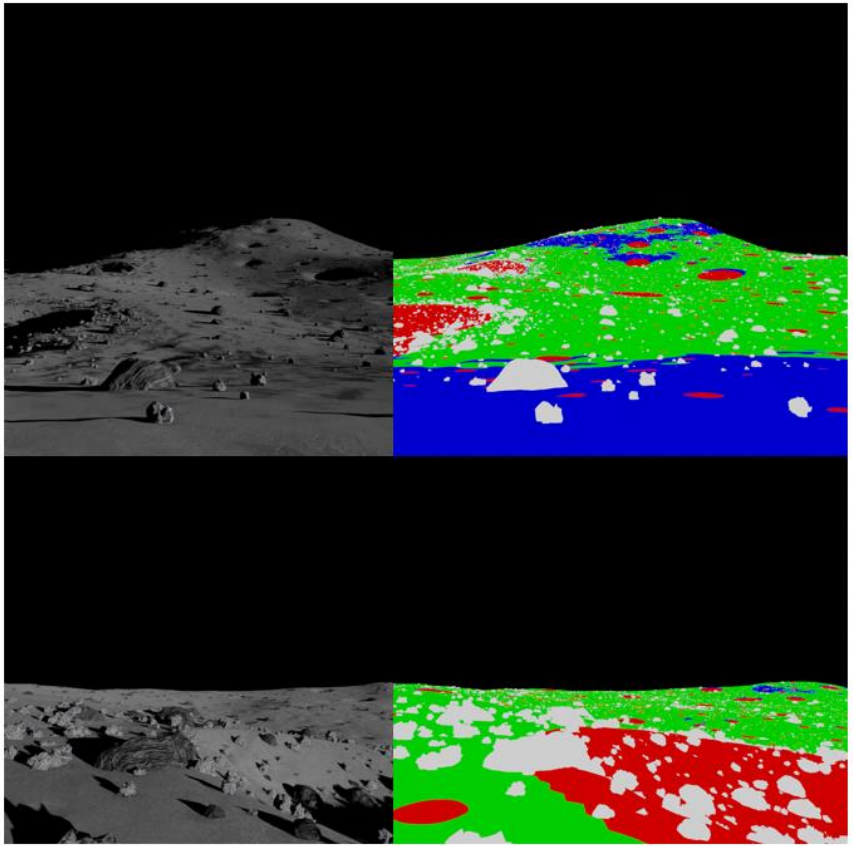
Diffuse | Diffuse + Regolith

Results in the following renders

SW Prototype 2: XR Serving AI

Planetary Terrain Classification

- Data availability of rover-perspective lunar imagery is scarce → even less with labels/ Ground Truth!!
- Training dataset is provided by GML POL as an extension to their ESA LHDAC activity
- This dataset is procedurally generated in Blender
- Provides operators with automatically-labelled segmentation masks and the ability to create new classes (slopes, caves)



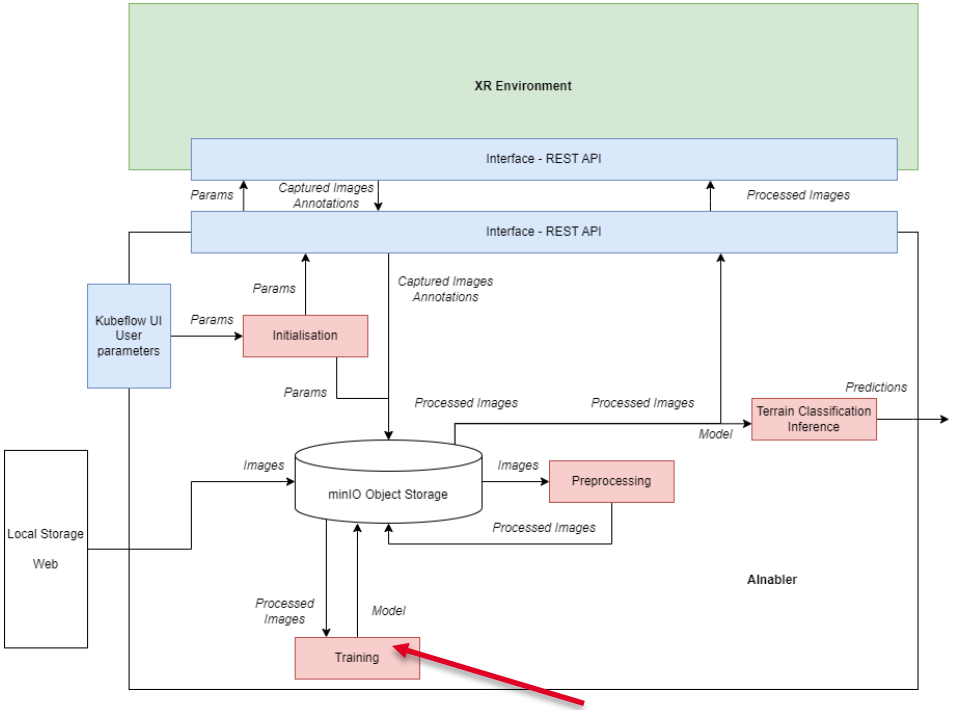
Flat area
Slope (10 degrees)
Crater
Sky

Note: classes are subject to change as model is developed further

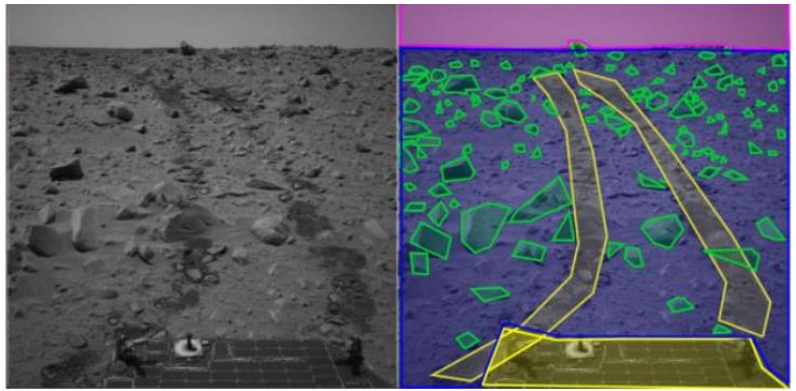
SW Prototype 2: XR Serving AI

Planetary Terrain Classification

[1]: S. Kay, et al., "AI Enabled Computer Vision Framework for Automated Knowledge Extraction in Planetary Rover Operations", In Proceedings of the 17th Symposium on Advanced Space Technologies in Robotics and Automation (ASTRA), 18-20 October 2023



- **Inherits the DeepLabV3+ model from the ESA ViBEKO activity[1], in which a 90%+ accuracy rate was achieved on a Martian landscape**
- **Lunar landscape is very different and will require different hyperparameters and preprocessing steps**
- **Investigating Incremental Learning approaches to complete the harmonious cycle between XR and AI**



Synthetic images are continually fed to the training component, incremental learning allows the model to test itself against older versi

Conclusions & Future Work

AI-Aided-XR is an activity funded by ESA to investigate the symbiotic and harmonious relationship between XR and AI technologies

Investigated use cases were varied in scope, ranging from Exploration to Space Debris and Astronaut training scenarios → Exploration was selected given the consortium past experience

AI-Aided-XR is the natural extension to the recently completed ESA ViBEKO activity, which identified the lack of good ML training data for Rover Exploration scenarios (synthetic or real)

This project is still in development with ~6 months to go, and the final solutions may evolve. The team aim to develop these SW prototypes and architecture up to TRL 4

This project is a demonstrator of GMV's expertise in AI and XR applications in the space domain, and we are looking at new and exciting ways to further build on the ESA AI-Aided-XR and previous ViBEKO activities

Thank you

Steven Kay (GMV-UK)
skay@gmv.com