ENHANCING LUNAR ROBOTICS ROVER THROUGH DEEP LEARNING AND EDGE AI

Bartosz Ptak, Dominik Pieczyński, Marek Kraft

Poznań University of Technology, Institute of Robotics and Machine Intelligence

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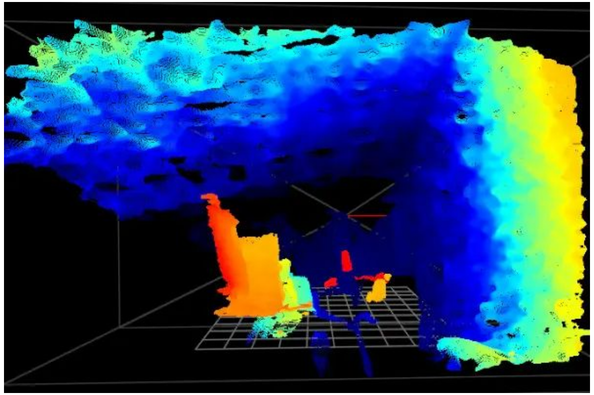
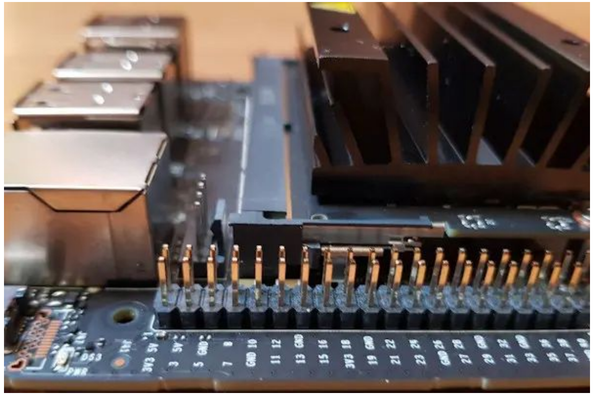
About us

Computer Vision Laboratory
Poznań University of Technology

Computer vision and signal processing



Perception beyond visible spectrum



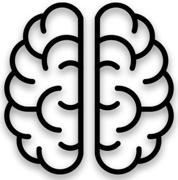
Edge AI and embedded systems

Project motivation

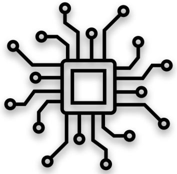
The growing number of lunar missions and limitations in Moon-Earth communications create the need for a DPU capable of processing at least some of the data on the lunar surface, thereby **reducing data transfer needs** to Earth and **increasing rover autonomy**.

DPU - Data Processing Unit

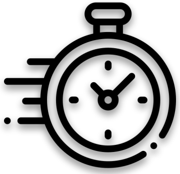
Project outline



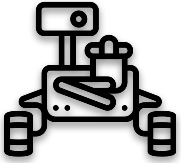
Develop a **deep learning** model for **segmenting rocks** on the **lunar surface**



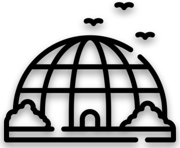
Deploy the model on **Edge AI** device with the **FPGA accelerator**



6 months



Integrate the **rover** with Edge AI device and **robotic software**



Test the system in an **analog lunar mission**

Icons by Prosymbols, VectorPortal, Smashicons, Freepik from Flaticon

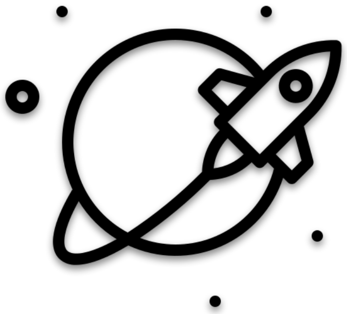
New Space paradigm

Approach:

- ➢ The usage of consumer electronics instead of qualified special devices

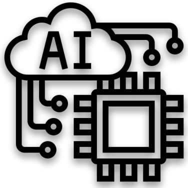
Benefits:

- ➢ Reduced time and costs
- ➢ Rapid Innovation
- ➢ Increased Accessibility



Icons by amonrat rungreangfangsai from Flaticon

Edge AI - features

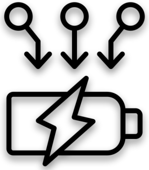


onboard processing

- ➢ no data streaming, permanent latency
- ➢ improved privacy and security

offline operation

- ➢ “order -> wait -> receive” approach
- ➢ reduced cost



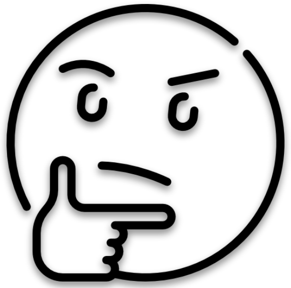
energy-efficient

- ➢ lower power consumption
- ➢ much higher FLOPS/W ratio

Icons by agus raharjo, gravisio, Eucalyp from Flaticon

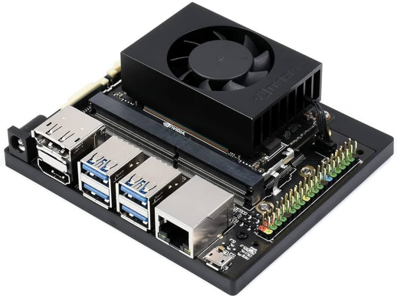
Edge AI - limitations

- ➢ processing power
- ➢ memory
- ➢ parallel processing
- ➢ storage
- ➢ support for deep learning layers
- ➢ weight quantisation



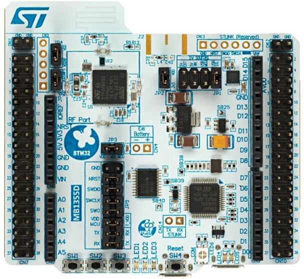
Icons by Freepik from Flaticon

Edge AI - devices



NVIDIA Jetson Family

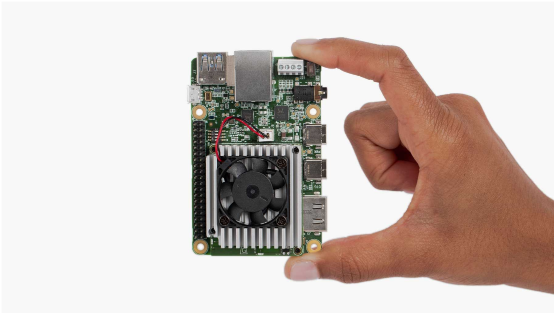
AMD/Xilinx Versal Devboards



STM32 AI Devboards

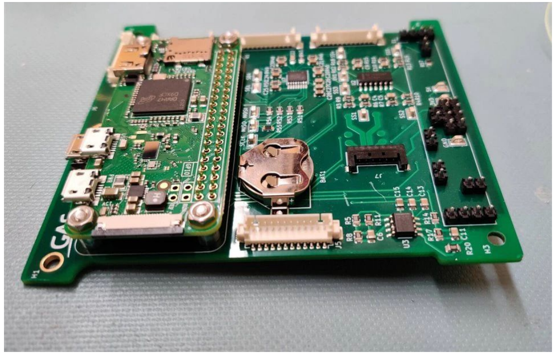
Intel VPU Accelerators

Hailo AI Accelerators



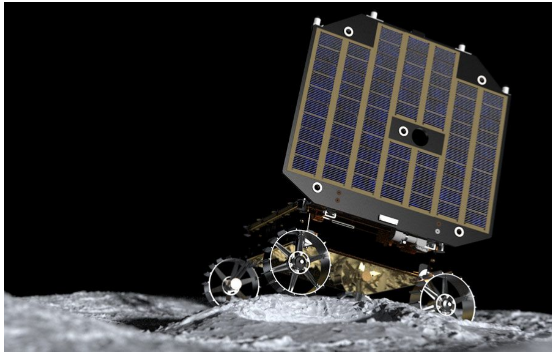
Google Coral TPU Accelerators

Edge AI devices in Space



Raspberry Pi Zero-based GSPACS Cubesat (launched December 2021)

Global Hyperspectral Observation Satellite constellation with Jetson AGX Xavier (3 of 6 have been launched)



MoonRanger rover with Nvidia Jetson TX2i (launch delayed to November 2023)

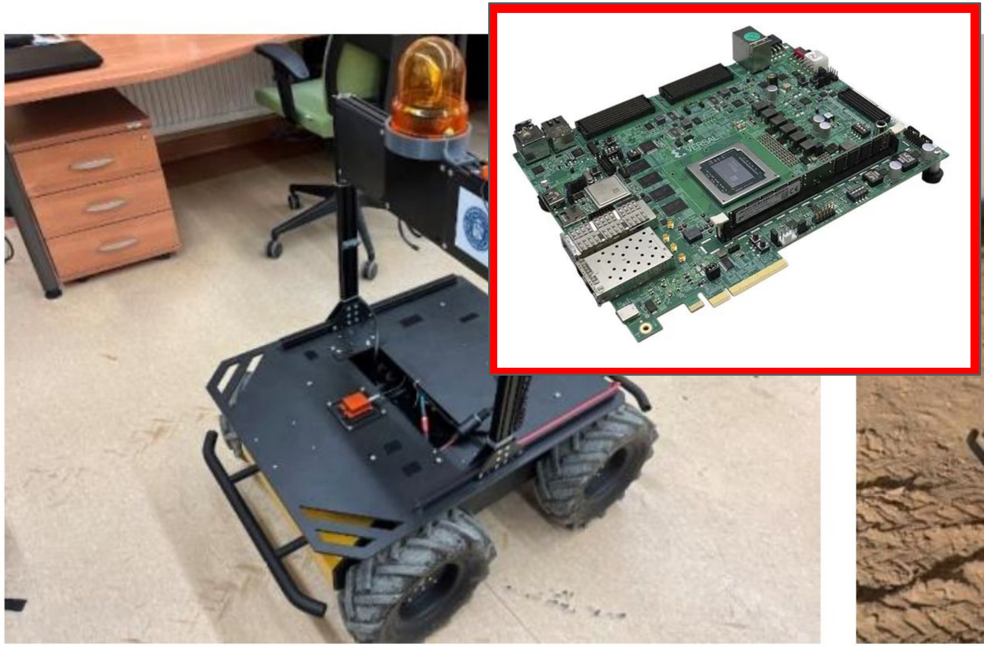
https://community.element14.com/technologies/sensor-technology/b/blog/posts/world-s-first-rasOrin AGXpberry-pi-satellite-completes-its-mission
https://space.skyrocket.de/doc_sdat/ghost-1.htm
https://parabolicarc.com/2022/07/14/cash-strapped-masten-space-furloughs-employees-moon-landing-mission-at-risk/

Our robotic platform

Clearpath Husky rover

Project-modified Husky rover

Our robotic platform



Clearpath Husky rover

Project-modified Husky rover

Robot Operating System (ROS)

What is the ROS framework?

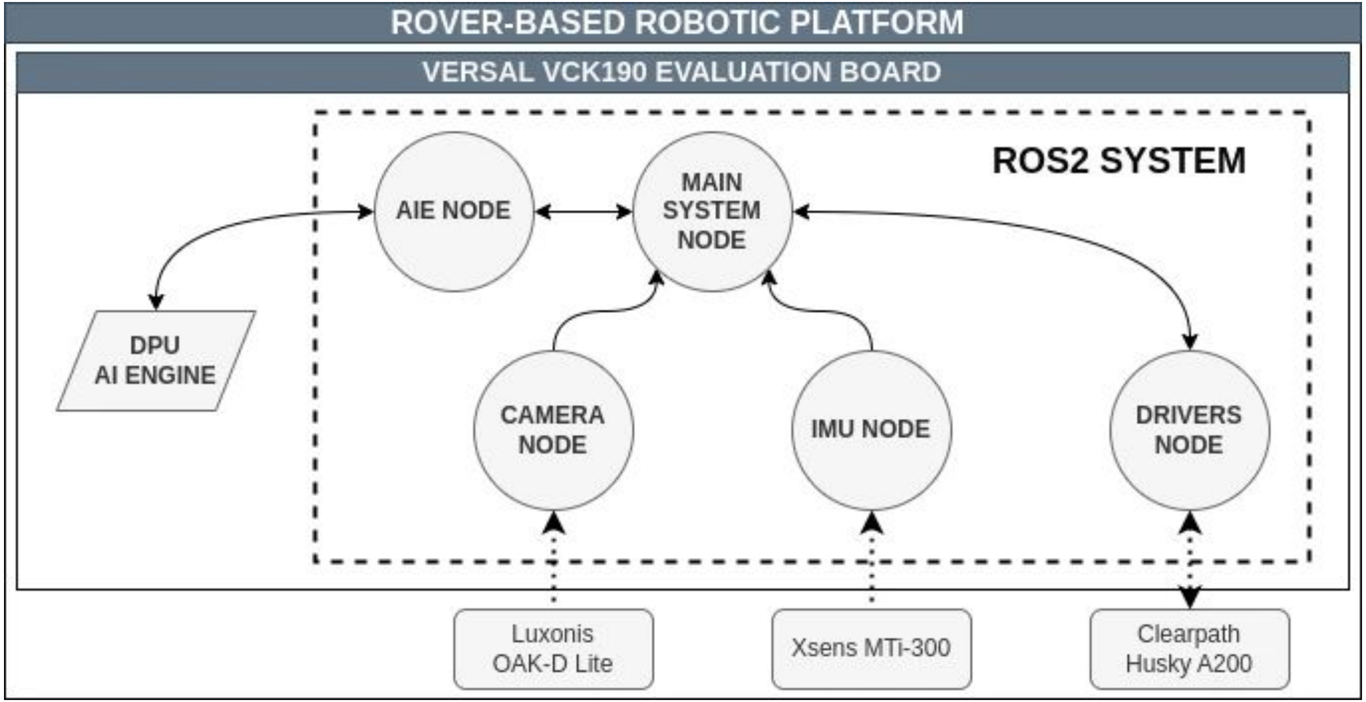
- ➢ provides a set of tools, libraries, and conventions for developing and controlling robotic systems

Why SpaceROS?

- ➢ provides software aligned with aerospace standards
- ➢ ease the adoption of the popular libraries

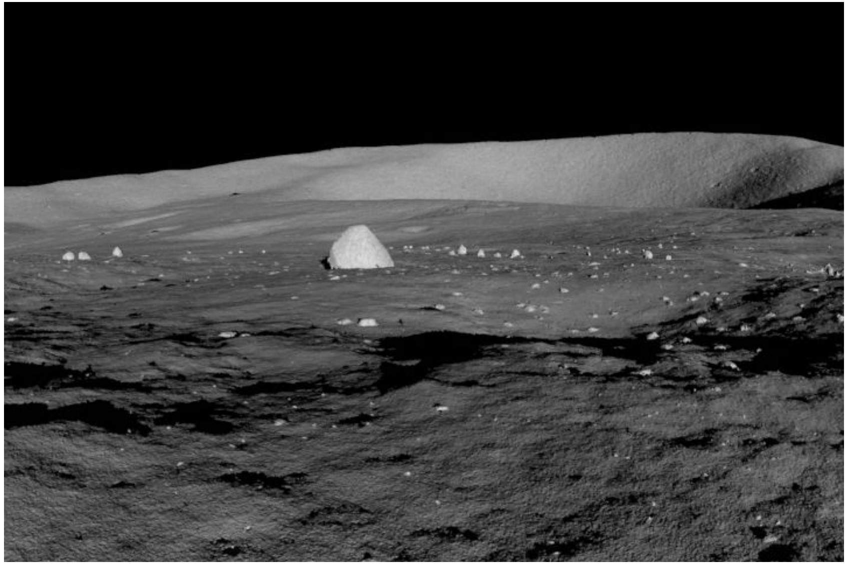
https://space.ros.org/

System scheme

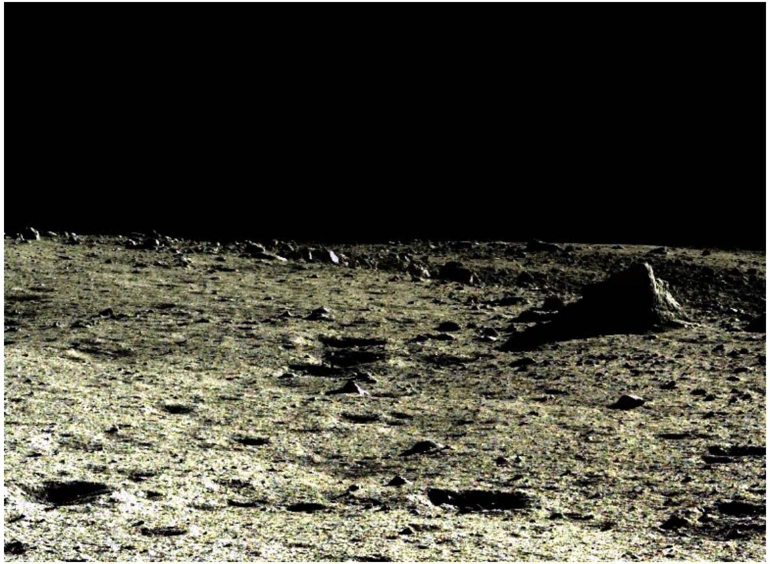


AIE - Artificial Intelligence Engine
IMU - Internal Measurement Unit
ROS - Robot Operating System

Dataset - Artificial Lunar Landscape Dataset (ALLD)

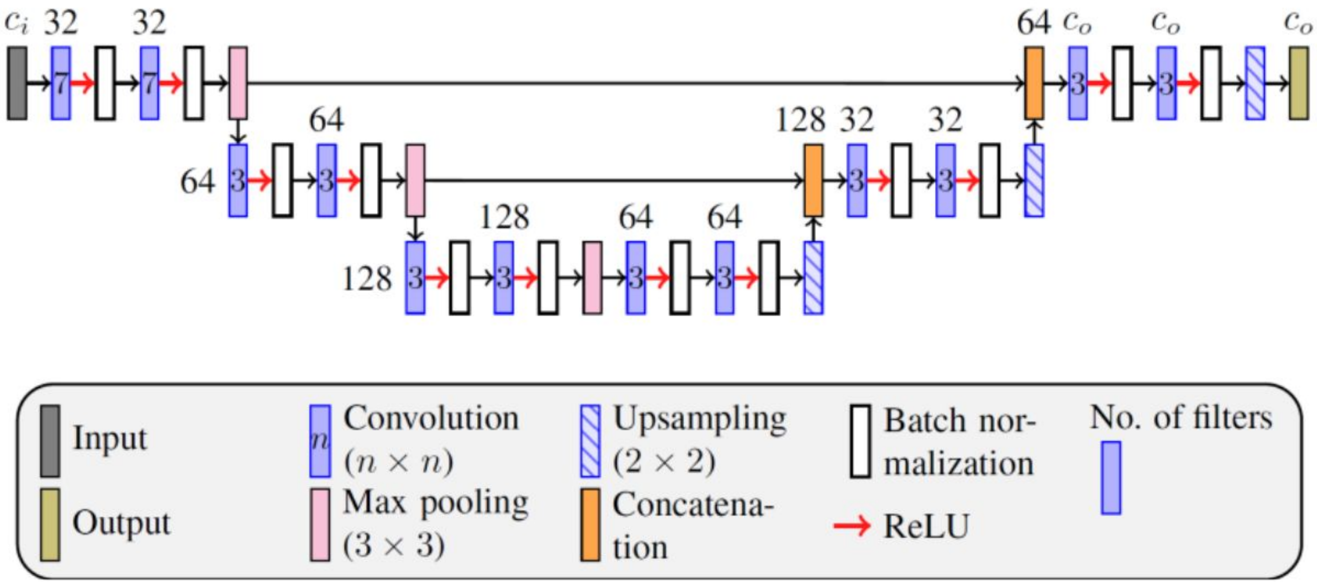


Sample image from **synthetic** part of ALLD



Sample image from **real** part of ALLD

Network architecture



“Towards robust cloud detection in satellite images using U-Nets” B. Grabowski, M. Ziaja, M. Kawulok, and J. Nalepa

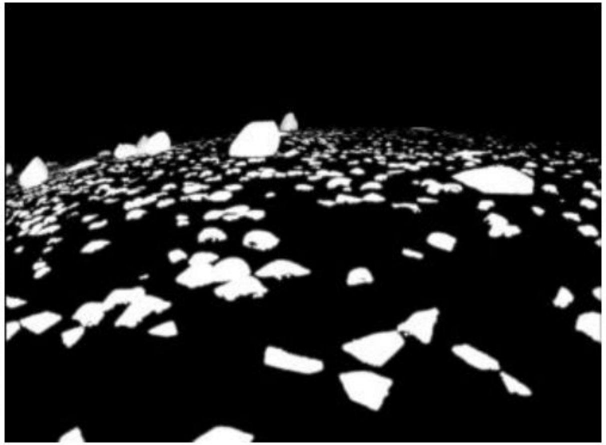
Results and weights quantisation

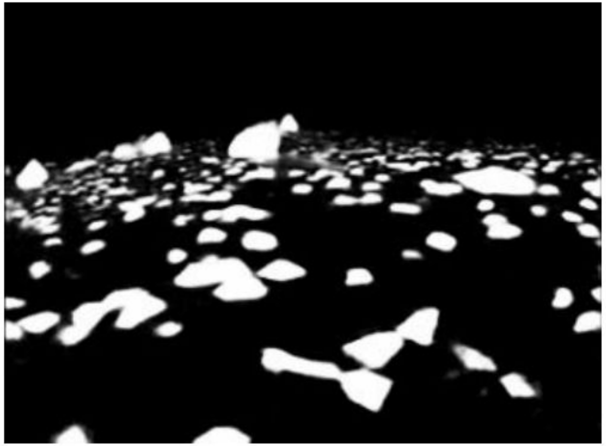
Stage	Loss	Precision	Recall	Dice	Jaccard	Dataset
float	0.3097	0.6764	0.7552	0.6977	0.5678	ALLD
quant	0.3101	0.6929	0.7428	0.7009	0.5722	ALLD
compiled	0.3085	0.6966	0.7399	0.7017	0.5733	ALLD

float - “raw” model weights after the training process
quant - weights quantised from FP16 to INT8
compiled - quantised weights compiled to the FPGA layers

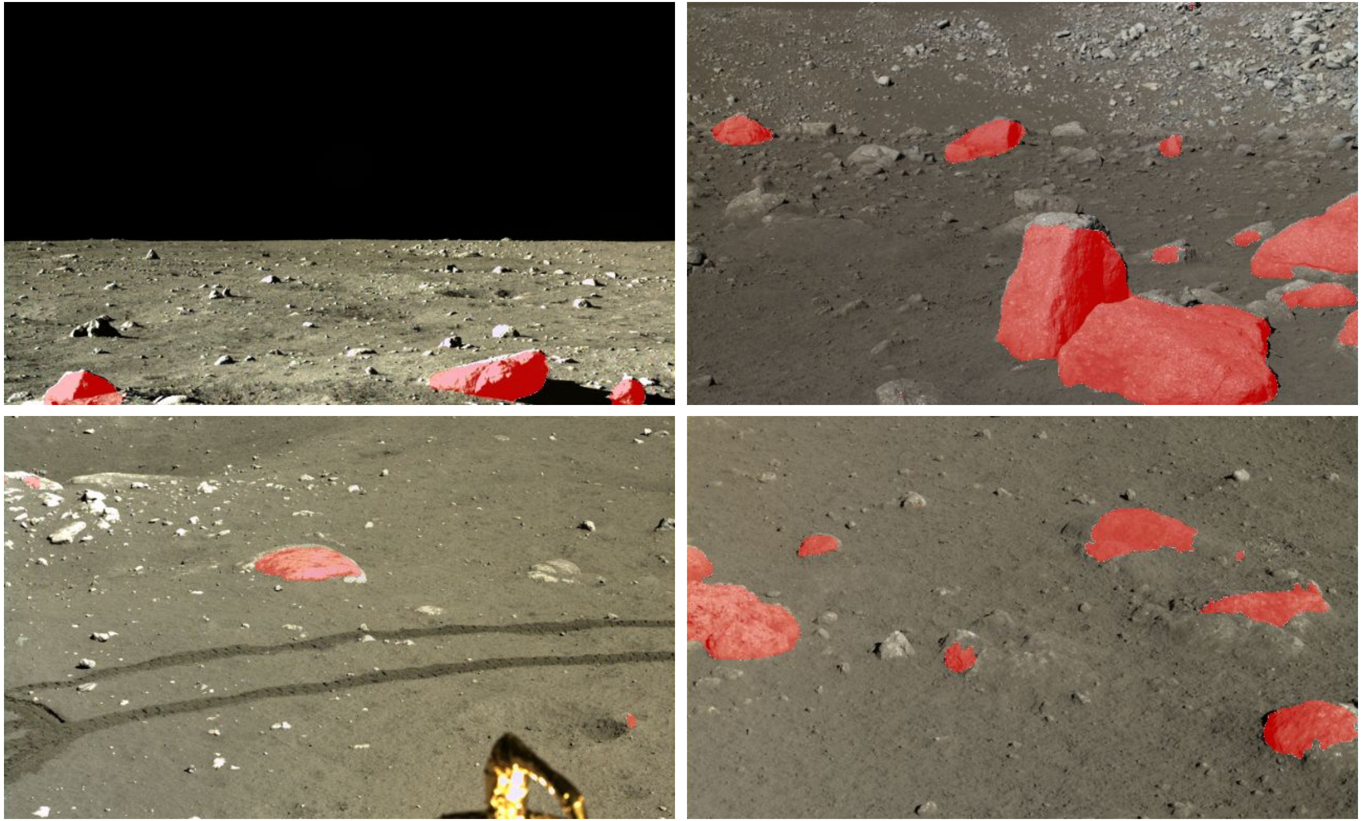
Example prediction (synthetic ALLD)


Input image


Ground-truth label


Model output

Example prediction (real ALLD)

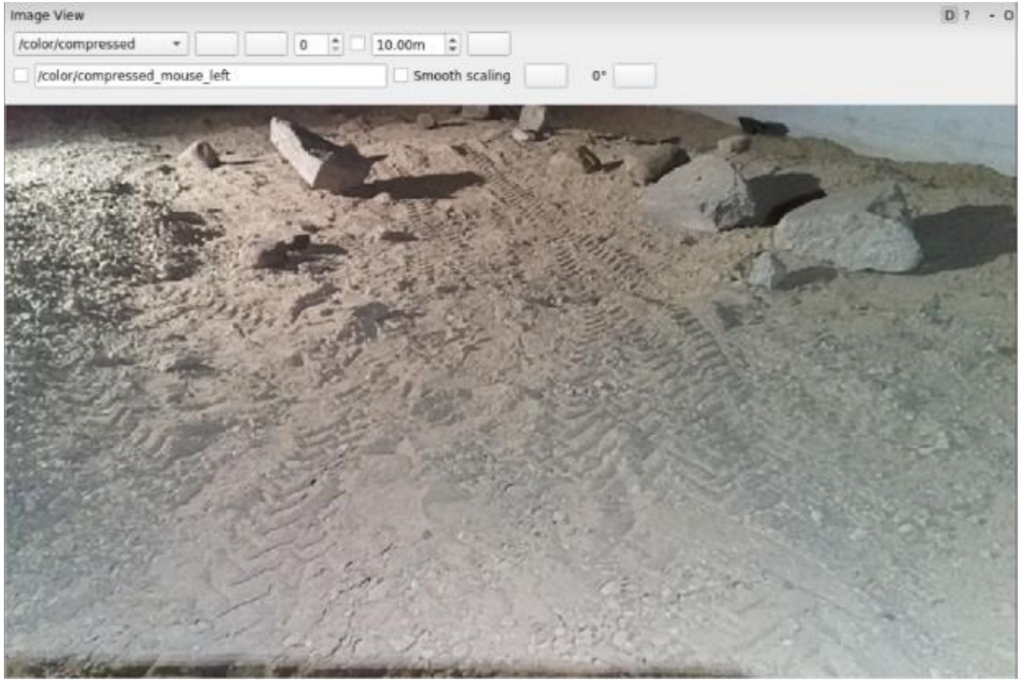


Analogue lunar research station (Lunares)

LUNARES Mobile Research Station

The rover during testing

Analogue lunar research station (Lunares)



Example frame from the camera mounted on the rover

Results and weights quantisation

Stage	PowerJaccard	Precision	Recall	DiceCoeff	JaccardIndex	Dataset
float	0.4328	0.7932	0.6322	0.6527	0.5290	Lunares
quant	0.4449	0.7607	0.6397	0.6421	0.5160	Lunares
compiled	0.4434	0.7749	0.6339	0.6426	0.5174	Lunares

float - “raw” model weights after the training process
quant - weights quantised from FP16 to INT8
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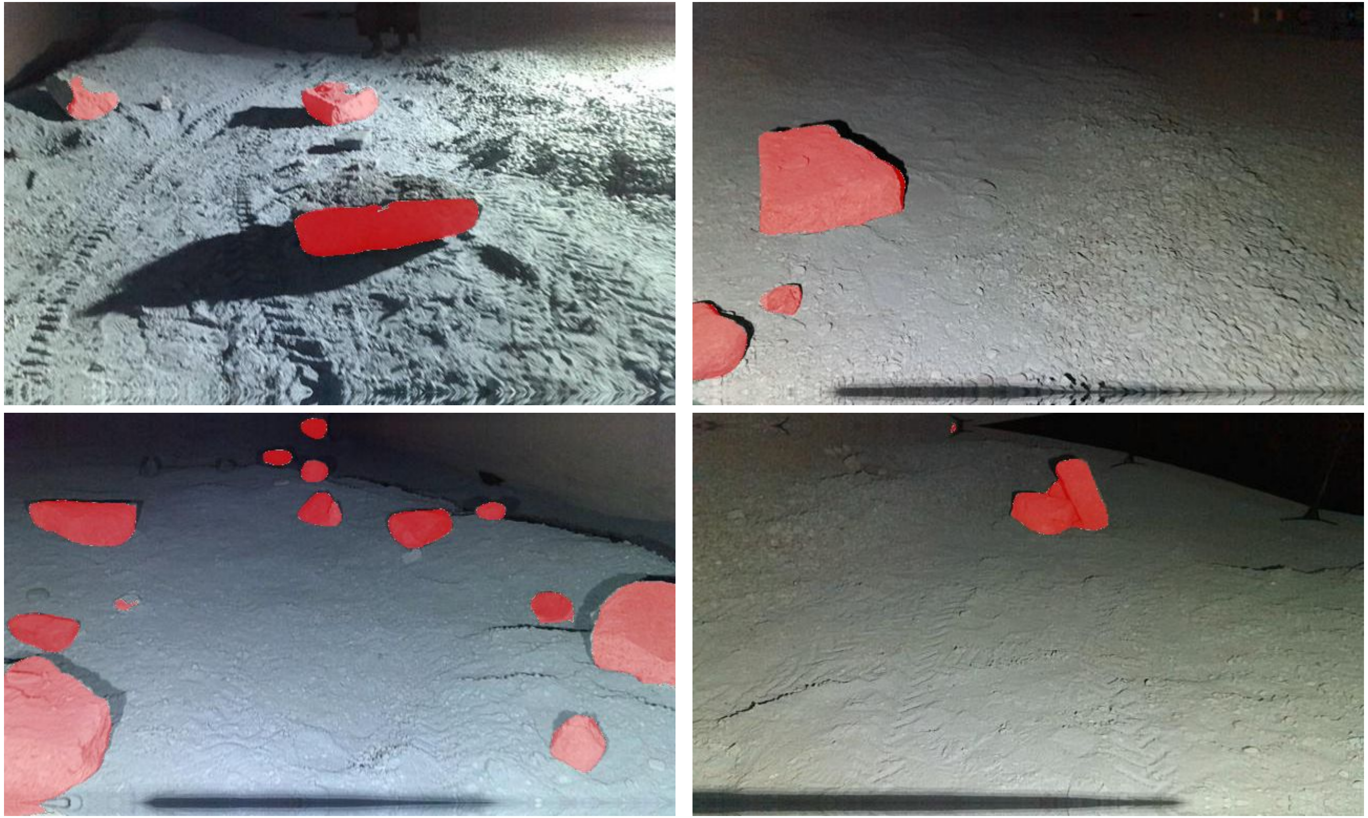
Example prediction (Lunares)



Thank you

Bartosz Ptak

bartosz.ptak@doctorate.put.poznan.pl

vision.put.poznan.pl

“Husky rover on the Moon” by DALL·E

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