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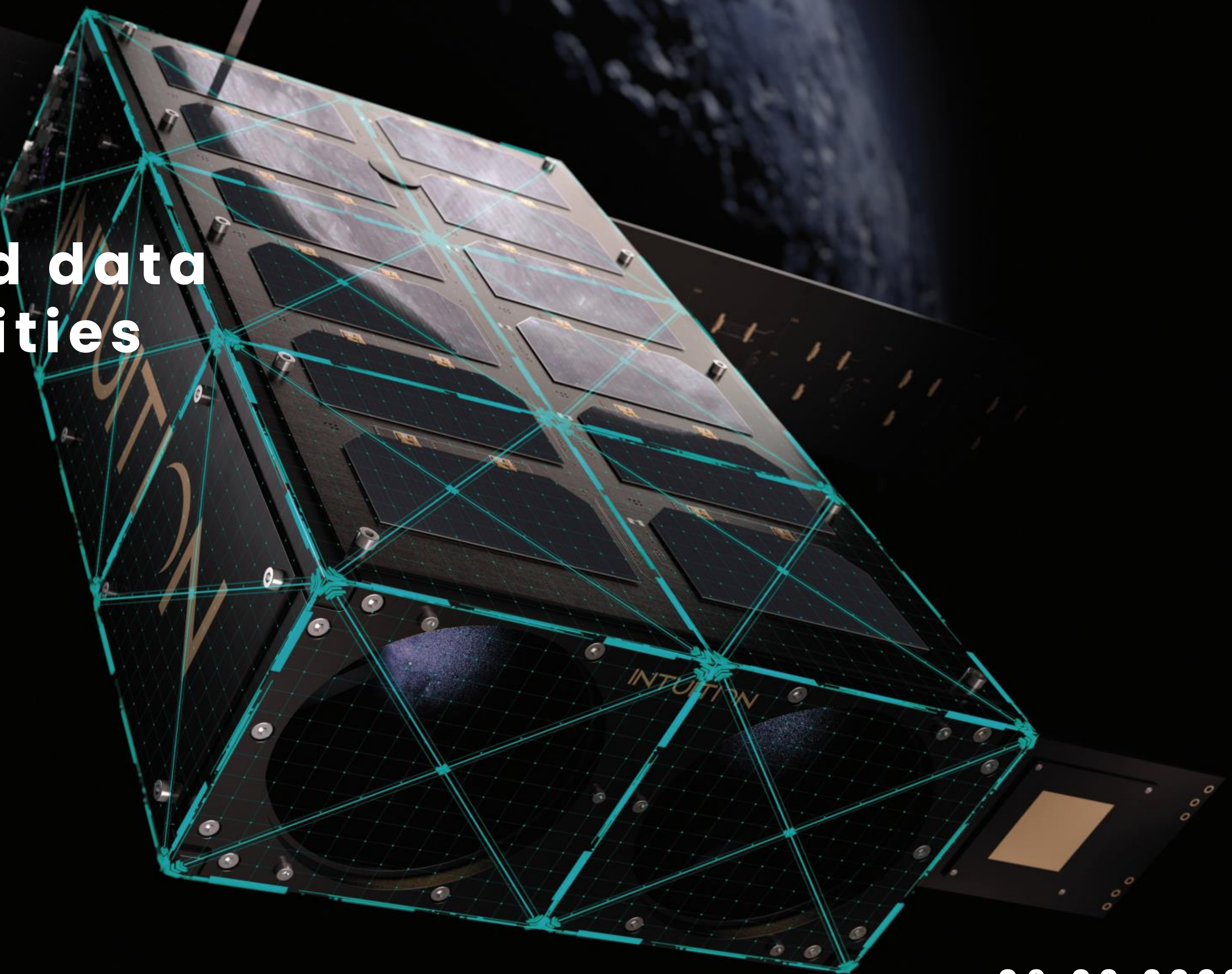
Executive summary

Cognition - distributed data system for lunar activities processing



KP LABS

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Background and motivation

Achieved objectives

- #1: To explore the capabilities of the AI development environment from Xilinx and benchmark two architectures (Leopard DPU and Versal AI)
- #2: To analyse the possibility of running robot operating system (ROS) on limited resources
- #3: To perform analogue tests with a DPU and a stereovision camera
- #4: To define the architecture for a future distributed processing system

Achievements

- Test case: rock detection and segmentation
  - A lightweight U-Net architecture[1] adapted, trained and deployed
  - Tests performed at LunAres Research Station
  - A new annotated dataset has been elaborated

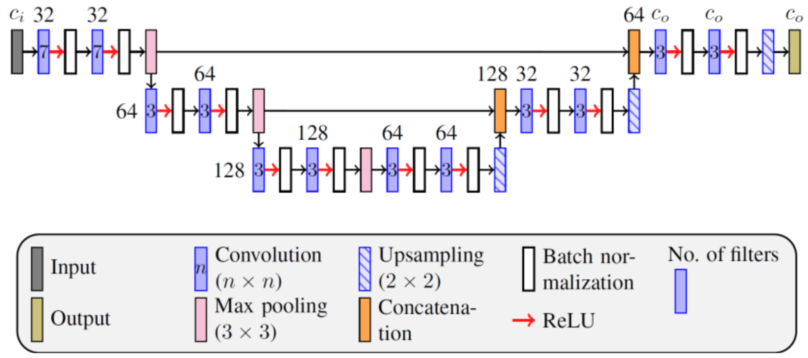
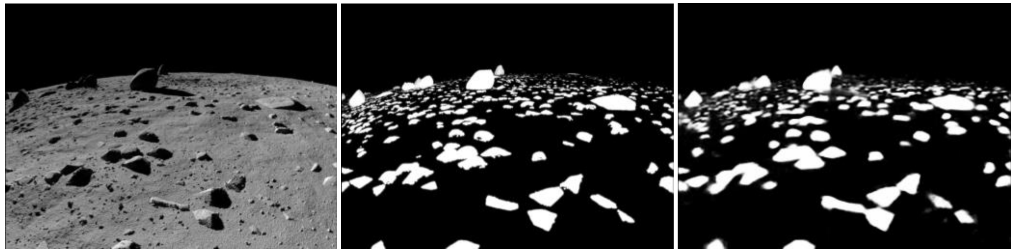


Figure: Lightweight U-Net architecture



Input image | Ground-truth mask | Segmentation outcome

Figure: Results for Artificial Lunar Landscape Dataset

Input image | Ground-truth mask | Segmentation outcome

Figure: Results for our real-world LunAres dataset

1. Grabowski, B., Ziaja, M., Kawulok, M., & Nalepa, J. (2021). Towards robust cloud detection in satellite images using U-Nets. In *2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS* (pp. 4099-4102). IEEE.

Achievements

- The network benchmarked and deployed in operational conditions

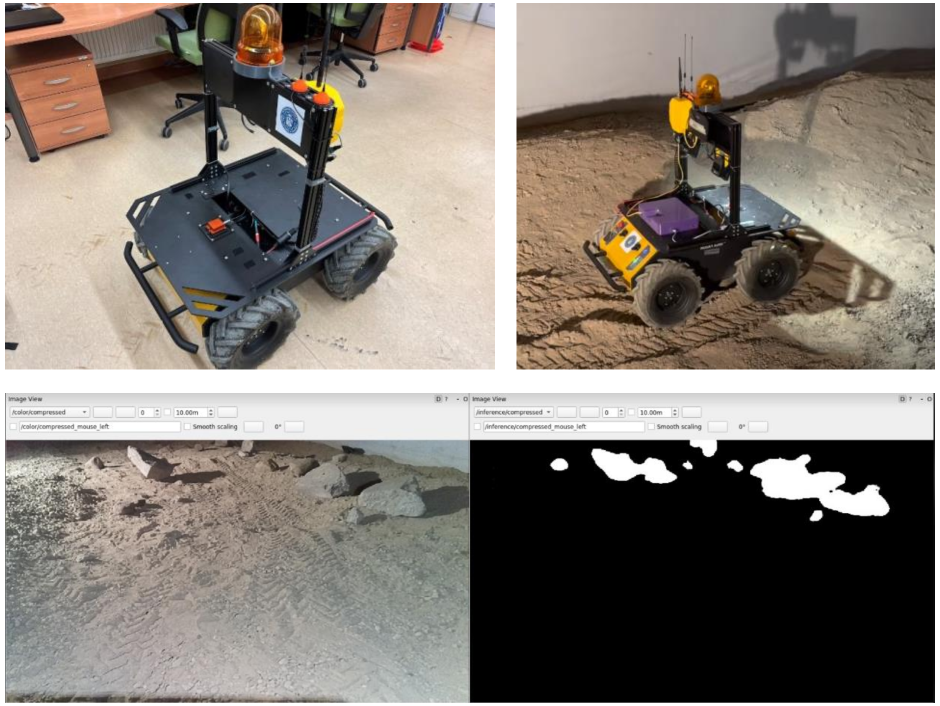


Figure: Developed mobile platform based on Clearpath Husky A200 robot (top row) and the analysis outcome (bottom row)

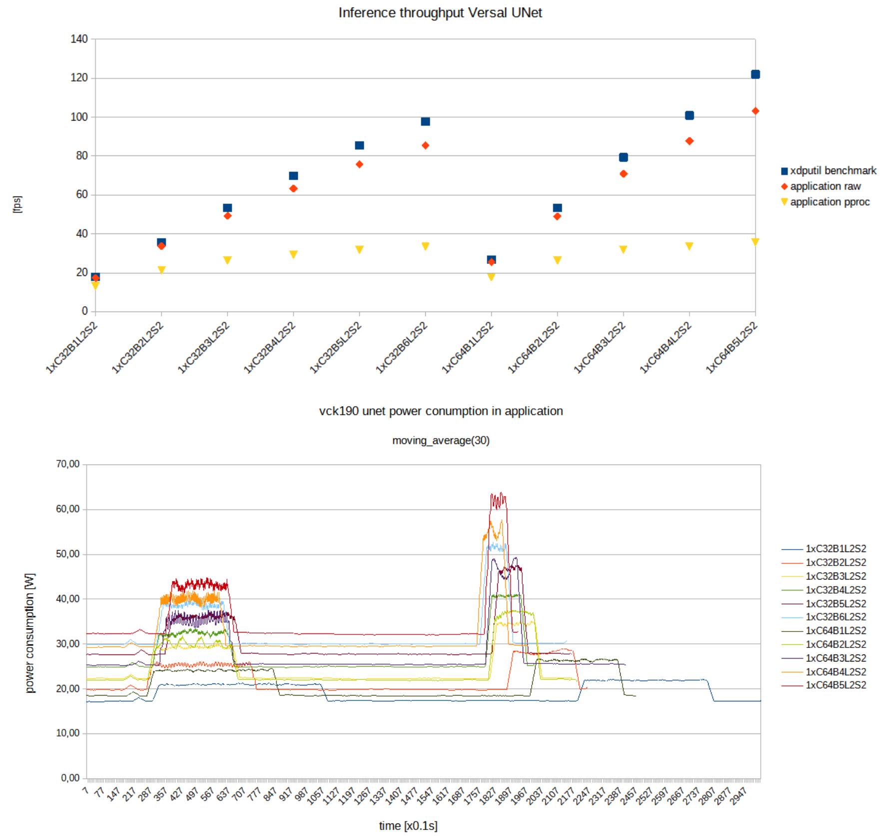


Figure: Processing speed and power consumption for different architectures

Achievements

- Hardware integration
  - ROS2 compiled and ported to the ARM procesor on the VCK190 Versal prototype board
  - The system is equipped with two stereo cameras that retrieve the depth image without any significant delays
  - Inertial measurement unit (IMU) sensor mounted on the robot base – applying extended Kalman filter improved localization in sloppy and unstable terrain (validated at LunAres Research Station)
- Most important lessons learned
  - Leopard's absolute power consumption is significantly lower than for Versal, however this is achieved at a cost of decreased number of frames per second and increased energy per frame metrics
  - Vitis AI framework appears to be still under intense development and suffers from its infancy problems
  - ROS2 provides a significant upgrade when compared to ROS1 in terms of development tools and standardization but still lags in terms of several readily available components
  - The IMU sensor is proved to be resilient in the sloppy terrain and keeps track of the localization of the rover

Figure: An example of a depth image retrieved by the robot in laboratory conditions

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Mission Complete

Conclusions and outlook

- Most important lessons learned
  - Leopard's absolute power consumption is significantly lower than for Versal, however this is achieved at a cost of decreased number of frames per second and increased energy per frame metrics
  - Vitis AI framework appears to be still under intense development and suffers from its infancy problems
  - ROS2 provides a significant upgrade when compared to ROS1 in terms of development tools and standardization but still lags in terms of several readily available components
  - The IMU sensor is proved to be resilient in the sloppy terrain and keeps track of the localization of the rover
- Future work
  - To further improve the capabilities of image analysis module (e.g., by deploying a model composed of combined U-Net and YOLO architectures)
  - To better understand the problems with model quantization relying on Vitis AI and learn how they can be overcome
  - To build a prototype of a more complex distributed system (embracing a rover and a lander)