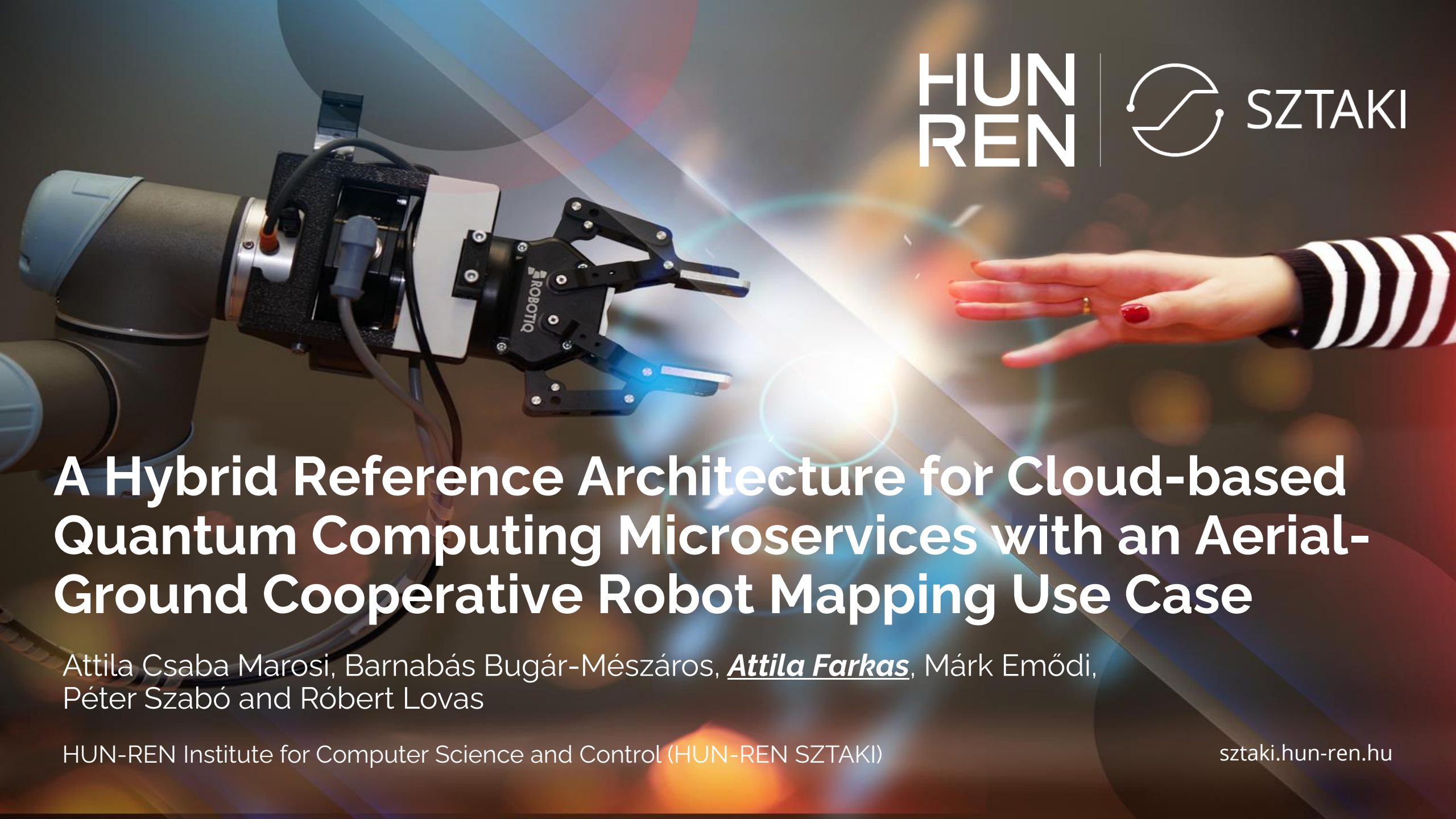

A Hybrid Reference Architecture for Cloud-based Quantum Computing Microservices with an Aerial-Ground Cooperative Robot Mapping Use Case

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Agenda

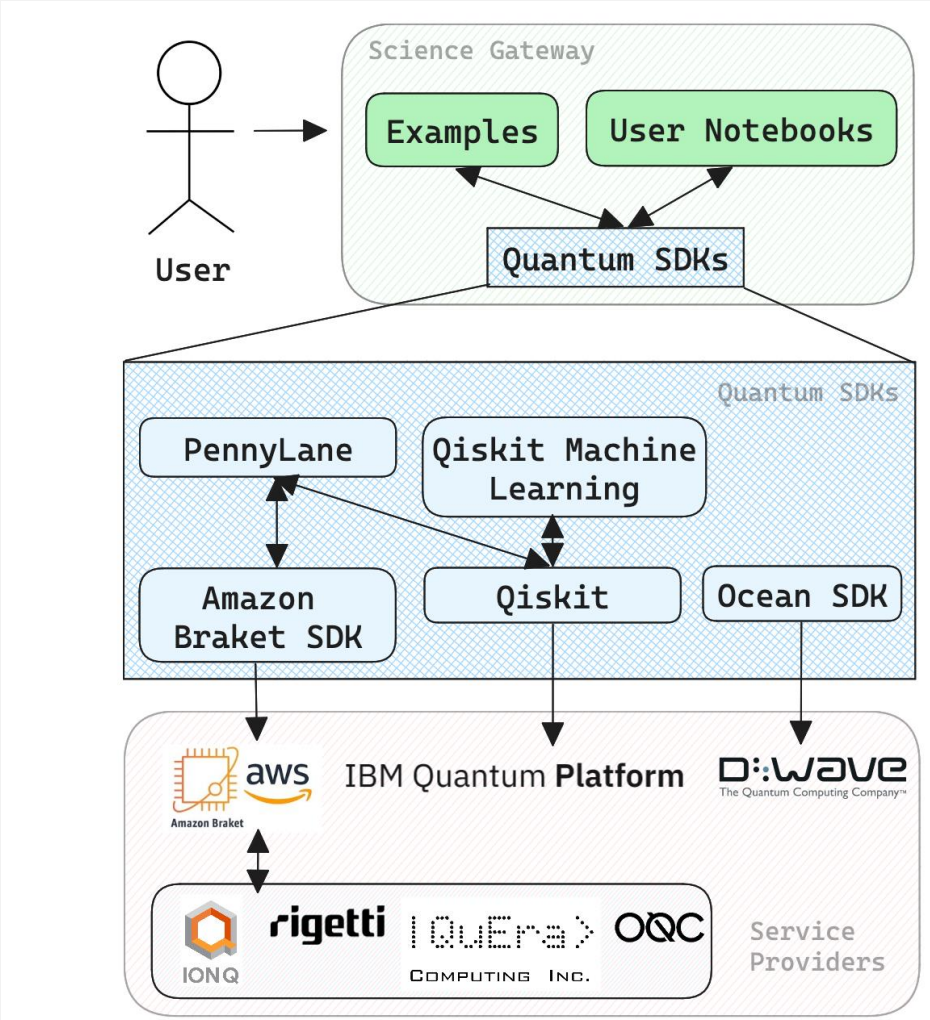
1. Quantum Reference Architecture
2. Use Case: Cooperative Aerial-Ground 3D Mapping
3. Demonstration

Quantum Reference Architecture

Quantum Reference Architecture on HUN-REN Cloud

The 'Quantum' reference architecture aims to provide an application layer for HUN-REN cloud users, making it easy to experiment with and learn about the available quantum resources.

https://science-cloud.hu/en/reference-architectures/quantum



- **JupyterLab** provides the user interface with pre-built examples - currently using **D-Wave Ocean**, **IBM Qiskit**, and **Amazon Braket** quantum resources
- **Custom framework** to build and deploy microservices from notebooks and access them via REST APIs (in-progress).

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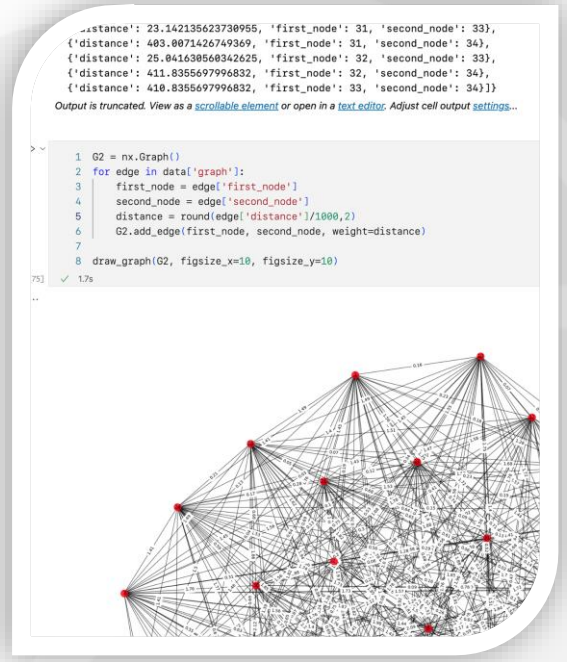
From Quantum Notebooks to Quantum Microservices

The Reference Architecture provides a framework for building and deploying microservices from Jupyter Notebooks accessible through REST APIs.

1. Develop in Jupyter



2. Push to Git

GitLab

3. Automatically Build Containers (Continuous Integration)

docker

4. Automatic Deploy (Continuous Delivery)

kubernetes

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Use Case: Cooperative Aerial-Ground 3D Mapping

POI system

- **PostgreSQL database on the Cloud**
  - Identifications
  - GPS location
  - Status
- **Each robot has access and means to forward and receive POI data.**
- **POI types:**
  - Mapping
    multiperspective reconstruction
  - Inspection
    change-detection,
    detailed ground observation
  - Waypoint
    traversability and patrol
  - Transfer
    transfer equipment, medicine
- **Future plans:**
  - live mission observation map

szerk.:
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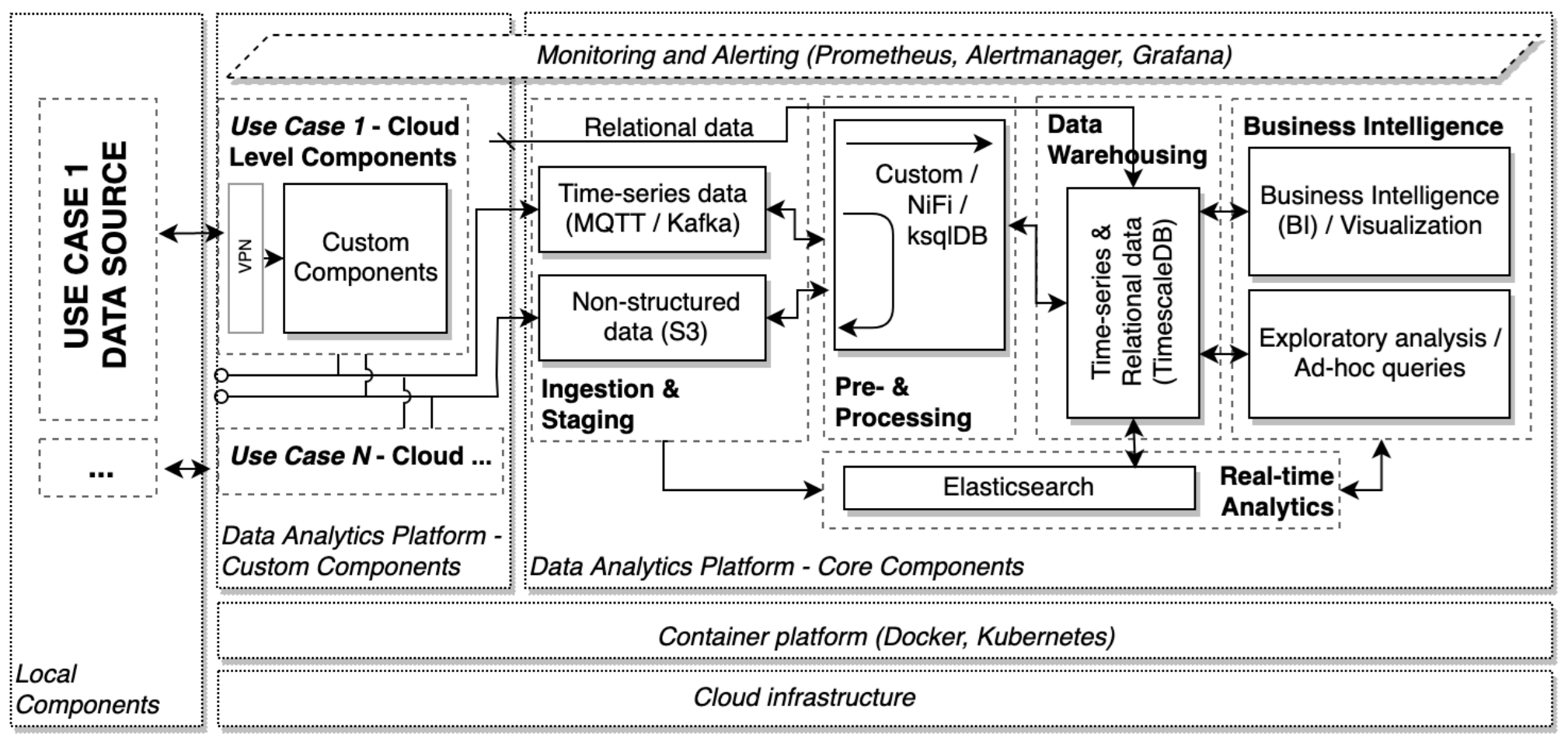
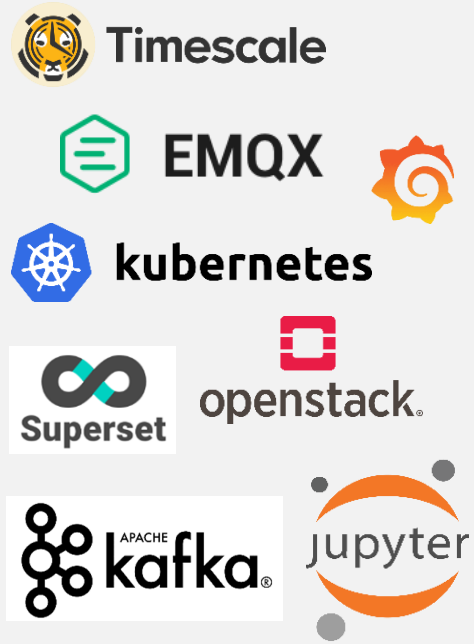
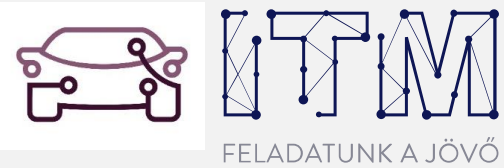
A Data Analytics Platform - Empowering all Use Cases[1]







1: A. C. Marosi *et al.*, "Toward Reference Architectures: A Cloud-Agnostic Data Analytics Platform Empowering Autonomous Systems," in *IEEE Access*, vol. 10, pp. 60658-60673, 2022, doi: 10.1109/ACCESS.2022.3180365.

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UAV - UGV Cooperation, Chapter 1,

Direct Observation Based Cooperation

- Unmanned Aerial and Ground Vehicle (UAV-UGV) cooperation
  - UAV: Patrol & detect
  - UGV: Detect & inspect
- Multi robot system (software stack)
  - No specific UAV & UGV platform
- Point of Interest (POI)
  - suspicious object
  - injured humans
  - signs of forced entry

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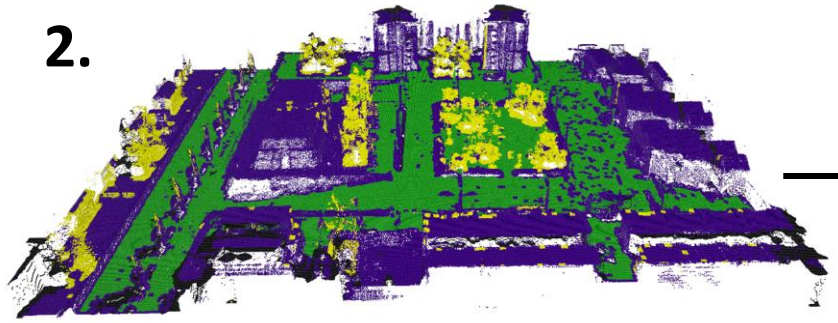
Dead spots in reconstruction made from aerial data only

Cooperative Aerial-Ground 3D Mapping

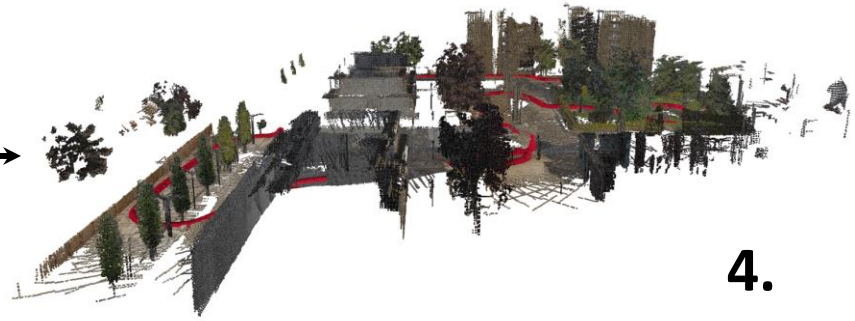
1.

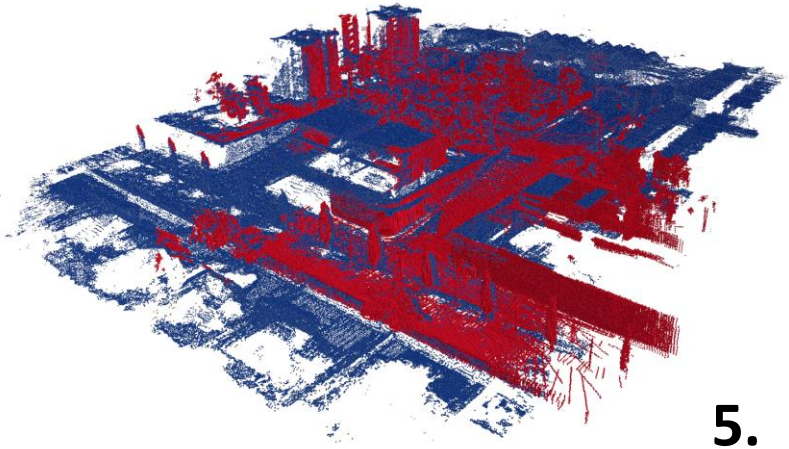
2.



Steps:

1. 3D reconstruction of aerial data
2. 3D model processing
3. Path planning
4. 3D reconstruction of ground data
5. 3D model fusion





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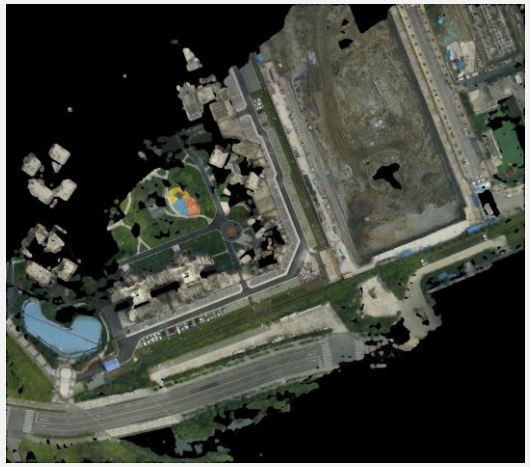
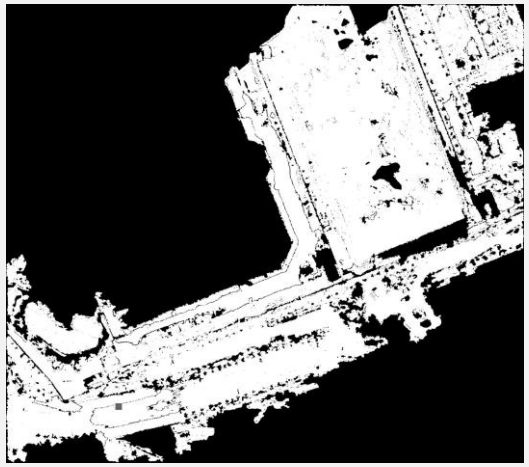
3D model processing to detect unmapped regions

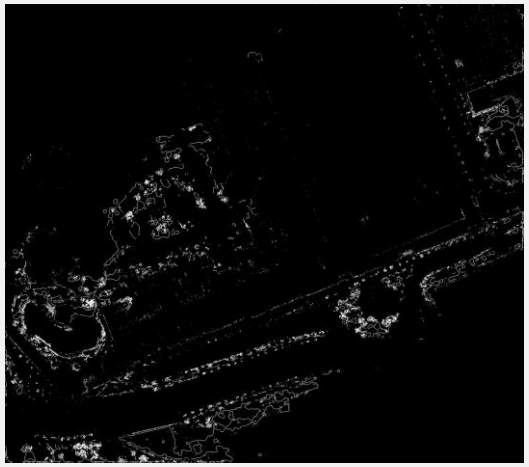
- Georeferenced aerial RGB images
- Dense 3D reconstruction of the scene



- Top-view of the scene
- Elevation and surface normal information is preserved



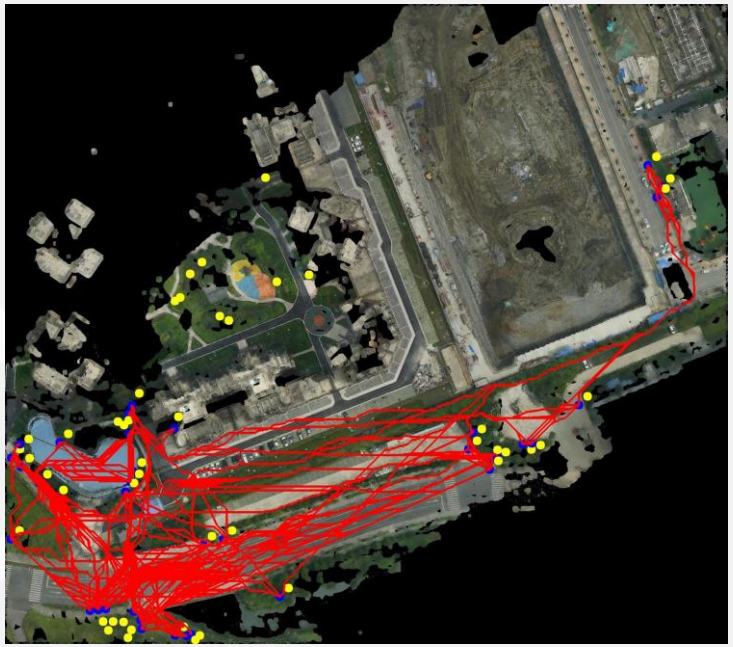
- Traversable regions for the ground vehicle
- Uncertainty, slope, elevation



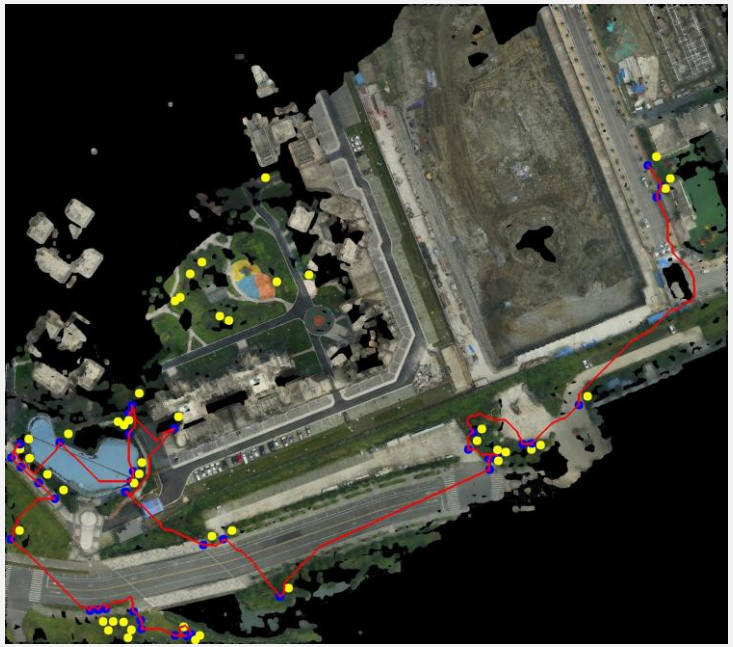
- Areas not visible from above
- Elevation change, vegetation index

Multi-goal path planning to the detected targets

- Defining points of interest (POI) at presumably unmapped parts
- Selecting waypoints close to the POIs in the traversable regions
- Computing pairwise shortest paths by A* algorithm



Connected graph of all waypoints

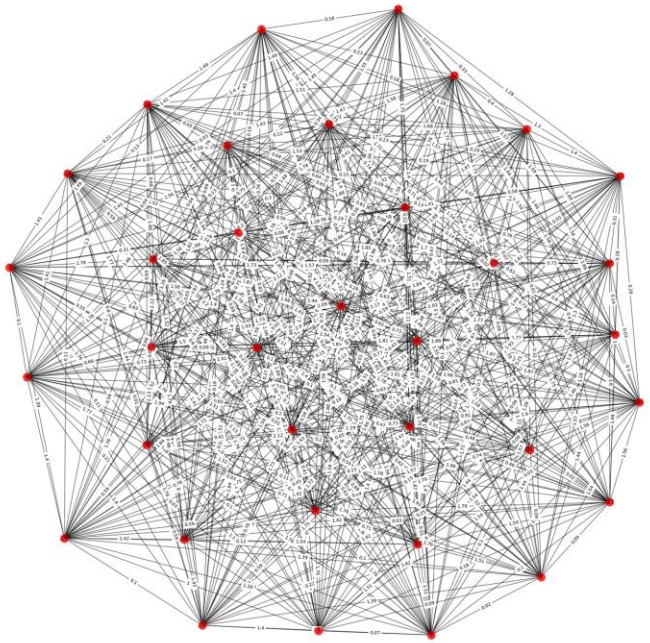


Shortest path connecting the waypoints

- Formulating a connected graph of the waypoints
- ***Solving the Travelling Salesman Problem (TSP) by computing the shortest global path between the waypoints using a genetic algorithm***

Demonstration

1. Quantum Reference Architecture
2. Use Case (TSP)
3. Notebooks to Microservices



References & Links

1. Quantum @ SZTAKI: https://q.sztaki.hun-ren.hu/
2. A. C. Marosi et al., "Toward a Quantum-Science Gateway: A Hybrid Reference Architecture Facilitating Quantum Computing Capabilities for Cloud Utilization," in *IEEE Access*, vol. 11, pp. 143913-143924, 2023, doi: 10.1109/ACCESS.2023.3342749.
3. A. C. Marosi *et al.*, "Toward Reference Architectures: A Cloud-Agnostic Data Analytics Platform Empowering Autonomous Systems," in *IEEE Access*, vol. 10, pp. 60658-60673, 2022, doi: 10.1109/ACCESS.2022.3180365.
4. Quantum | HUN-REN Cloud (science-cloud.hu): https://science-cloud.hu/en/reference-architectures/quantum
5. National Laboratory for Autonomous Systems - https://autonom.nemzetilabor.hu/
6. HUN-REN Cloud - https://science-cloud.hu/en

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We are grateful for the opportunity to use the HUN-REN Cloud, which helped us achieve the results presented in this demonstration.

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Thank You!