Transparent, Adaptive Application Deployment on the Edge–Cloud–HPC Continuum

Andry Razafinjatovo

The Continuum Challenge:

› Modern applications span heterogeneous infrastructures: Edge, Cloud, HPC.

› Each layer brings unique constraints: latency, performance, rigidity, scalability.

Challenges include:
- ✓ latency, resource allocation,
- ✓ security, isolation
- ✓ AI integration accross tiers
- ✓ Developper transparency: no rewriting code

Approach:

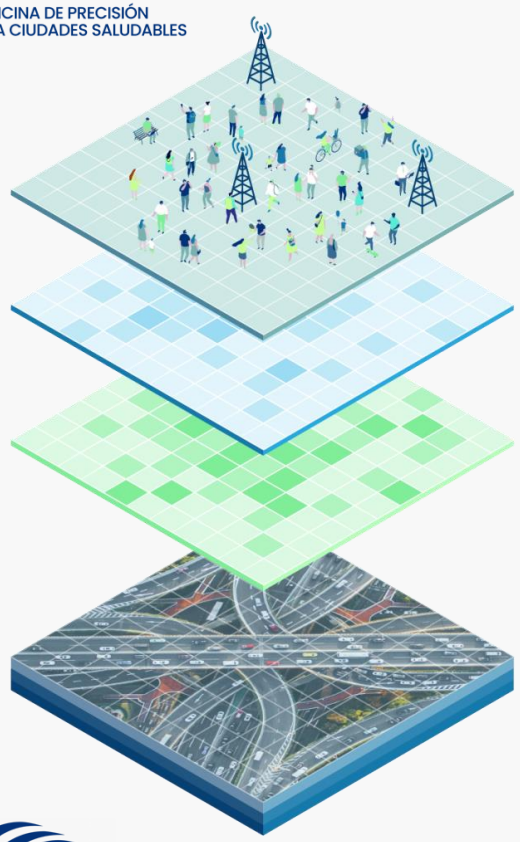
Orchestrate hybrid data-treatment workflows across the continuum automatically, adaptively, and securely with the open source platform Ryax[1].

› **UC1: Epidemiological Simulations**

› **UC2: Precision Agriculture**

Use Case 1: Epidemilogical Simulations

MePreCiSa
MEDICINA DE PRECISIÓN
PARA CIUDADES SALUDABLES



Subject:

- ✓ Run specialized HPC-based scientific simulations elastically on Cloud (MePreCiSa project [2])
- ✓ The core application is related to large-scale epidemiological simulations running on either HPC or Cloud infrastructures.

Goals:

- ✓ Provide a Cloud platform enabling the execution of data ingestion, visualizations and simulations related to precision medicine.
- ✓ Enable the deployment of HPC specific Emews-Swift/T framework [3] to the Cloud.
- ✓ Propose high-level abstraction

Challenges:

- ✓ Ease of use, Interoperability, container complexity, secure access.

BSC

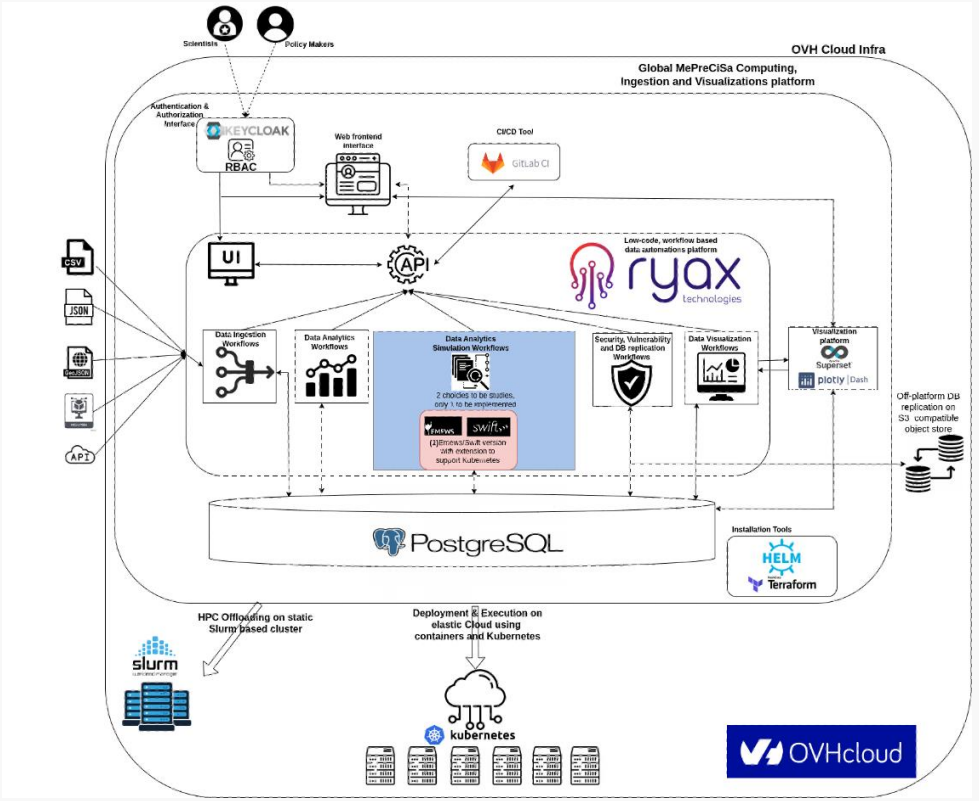
doitnow
HPC Services

Use Case 1: Epidemilogical Simulations

Solution approach

Techniques and Tools :

- ✓ Automatic orchestration with Ryax across K8S and Slurm infrastructures.
- ✓ Elastic Slurm clusters via Nebius/Soperator or SchedMD/Slinky.
- ✓ Workflow-driven deployment; abstraction via ssh/scp.
- ✓ Open-source tools to ensure portability and avoid vendor lock-in.



Use Case 1: Epidemilogical Simulations

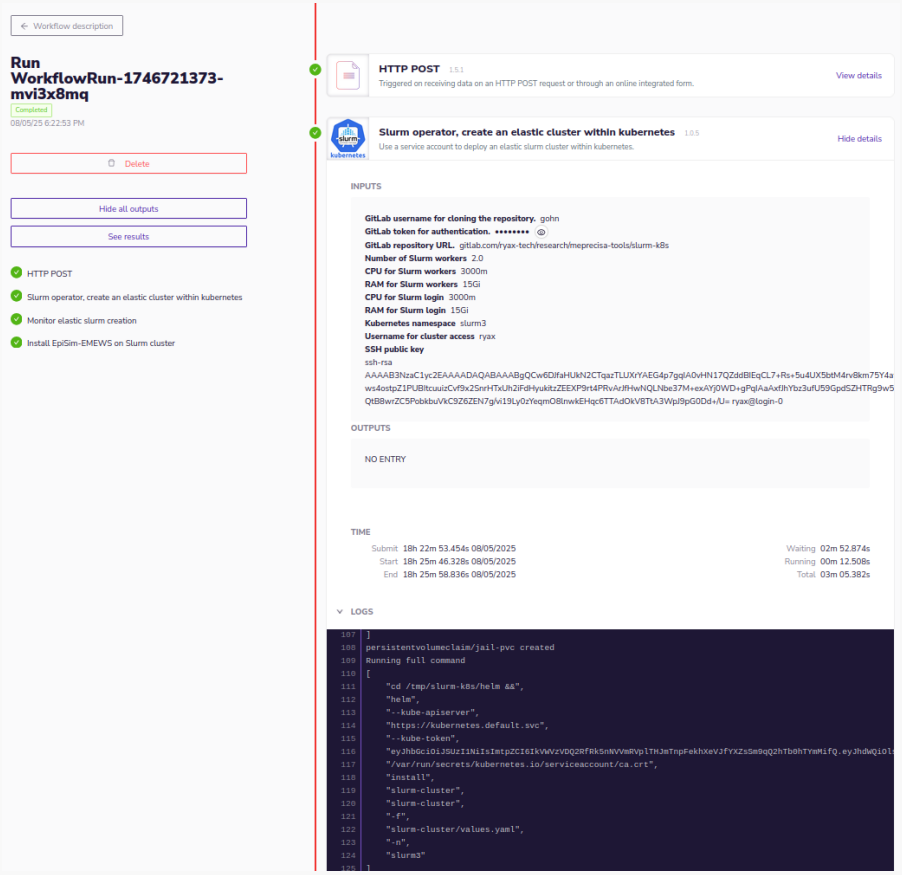
User friendly interface

High-Level configurable workflows:

- ✓ Simple on-demand creation of elastic Slurm cluster on K8S
- ✓ Environment setup with existing HPC install scripts.
- ✓ Simulations automated on the cloud through ssh/scp abstraction
- ✓ Centralized logging and monitoring
- ✓ Pre / Post treatments and vizualisations on K8S Cluster

Ongoing work:

- ✓ Cloud-native auth with Keycloak and opkssh [6]
- ✓ On the fly cluster scaling



Use Case 2: Precision Agriculture

Subject:

- ✓ Real-time Soil Organic Carbon assessment (Empyrean project).

Goals:

- ✓ Empowers farmer-driven decisions with timely, localized insights.
- ✓ Supports adaptive, sustainable farm practices.
- ✓ Minimizes data transfers, ensures data privacy, and reduces latency.
- ✓ Enables transparent deployment across edge-cloud-HPC environments

Specifications:

- ✓ Data acquisition from UAV, field robots, spectrometeres
- ✓ Edge-first processing due to rural constraints and latency needs
- ✓ Multi-sources data integration and actionnable SOC management for decision system

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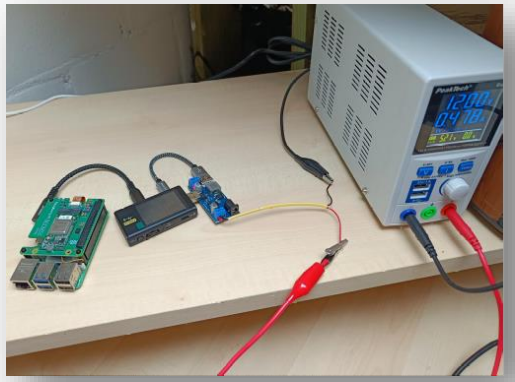
EMPYREAN

Use Case 2: Precision Agriculture

Challenges:

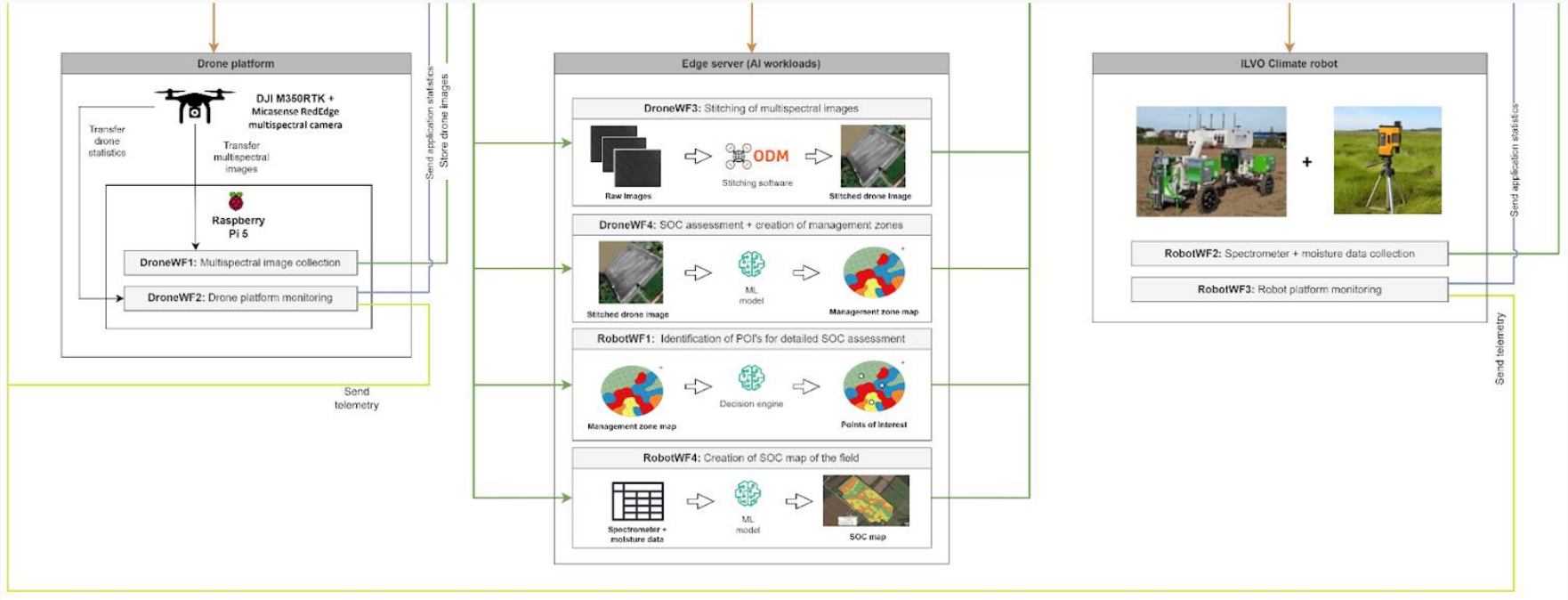
- ✓ **High Data Volume**: Real-time edge processing of high-res sensor data
- ✓ **Poor Connectivity**: Limited rural access → edge-first approach
- ✓ **Data Integration**: Harmonize UAVs, spectrometer, and moisture data
- ✓ **Energy Constraints**: Require low-power, renewable-ready systems
- ✓ **Security & Privacy**: Ensure decentralized, robust data protection
- ✓ **Scalability:** Modular design supports varied fields and crops



Use Case 2: Precision Agriculture

Approach:

- ✓ Execution on diverse architectures: ARM64 (drones) and x86_64 (servers).
- ✓ Packaged environments run on edge-cloud-HPC via Ryax.
- ✓ Multi-site, constraint-aware scheduling chooses optimal deployment.



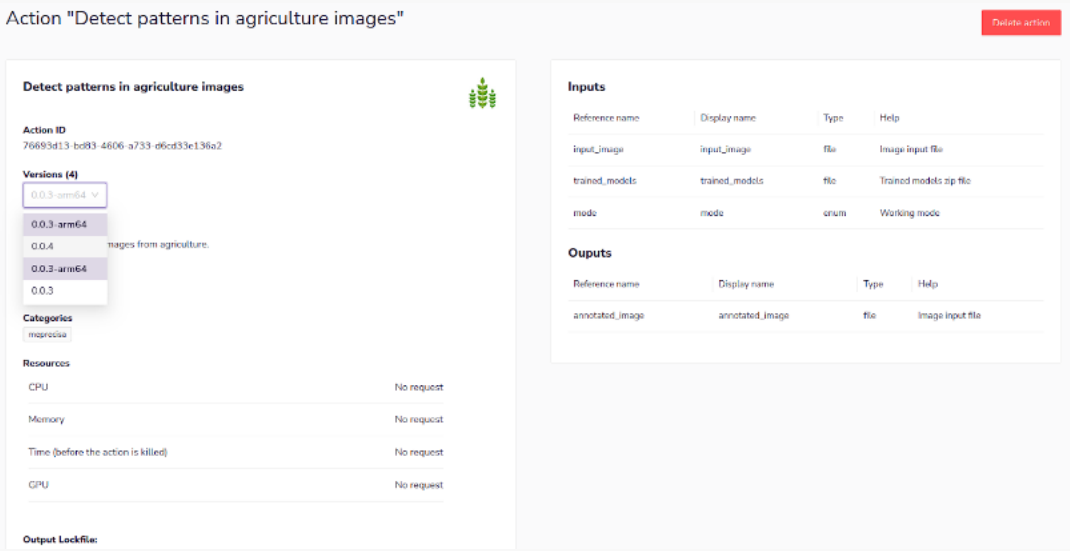
Use Case 2: Precision Agriculture

Techniques and Tools :

- ✓ Lightweight K8S (K3S) on constrained edge devices (e.g., Raspberry Pi).
- ✓ Ryax enhanced with multi-site support and Nix-based packaging [10].
- ✓ Skupper [9] enables cross-cluster communication.
- ✓ Advanced scheduling based on energy, performance, and more.

Ongoing work:

- ✓ Unikernel integration for fast, secure, low-energy edge deployments.
- ✓ Collaborations with Bunny [11] and Unikraft [12] for seamless DevOps.
- ✓ Future improvements in meta-scheduling and policy optimization. [13]



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Conclusion

- ✓ **Edge, Cloud, and HPC have distinct requirements; need seamless integration.**
- ✓ **Ryax enables Continuum-native orchestration, packaging, monitoring.**
- ✓ **Focus on security, transparency, and optimized resource utilization.**

- ✓ Ongoing R&D via CAPE and E2CC projects to push the frontier further.

Join us to build the future of adaptive continuum computing!

Yiannis@ryax.tech
Andry@ryax.tech

References

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[6] https://github.com/openpubkey/opkssh
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[10] https://github.com/NixOS/nix
[11] https://github.com/nubificus/bunny
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