GIS4IORT: A Plug-and-Play Middleware for Integrating Robot Sensor Data with GIS Tools in a Cloud Environment

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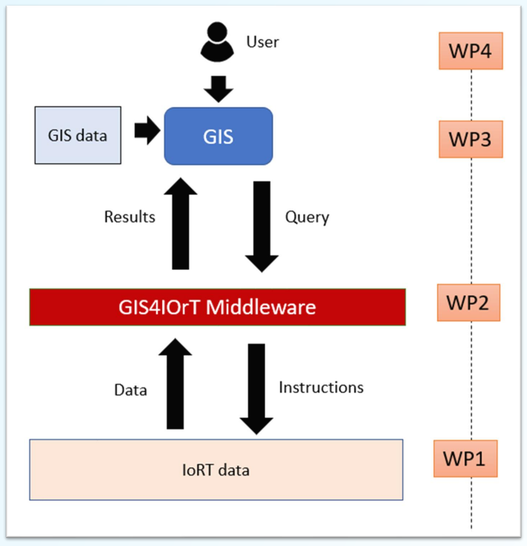
Introduction

The convergence of robotic technologies and sensor networks has generated vast amounts of data with potential applications in several domains like agriculture and urban planning. However, the lack of interoperability between this data and Geographic Information System (GIS) tools poses a challenge. The **objective of GIS4IoRT** (Geographic Information Systems for Internet of Robotic Things) project is the development of a "plug and play" and cloud-based middleware to bridge this gap, enabling seamless integration and visualization of multidimensional IoRT datasets within GIS environments.

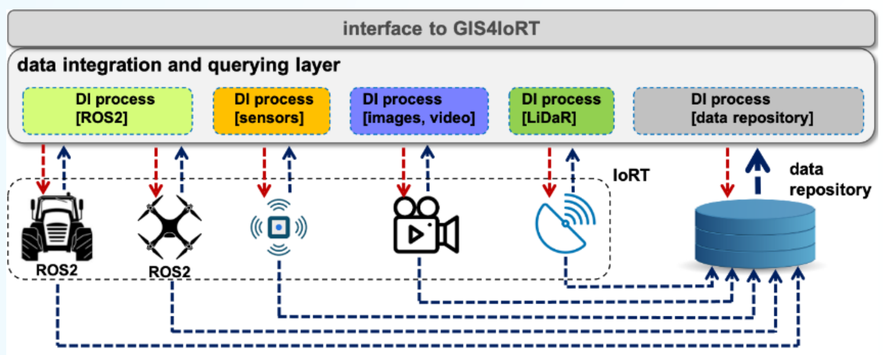


GIS4IoRT key components include:

- middleware architecture,
- cloud-based infrastructure,
- real-time interrogation of robots,
- AI-based approaches to ensure data reliability and completeness,
- spatio-temporal query support in the cloud,
- GIS integration,
- adherence to standards,
- support diverse data types (lidar, imagery, sensor, …)
- validation by agriculture case study

Project starting date: June 2025
Project duration: 3 years

Data sources (WP 1)



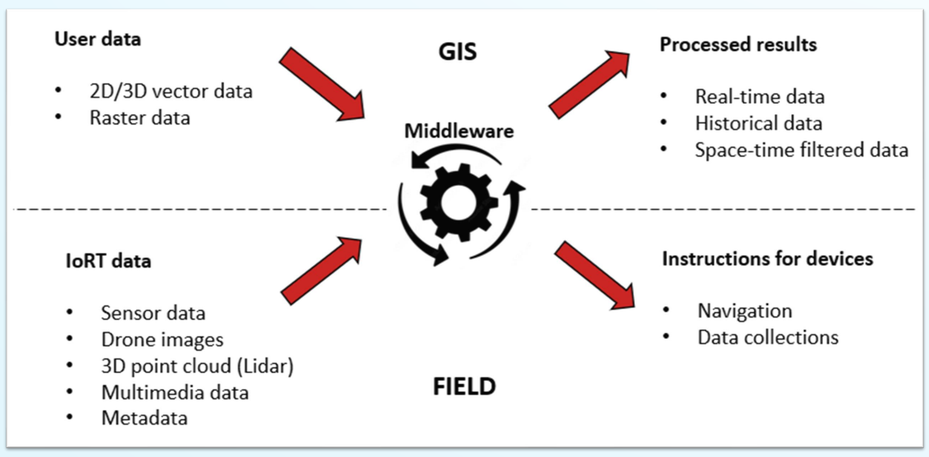
WP1 aims to develop an intermediate software, referred to as the WP1 layer, bridging robotic machinery (Internet of Robotic Things - IoRT) and the GIS4IoRT middleware. **Objectives** are to:

- integrate multi-modal and heterogeneous IoRT data,
- automate detection and cleaning of erroneous data,
- enable real-time robot management and querying,
- provide adequate spatio-temporal data for the GIS layer,
- enhance overall system performance and scalability.

The WP1 layer adopts an agent-based structure, featuring reactive/proactive persistent agents tailored to IoRT requirements. Its output will be compatible with GIS4IoRT middleware data formats and methods from WP2

Middleware and cloud (WP 2)

The middleware integrates **diverse field data** and processes it to respond to **GIS queries**. Some processing tasks are handled directly by the middleware itself, such as spatio-temporal queries. Others are delegated to external Web Processing Services (WPS), for instance, AI-based object detection within point clouds.

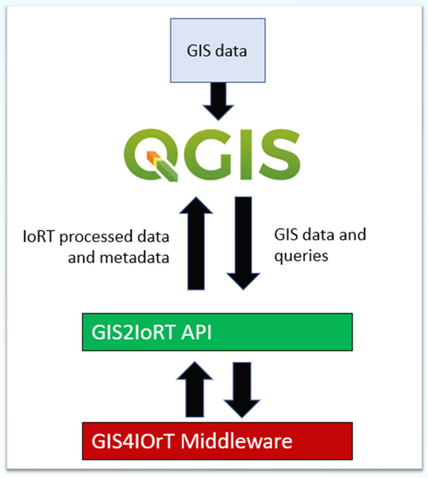


The middleware enhances **cloud performance** by efficiently handling

- joins in disaggregated databases,
- leveraging ephemeral data caching,
- applying advanced optimization techniques.

These mechanisms reduce query latency, improve data retrieval efficiency, and ensure scalable processing for GIS user requests.

GIS integration (WP 3)



The **objective** of this WP is to guarantee the interoperability of the middleware with GIS tools. To do so, we intend to connect to GIS standards and develop GIS client interfaces as proof of concept. The WP includes

- a complete state of the art of relevant GIS standards for IoRT which will be implemented both in server and client side.
- an open and documented API to allow developers to connect applications to the middleware
- an open source extension for QGIS.

The **QGIS** interface will allow users to send spatio-temporal queries to the middleware without coding.

Example of relevant **GIS standards**:

- **OGC**: Sensor Observation Service, SensorThings API, Moving Objects, Maps, Features, Processes, CityGML
- **ISO**: 19115 (metadata), 19157 (data quality), 19110 (data catalog)

Agriculture case study and validation (WP 4)

Monitoring and scheduling autonomous agricultural data mobilizes different types of IoRT data that must be integrated, queried and processed to identify the behaviors of the robots in the field. In this WP, we will validate the proposals of the project.

Agroecological IoRT-based **applications require**:

- the use of complex spatio-temporal data (e.g., robot trajectories, time-stamped meteorological data);
- the use of stream data (e.g., from sensors deployed in fields), multimedia data (e.g., video, images)
- historical data (e.g., warehoused data on all the aspects of an IoRT system),
- contextual data representing the robots environment (such as cartographic data in 2D, building data as 3D data, etc.).

Based on these various data, the GIS client will be able to ask **spatio-temporal queries** to the middleware. For example:

- Which parcels have been traveled by robots where humidity > x?
- Update drone trajectory to avoid buildings and trees

This specific case study will help to formalize specifications about generic data standards, communication protocols and IoRT queries that could be used by other applications involving IoRT (urban digital twins, natural disaster management, etc).

Expected outcomes

GIS: The GIS4IORT project aims to advance the integration of real-time Internet of Robotic Things (IoRT) data into Geographic Information Systems (GIS).

Agriculture domain

- Enhanced spatial analysis and decision support
- Improved resource management
- Increased operational efficiency
- Promotion of environmental sustainability

Transferability: The solution will be adaptable to other domains, including

- Urban digital twins
- Environmental monitoring

Partners

Funder	Country	Institution	Investigator(s)	WP leader
FNRS	Belgium	ULiege	Roland Billen, Jean-Paul Kasprzyk	Project coordinator, WP3
/	Belgium	ULB	Dimitris Sacharidis	
ANR	France	INRAE	Sandro Bimonte	WP 4
ANR	France	UNIVREN	Laurent D'Orazio	WP 2
NCN	Poland	PUT	Robert Wrembel, Piotr Skrzypczynski	WP 1