System Integration of Multi-Modal Sensor for Robotic Inspection of Power Lines

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Discussion

- Challenges of Power Line Inspection
- Limitations of Standard Methods
- The LaRa Robot
- Global localization of multi-modal inspection
- Object Classification and Recognition
- Results and Discussion
- Conclusion and Future Work

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Challenges of Power Line Inspection

- **High Safety Risks:** Significant danger from high-voltage electricity
- **High Costs & Time:** Labor-intensive, requiring specialized personnel and equipment; extensive travel time
- **Accessibility Challenges:** Difficult access to remote locations, especially in harsh weather
- **Inspection Inconsistency:** Human error and fatigue lead to unreliable reports
- **Environmental Impact:** Helicopter inspections can cause noise and emissions

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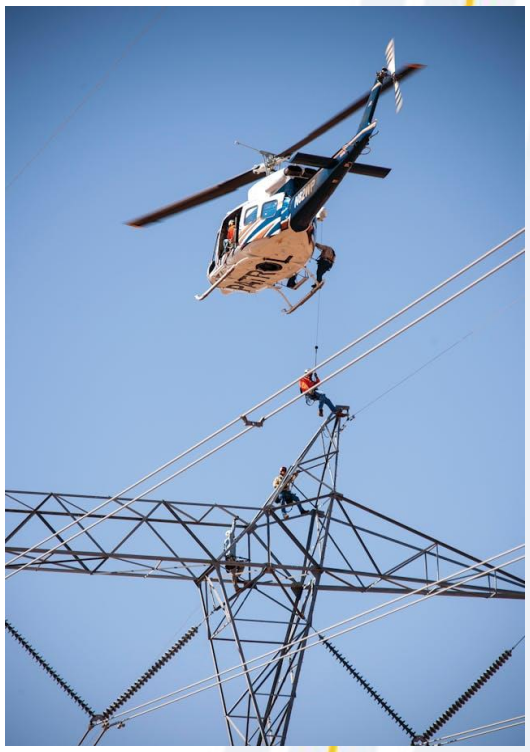
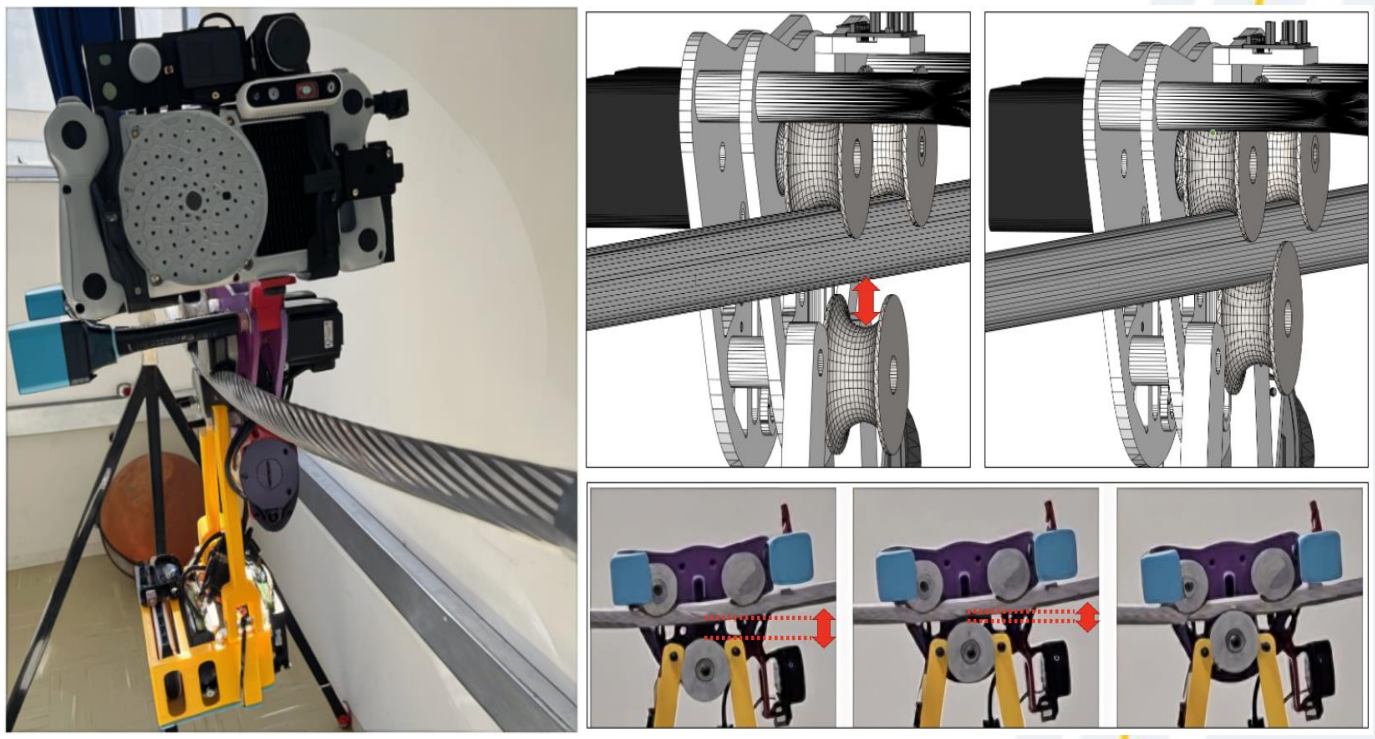
Limitations of Standard Methods

- **Ground Visual Inspection:** Extremely dangerous, time-consuming, limited access, subjective assessments
- **Drone Inspection:** Weather dependent, limited payload and range, potential signal issues
- **Helicopter Inspection:** Very expensive, weather dependent, noisy, and still involves safety risks



The LaRa Robot

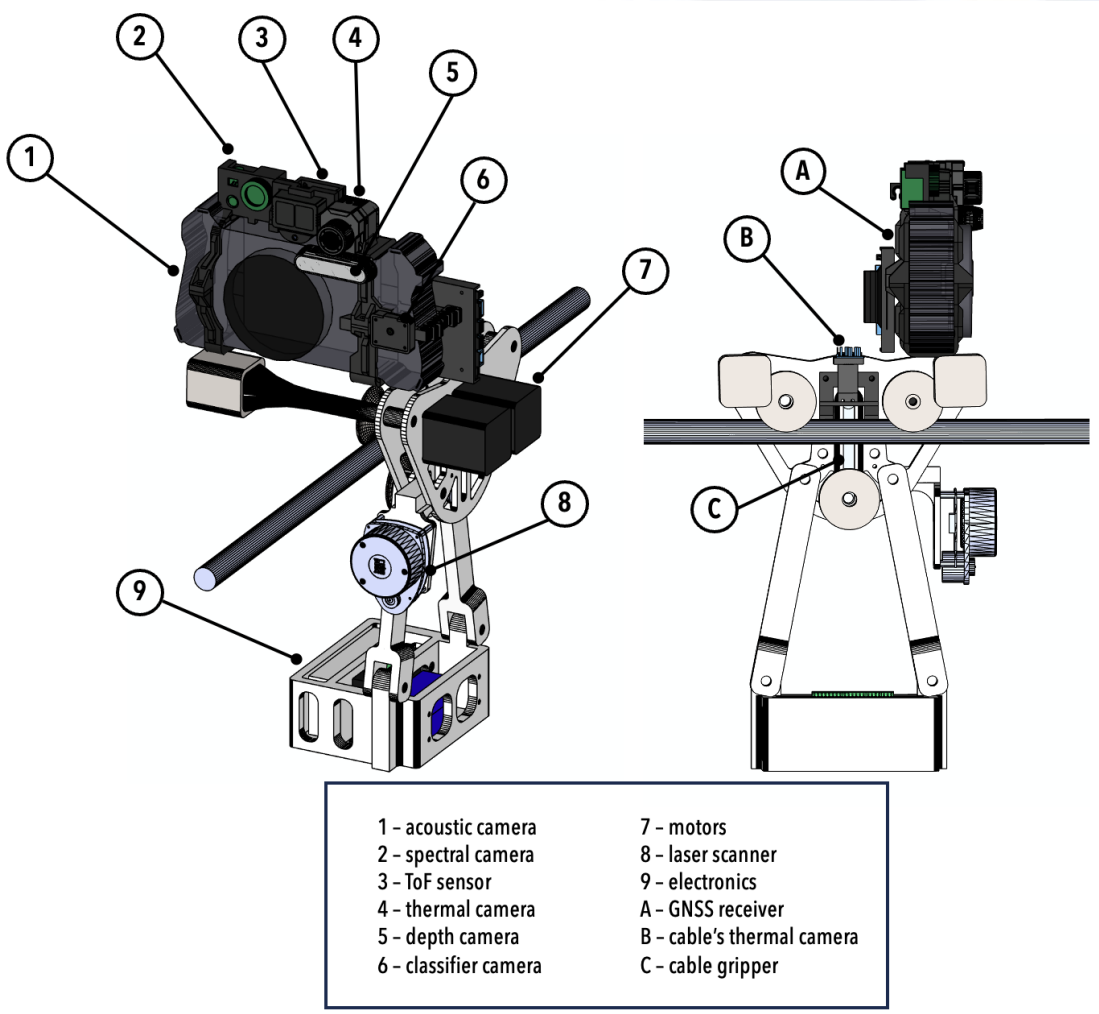
- Developed to autonomous power line navigation
- Aims to ensure the secure cable gripping
- Equipped with Multimodal sensor integration to predictive inspection



The LaRa Robot

Control and Sensing

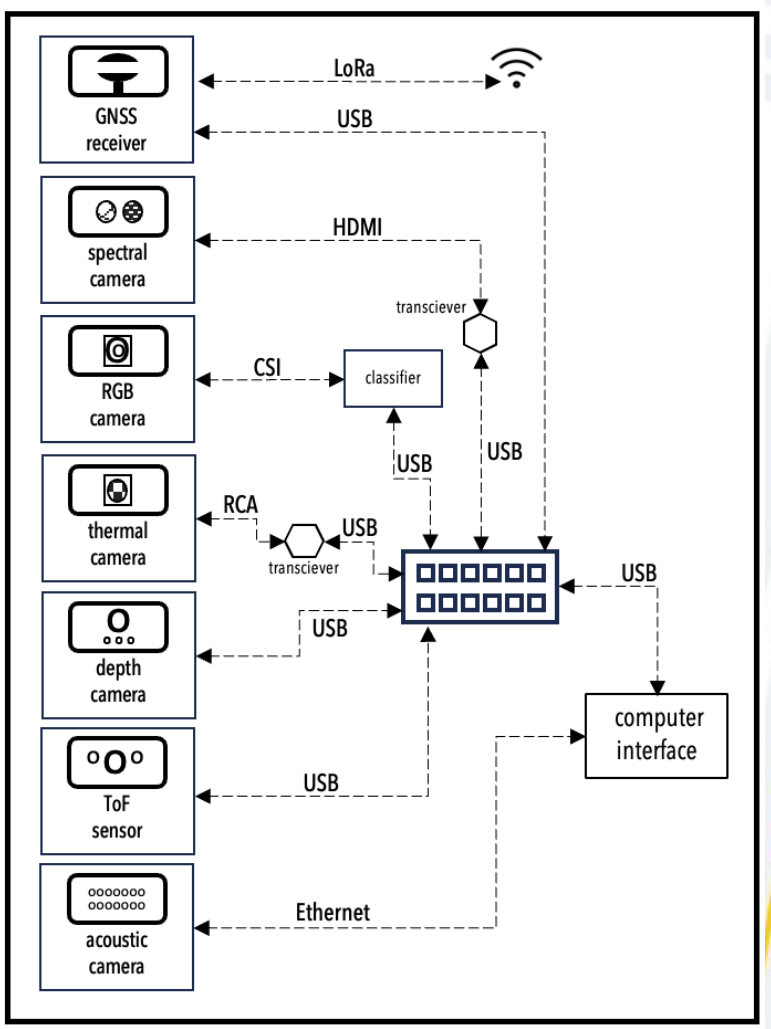
- **Independent Sensor Data Acquisition:** Each sensor (acoustic, spectral, ToF, thermal, depth, classifier, LiDAR) collects specific data
- **Data Fusion:** Sensor data is combined for a comprehensive assessment
- **Control System Coordination:** Fused data drives the robot locomotion, sensor positioning, and data logging
- **Data Transmission:** Processed information is sent for remote analysis and reporting



The LaRa Robot

Sensor Integration

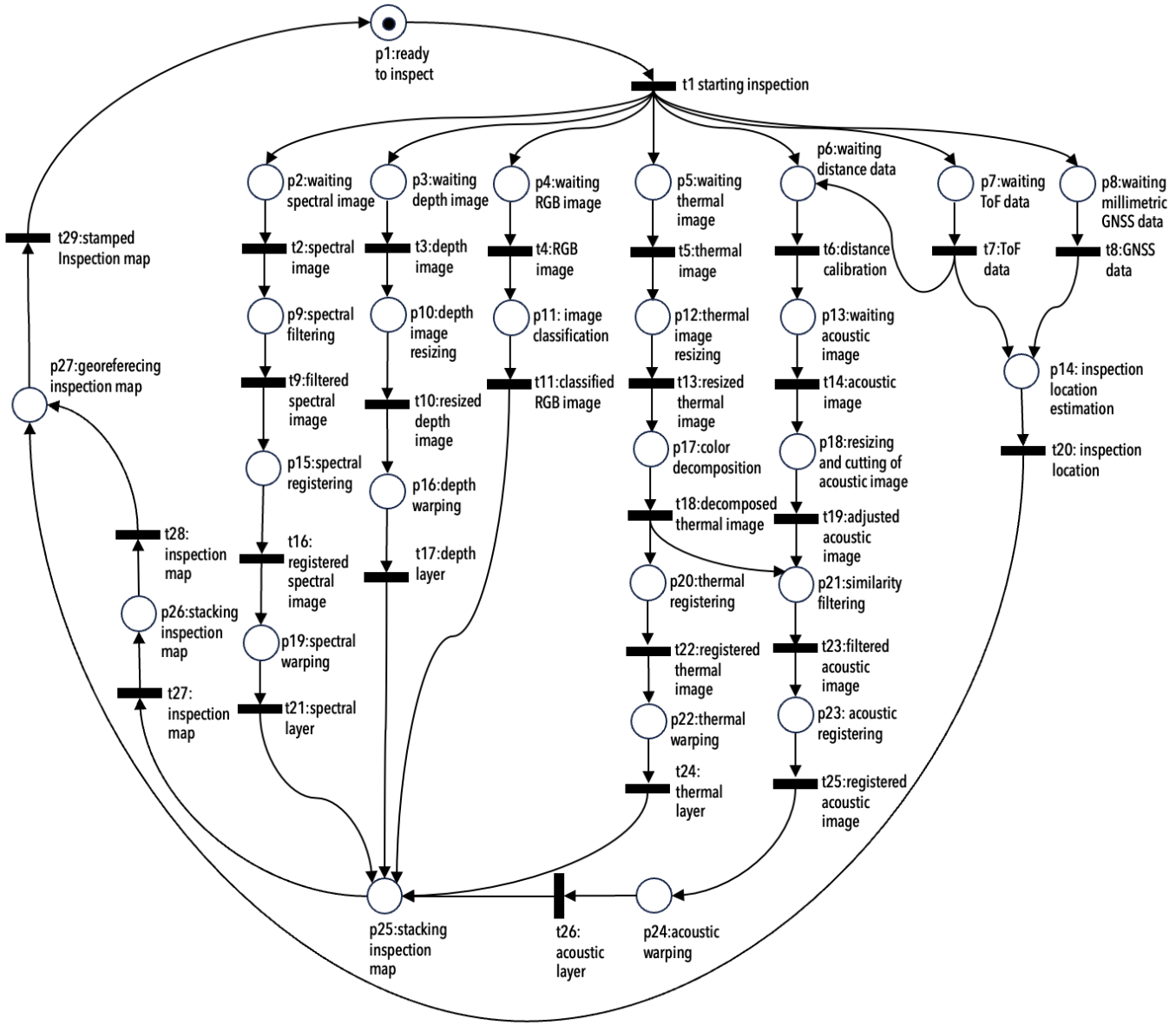
- Several sensors to collect data related to different aspects of the transmission line (thermal, visual, spatial, acoustic, spectral, location).
- Each sensor uses a specific interface to transmit its data to the processing unit.
- The GPU classifier handles real-time image processing, while other data might be processed by the computer interface.



The LaRa Robot

Sensor Logic Integration

1. Data acquisition begins in multiple sensors
2. Data is pre-processed and formatted The system combines and filters data to form a stacked inspection map
3. Georeferencing to ensure data is mapped into coordinates.
4. Output of detailed inspection maps of the location.



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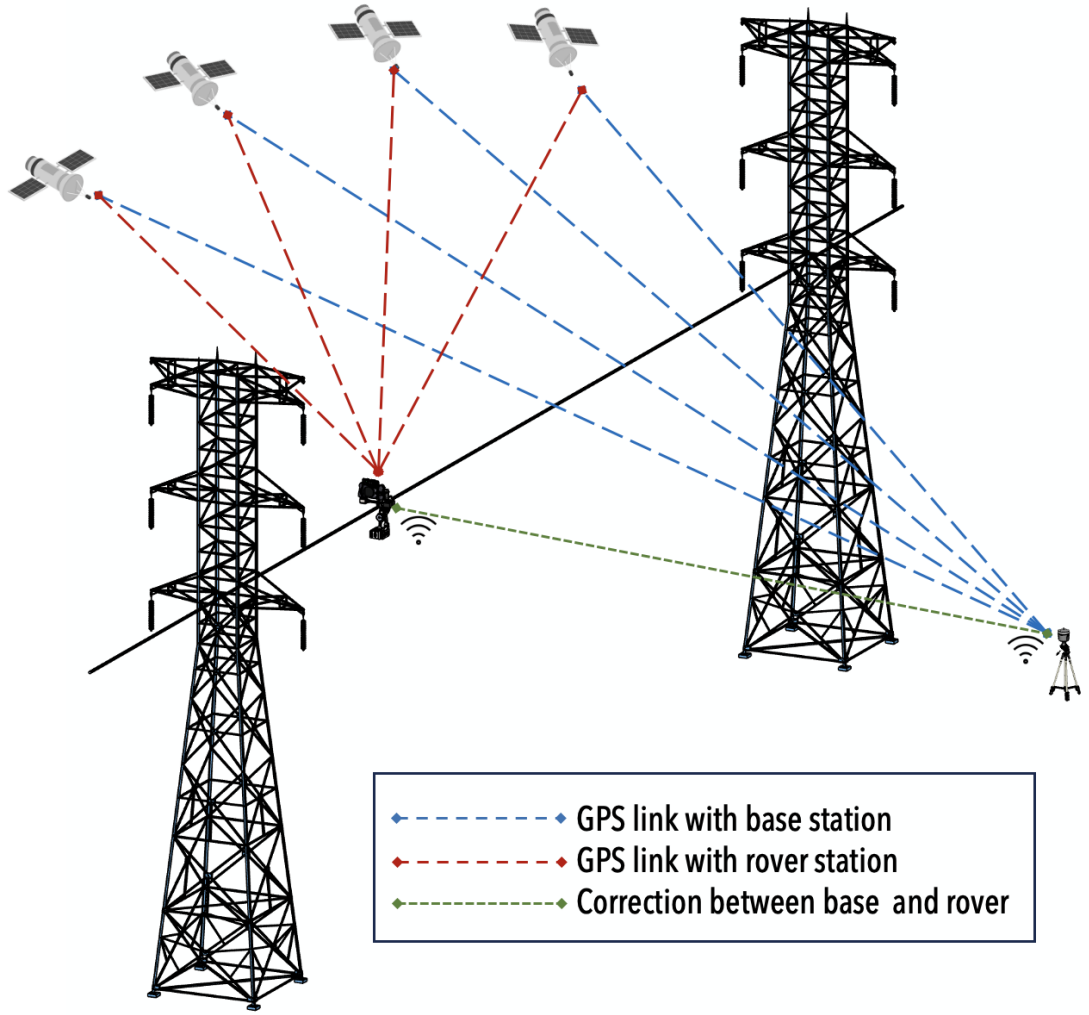
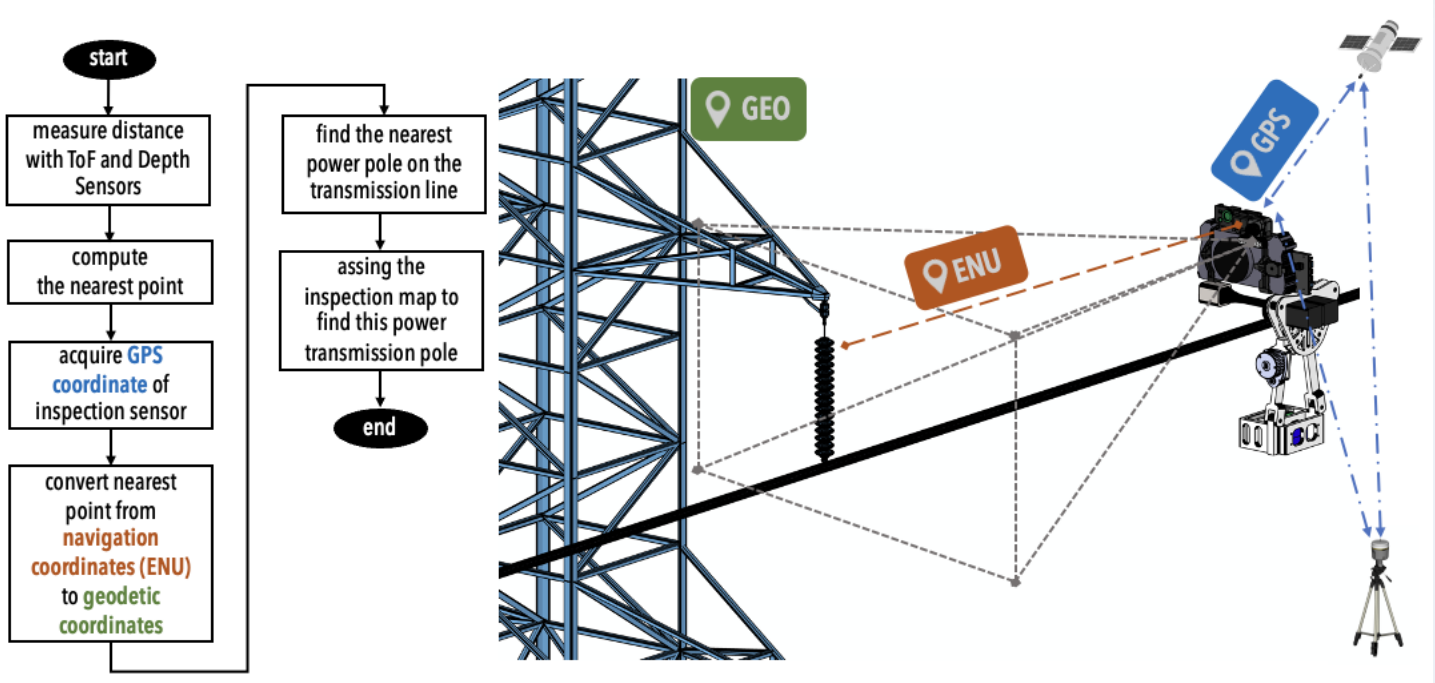
Global localization of multi-modal inspection

- RTK GNSS ensures accurate positioning of the sensor system on the transmission line
- Precise location data is crucial for correlating sensor data with specific elements and predicting behavior
- The base station calculates corrections for atmospheric conditions, satellite orbit inaccuracies, and other errors
- Corrections are transmitted to the LaRa robot via a communication link (LoRa)



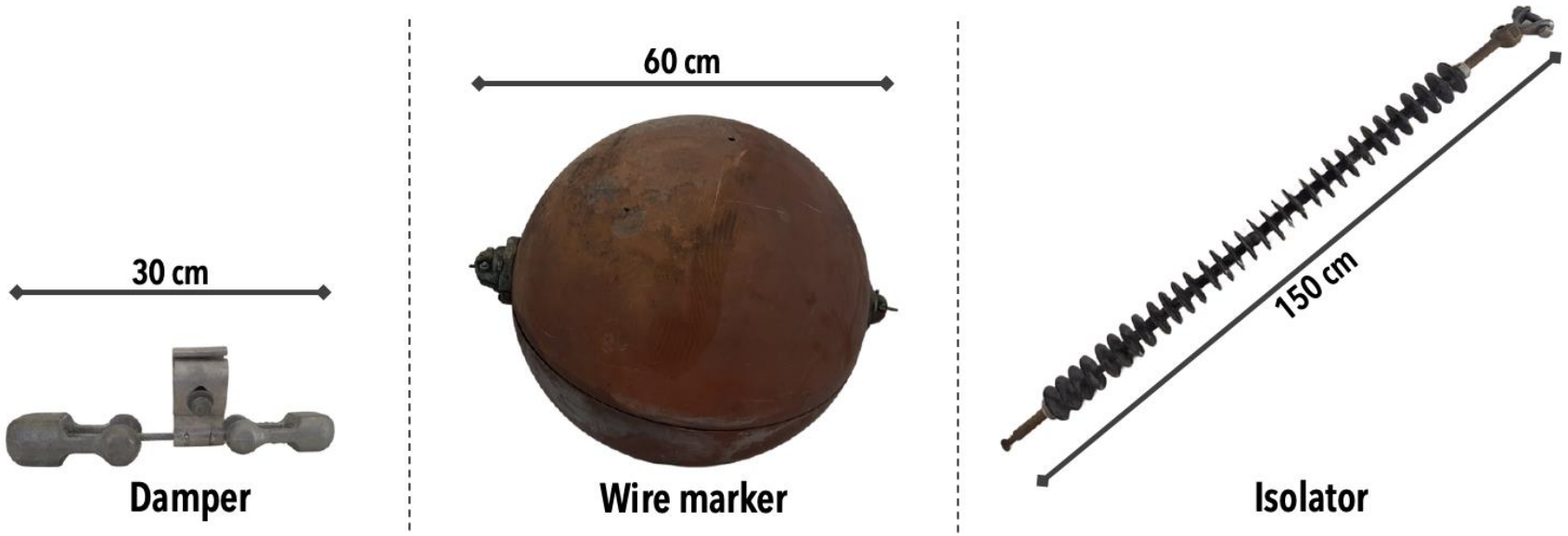
Global localization of multi-modal inspection

- Geodetic coordinates (latitude, longitude, altitude) must be converted to navigation coordinates to correlate its local spatial perception



Object Classification and Recognition

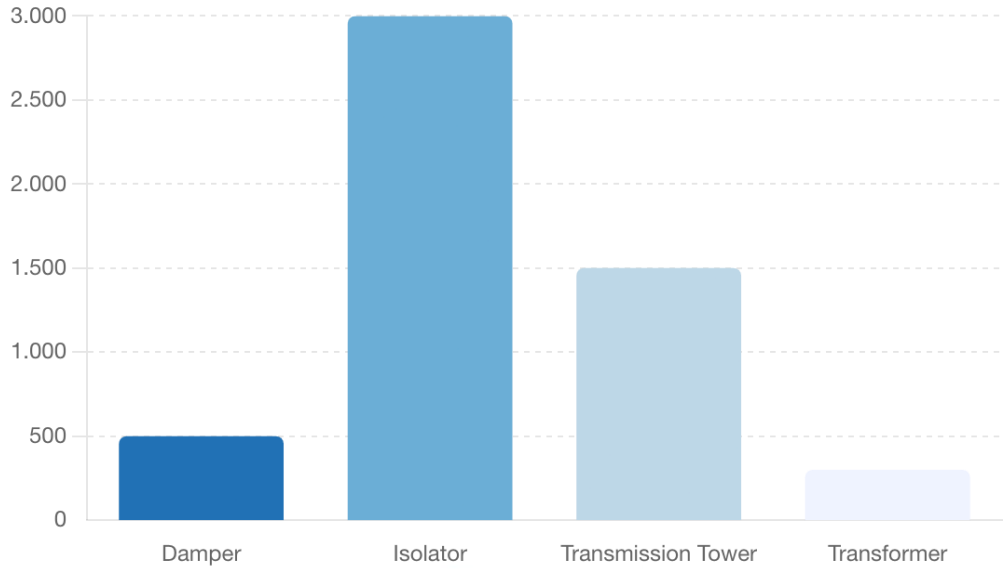
- Aims to detect the key elements (such as insulators, transmission towers, and dampers)
- We use the YOLOv8 over NVIDIA Jetson Nano with aspberry Pi V2 câmera on CSI interface to acquire images

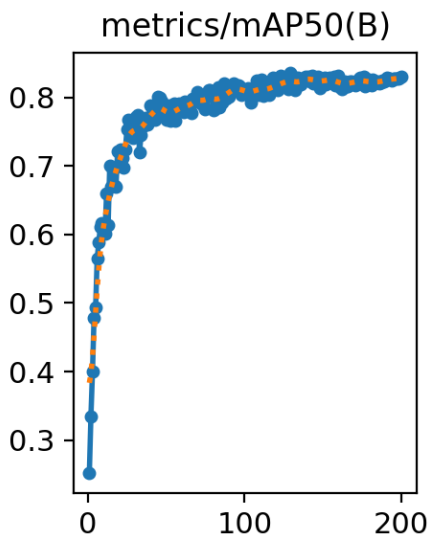


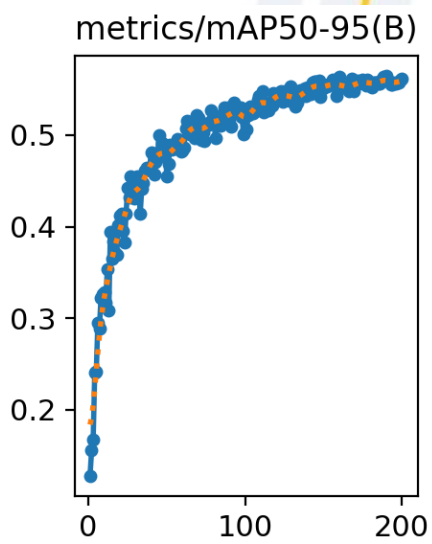
Object Classification and Recognition

- YOLOv8 neural network is applied to the real-time detection of elements, chosen for their high reliability and ease of application

- The training and evaluation of the YOLOv8 model highlighted potential accuracy variations based on the class representation







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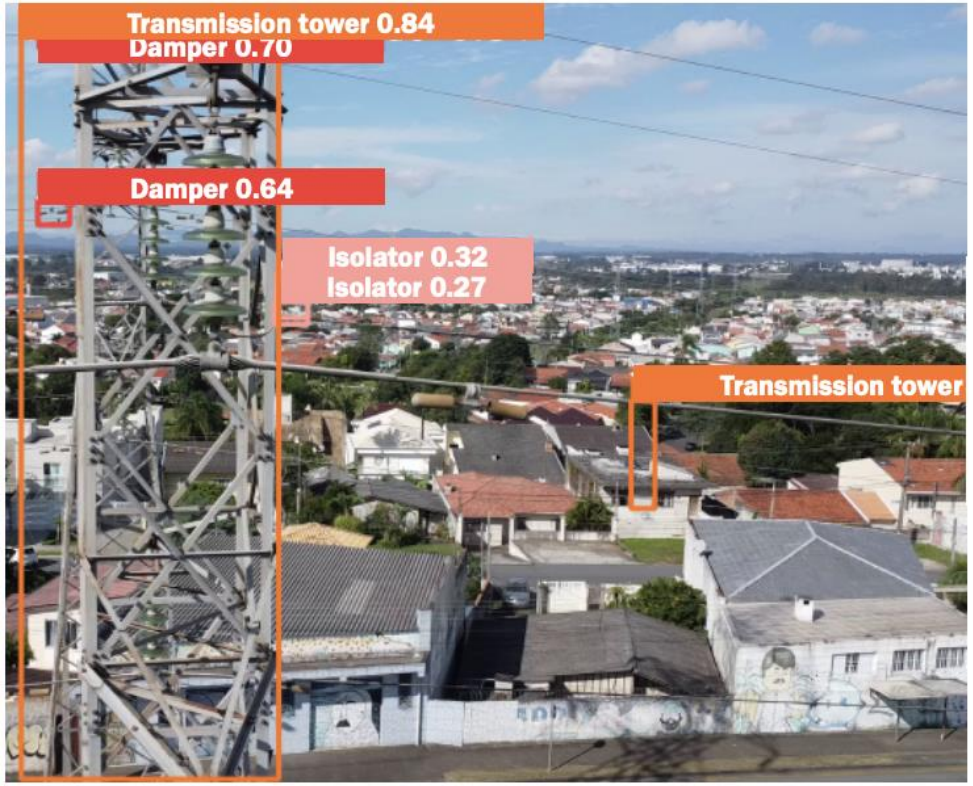
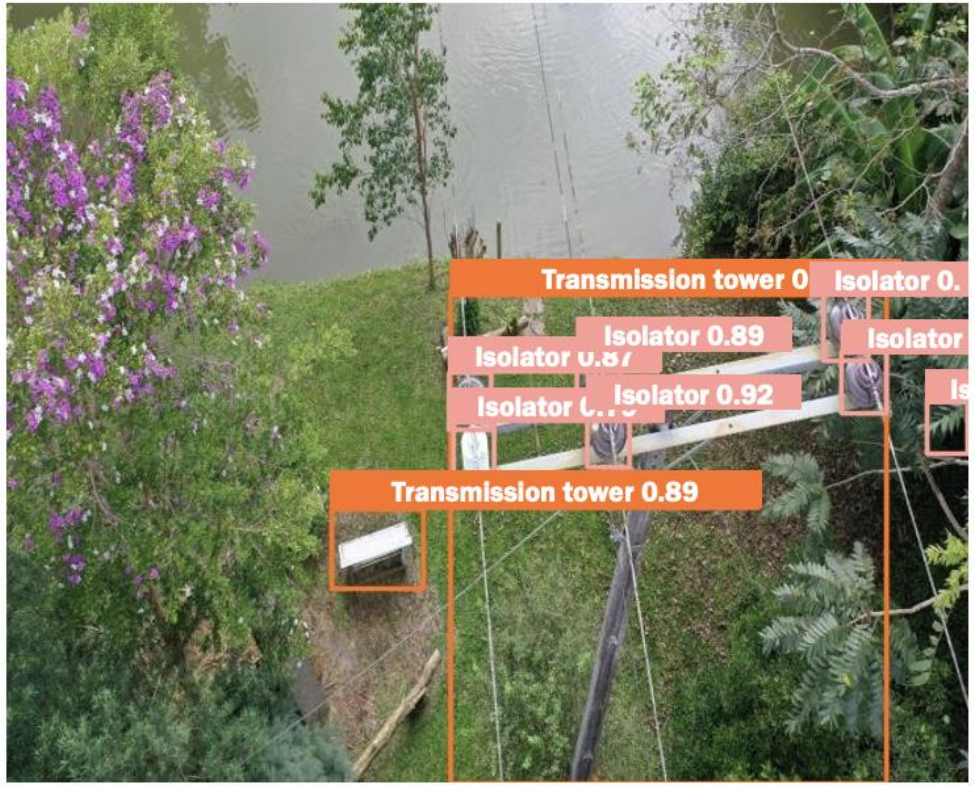
Results and Discussion





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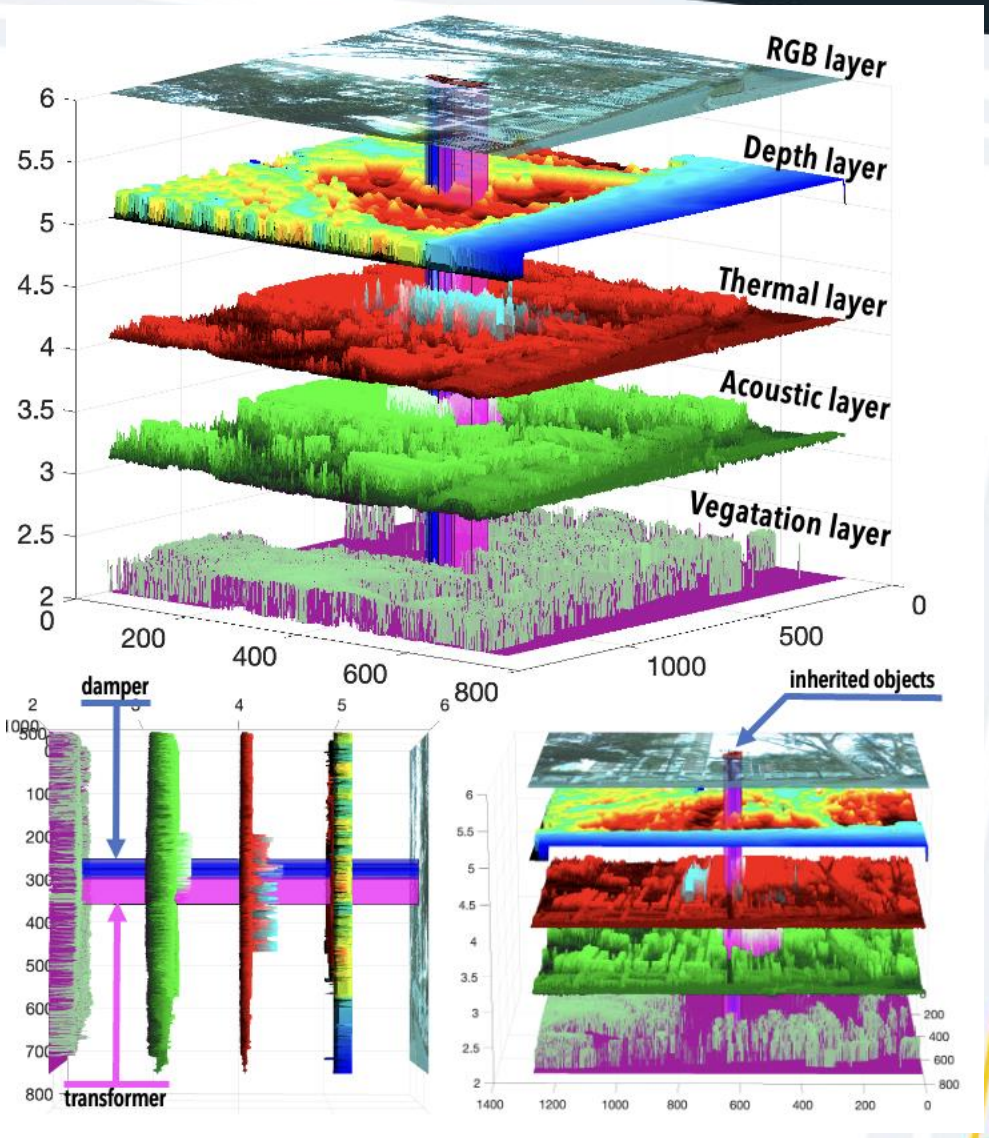
Results and Discussion

- Multi-modal inspection is consolidated into a multi-layer inspection map with global referencing
- Each layer of the map represents a distinct spectrum of analysis for the transmission line elements
- Information about classified element from RGB Layer is inherited by all other layers



Conclusion and Future Work

Conclusion

- Multispectral sensor ensures precise localization with centimeter-level accuracy that is crucial for correlating data from different inspections over recognized objects in the RGB layer

Future work

- Expand the classification to more elements
- Fuse this information with other perception sources

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Thanks!

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