

A Tracked Robot for Proximal Ecological Sensing in Coastal Dune

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Motivation & Objective

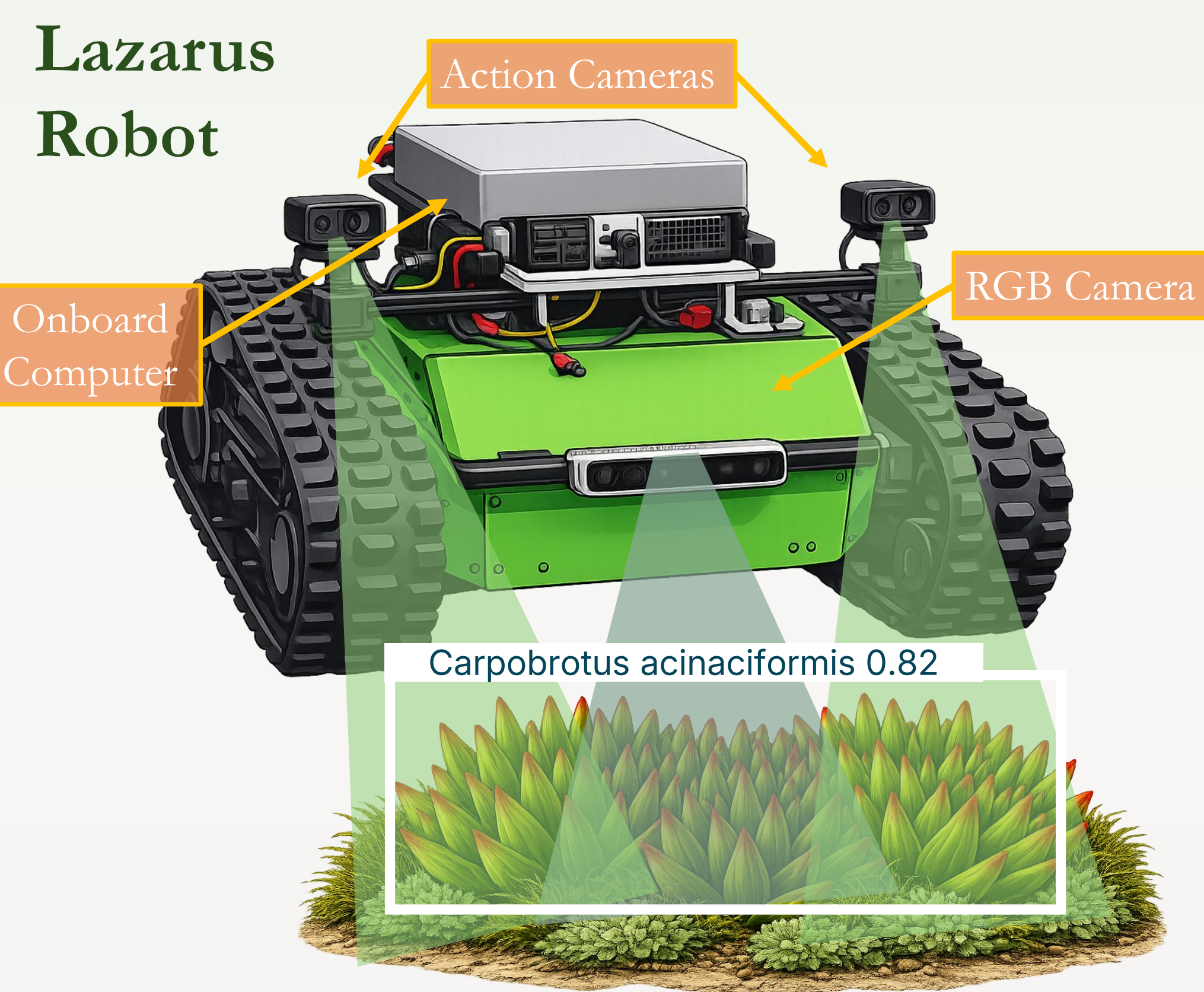
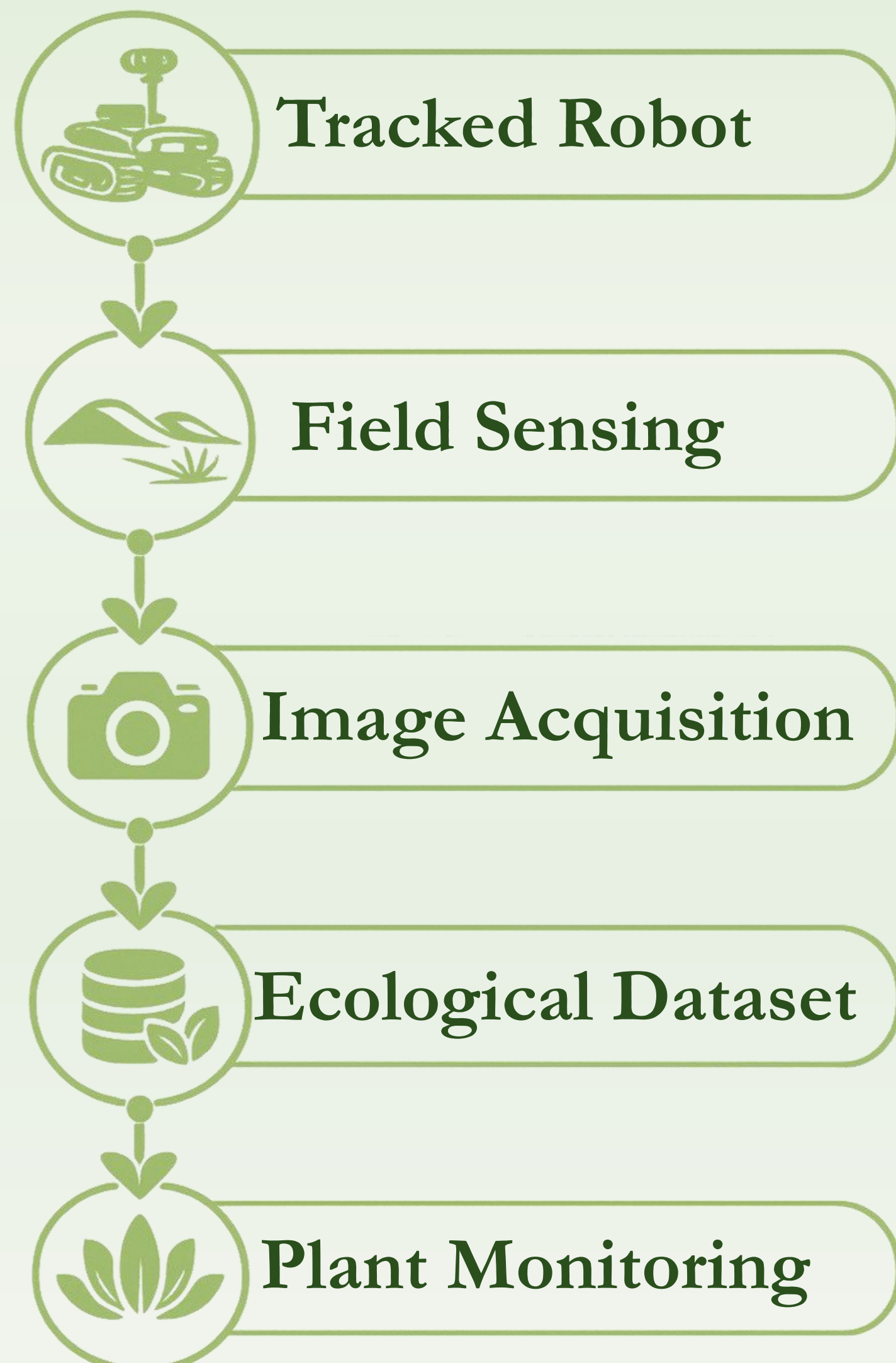
Coastal dune ecosystems require regular monitoring to support conservation and detect invasive vegetation. However, species such as *Carpobrotus acinaciformis* grow close to the ground and spread horizontally, making them difficult to identify reliably from aerial viewpoints, especially when partially occluded by surrounding vegetation.

We investigate a tracked ground robot for **ecological sensing** in coastal dunes, aiming to:

- enable **close-range observation** of invasive vegetation in dune habitats
- show that **ground-level sensing complements aerial imagery** for occluded plants



Monitoring Pipeline



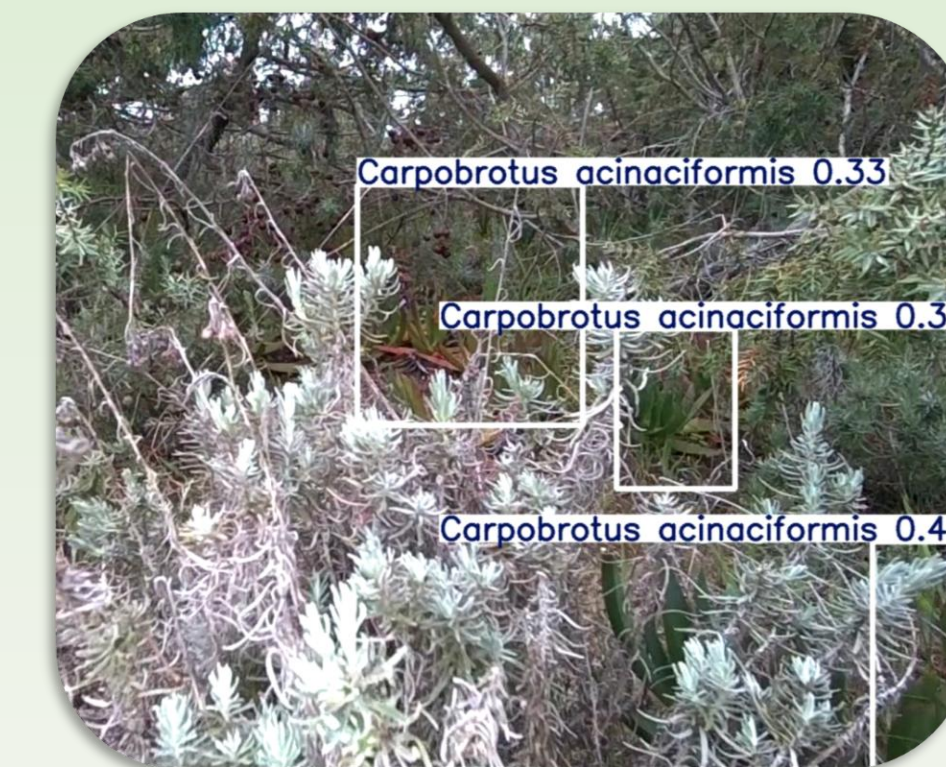
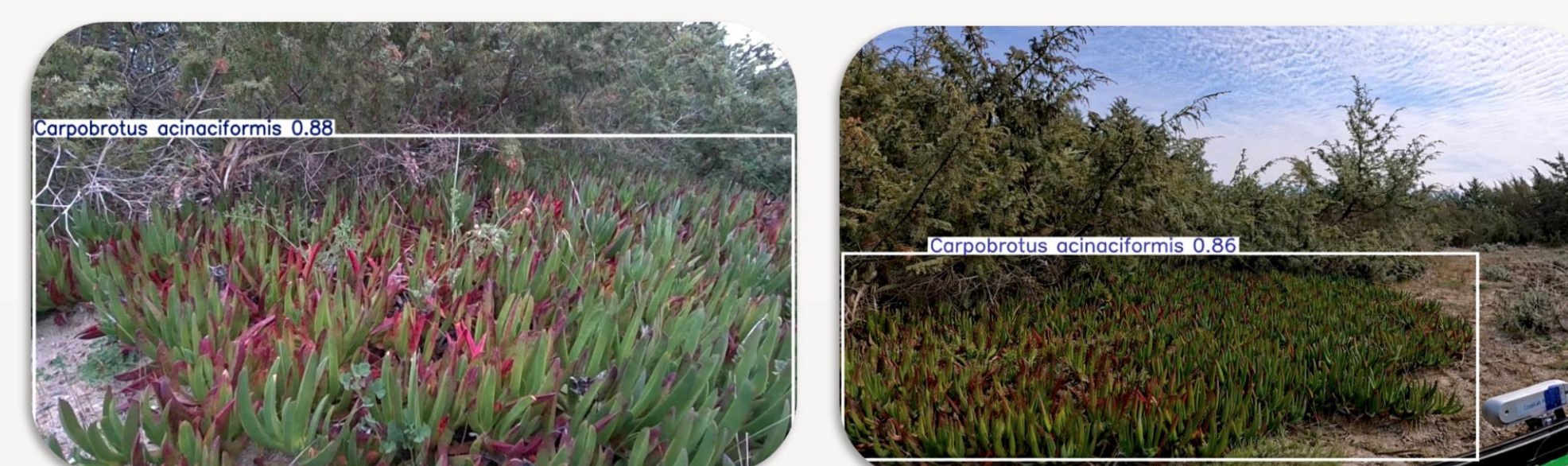
Mobility and Data Acquisition

The robot covered up to **30 m** in **2.5 min**, collecting nearly **10,000** close-range images, about **75%** of which were suitable for analysis. Experiments were carried out near our campus in Navacchio (PI) and on the Marina di Vecchiano (PI) beach.



Vision-Based Analysis

We employed a YOLOv11x **object detection model** trained on a custom dataset developed during the **Nature Intelligence** project^{1,2}, allowing us to perform consistent analysis across images acquired from both RGB and action cameras.



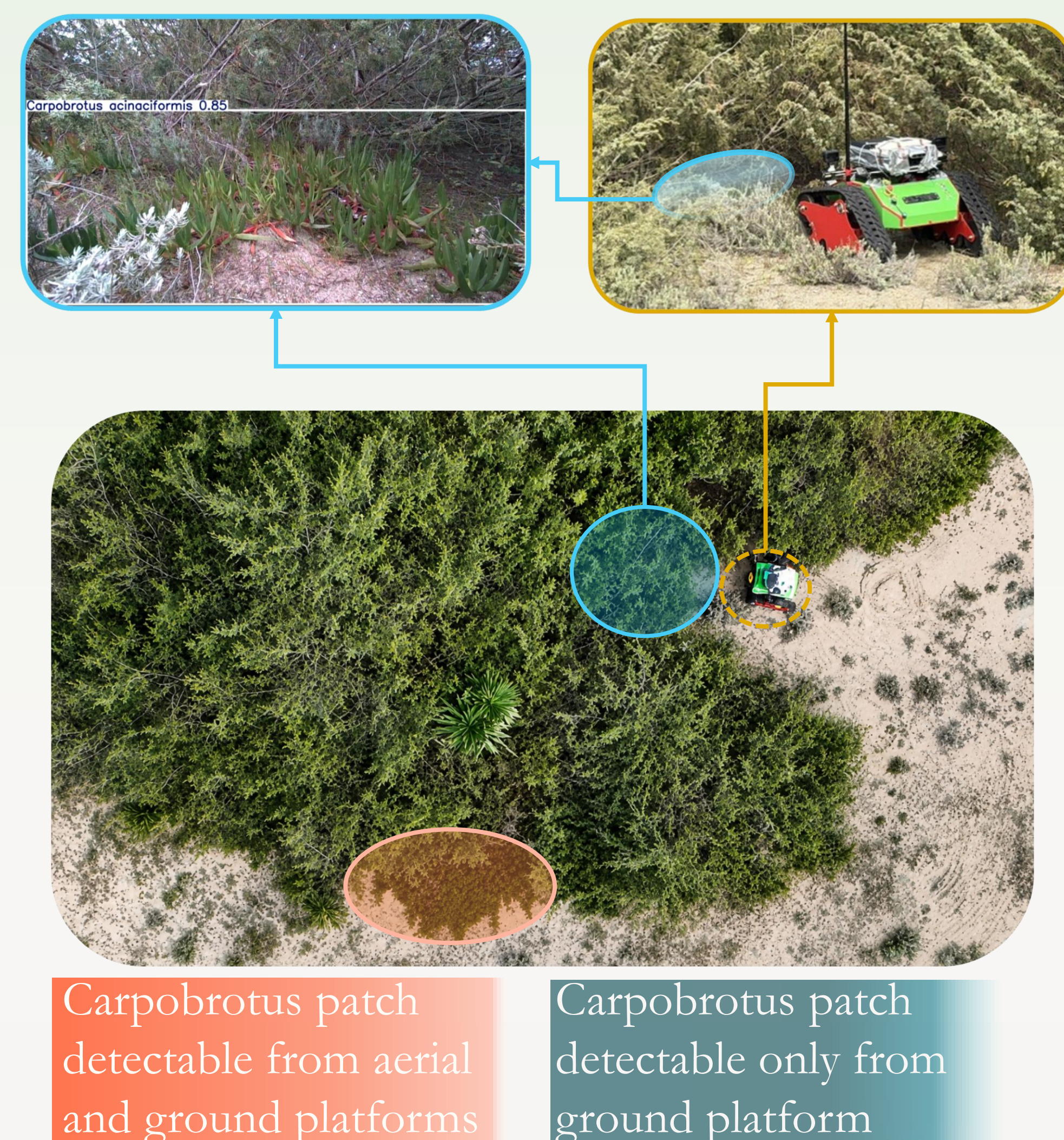
Reliable plant detection even in cluttered backgrounds.

Preliminary Outcomes:

Class	Instances	Precision	Recall
Carpobrotus	317	0.889	0.753

Comparison with Aerial Sensing

Aerial sensing enables efficient large-area coverage, but **low-growing invasive plants can remain undetected** when they are partially occluded by surrounding vegetation, making ground-level observation essential for complete detection.



Conclusion & Future works

- Successful deployment of a tracked robot for **proximal ecological sensing** in coastal dunes.
- Acquisition of **close-range ecological imagery** in fragile, sandy terrain.
- Ground-level sensing revealed **invasive vegetation not fully visible from aerial imagery**.

Future work will focus on **multimodal sensing** and **autonomous invasive plant detection** for habitat monitoring.

References

- [1] Angelini, F et al., "Robotic Monitoring of Habitats: The Natural Intelligence Approach," *IEEE Access*, vol. 11, pp. 72575–72591, 2023.
- [2] Di Lorenzo et al., G., "Robotic monitoring of European habitats: A labeled dataset for plant detection in Annex I habitats of Italy," *Scientific Data*, vol. 12, p. 822, 2025.

