DigiForest

Digital Analytics and Robotics for Sustainable Forestry

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DELIVERABLE 2.4

Demonstration of marsupial deployment and then surveying

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Contents

1 Introduction

This deliverable presents an indicative demonstration of the marsupial legged-aerial robotic system in the context of a mission for forest exploration and mapping. Building upon earlier work in the project, documented in associated deliverables, we demonstrate that we can achieve efficient teamed operation of ground and flying systems for digital forestry.

2 Marsupial System Summary

The marsupial robotic system is a dual-agent platform composed of a quadruped (ANYmal) and an aerial robot (RMF), extending earlier developments from NTNU and ETHZ [2]. The latest development, both in terms of mechatronic configuration and multi-robot autonomy software, is presented in [4].

By integrating the mobility of legged robots with the aerial reach of drones, the setup enables exploration in environments that neither platform could fully cover on its own. This combination is particularly advantageous in forested or uneven terrains, where ground endurance and airborne agility complement each other. Each agent is equipped with lidar and depth cameras, and relies on its own autonomy stack instance based on our graph-based exploration planner (GBPlanner) [1, 3]) which is being improved within DIGIFOREST (new release to take place soon). The planner decides when deploying the drone is beneficial, for instance, when ground-based progress is hindered by terrain. Once airborne, the two agents share information over wifi and pursue parallel mapping and exploration of the target environment. Importantly, the latest open-source version of our planner is available at https://github.com/ntnu-arl/gbplanner_ros/tree/gbplanner3.

A specially designed carrier is installed on the back of the quadruped to transport the aerial robot during ground operation phases. This carrier mechanism can be opened via a single actuator, powered from the quadruped, to release the aerial robot for surveying missions in non-traversable areas.

Figure 1: Deployment of a marsupial mission, including (left to right) the walking phase on easy terrain, the carrier mechanism opening, and the aerial robot being deployed.

During marsupial deployment, the robots share maps based on the work in [4]. The core architecture for map sharing is visualized in Figure 2. The method enables

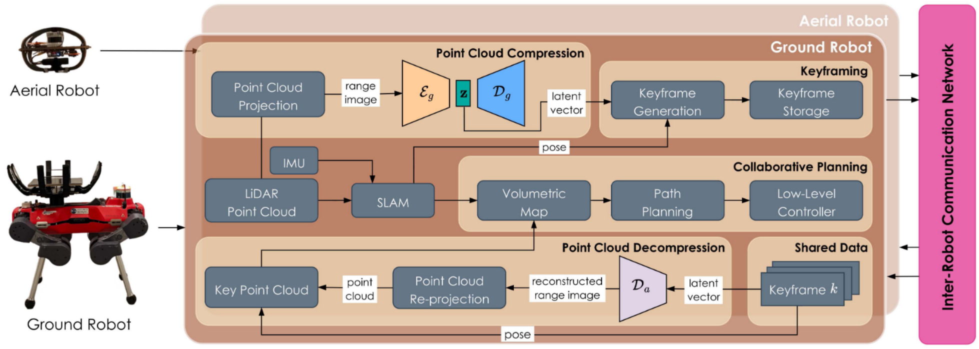

Figure 2: The architecture of the proposed framework for marsupial teamed robot exploration and mapping exploiting neural point cloud compression.

collaborative exploration with bandwidth-efficient map sharing in a marsupial ground-aerial robot system-of-systems. As the ground robot explores while ferrying the aerial robot, it continuously decides whether to deploy the aerial vehicle by comparing their expected exploration gains. During this phase, the legged robot compresses selected point clouds and stores them as keyframes. When the flying robot is then deployed, a subset of these keyframes is transmitted to initialize its volumetric map. Co-localization is also achieved at deployment time. Subsequently, both robots explore in a decentralized manner while simultaneously exchanging keyframes (compressed point clouds) bidirectionally over the communication network. Pointcloud compression is achieved through a purposefully-trained Variational Autoencoder (VAE)-based neural architecture. Based on such a neural network, each robot encodes its own keyframes and decodes those received from the other. After a fixed exploration period, both systems return to the deployment point and conclude the mission

3 Forest Deployment Results

Our team has conducted a set of deployments of the marsupial system including extensive field testing. Figure 3 presents in detail one such indicative mission. Exploiting our multi-robot map sharing and collective exploration path planning solution, the legged robot initializes the mission by walking to explore through iterative planning steps. At an appropriate spot (based on the relative calculation of exploration gains for the systems). The aerial robot is performing its subset of the mapping mission, while the ground system also continues to further explore. Importantly, the systems exchange compressed maps as long as they are in communication range (and ensure to send all maps not shared if they have an intermittent connection). The legged and aerial robot eventually regroup at the deployment point. As demonstrated, the marsupial system presents advanced mapping and surveying capabilities owing to the diverse skills of the ground and aerial systems. It is the flying robot that entered in the most dense area which also involved challenging terrain.

A set of other indicative missions can also be found online through the following video links:

- Early field testing inside a forest in Switzerland: https://youtu.be/CQx_F1t-bEc
- Collaborative marsupial exploration at NTNU's campus: https://youtu.be/CQx_F1t-bEc

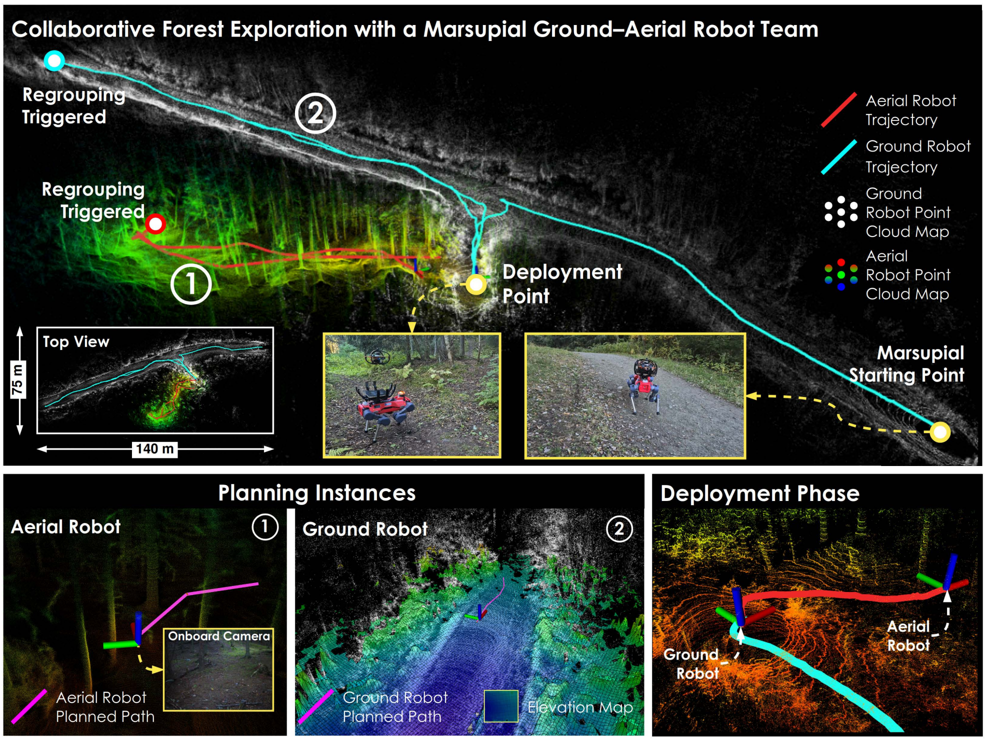

Figure 3: Instances from a mapping mission inside a forest using the marsupial legged-aerial system. The test is conducted in Trondheim, Norway.

- Methodological presentation and representative results linked to our work in [4]: https://youtu.be/VEYS5BjmZP8

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