Iceland Liechtenstein Norway grants

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Introduction to path planning algorithms for adaptive pollution sampling

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Agenda

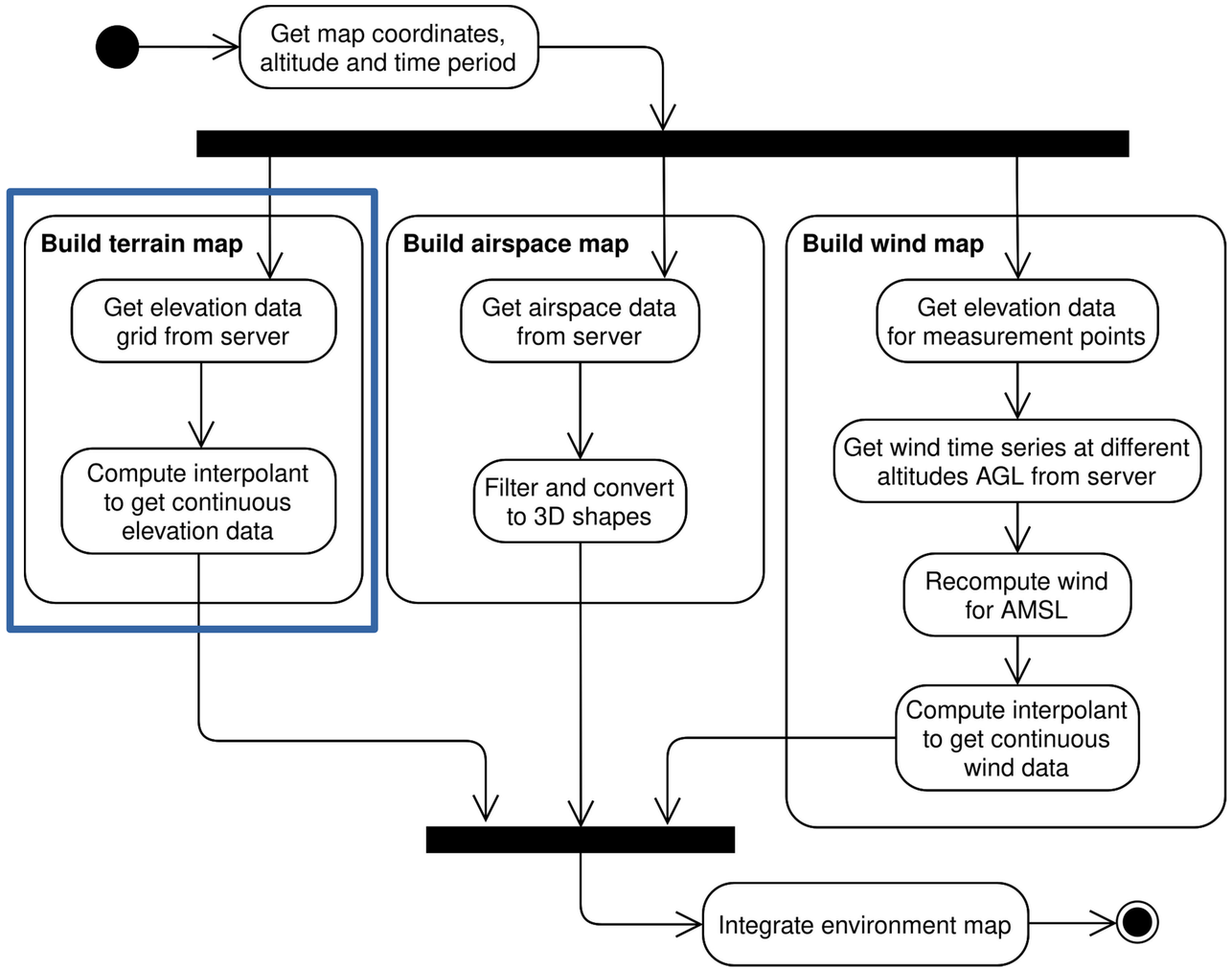
1) The problem
2) Environment modeling
3) Adaptive Path Planning algorithm (APP)
4) Global Path Planner (GPP)
5) Local Path Planner (LPP)
6) Summary & conclusions

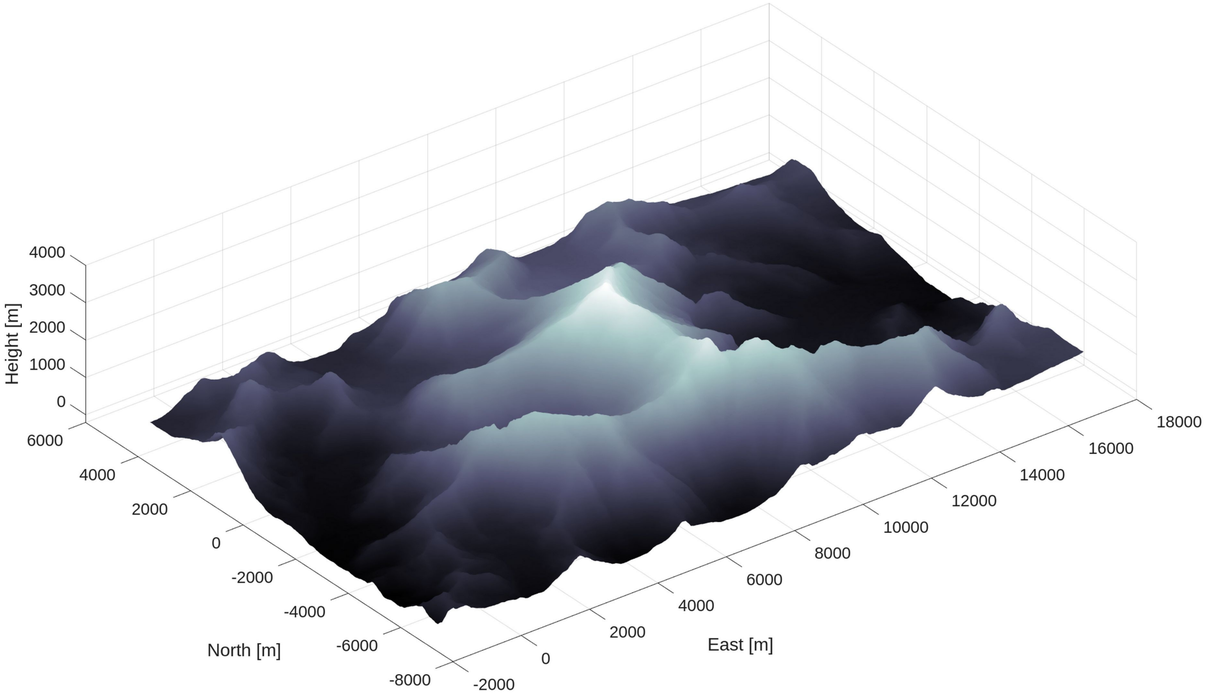
The problem

- Develop a path planning algorithm for autonomous flight & adaptive pollution sampling of a HALE UAV
- Solve a multi-criteria optimization problem of an autonomous flight constrained by the UAV limitations and its environment
- Compare chosen path planning & optimization algorithms
- Verify the path planner in simulation*
- Integrate the planner with the UAV and the ground control station

* addressed in another presentation

Environment modeling





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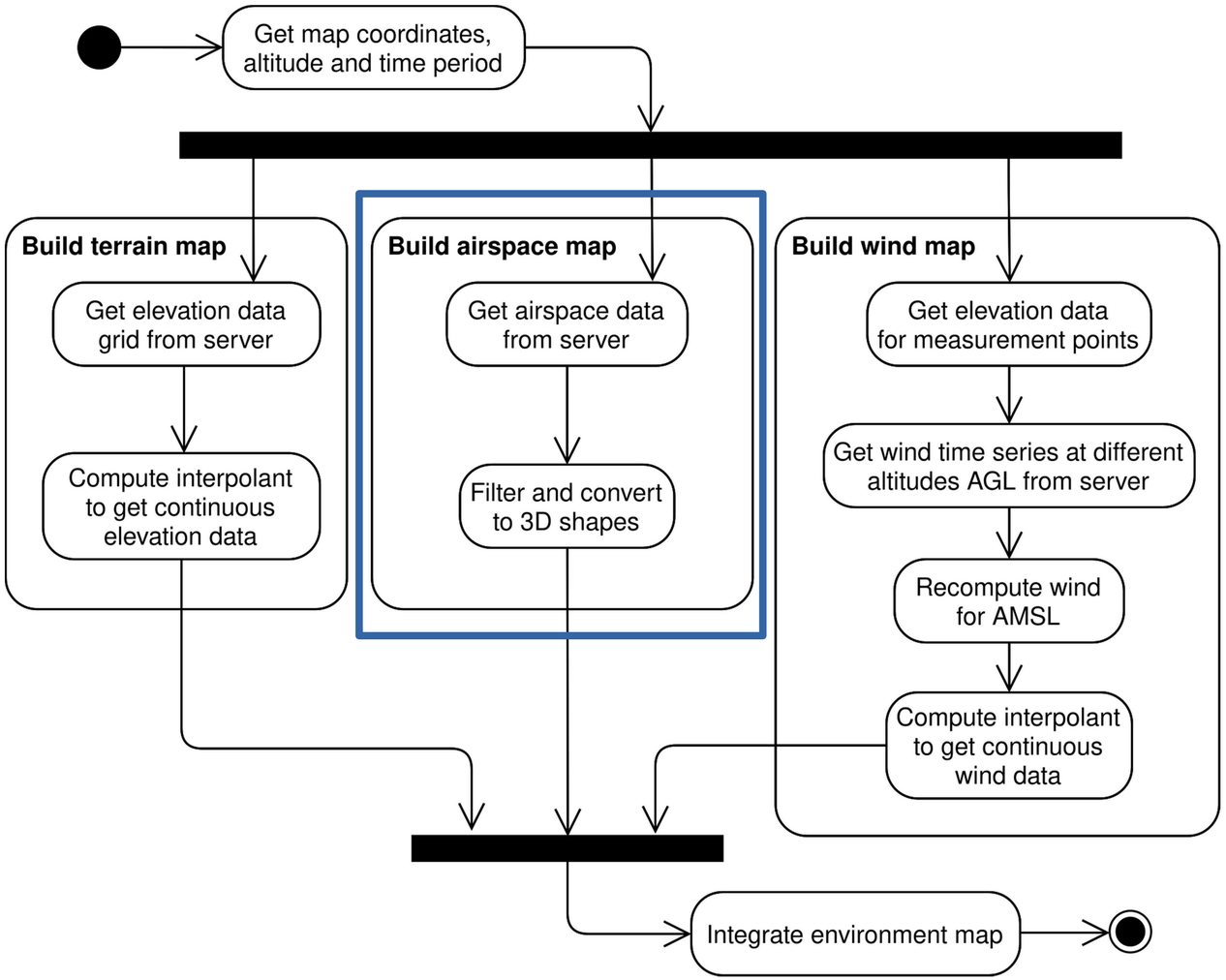

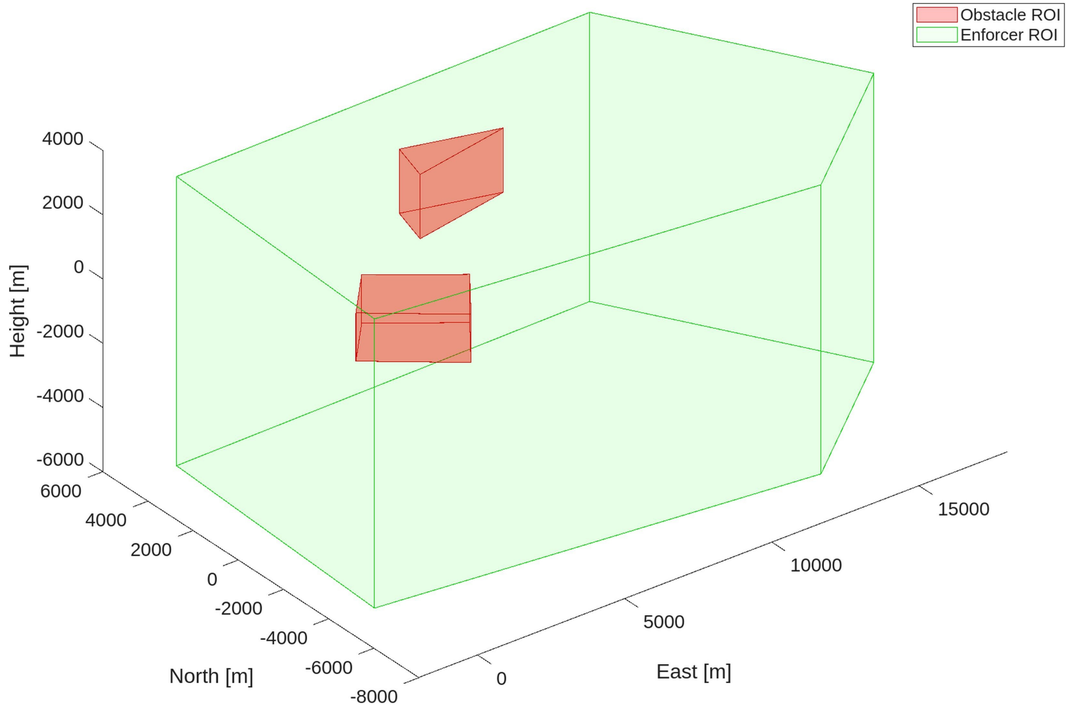

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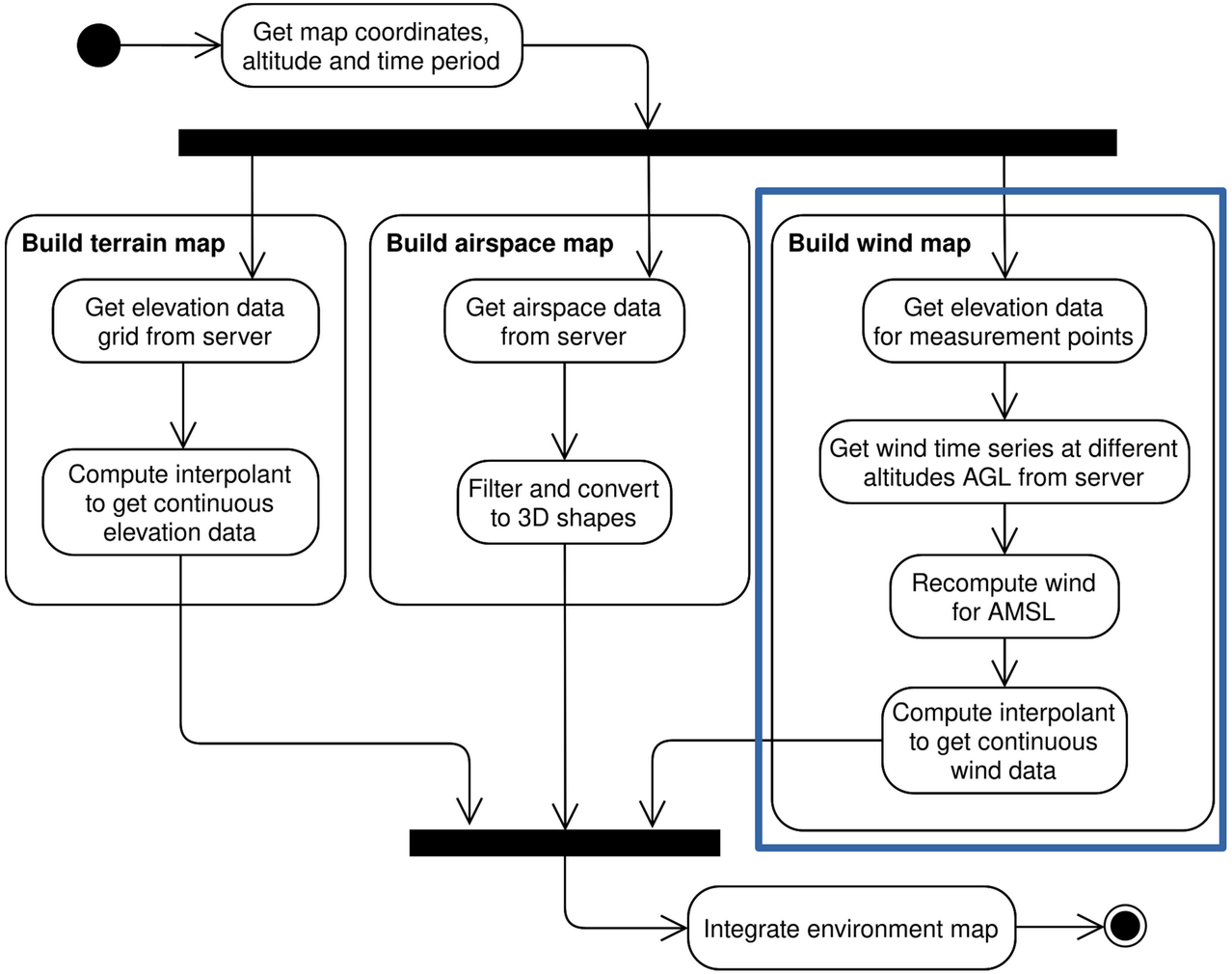

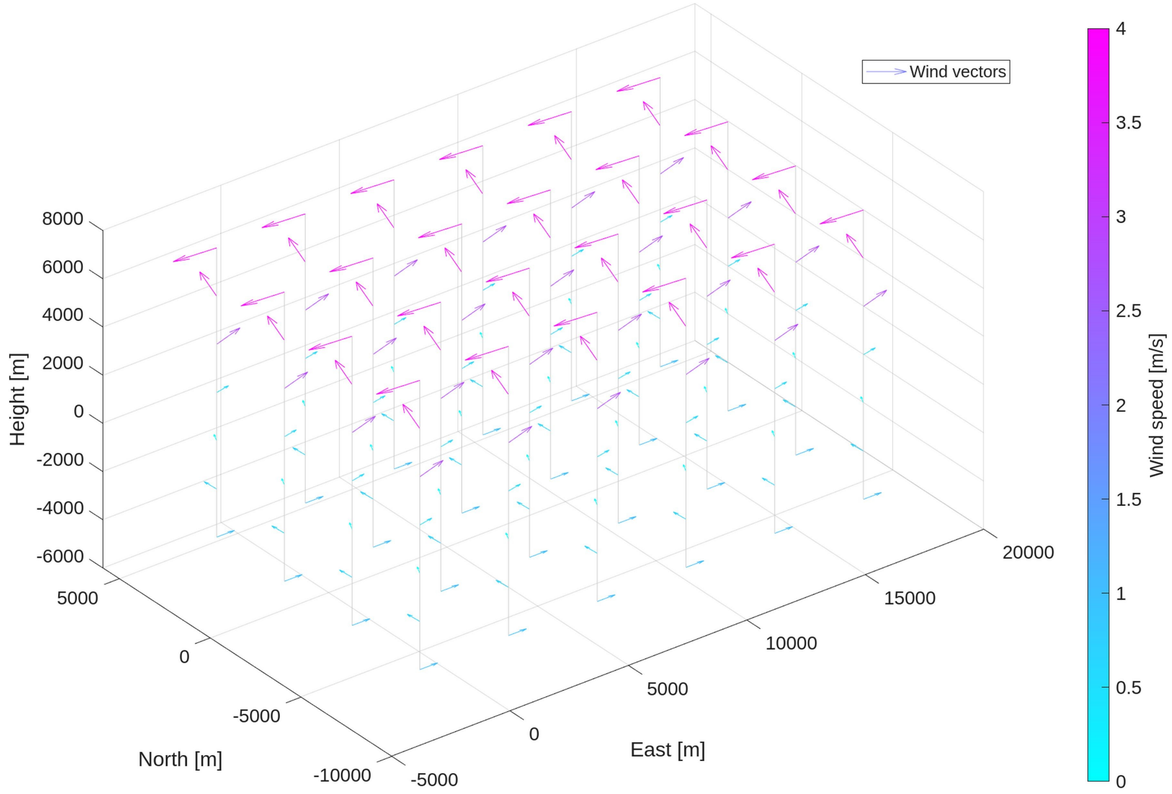

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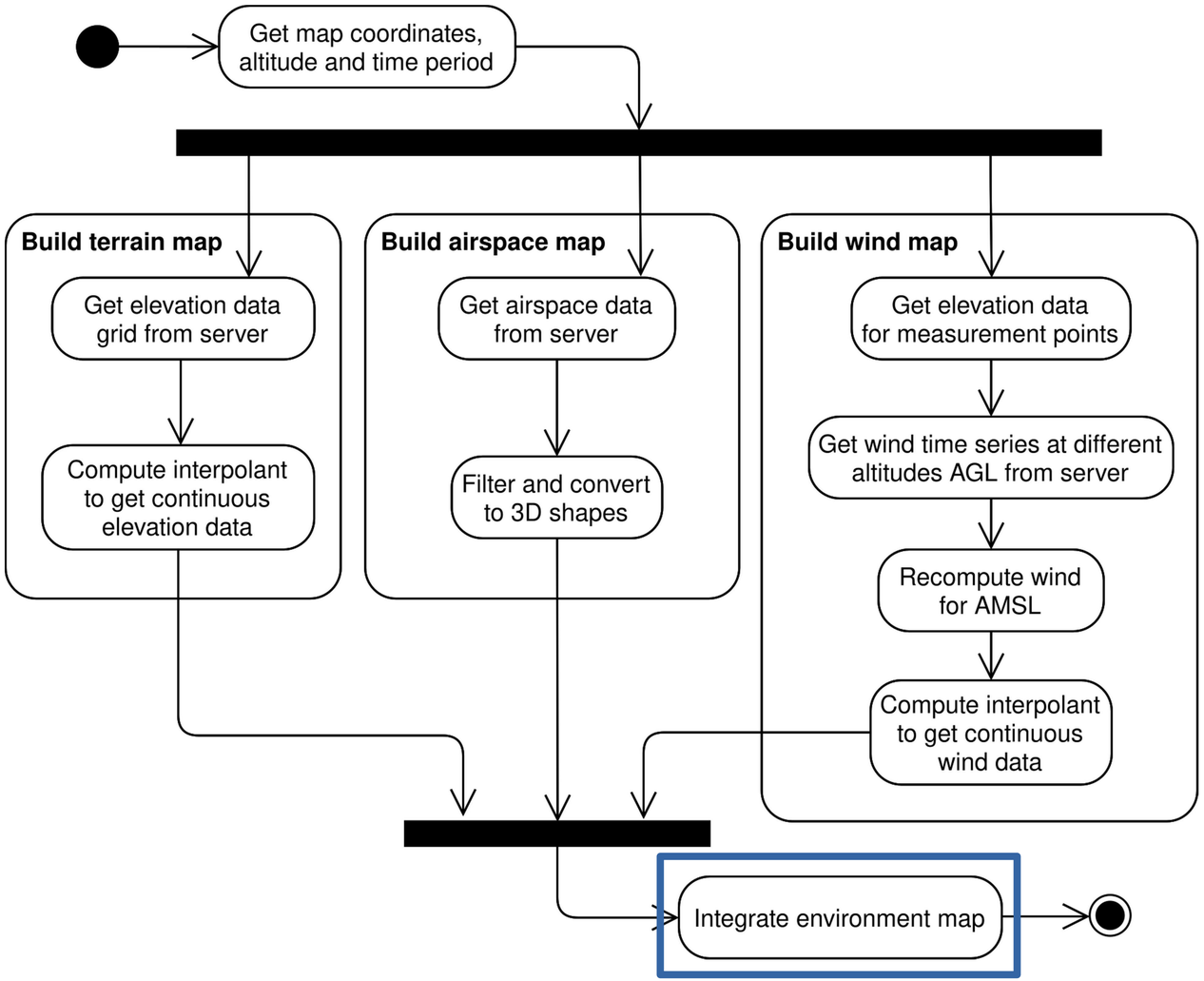
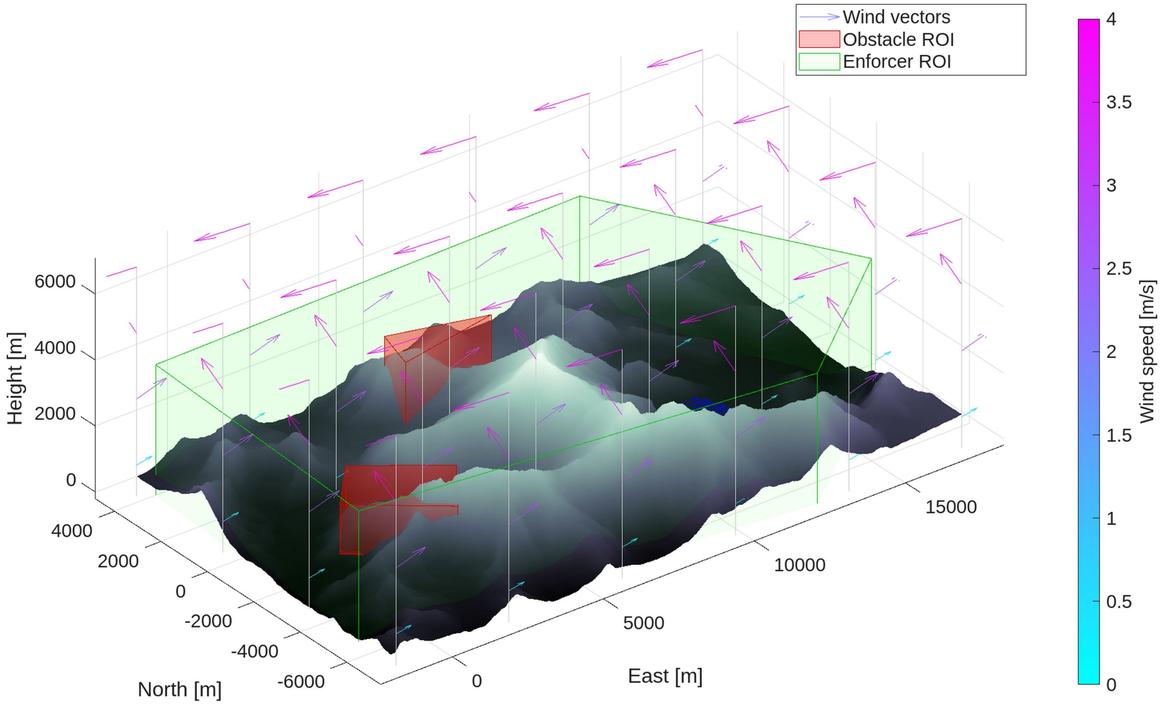
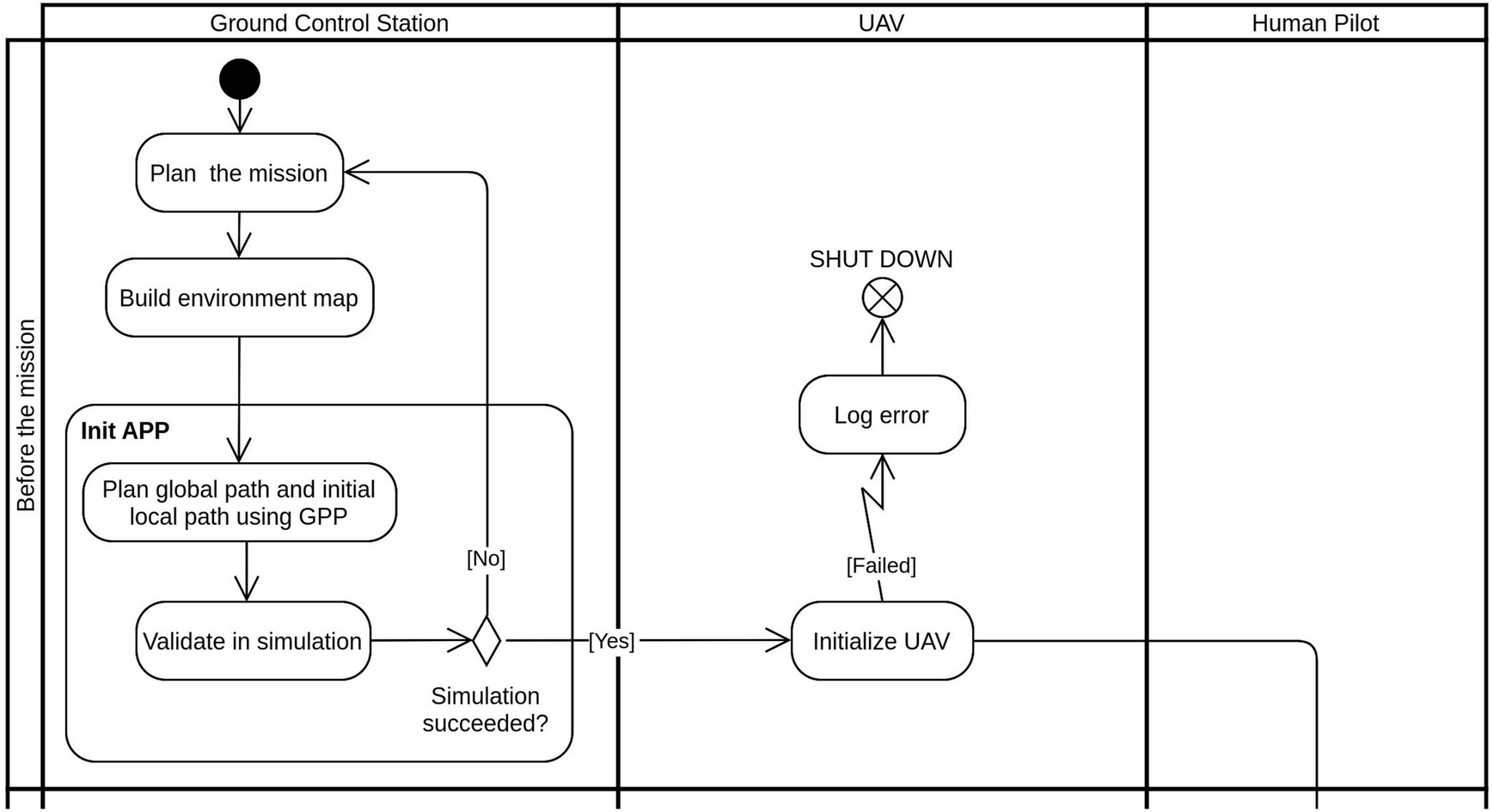
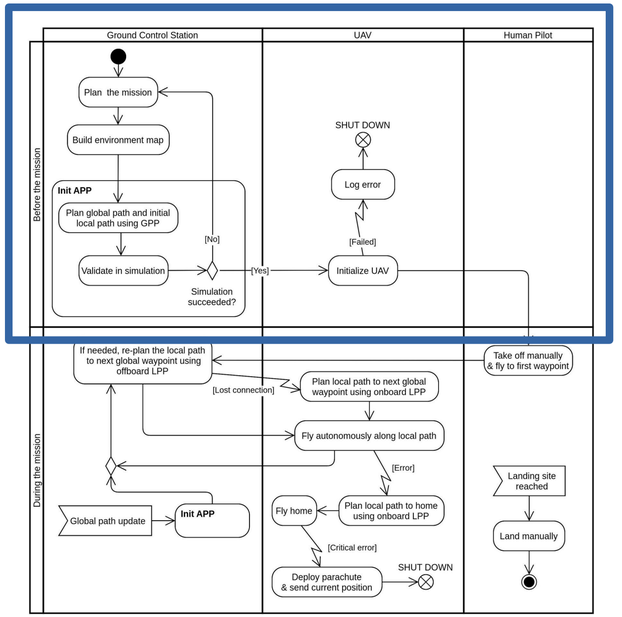


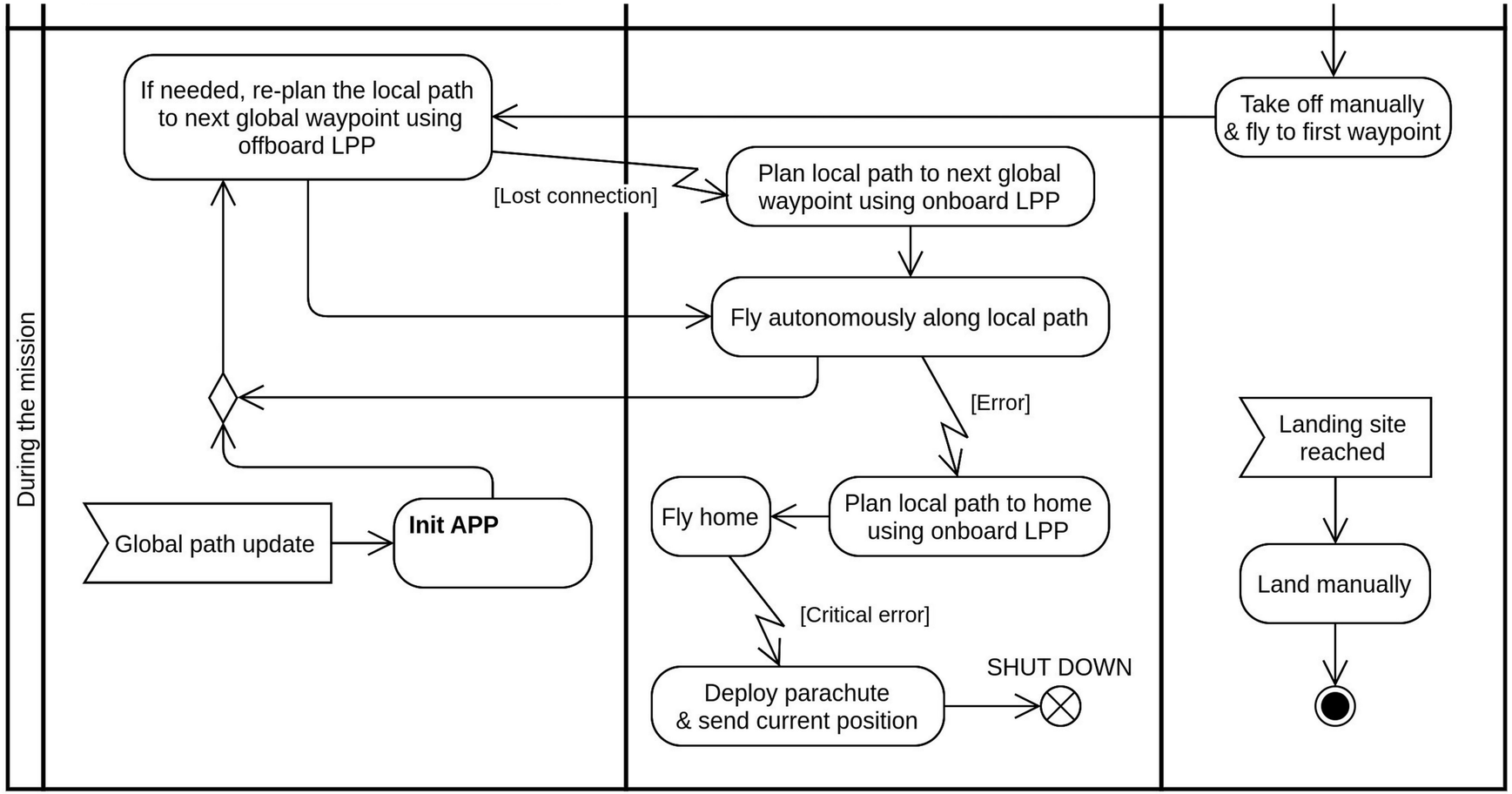


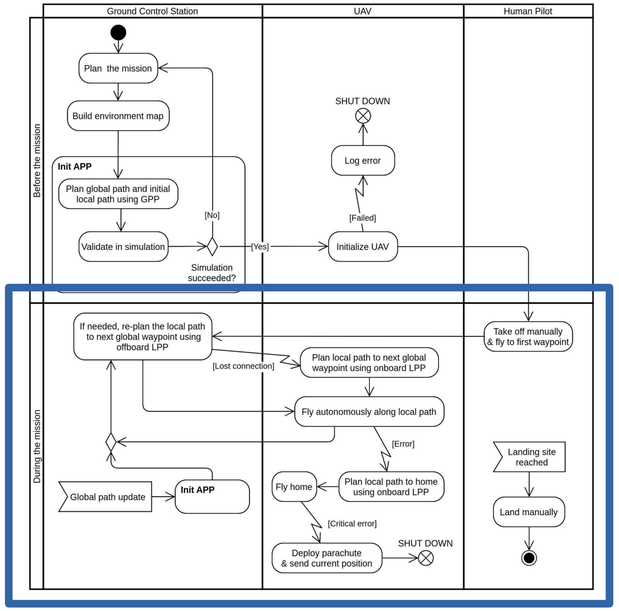
Adaptive Path Planning algorithm





Adaptive Path Planning algorithm





Adaptive PP = Global PP + Local PP

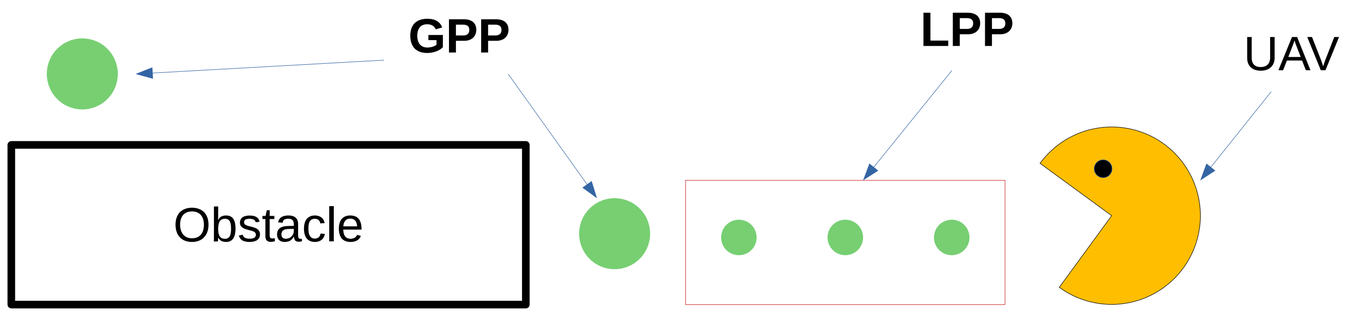
Global Path Planner (GPP)

- Provides one rough merged path for LPP
- Computation intensive & not responsive
- Implements general optimization algorithms (ACO_R, I-GWO, PSO, GA)
- Minimizes energy expenditure
- Uses a wind model (wind map)
- Runs offboard only

vs

Local Path Planner (LPP)

- Provides smooth collision-free path for 2 poses
- Rapid computations & responsiveness
- Implements stochastic collision avoidance algorithms (RRT, RRT*, BiRRT)
- Lacks wind and energy models
- Runs onboard or offboard



Global Path Planning – minimization problem

$$\text{minimize } \mathbf{C}(\mathcal{S}, \mathbf{p}) = c_1(\mathcal{S}, \mathbf{p}), c_2(\mathcal{S}, \mathbf{p}), ..., c_n(\mathcal{S}, \mathbf{p}), ..., c_N(\mathcal{S}, \mathbf{p})$$

$$\text{subject to } \Omega(\mathcal{S}, \mathbf{p})$$

Constrains

$$\mathbf{C}(\mathcal{S}, \mathbf{p}) = C(\mathcal{S}, \mathbf{p}) = \sum_{n=1}^{N_c} \omega_n c_n$$

Scenario

Weights

Mission parameters

$$\mathbf{p} = \left[\mathbf{w^S} \quad \mathbf{w^1} \quad \mathbf{w^2} \quad \cdots \quad \mathbf{w^i} \quad \cdots \quad \mathbf{w^N} \quad \mathbf{w^E}\right]$$

Start waypoints matrix

Transitional waypoints matrices

Transitional waypoints matrices

n	Criterion
1	Obstacle avoidance
2	Path length
3	Wind influence
4	Energy expenditure

Local Path Planning – rapid re-planning

Dubins airplane path

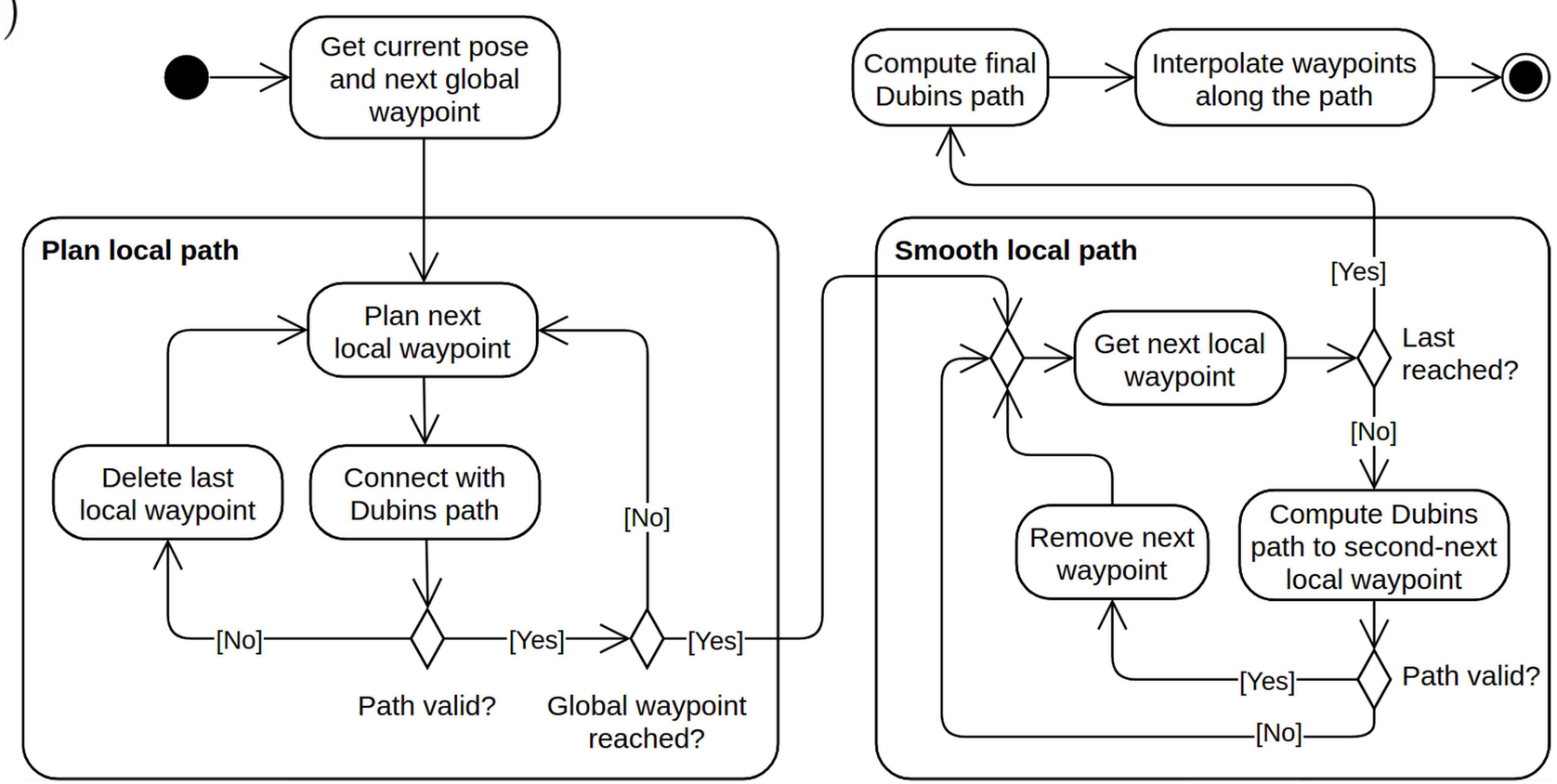
Environment model (obstacles)

$$\text{find } \mathcal{P}^L(\mathcal{S}) \in \mathcal{D} | \mathcal{P}^L(\mathcal{S}) \cap \mathcal{M}_o(\mathcal{S}) = \{\emptyset\}$$

$$\text{subject to } \Omega_k(\mathcal{S})$$

Collision-free path

Constraints



Summary & conclusions

- APP comprises two sub-algorithms: Global PP & Local PP
- GPP currently implements 4 optimization algorithms: ACO_R, I-GWO, PSO & GA
- GPP generates energy-optimized obstacle free path connecting the measurement sites
- LPP enables rapidly computing the obstacle free path, even on the embedded hardware, but the path is not energy-optimal
- LPP implements 3 algorithms: RRT, RRT* & BiRRT

Related publications

- **Kosior** M.: *Model-Based Adaptive Path Planning Algorithm for Unmanned Aerial Vehicles*. PhD thesis. Silesian University of Technology, Faculty of Mechanical Engineering, 2022.
- **Kosior** M., **Przystałka** P., **Panfil** W.: *Wind Forecast Map for Adaptive Path Planning with an Unmanned Aerial Vehicle*. Metody komputerowe - 2022. Student scientific conference. Silesian University of Technology, 2022, pp. 69-72.
- **Kosior** M.: *A Glimpse into the Adaptive Path Planner for a UAV*. Proceedings of the 3rd Polish Conference on Artificial Intelligence. Gdynia Maritime University, 2022, pp. 94-77.

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