Dynamic REAP: Bringing Life into Simulations for UAV Planning and Acting Frameworks

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Abstract

Developing intelligent Unmanned Aerial Vehicles (UAVs) entails more than ensuring safe navigation; it also involves equipping them with high-level decision-making abilities through AI planning. Simulation-based testing is a necessary gateway in transitioning research works into operational real-world UAV missions. We demonstrate Dynamic REAP[1], a simulation environment that considers accurate physics of the vehicle, while providing georeferenced semantic segmentation and tools to include dynamic background characters, removing thereby the assumption of a static world when used for validating planning and acting methods. A system demonstration based on a Search and Rescue (SAR) scenario can be found at: https://www.youtube.com/watch?v=mthOS7hksZQ

Motivation

Designing and developing software systems with AI planning capabilities for UAV missions requires extensive testing. However, real flight tests often involve risks and legal constraints. Simulators offer a viable approach for initial debugging and proof-of-concept of AI planning methods in real-world missions. To reflect the challenges of real-world missions, a simulator needs to consider both the physical constraints of action execution as well as a semantic representation of the world. Gazebo-based simulation platforms (Koenig and Howard, 2004) emphasize more the physics accuracy of the vehicle, but offer a low visual fidelity (Dimmig et al., 2024). This makes them powerful for testing control and path planning algorithms, but less suitable for validating symbolic planning and acting capabilities, in which symbolic interpretation through perception of the environment is necessary. Other simulation frameworks like Isaac Sim[2] focus on photorealistic image generation for the training of learning algorithms. However, Isaac Sim is not fully open-source and lacks support for creating geodata-based environments. REAP, introduced by Kraus, Mair, and Kiam (2023), enables the execution of plans generated using automated planning techniques in simulated environments built with Unreal Engine. It integrates LIDAR-based georeferenced data for environmental modeling and leverages AirSim (Shah et al., 2017) to simulate realistic vehicle physics. While intended to bridge the gap between highly abstract simulations focused on symbolic knowledge processing and low-level simulators that emphasize physics accuracy (i.e., flight dynamics), REAP has two major drawbacks: first, it assumes a static world; second, it does not provide a semantic segmentation of the environment due to the characteristics of a laser scan map. Hence, the agent is not able to extract symbolic knowledge from the environment, making it impossible to include perception-based semantic interpretation necessary for validating symbolic planning and acting methods. Dynamic REAP builds upon REAP by addressing both shortcomings.

System Description

To overcome the version limitation of AirSim as experienced by its predecessor, Dynamic REAP is built upon Unreal Engine 5.2 and Colosseum[3], an AirSim fork. A detailed system diagram is shown in Figure 1. For the planning and execution framework, a simulated PX4 flight controller exposes its interface via a μXRCE-DDS Client to receive commands for flight control and to send telemetry data.

Georeferenced Semantic Segmentation of the Environment

In order to address the lack of semantic segmentation of LIDAR-based maps, Dynamic REAP uses height maps, which can be retrieved as a 16-bit greyscale PNG, file[4] (see Figure 2a) and imports them to Unreal Engine as a basis for the simulation level. With a georeference plugin, a WGS 84 coordinate system can be used for navigation and placement of 3D objects within the simulation environment. The latter is leveraged to create a manually crafted landscape. Objects can be annotated with semantic information (e.g., object class) and are clearly GPS-located, which forms a semantic map for the AI planning system.

Another benefit compared to LIDAR-based maps is that 3D objects in the environment can be sensed by the agent,

[1]https://github.com/UniBwM-IFS-AILab/REAP
[2]https://developer.nvidia.com/isaac/sim
[3]https://github.com/CodexLabsLLC/Colosseum
[4]https://manticorp.github.io/unrealheightmap

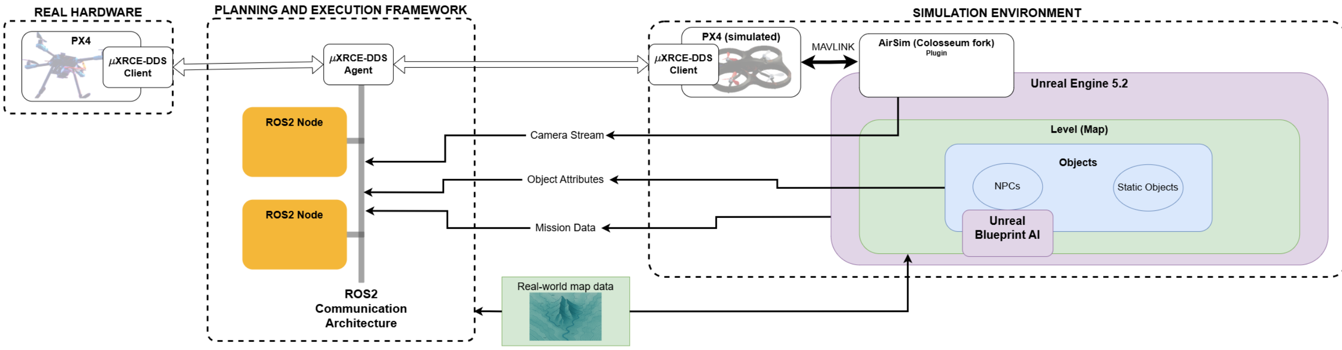

Figure 1: System architecture of Dynamic REAP.

see Figure 2b, which can be utilized as symbolic representations for planning and acting. Technically, this is enabled by exposing a simulated camera view as a ROS 2 (Macenski et al., 2022) message.

(a) Grayscale height map (b) Perception in the simulation

Figure 2: Two aspects of the simulation environment.

Adding Dynamics to the Environment

Background agents that move continuously cannot be easily neglected in real-world missions, as the reaction of the UAVs when encountering these agents can be key to mission success. Dynamic REAP includes Non-Player Characters (NPCs), which can be configured via Unreal's Blueprints logic. This includes both autonomously following a predefined path and randomly walking inside a certain radius. In addition, multiple branches of a path have been implemented, from which one is randomly selected during execution. To exhibit behaviors even closer to human characters, a Third-Person-Player mode is provided, where a NPC can be controlled by a human using an external input device.

Results

For demonstration, we built an exemplary Search and Rescue (SAR) scenario[5], drawn from real-world SAR procedures, where a hiker NPC tries to reach a summit and potentially gets lost on its way. Information such as the last known position (LKP), planned endpoint, or vegetation type around the LKP, can be parsed into the problem instance. For the planning and execution part, we deployed AUSPEX (Döschl, Sommer, and Kiam, 2025), a modular and open-source software framework for decision-making for UAVs in SAR missions. AUSPEX includes the Unified Planning (UP) library (Micheli et al., 2025) as a planning capability and instantiates for each UAV agent an execution module as well as a sensing module, which is able to detect the NPC in the simulation. A dedicated knowledge base module serves as a bridge between the semantic map and defining the planning problem.

Acknowledgements

This work is funded by the Bundesministerium für Forschung, Technologie und Raumfahrt (BMFTR) (Project MENTHON) and by dtec.bw, which we gratefully acknowledge. The scenario modeling benefited from valuable input provided by the Mountain Rescuers of Penzberg (Bergwacht Penzberg).

[5]https://github.com/UniBwM-IFS-AILab/REAP

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