SimUAVs - A UAV Telepresence Simulation Platform with Multi-agent Sensing and Dynamic Environment

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Figure 1: SimUAVs is a telepresence simulation platform for UAV synthetic data generation. This system provides multiple agents and multi-modal sensors for manipulation, with dynamic real-world weather and environment conditions for emulation.

ABSTRACT

Unmanned Aerial Vehicles (UAVs) are necessary across diverse domains, including disaster surveillance and wildlife conservation. However, the development and evaluation of UAV-related algorithms often encounter a significant hurdle: the scarcity of authentic training data. In this paper, we introduce SimUAVs, a telepresence simulation platform with a dynamic environment, serving as a realistic synthetic data generation, performance evaluation, and visualization tool for multi-agent collaboration learning. This paper presents the architecture, features, and capabilities of SimUAVs. Leveraging Unreal Engine (UE), AirSim APIs, and ROS (Robot Operating System), our platform enables realistic simulations, mirroring real-world conditions and facilitating research in UAV technology.

CCS CONCEPTS

• **Human-centered computing → Visualization systems and tools**; • **Computer systems organization → Real-time systems**; • **Information systems → Multimedia information systems**.

KEYWORDS

UAV, Simulation Platform, Multi-agent, Dynamic Environment

1 INTRODUCTION

Thanks to advancements in artificial intelligence algorithms, multi-rotor unmanned aerial vehicles (UAVs) have transformed into intelligent agents capable of navigating through unknown environments. This evolution underscores their ability to operate autonomously and adapt to diverse and challenging scenarios. The development and evaluation of UAV-related algorithms frequently face a significant problem: the lack of authentic and diverse training data. To address this, we introduce SimUAVs, a telepresence simulation platform, designed for realistic synthetic data generation, performance evaluation, and visualization in multi-agent collaboration learning.

Simulation offers an effective solution to implement real-time capabilities, high maneuverability, high-resolution imagery, and cost-effectiveness [6]. Previous simulation platforms, such as Airsim-W [2], XTDrone [5], SmrtSwarm [1], are limited in mirroring real-world environment. With significant advantages in scene development and user-friendly interaction, we employ Unreal Engine to create a dynamic realistic environment. Inspired by the ROS-Gazebo-PX4 toolchain, renowned for visual SLAM and UAV navigation [3], we proposed the SimUAVs framework, utilizing UE, Airsim [4], and ROS, to construct a real-time interactive platform with dynamic and realistic virtual environment.

2 SYSTEM DESIGN

The simulation environment is based on the physical computation and image rendering process of the Unreal Engine, and the construction of the simulation scene is completed through model files output by external DCC software such as FBX or OBJ. SimUAV, as an independent plugin of UE, can obtain rendering information, the position of drones, sensor data, and commands in real time. SimUAV provides various control schemes, which can directly control the aircraft for manual flight from simulated scenarios, or use SimUAV's control API for command line control.

2.1 Framework

Depending on the scope of the simulation, SimUAVs is integrated with multiple sensor plugins and extensions, shown in Figure 2, to implement perception sensors, a UAV control module, a dynamic weather module, and 3D scene construction. Plugins extension sensors, such as IMU and GPS, are used to obtain UAV-related information. Engine extensions are employed to capture environmental

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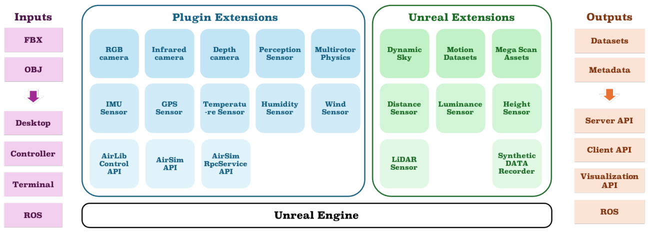

Figure 2: The framework of SimUAVs.

data. In this system, there are diverse input and output methods. FBX and OBJ assets could be directly imported into the platform. Users can also use desktop, controller, terminal, and ROS to manipulate UAVs. For outputs, visual datasets and metadata can be exported into specific file format, and can also be directly sent to server API, client API, visualization API, and ROS for further processing.

2.2 Multi-agent Sensing

SimUAVs enables the simultaneous control of multiple UAVs and the acquisition of sensor data, facilitating collaborative operations among multiple intelligent agents. The 3D UAV model can be customized as needed. In SimUAVs, each UAV is equipped with five cameras, whose orientation and positions can be configured in the setting file. Each camera can work as RGB, depth, segmentation, and infrared camera.

The IMU data in simUAVs is derived from motion data of the aircraft object within the engine, which is then transformed relative to the simUAVs coordinate system before output. The coordinate system in simUAVs is a right-handed one with the drone's takeoff coordinates as the origin, oriented such that $+X$ is north, $+Y$ is east, and $+Z$ is downward, measured in meters. The IMUs data is calculated by mapping the longitude and latitude coordinates of the UAVs onto an idealized model of the Earth's magnetic field, where random fluctuations are applied to emulate a complex, realistic geomagnetic environment.

2.3 Environment Dynamic

The simulation environment in SimUAVs contains a complex terrain with a maximum relative height difference of 1000m, including mountains, hills, plains, and lakes. There are more than 25 types of plants with varied distributions, referencing the real-world terrain of Yunnan. Environmental data includes luminance, temperature, humidity, altitude, windspeed, fog thickness, timecode, and weather type, which are all recorded in the metadata file.

As UAVs traverse various paths through the scenes, they experience dynamic and track-repeatable variations in weather and terrain conditions. All the weather, temperature, and humidity data in SimUAVs demo are derived from real climate data in Yunnan. Weather data is blended with mapping and interpolation of simulation information, coordinating with UAVs' location coordinates. More real-world weather data could be embedded according to the testing requirements.

2.4 Real-time System

SimUAVs is a telepresence simulation platform for UAV synthetic data generation, with multi-agent, multi-modal and dynamic environments. SimUAVs are currently developed with 4 types of visual sensors (RGB, Depth, infrared, and perception), 4 terrains (plains, mountains, forests, lake), and 6 weather conditions (sand storm, fog, rain, snow, overcast, clear sky).

SimUAVs leverages Unreal Engine (UE) for scene development and interaction. A notable advantage of using Unreal Engine is its robust support for scene editing and layout. 3D assets in UE can be constructed by Digital Content Creation (DCC) software, generated by 3D reconstruction, or downloaded from copyright assets, such as Megascans, etc. Additionally, UE provides numerous ready-made visual effects and physical simulator plugins, such as Ultra Dynamic Sky and particle system, further augmenting the simulation environment.

The UAV control API is based on Airsim and ROS. Airsim for capturing and manipulating UAVs, and ROS for control interfaces and APIs. For signal transmission and processing between servers and clients, the ROS plays an important role in controlling and obtaining data from UAVs. The synthetic system can export metadata files and image sequences, with a maximum frame rate of 60 fps, and communicate with a server for data processing, learning, and management timely. The HUD (Head-Up Display) interface, shown in Figure 3, is designed for monitoring and data visualization.

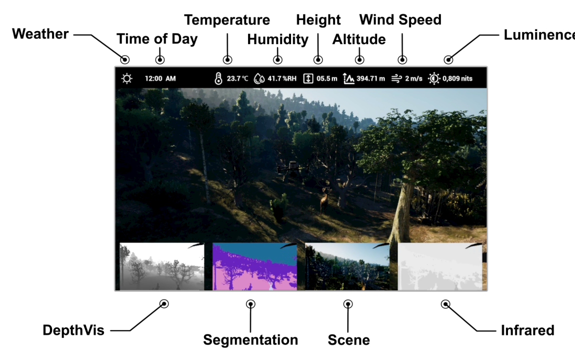

Figure 3: The HUD of SimUAVs.

3 CONCLUSION

SimUAVs is designed to support the research and development of UAVs, enhancing the realism and effectiveness of simulations. To address the demand for authentic training data through a sophisticated telepresence platform, we leverage Unreal Engine, AirSim APIs, and ROS, to offer a robust and dynamic environment that can mirror real-world conditions. This platform not only facilitates the generation of realistic synthetic data but also provides a comprehensive tool for performance evaluation and visualization in multi-agent collaboration learning. In SimUAVs, animal agents can adaptively adjust their motion according to the landscape, however, the impact of altitude on UAVs has not been taken into account yet. In the future, additional plugins and extensions will be integrated into this framework as needed. We would like to develop FPGA-based hardware-in-the-loop simulations for real-time virtual-reality-fusion systems.

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