Drone, ground robot and human navigation in 3D realistic simulation

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Abstract

This paper presents a new realistic and comprehensive simulation environment for navigation algorithms on a three-dimensional space featuring drones, terrestrial robots and human-like agents. Through several experiments we demonstrate the practical applicability and robust performance of traditional planners in multi-agent 3D scenarios.

Introduction

Improving robot navigation in densely populated areas is a key step towards integrating robots into our society in a way that promotes mutual understanding and coexistence. Advancing robot navigation in such environments requires robust testing, and simulations in realistic scenarios are indispensable to achieving this goal.

Collision avoidance in dynamic environments with multiple agents is a fundamental challenge in robotics. The ability of robots to navigate safely, avoiding obstacles and other agents, is crucial for real-world applications. Traditional methods, such as *AVOCADO* [1] and *ORCA* [2], are used to prove the effectiveness of our simulation environment. While highly effective, the previously mentioned algorithms have, until now, primarily relied on simulations within 2D scenarios. Although *Aerostack2* [3] provides several methods of simulation with drones, there are not realistic simulations including drones and ground agents. To validate and demonstrate the performance of previously mentioned planners, an advanced but practical realistic simulation environment, featuring drones and ground agents, has been developed.

Drone implementation

This environment has been built using cutting-edge robotics technologies, including *ROS2* (Robot Operating System 2) for node communication and management, *Ignition Gazebo Fortress* for accurate physical simulation of the robots and the environment, and *Aerostack2* for drone control. The combination of these tools allows for a rigorous evaluation of the method in realistic and complex scenarios.

Regarding drone implementation, the models provided by *Aerostack2* have been used as an axe for the simulation, delivering several behaviours (predefined commands to control movements of the drone) as "Take off" and "Land" but also several velocity control behaviours. The behaviours have been integrated to be used during simulation time for each drone simultaneously, providing a fast and coordinated response.

Aerostack2 provides its own Ignition Gazebo Fortress drone model. Leaning on this, it has been adapted to automatically spawn and initialize the simulation environment.

First, the drones are placed in their specified positions and are set as cooperative, controlled by the multi robot system planner, or non-cooperative, acting as dynamic obstacles for the rest. Once the simulation is ready, it starts. Drones' frameworks are initialized followed by the "Take off" behavior until they reach an appropriate height to start hovering. With all drones prepared, the simulation continues in loop as follows:

1. Read drone position and velocities from sensor measurements.
2. Compute new velocities using *AVOCADO*, *ORCA* or any other 3D planner.
3. Check if collision has occurred.
4. Check if the drone has reached its goal.

Subsequent to all drones reaching their goals, they are set to land and shutdown, turning off their framework. Results of the simulation are then stored.

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Ground agents implementation

Once drones have been initialized into the simulation, ground robots are launched into the world.

The models are created as cylinders of several radiuses and heights to differentiate between humans and ground robots. Models have been added to the previous *Gazebo* environment interspersing drones and ground robots through the circle.

We assume holonomic movement for both humans and terrestrial vehicles for speed control. This control has been done using plugins which allow applying a given velocity to the model on a given *Gazebo* topic, and obtaining odometry information of the model at a given topic.

The spawn of ground robots into the simulation has been automated by just adding their name and position into a .yaml document, simplifying their usage. The same simulation methodology as with the drones is used, now extended to consider ground agents.

Results

We conducted experiments to prove the effectiveness of our simulation environment featuring *AVOCADO* as global planner.

We placed five drones in a circle, and their goal was taking the shortest path to the opposite part of the circle while avoiding all possible obstacles. When setting one of the drones as non-cooperative, the average time for the drones to reach their goal on five simulations was 16.516 seconds and no collisions were recorded. Figure 1 shows a frame of the simulation.

We have also done experiments combining drones and ground agents, as in Figure 2, including five drones, three human-like agents and two terrestrial robots. All agents have been set to cooperative, leading to a total average simulation time of 18.267 seconds and no collisions.

Conclusions

This work advances the validation of robot navigation algorithms by transitioning from conventional 2D to sophisticated and realistic 3D simulations. Through this simulation environment, we have successfully demonstrated the practical applicability and robust performance of algorithms such as AVOCADO or ORCA in complex, dynamic, multi-agent 3D scenarios involving drones, ground robots and humans.

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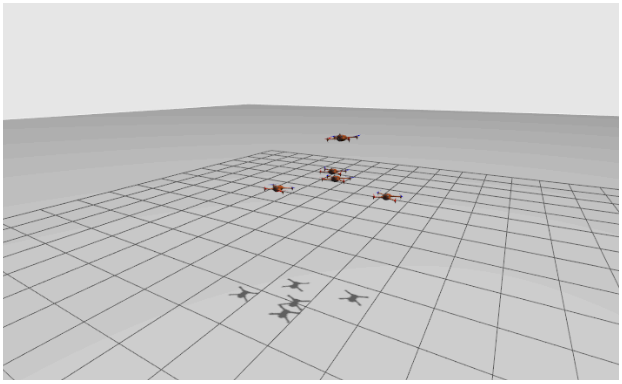

Figure 1. Drone simulation frame of 5 drones while avoiding collision at the center of a circle of radius 4 meters.

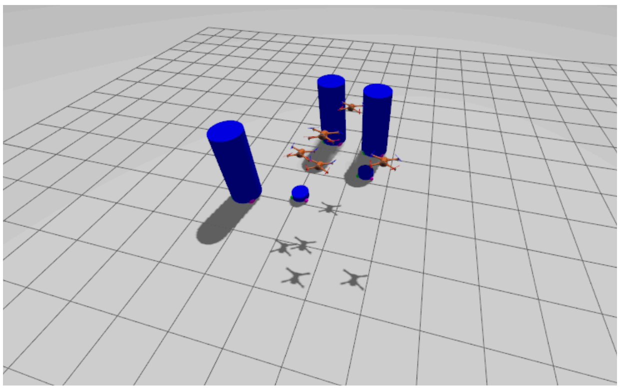

Figure 2. Aerial and ground agents simulation frame of 5 drones, 3 human-like agents and 2 terrestrial robots while avoiding collision at the center of a circle of radius 4 meters.