# Final Project: Path Planning with RTAP-Map and RRT

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## ABSTRACT

The objective of this project is to simulate a vision-based autonomous drone navigation system within a mixed reality environment using ROS 2. A simulated "ghost" drone was deployed and equipped with a synthetic RGB-D camera and odometry publisher to simulate the onboard perception of a real drone. The virtual perception system sends data into RTAB-Map and visual odometry is performed to construct a 3D map of the environment in real time. Red, green and blue blocks were placed in the environment as obstacles to allow the system to interpret the free space for navigation. After making the 3D environment, a Rapidly-exploring Random Tree (RRT) algorithm is created to generate a collision-free path from the start node to the goal node. The planned trajectory avoids the obstacles and simulates drone motion through the environment.



## 1. METHODOLOGY:

This project integrates a mixed reality simulation environment with visual Simultaneous Localization and Mapping (SLAM) and sampling-based path planning to validate drone navigation logic. This work is centered around two main components: sensor simulation using RTAB-Map and motion planning with the RRT algorithm. To initially validate the RRT implementation, the TurtleSim package in ROS2 was used. A custom RRT planner node was made to navigate from a fixed start and goal node while avoiding the obstacles. Ten additional turtles were spawned to act as obstacles in the environment and represented by their known position. The RRT path planner creates paths that avoid the obstacles by performing collision checks based on Euclidean distance. This served as a baseline for testing the RRT logic. A Python-based ROS2 node was created to simulate onboard sensors at a frequency of 10 Hz. The nodes published were: RGB images with red, green, and blue blocks to simulate camera input, depth images to emulate spatial variation and odometry data that approximated circular motion. The red, green and blue blocks were used to represent physical obstructions in the environment. These blocks were used as visual and depth cues for the drone to allow RTAB-Map to find obstacles and free space. RTAB-Map was configured to subscribe to the simulated depth, RGB and odometry topics. It performed visual odometry and real-time SLAM to build the 3D map of the environment. This resulted in a point cloud and this was visualized in RViz to validate the integration of simulated inputs. Once the cloud map was developed, the occupancy grid was generated to apply the RRT algorithm and plan a path. The start node and goal node were manually selected within the map. The path planner avoided grid cells that were marked as occupied and found a path around those obstacles. The final trajectory demonstrates how an autonomous drone can safely navigate using onboard SLAM and perception in the real-world.

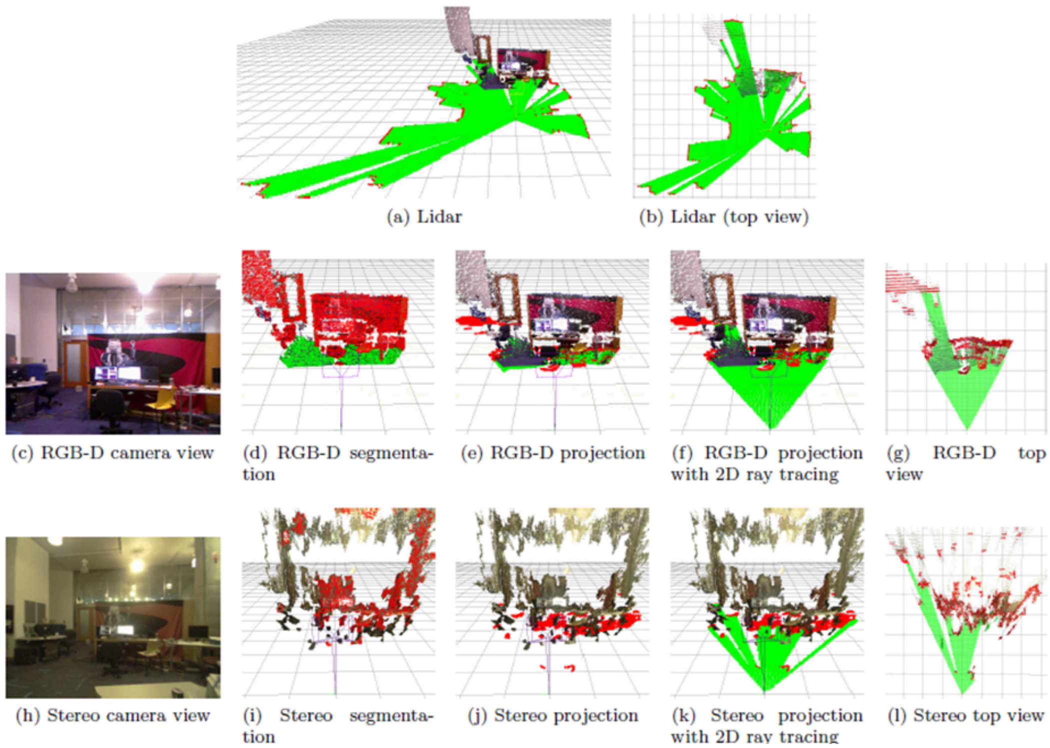


Figure 1. Comparison of 3D Mapping using Lidar, RGB-D and Stereo Camera in RTAB-Map [1].

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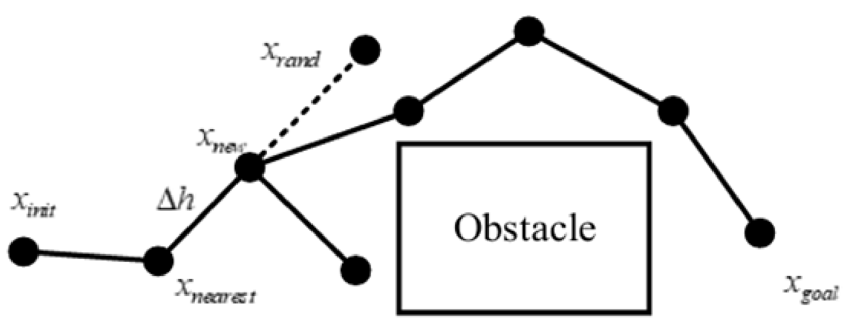


Figure 2. Node expansion process in the RRT algorithm [2].

## 2. RESULTS:

The outcomes of this project demonstrate the possibility of using a mixed reality simulation framework for testing SLAM-based path planning with a simulated drone. The RRT code was tested using the TurtleSim package, where ten different turtles were spawned to act as static obstacles that the main turtle bot had to navigate around. The visual trajectory in TurtleSim displayed an accurate path generation as the nodes expanded through the free space avoiding the obstacles around the map (figure 3). This planner converged in fewer than 500 iterations across most tests, even in constrained environments. The simulated RGB-D sensor node published artificial RGB, depth and odometry data at a rate of 10 Hz. RTAB-Map subscribed to these topics and performed visual odometry in real time (figure 4). The constructed point cloud accurately reflected the spatial configurations of the simulated red, green and blue blocks. These were placed at distinct locations and depths in the environment. RViz was used to visualize the generated map of the blocks in the environment, this confirmed the obstacle positions and distances aligned with the ground truth. The odometry trace showed smooth pose estimation during simulated motion which indicates the SLAM pipeline remained stable through the mapping process. Once the 3D point cloud was established with RTAB-Map (figure 5), it was successfully down-projected into a 2D occupancy grid. The grid distinguished between occupied and free space, this enabled consistent path planning across multiple mapping cycles. With this occupancy grid, the RRT path planner was deployed to find a collision-free path from manually selecting the start to goal location. The planner navigated around the obstacle boundaries and successfully avoided all occupied grid cells. The path was visualized and confirmed to match expected navigation patterns as seen in figure 6. The planner was able to dynamically compute paths and demonstrated adaptability to changes in the obstacle layout. The use of SLAM data for path planning confirmed the advantage of integrating RTAB-Map outputs with real-time decision-making algorithms.


Figure 3. Turtle Sim with 10 additional turtle obstacles to demonstrate RRT path planning

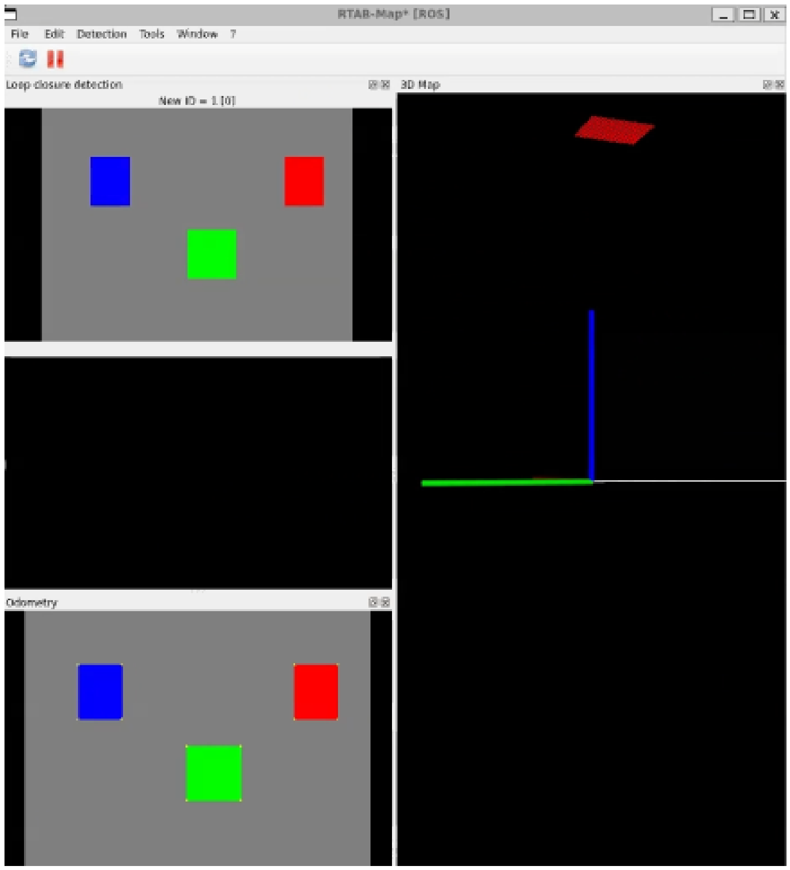

Figure 4. RTAB-Map during visual SLAM processing using obstacles for loop closure detection.

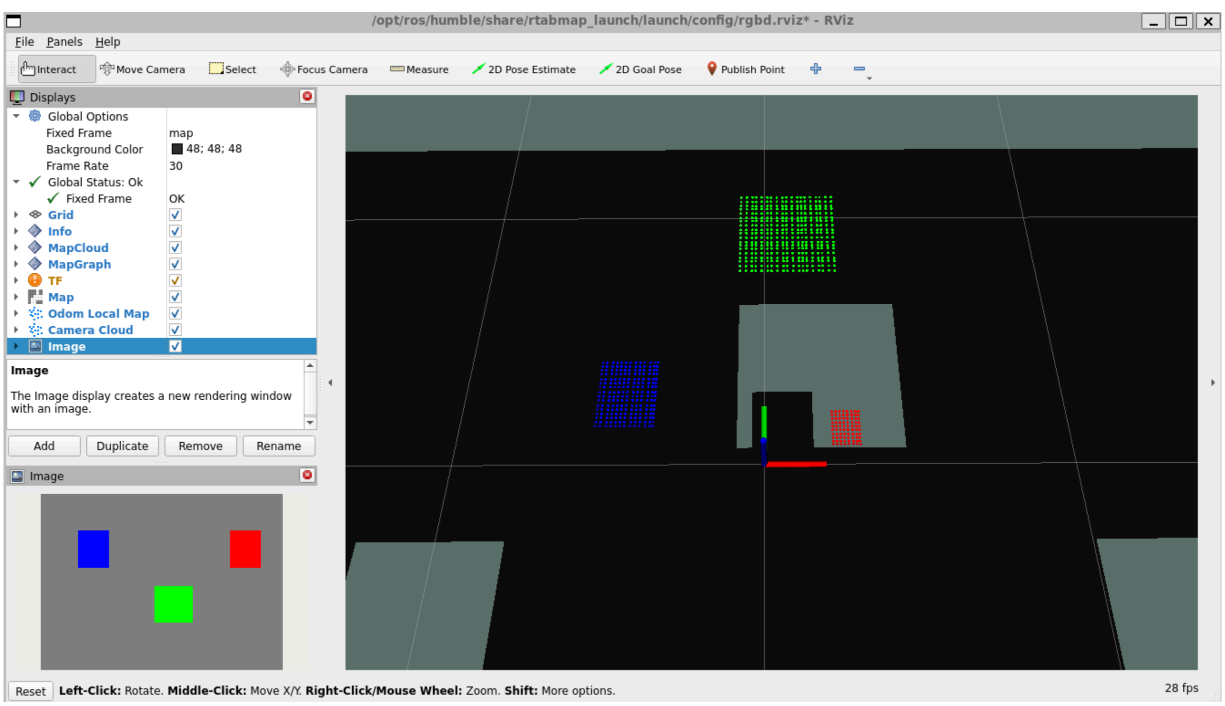

Figure 5. Visualization of detected obstacles in RViz.

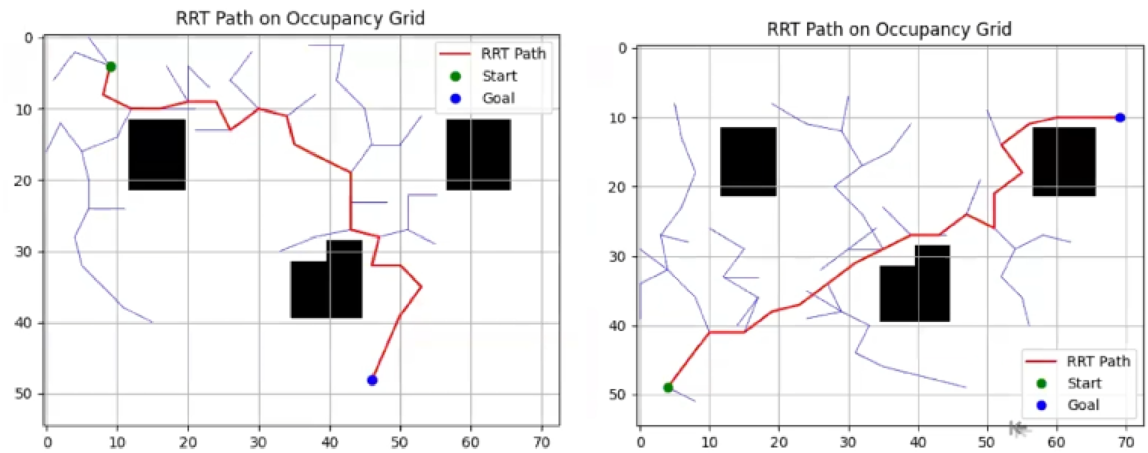

Figure 6. Comparison of RRT path planning over the occupancy grid map with obstacles.

## 3. VIDEO RECORDING:

**TurtleSim RRT:**
**RASSES598_FinalProjectP1.mp4**

**RTAB-Map:**
**RASSES598_FinalProjectP2.mp4**

**RRT Path Planning:**
**RASSES598_FinalProjectP3.mp4**

## 4. CONCLUSION:

This project successfully demonstrated the implementation of a mixed reality simulation framework for testing autonomous drone navigation using visual SLAM and path planning algorithms. Through the simulation of RGB-D sensor inputs and odometry in ROS2, RTAB-Map was able to be used to perform visual odometry and environment mapping. The 3D cloud point was successfully converted into a 2D occupancy grid. This grid was used as the basis for RRT-based path planning. The system was able to detect the synthetic obstacles from the depth and visual cues, create the spatial map and generate the collision-free paths in the virtual environment. TurtleSim was used to perform primary testing of the custom RRT algorithm. The modular design of the system enabled seamless interaction between SLAM and the real-time path planning logic. Overall, this method provides a cost-effective and safe platform to test navigation logic. Future work may extend this system to include dynamic obstacle tracking and testing with different virtual PX4 drone models available in Gazebo .

## REFERENCES:

[1] M. Labbé and F. Michaud, “RTAB-Map as an Open-Source Lidar and Visual SLAM Library for Large-Scale and Long-Term Online Operation,” Journal of Field Robotics, accepted for publication, preprint available: [Online]. Available: https://doi.org/10.1002/rob.21831.

[2] B. Ye, C. Liu, F. Han, X. Hu, and L. Chen, “Obstacle avoidance motion planning for space redundant manipulator based on improved RRT algorithm,” J. Phys.: Conf. Ser., vol. 2764, no. 1, p. 012052, 2024. doi: 10.1088/1742-6596/2764/1/012052.