HACETTEPE UNIVERSITY
DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING
ELE 401-402 GRADUATION PROJECT

OUTDOOR STATE ESTIMATION VIA SENSOR FUSION USING A FOUR-LEGGED ROBOT PLATFORM

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Project Description

The primary objective is to combine data from a 3D LiDAR and a stereovision camera to improve the robot's outdoor state estimation, with performance assessments conducted against RTK-GPS data. The project encompasses the establishment of the robot's basic infrastructure to receive RTK-GPS data, the implementation of sensor fusion algorithm to integrate data from the 3D LiDAR and ZED stereo camera. Also, we will employ VR to visualize the maps generated by the LiDAR and ZED stereo camera.

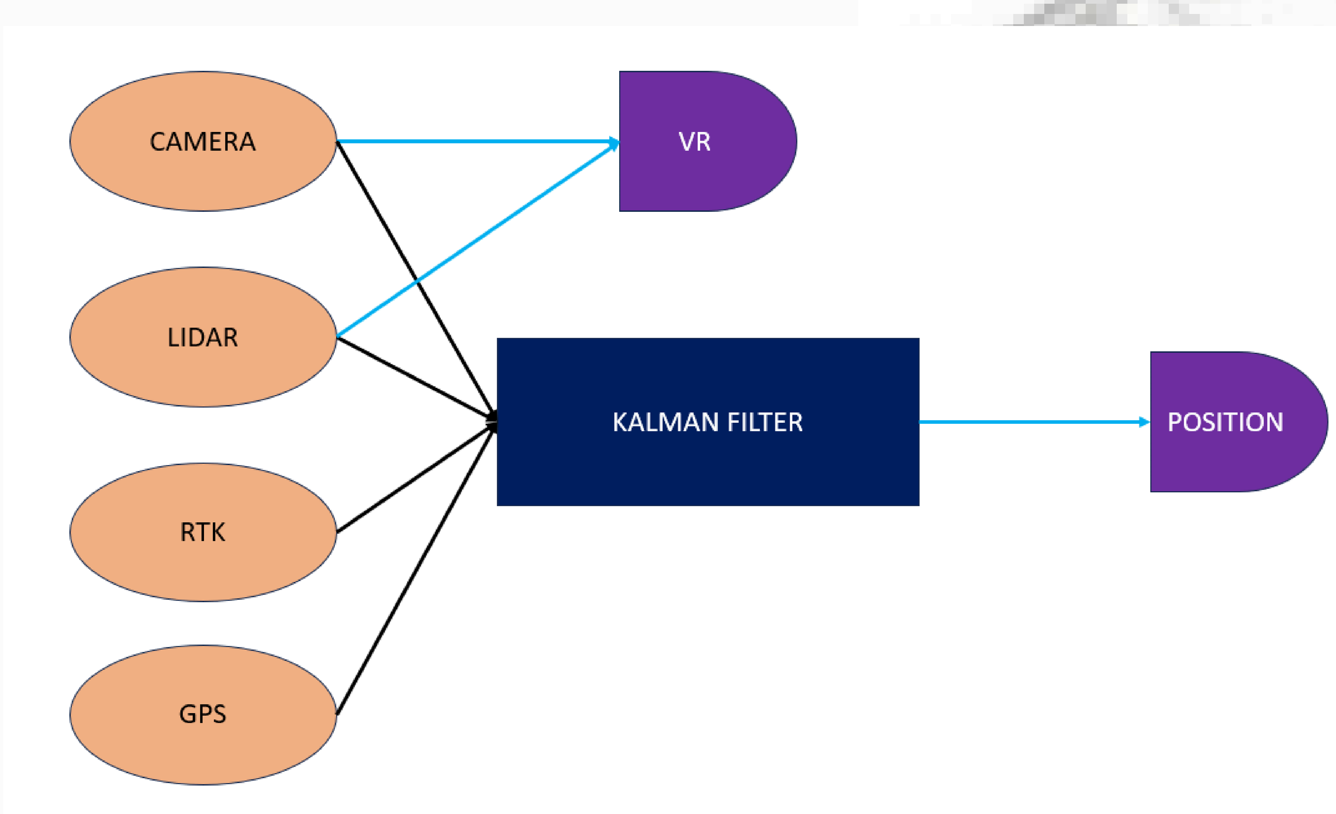

Figure 1. Schematic of the system

Methodology & Solution

Initially, the ZED camera was employed to generate detailed maps of the environment through RTAB-Map, capturing high-resolution visual data. Concurrently, mapping with the LiDAR provided precise distance measurements and spatial information, also using RTAB-Map.

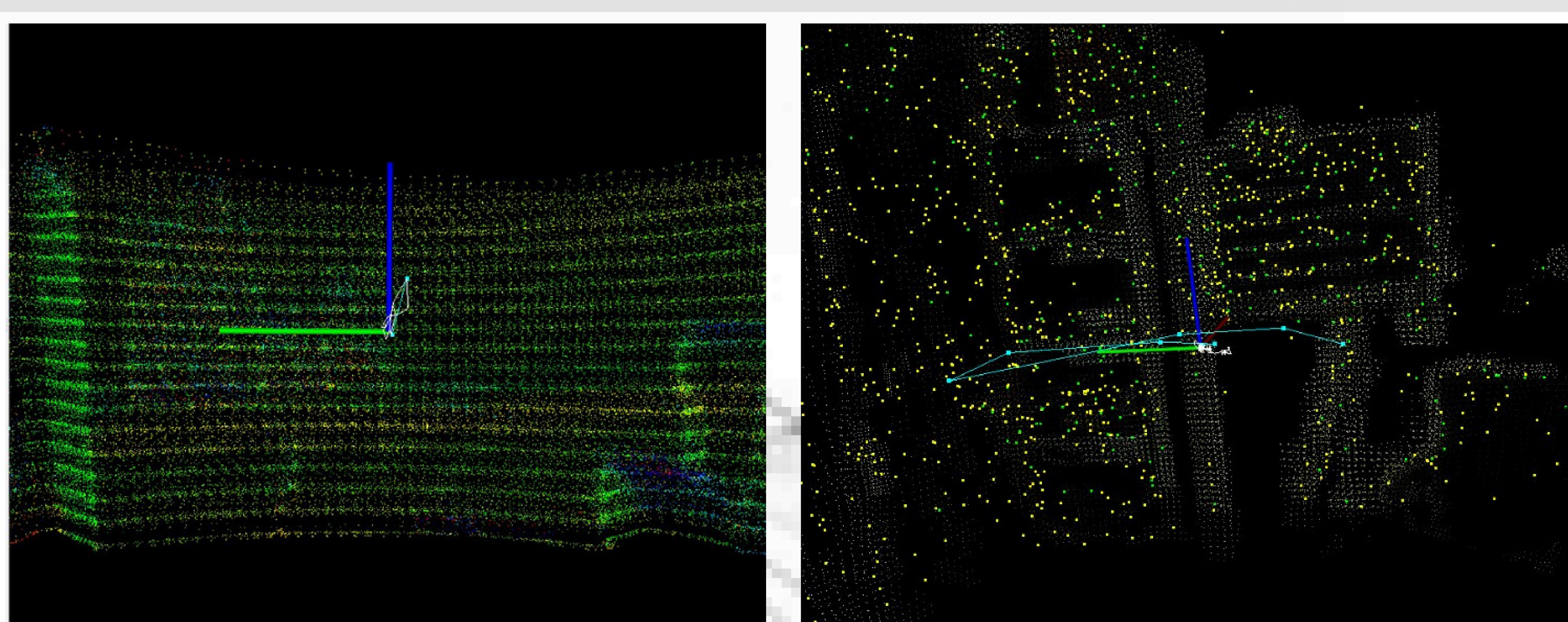

Figure 2. Mapping on RTAB-Map with Stereo camera

The odometry data obtained from these mappings was subsequently integrated into the robot localization package to achieve accurate position estimation. This comprehensive approach leveraged the strengths of each sensor, combining visual and spatial data to achieve a more reliable and precise state estimation for the robot.

$$K = \hat{P}_k H^T (H \hat{P}_k H^T + R)^{-1}$$

$$x_k = \hat{x}_k + K(z - H\hat{x}_k)$$

$$P_k = (I - KH)\hat{P}_k (I - KH)^T + KRK^T$$

Figure 3. Sensor Fusion with Robot Localization Package

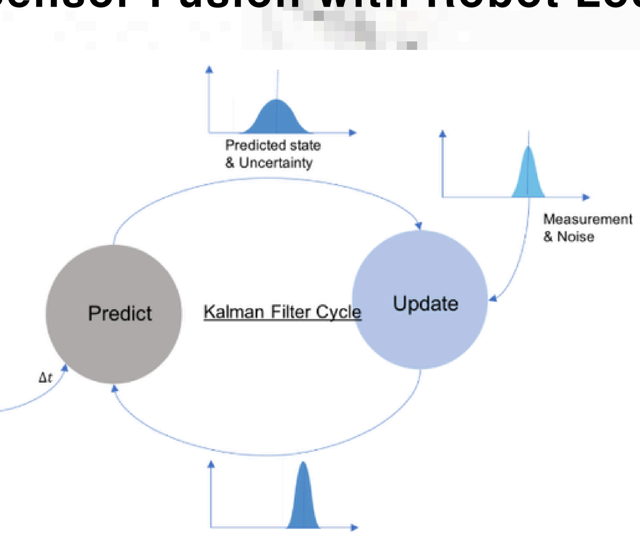

Figure 4. Kalman Filter Cycle

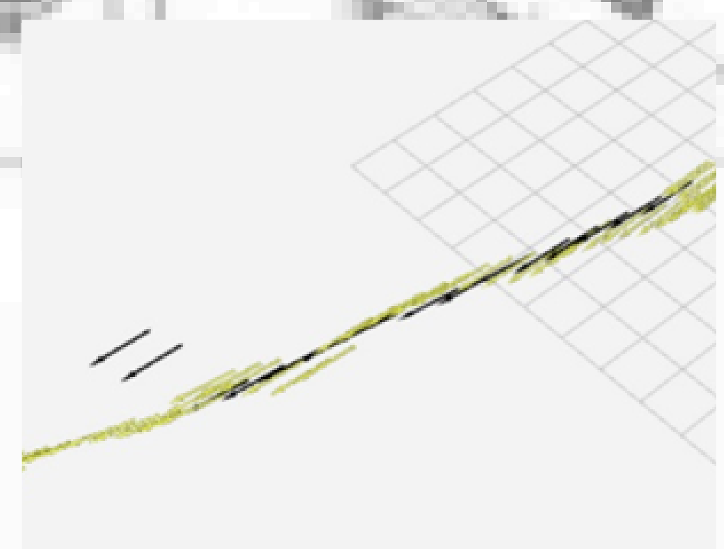

Figure 5. Lidar & Stereo camera data

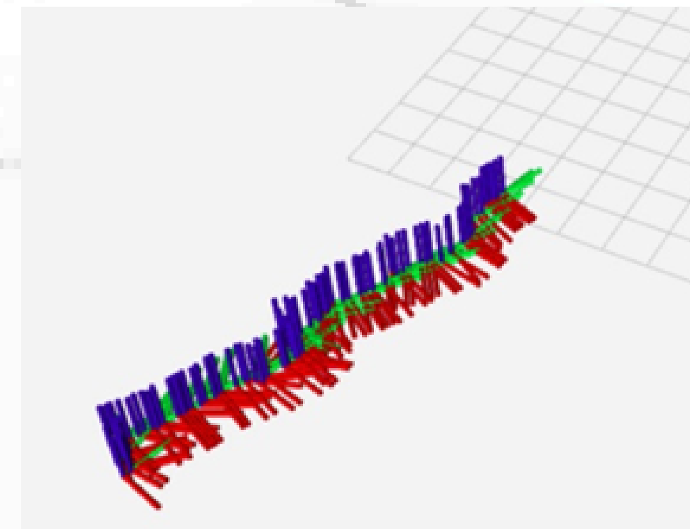

Figure 6. Robot Localization out

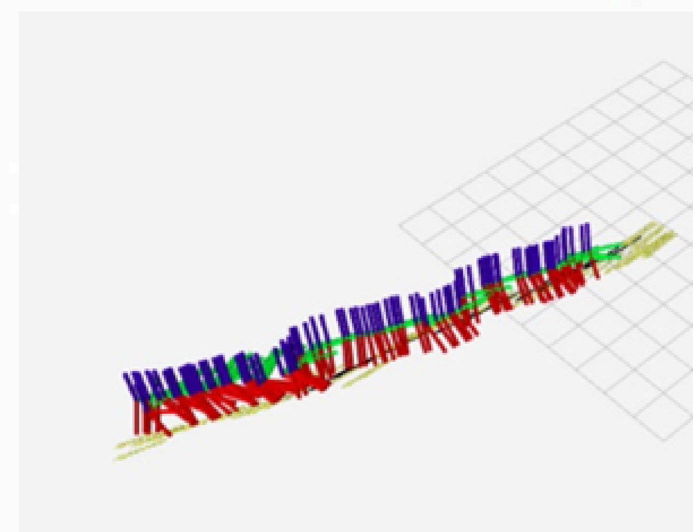

Figure 7. Lidar, Stereo camera and Robot localization data

The comparison between raw GPS data and RTK-verified data highlights a significant difference in stability and accuracy. The raw GPS data exhibits a broad distribution of position estimates, indicating a lack of precision with potential drifts of several meters. In contrast, the RTK-verified data is much more concentrated and stable, demonstrating centimeter-level accuracy. This high level of precision is achieved through RTK corrections.

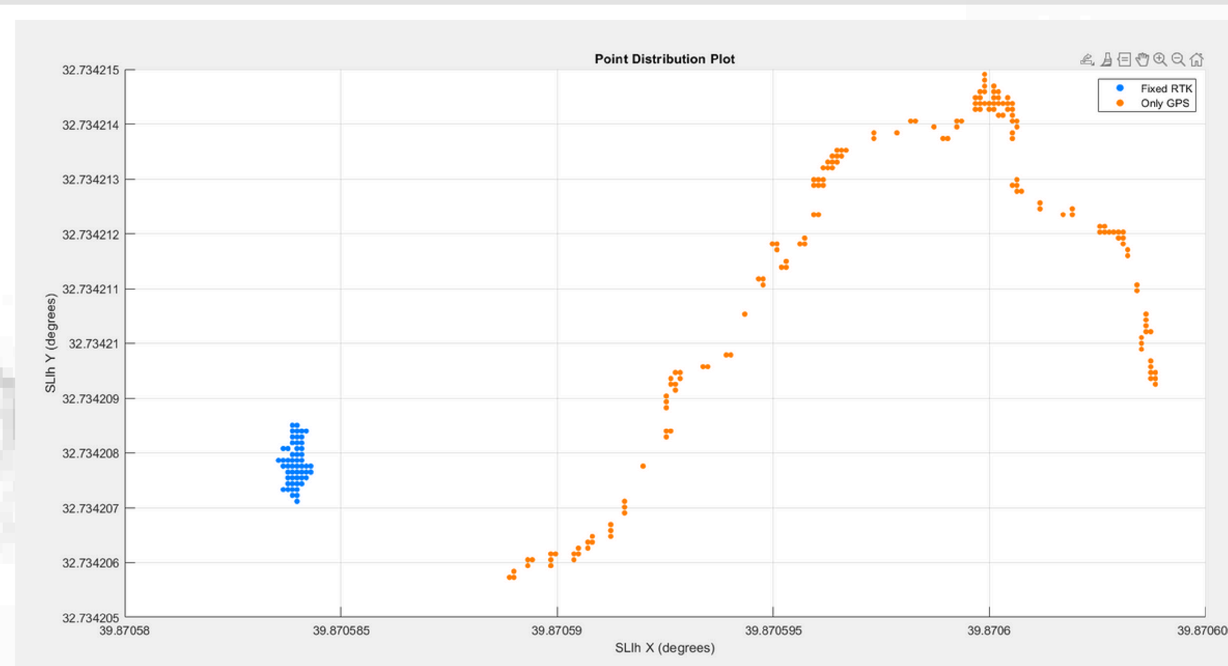

Figure 8. GPS-RTK Tests

Point cloud data from 3D LiDAR and stereovision cameras are broadcast as ROS topics over the network and received by an Ubuntu system in VirtualBox. The data are transmitted via WebSocket to Unity on the host Windows machine. This enables 3D visualization in VR, allowing real-time assessment of the robot's environmental perception from various sensor locations.

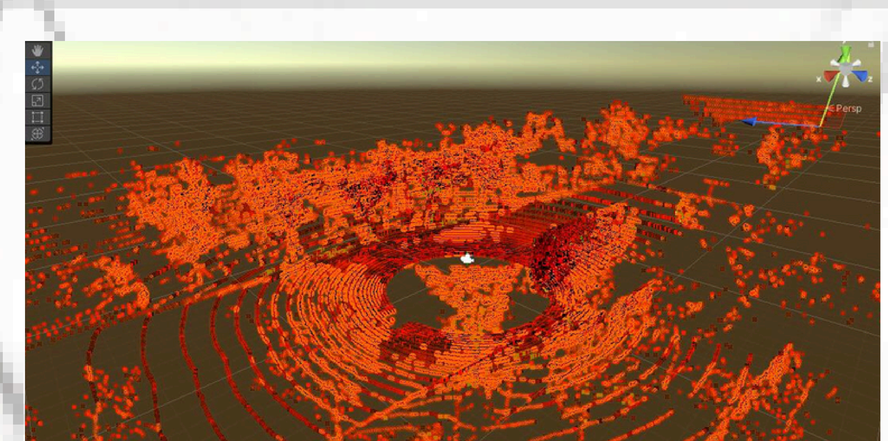

Figure 9. Lidar Point Cloud on Unity Scene

Figure 10. Oculus

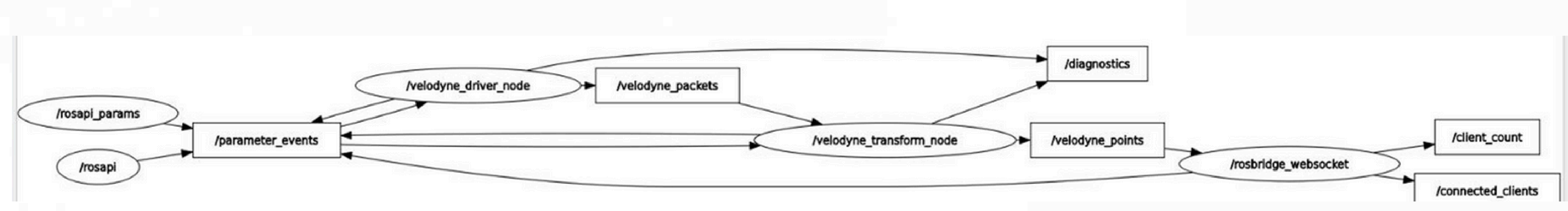

Figure 11. Rqt Graph of VR Visulation

Acknowledgements

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