Drones for Autonomous Descent in Sewer Manholes

Embark on our autonomous drone quest in urban sewers. We combat platform limits, detect manholes, navigate to their centers, and execute descents, translating simulation wins to real-world achievements. Join us in this underground exploration!

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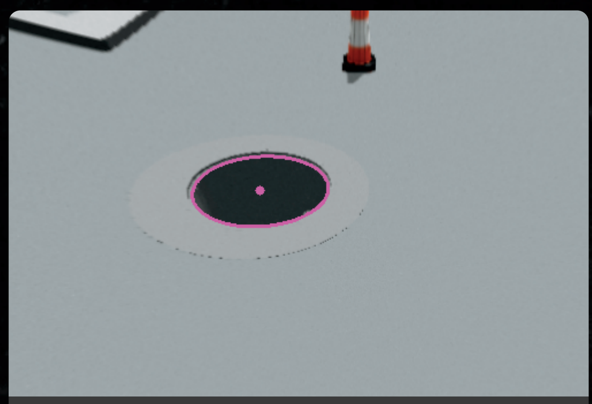
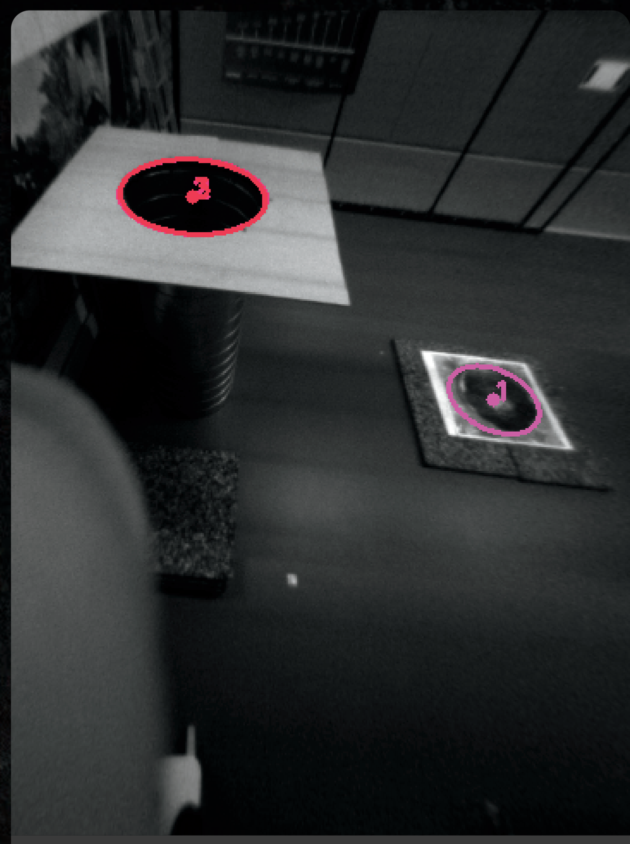
Question 1.1: How do we precisely locate sewer manholes in a complex environment?

Answer 1.1: We utilized two ellipse detection algorithms for sewer manhole identification - an OpenCV-based method and a modified AAMED-based technique [1]. The AAMED method showed resilience, effectively detecting manholes in all scenarios, thus selected for subsequen research.

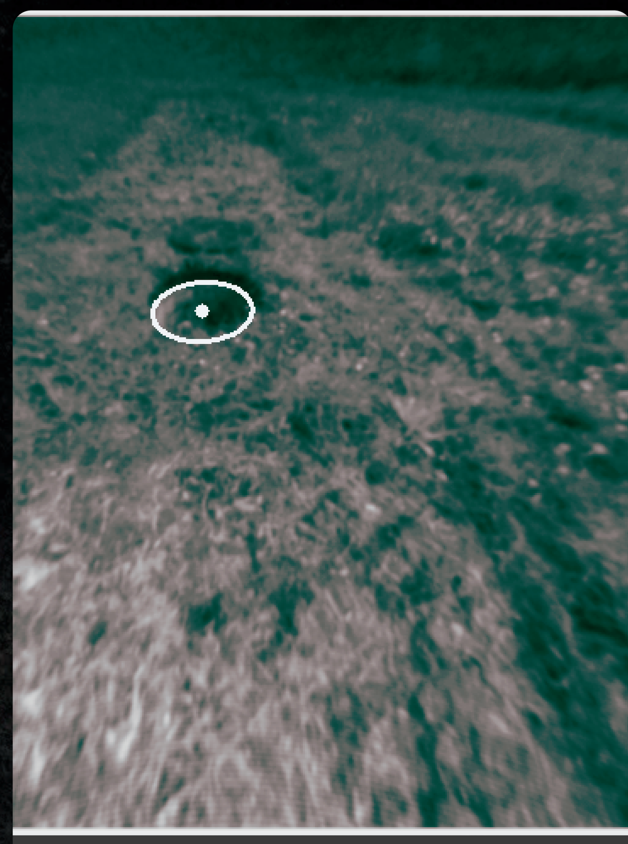


Detecting Manhole in Gazebo

Detecting Printed Manhole



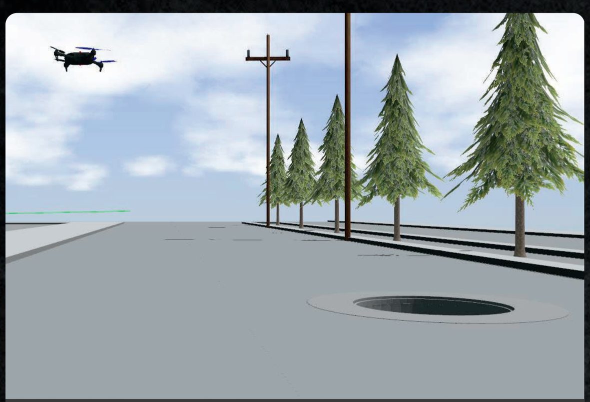
Detecting Tube and Printed Manholes at Eurecat Lab



Detecting Manhole in the Heart of Girona

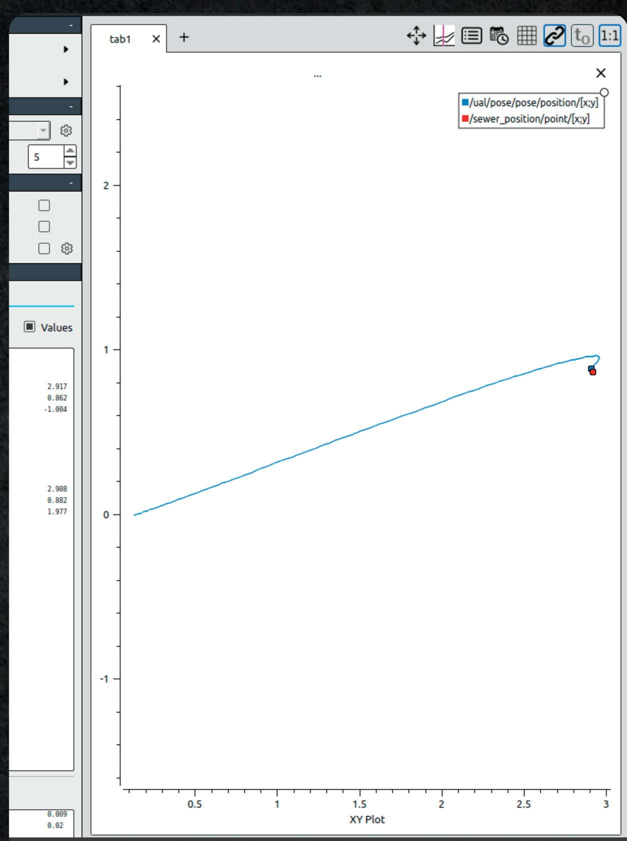
Question 1.2: How to translate manhole image detections into drone navigation commands?

Answer 1.2: We transform 2D manhole data into 3D navigation coordinates through back-projection. This includes pixel-to-camera conversions, locating where the 3D vector intersects the ground from the image center, and transitioning the 3D point from camera to world frame.

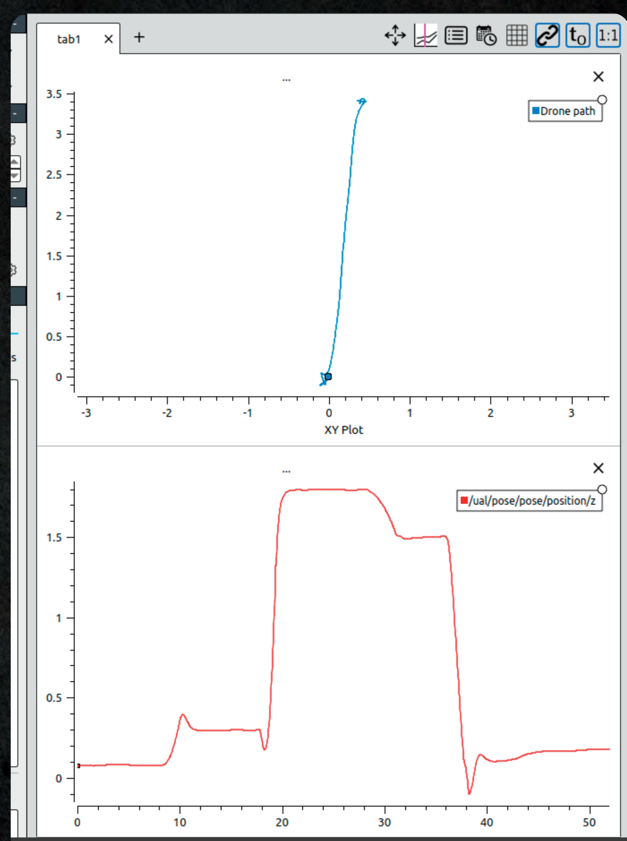


Navigation in Gazebo

Navigation at the Lab



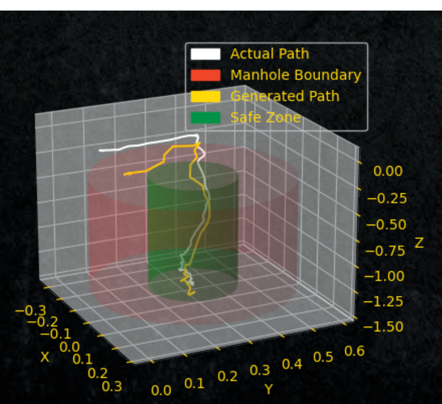
Drone's Path to Manhole Center via Back Projection (Gazebo)



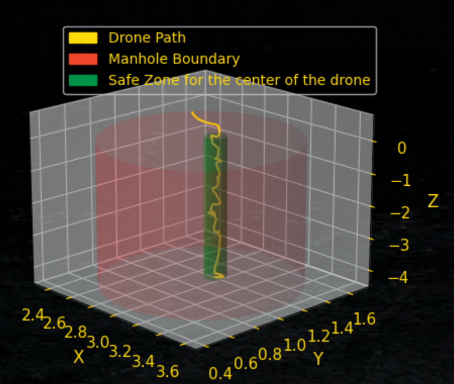
Drone's Path to Manhole Center via Back Projection (Lab)

Question 2: Which algorithm can ensure a safe drone descent in sewer manholes?

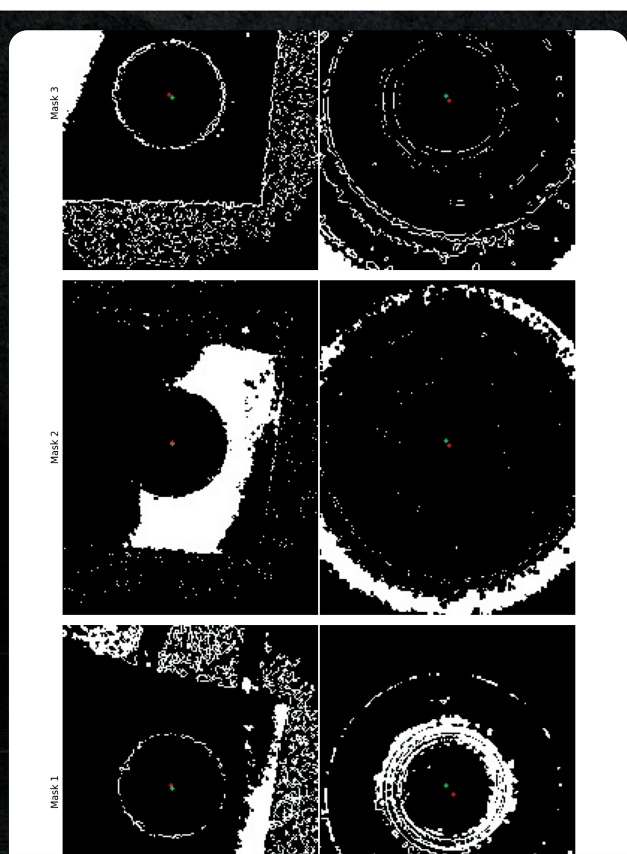
Answer 2: Our depth-based algorithm segments depth images into masks, identifies safe areas, and back-projects these centers into real-world coordinates, creating a path. The algorithm continuously updates this path with new images for a responsive descent.



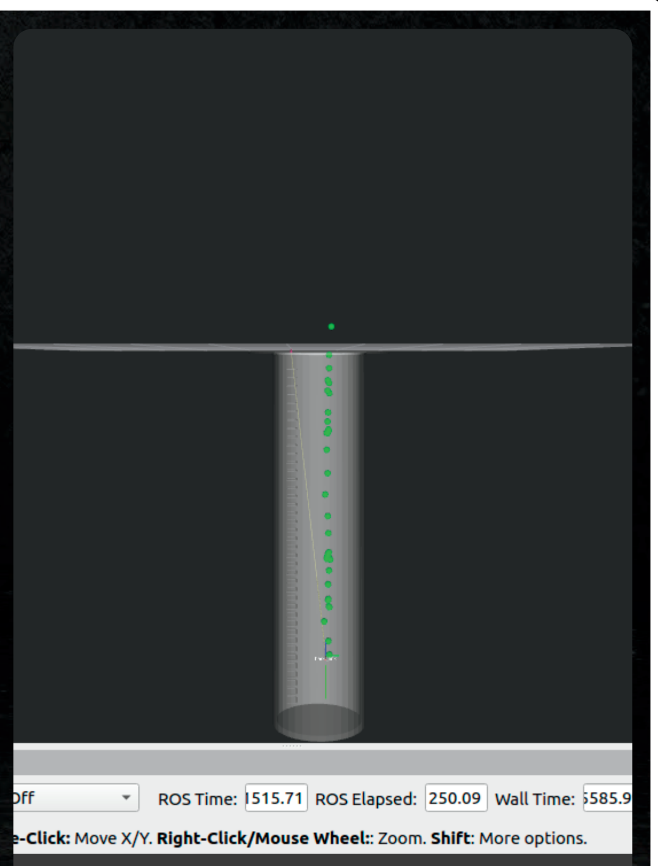
Simulated Descent Path



Real-World Descent Path



Algorithm's Predicted vs. Actual Tube Centers using Real Depth Images

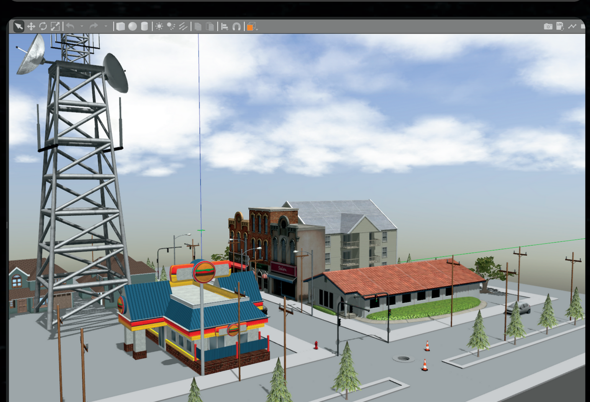


Simulated Descent Path RVIZ

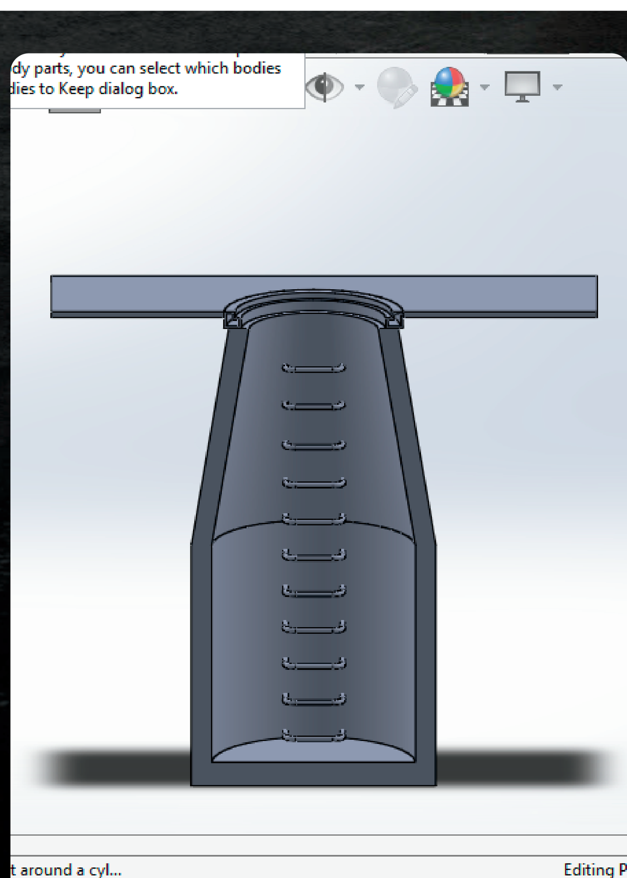
Question 3: How do we model the mission accurately for real-world use, considering complex sewer geometry?

Answer 3: We used SolidWorks for custom sewer manholes in a Gazebo urban simulation. We paired this with a scaled Iris Quadrotor model with simulated cameras for realistic testing. This ensures reliable mission simulations amid varying tunnel geometries.

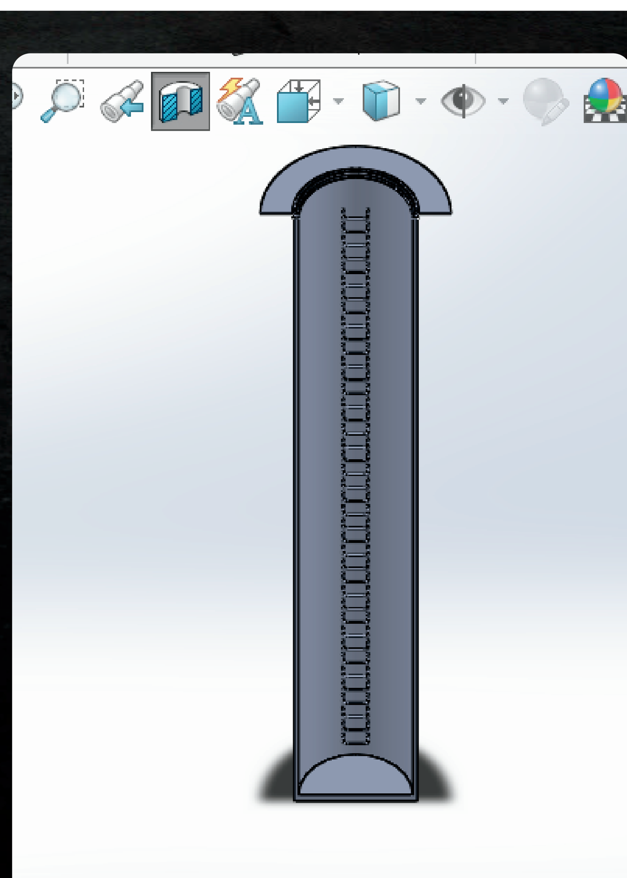
Scaled Iris Quadrotor



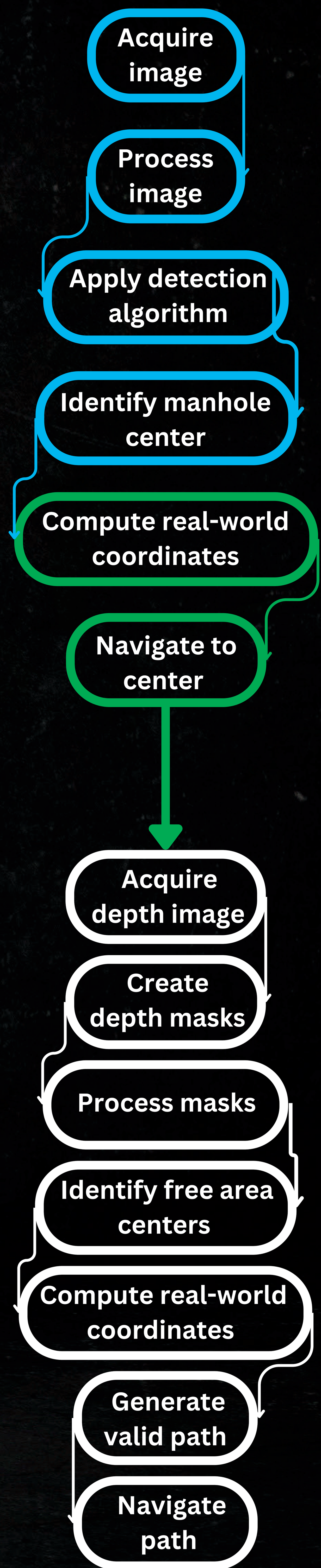
Gazebo-based Sewer Manhole



SolidWorks: Tapered 600-900mm Manhole Design



SolidWorks: Fixed 600mm Manhole Design



SCAN ME

References
[1] Cai Meng et al. "Arc Adjacency Matrix-Based Fast Ellipse Detection". In: IEEE Transactions on Image Processing PP (Jan. 2020), pp. 1–1. doi: 10.1109/TIP.2020.2967601

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