Voxel Size Selection for Rover Path Planning

1 Objective

The goal of this analysis is to determine an appropriate voxel size for downsampling LiDAR terrain data used in rover path planning. The voxel size must preserve terrain features that affect rover drivability while reducing noise and computational complexity for graph construction and path planning.

2 Rover Parameters

The following rover specifications are used in the analysis:

- Wheel diameter: 8.5 in (≈ 0.216 m)
- Wheel radius: 0.108 m
- Wheel width: 8 in (≈ 0.203 m)
- Ground clearance (with arm): 8.5 in (≈ 0.216 m)
- Maximum climbable slope: 36°

Rover length and width are not directly used for voxel size determination, as they are more relevant for later footprint-based collision checking.

3 Core Principle

A rover cannot meaningfully respond to terrain features smaller than the physical scale of its wheel–ground interaction. Therefore, the voxel size should reflect the minimum terrain feature size that can influence rover mobility, such as slope, grounding risk, or loss of traction.

4 Vertical Terrain Constraint

The rover risks grounding when vertical terrain variation exceeds ground clearance. To maintain a safety margin, vertical variations are limited to a fraction of the ground clearance:

$$\Delta z_{\text{safe}} \leq (0.3 - 0.5) \times \text{ground clearance} \tag{1}$$

$$\Delta z_{\text{safe}} = 0.4 \times 0.216 \approx 0.086\,\text{m} \tag{2}$$

Vertical changes smaller than approximately 8.6 cm can therefore be safely smoothed.

5 Slope-Based Horizontal Resolution

Using the maximum allowable slope:

$$\tan(\theta) = \frac{\Delta z}{\Delta x} \tag{3}$$

Solving for Δx:

$$\Delta x = \frac{\Delta z}{\tan(36^\circ)} \tag{4}$$

Since $\tan(36^\circ) \approx 0.726$:

$$\Delta x = \frac{0.086}{0.726} \approx 0.118\,\text{m} \tag{5}$$

This implies that horizontal terrain features smaller than approximately 12 cm cannot generate slopes critical to rover operation.

6 Wheel Width Constraint

The voxel size must not be smaller than the wheel width. If voxel size is less than wheel width, the terrain model may capture features affecting only a single wheel, which is incompatible with point-based graph representations.

$$\text{voxel size} \geq \text{wheel width} \approx 0.20\,\text{m} \tag{6}$$

7 Final Voxel Size Selection

The lower bounds for voxel size are summarized below:

Constraint	Minimum Value
Slope realism	0.12 m
Vertical clearance smoothing	0.15 m
Wheel width	0.20 m

Following robotics best practices, the voxel size is chosen to be 1.5–2 times the strict minimum to provide robustness against noise and modeling error.

8 Recommended Voxel Size

$$\boxed{\text{Voxel size} \approx 0.35\,\text{m}} \tag{7}$$

This value:

- Exceeds wheel width, avoiding false obstacles
- Preserves slopes near the rover's maximum capability
- Smooths sub-wheel-scale noise
- Significantly reduces graph size and computation time

9 Conclusion

The selected voxel size of 0.35 m is grounded in rover kinematics, terrain interaction physics, and slope constraints. This choice ensures that the downsampled terrain remains physically meaningful for path planning while enabling efficient graph construction and fast A* execution.