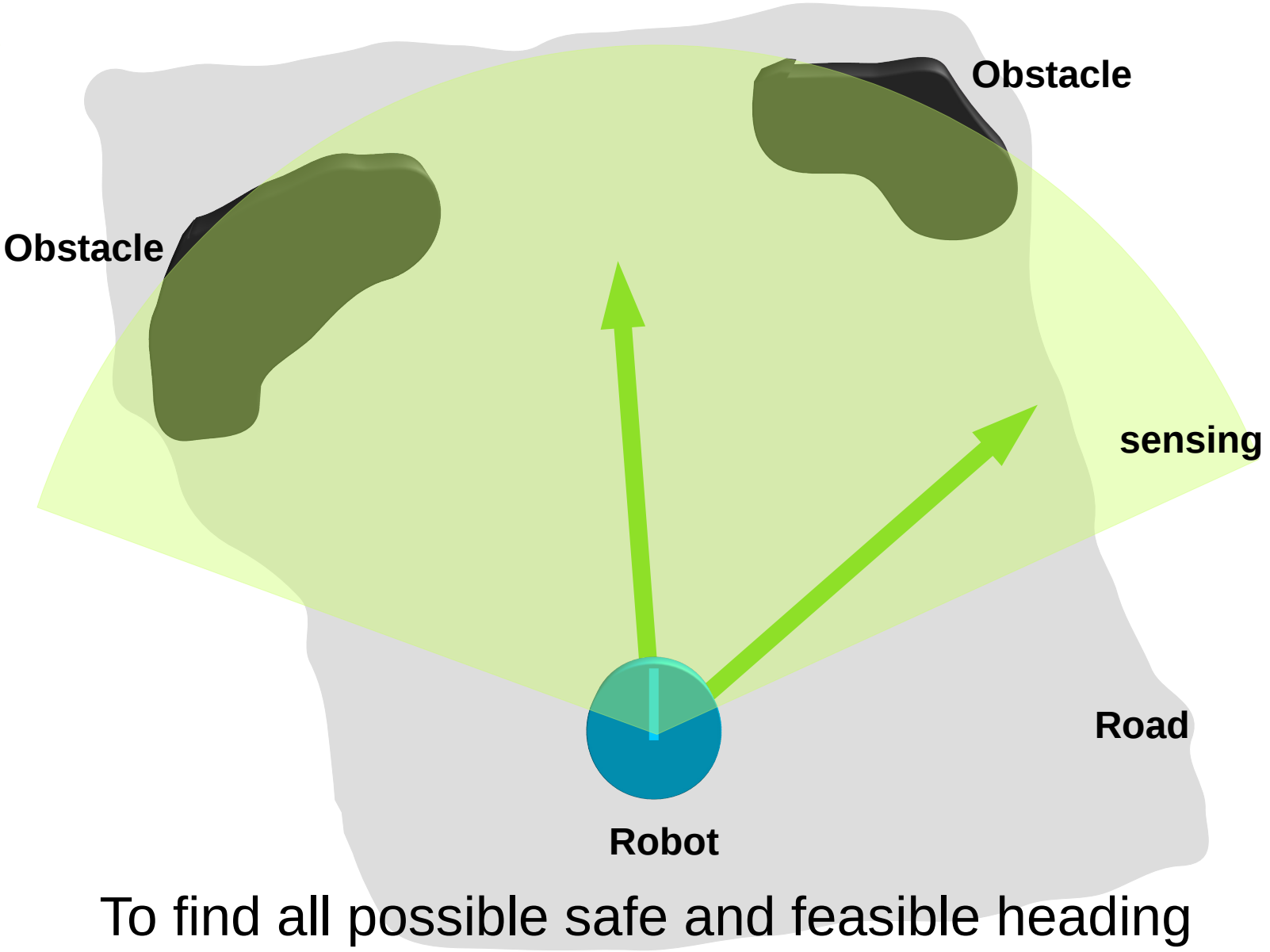
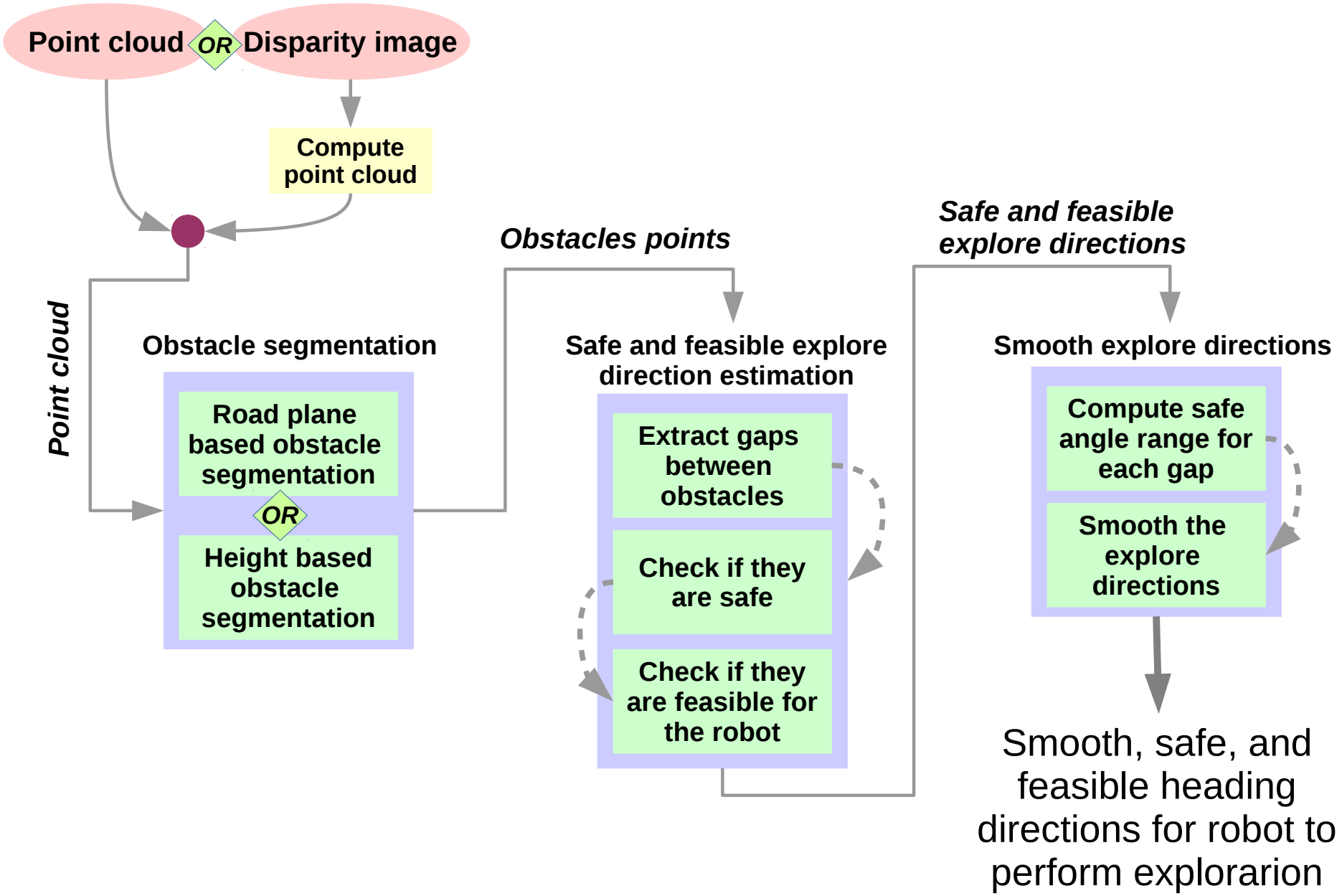
Exploration in single-robot SLAM

Objective



To find all possible safe and feasible heading directions for the robot to explore

Explore Direction Estimation Pipeline



Obstacle Segmentation

Height based obstacle segmentation

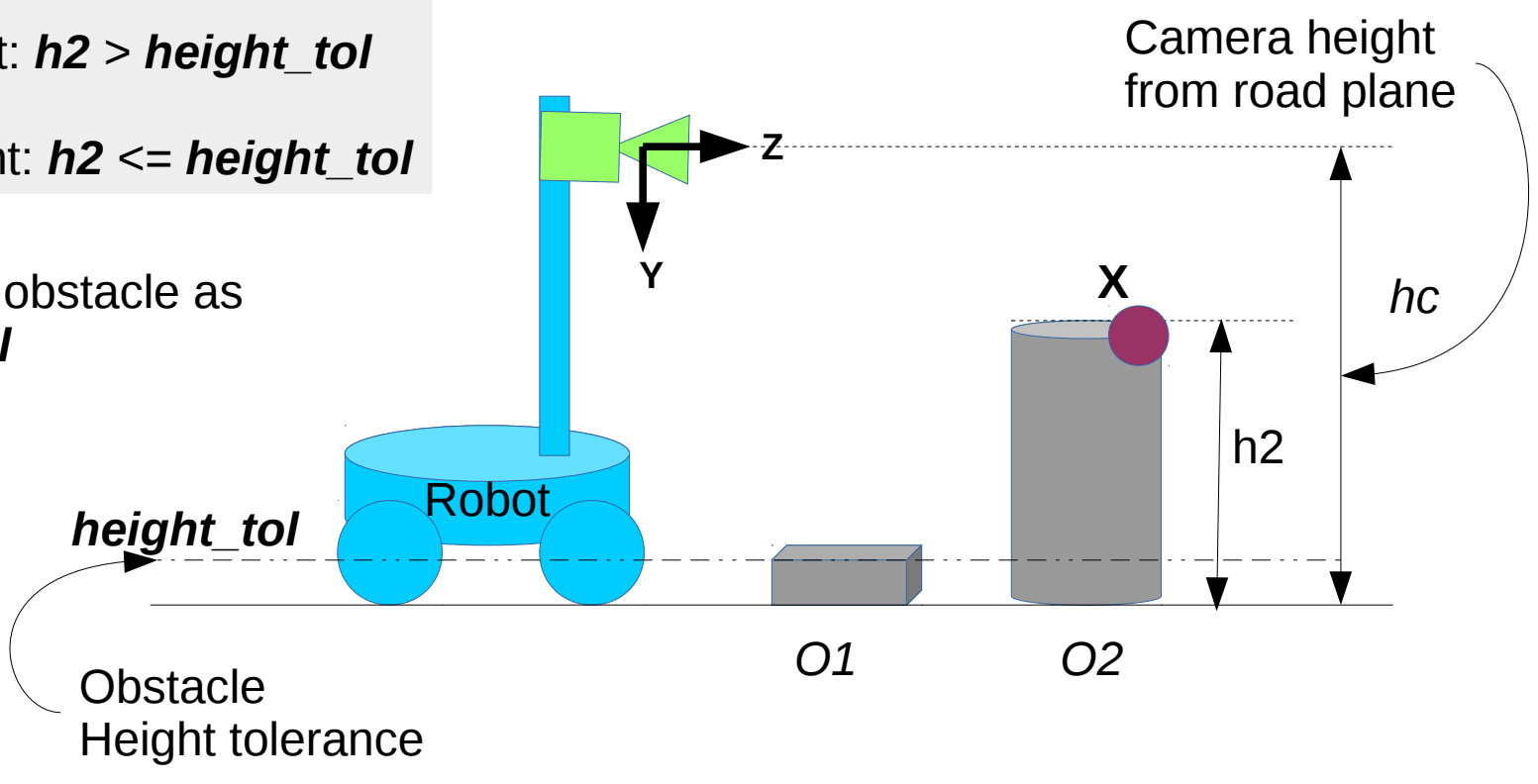
- Simple and Fast
- Depends on camera's height from road
- We only need to consider the Y coordinate of a point to qualify it as an obstacle
- Assumes road to be (approx) planar and parallel to camera's Z-axis

h2 = {X.y – hc}

X is an Obstacle point: ***h2*** > ***height_tol***

X is not Obstacle point: ***h2*** <= ***height_tol***

O1 is not considered as obstacle as
height(*O1****)*** < ***height_tol***



Obstacle Segmentation

Road plane based obstacle segmentation

- Robust
- Fits a plane to the set of points close to road
- Uses RANSAC and SVD for robustness and least square optimization
- Categorizes points in two sets: road points and obstacle points
- Only assumes the road to be (approx) planar

$$argmin \sum_{i=1}^{N} ((\mathbf{p}_i - \bar{\mathbf{p}})^T \mathbf{n})^2$$

Road plane fitting (n is the normal to be estimated)

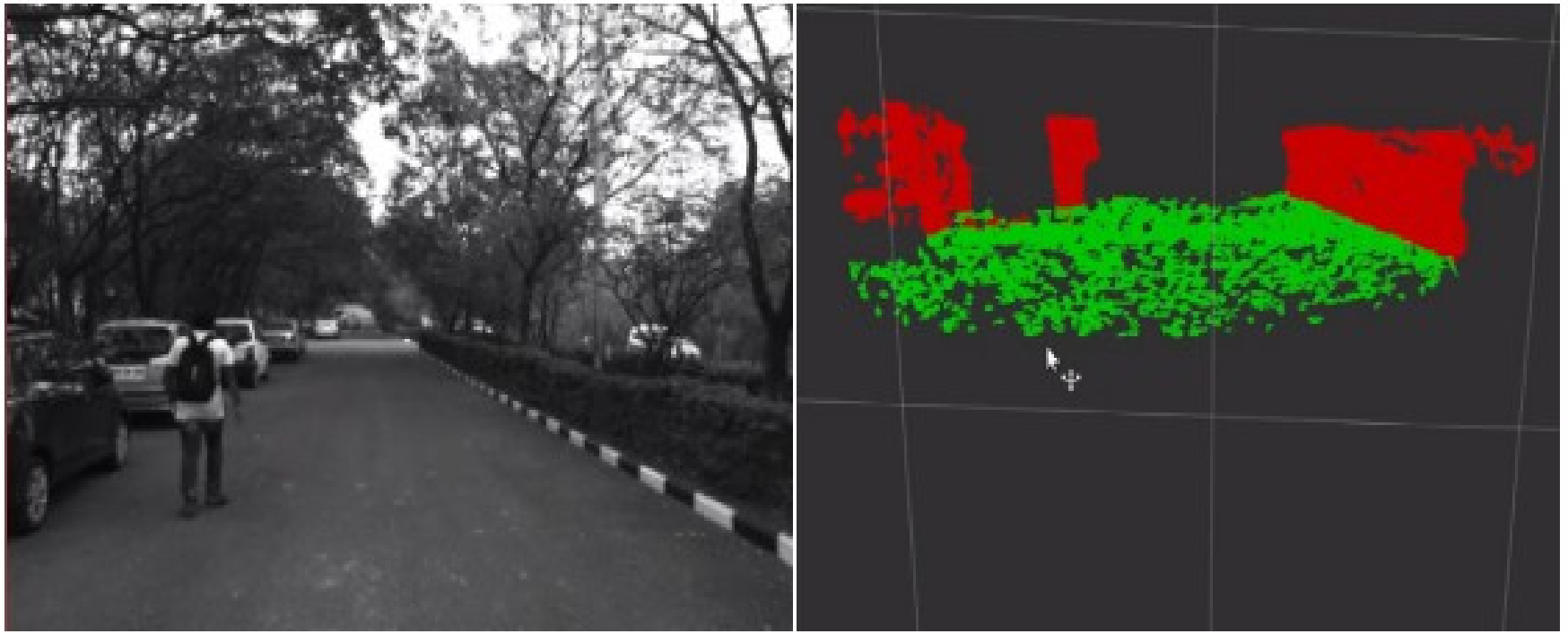
$$p_i \in obstacles \iff \{(\mathbf{p}_i - \bar{\mathbf{p}})^T \mathbf{n}\} > road\_plane\_tolerance$$

$$p_i \in road \iff \{(\mathbf{p}_i - \bar{\mathbf{p}})^T \mathbf{n}\} \leq road\_plane\_tolerance$$

Road plane normal, n, is used for qualifying points as road or obstacle points

Obstacle Segmentation

Road plane based obstacle segmentation - Result



Road and Obstacle points are rendered in red and green color, respectively

Safe and feasible explore direction estimation

Extracting safe gaps between obstacles

To extract gaps:

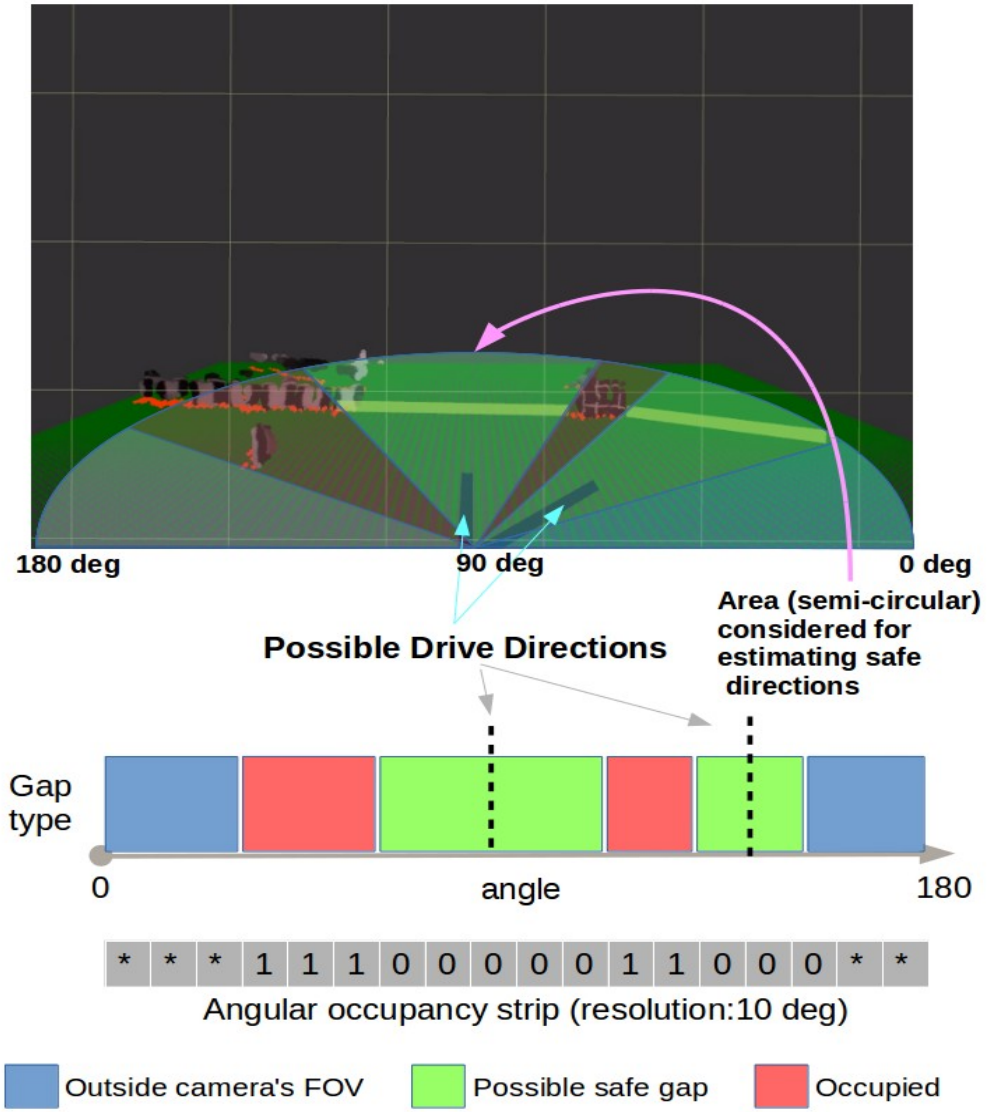
- Obstacles are represented in polar coordinates

- Angular occupancy strip is generated

- connected non obstacle cells in angular occupancy strip are labelled as gaps

Safety check:

- gaps of considerable width are chosen as safe gaps

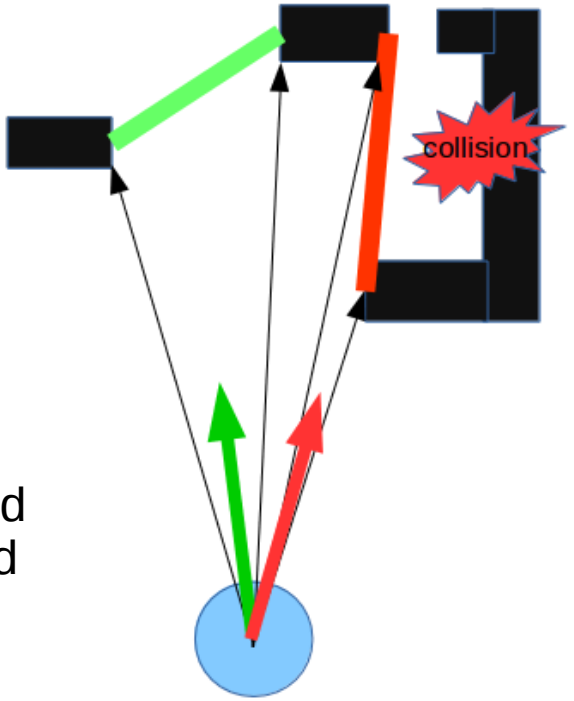


Safe and feasible explore direction estimation

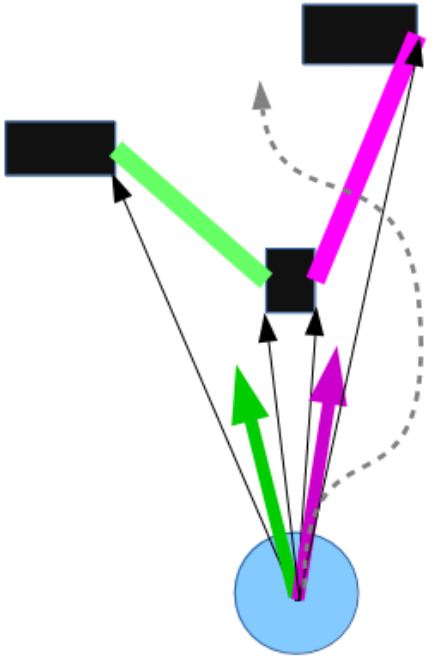
Extracting feasible explore directions

- False gaps caused by occulsion are detected by looking at their orientation and the corresponding explore direction's (case 1)

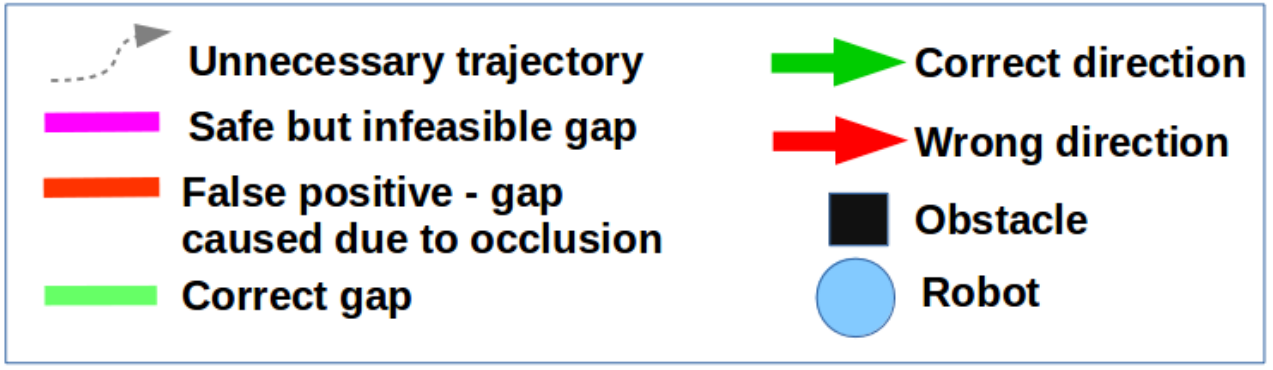
- Infeasible gaps which might require the robot to make unnecessary maneuvers are detected and rejected by considering their orientatation and spatial location (case 2)



Case 1: False gap



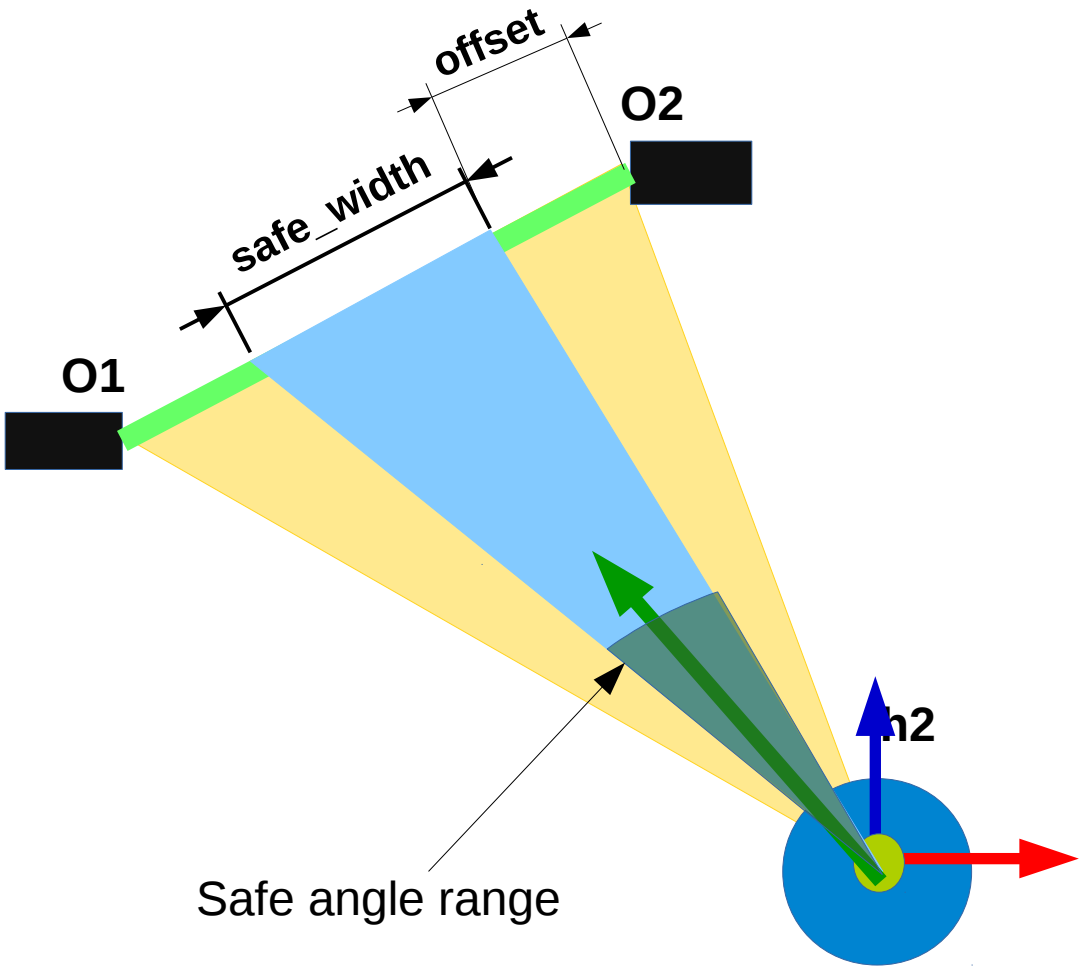
Case 2: Infeasible gap



Smoothing the estimated explore directions

Compute safe angle range for safe and feasible gaps

- Gap's width is reduced by an **offset**
- the **offset** is typically equal to half the robot's width
- safe angle range is the range of angles in the **safe_width** of the gap



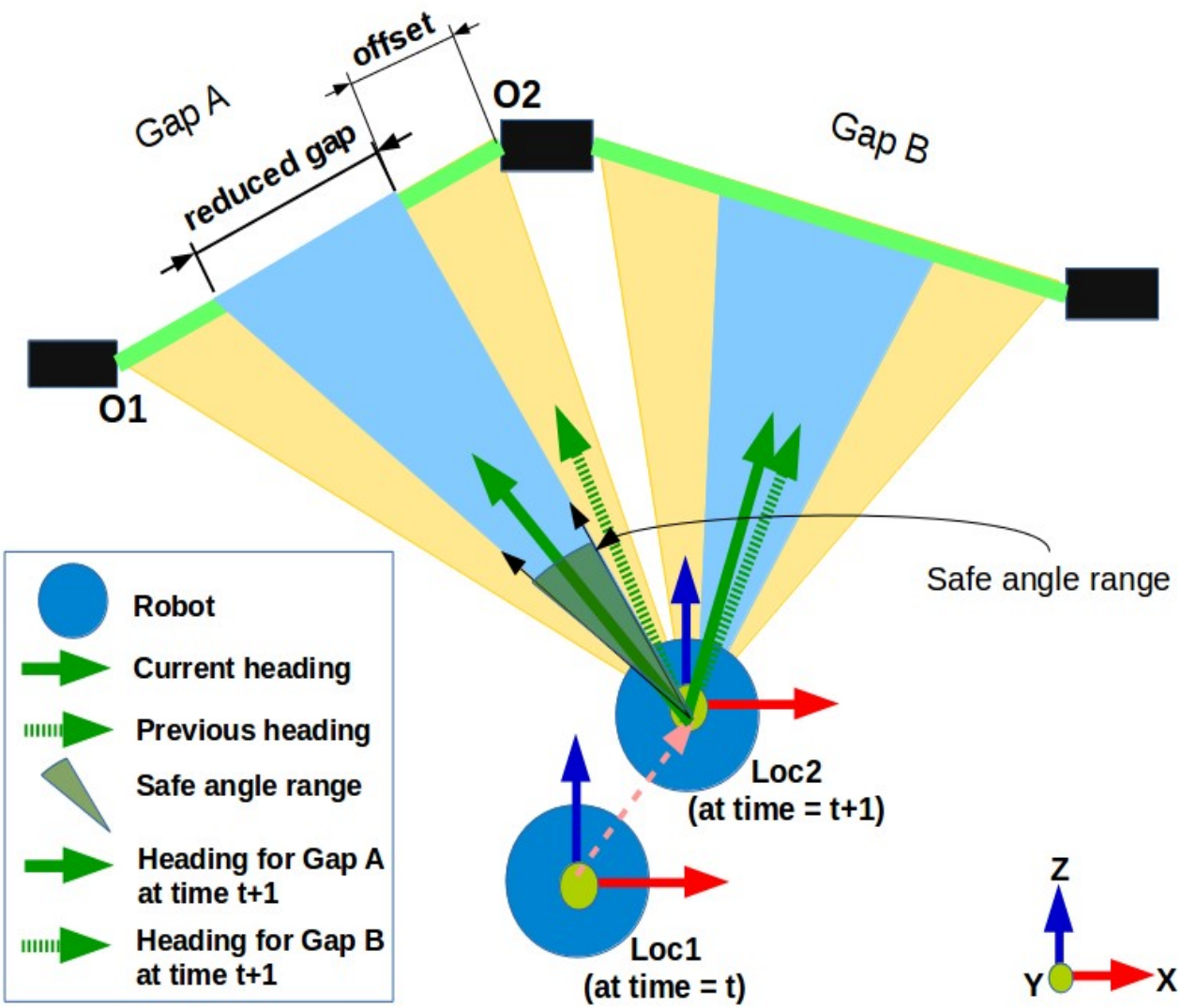
Smoothing the estimated explore directions

Smoothing the directions

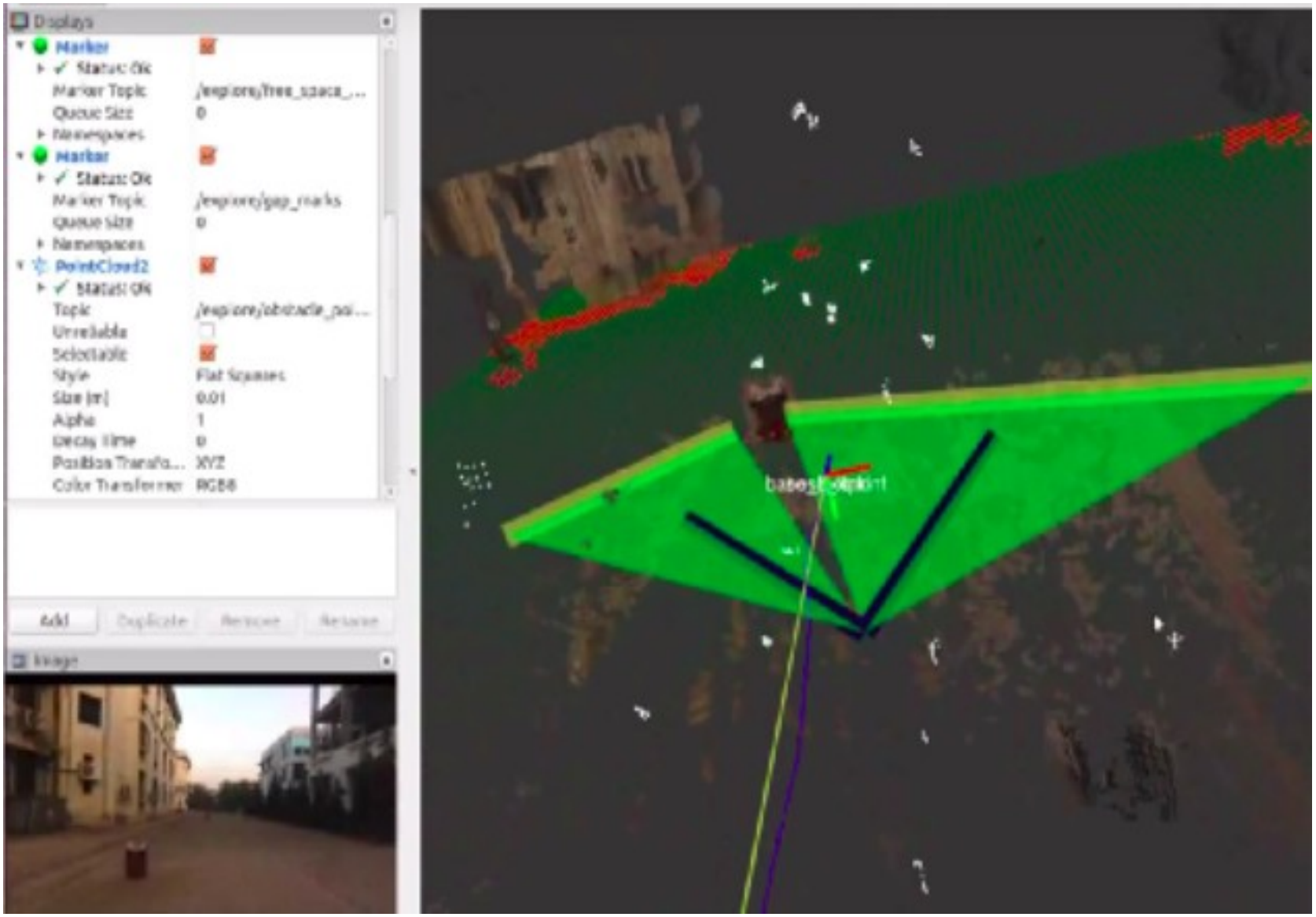
- An explore direction is only changed if it is necessary and unsafe

- An explore direction is only updated if the previous the explore direction corresponding to its gap lies out of the safe angle range of the gap

- Otherwise we maintain the previous direction.



Result



Explore Direction Estimator integrated with RTAB framework