Kobe University | Function-Oriented Robotics Laboratory

Environmental Recognition and Mapping for Autonomous Mobile Robots

Prepared: October 2026

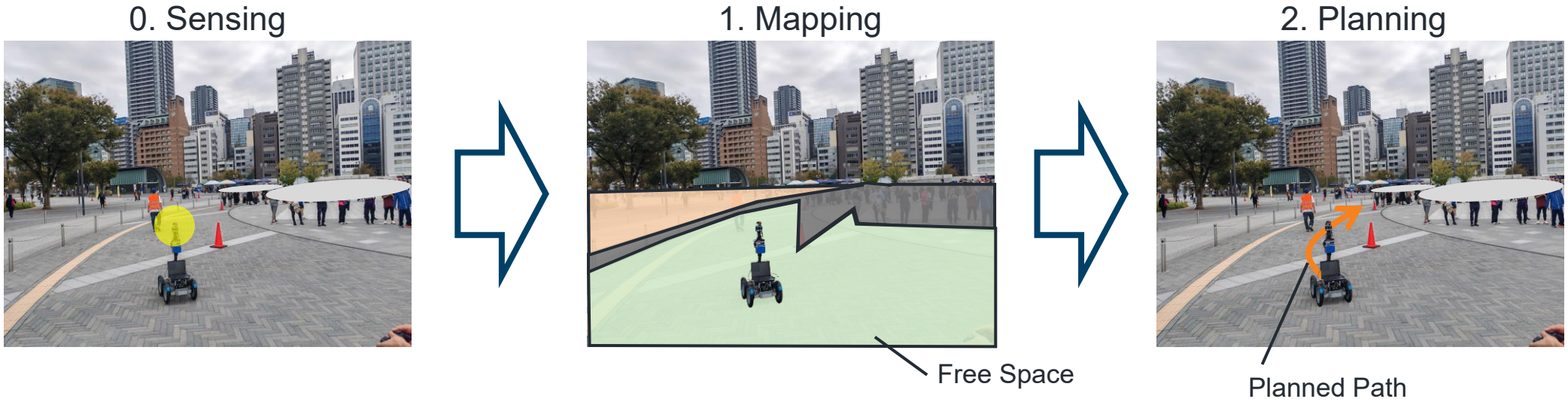
Autonomous Mobile Robots

- **Robots operating autonomously**
  1. Recognize free space
  2. Plan actions
  3. Execute tasks

For autonomous navigation

1. Build a map
   Classify space as free, occupied, or unknown
2. Plan a path to move
3. Estimate pose and follow the path (navigation)

- **Example Navigation Workflow**



Map size and structure affect computational cost and navigation performance.

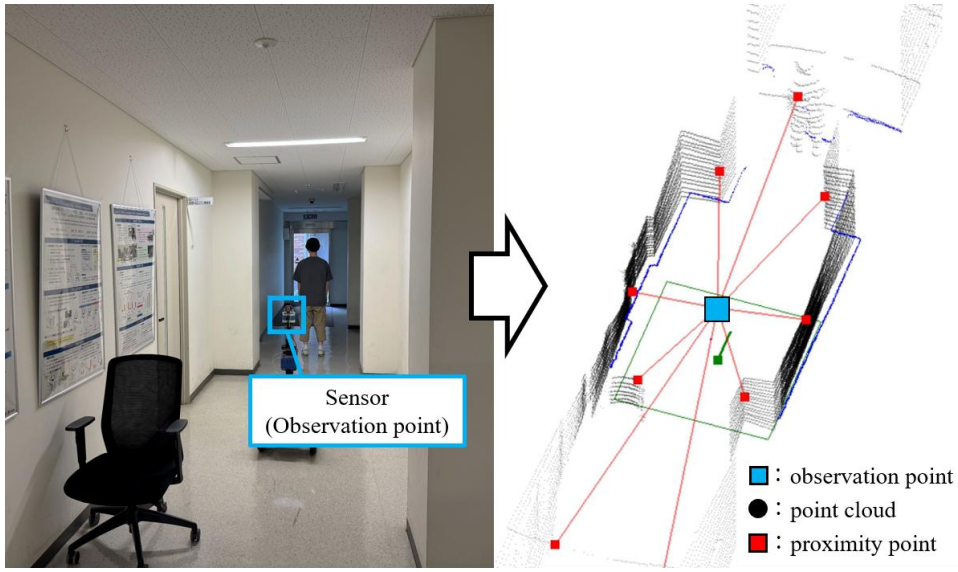
Mapping and navigation must balance computation and motion performance.

Point Clouds and Proximity Points [Y. Tazaki et al., 2023]

➢ **Point cloud:** Coordinates of laser returns from object surfaces, measured using LiDAR or depth cameras.

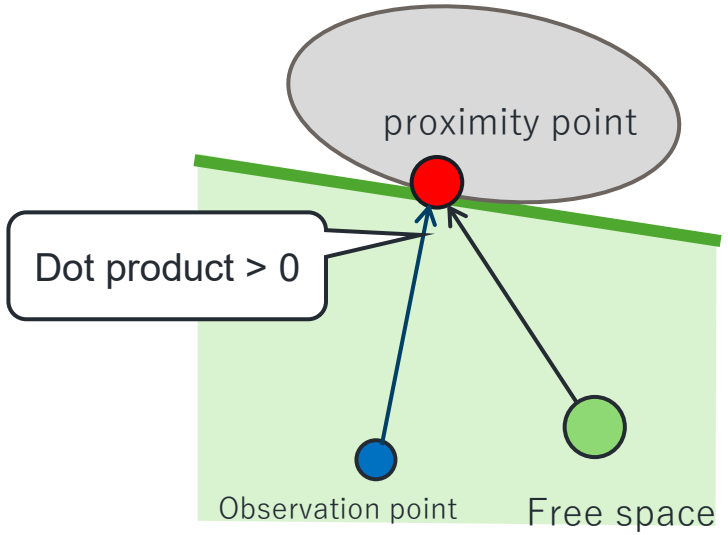
➢ **Proximity point:** A point at a local minimum of sensor distance, closer to the sensor than its neighboring points.

- Typically one is detected for each nearby convex object.
- Stored together with the corresponding sensor position.



➢ <u>Geometric Properties of Proximity Points</u>

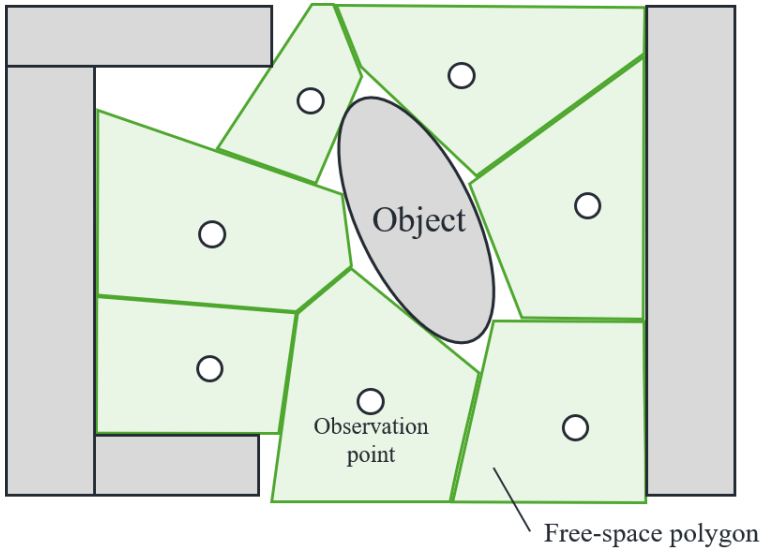
- The tangent line/plane at a proximity point defines an obstacle-free half-space toward the sensor.
- **Free-space extraction:**
  A candidate point is in free space if the dot product of its vector to the proximity point and the observation-to-proximity vector is positive.



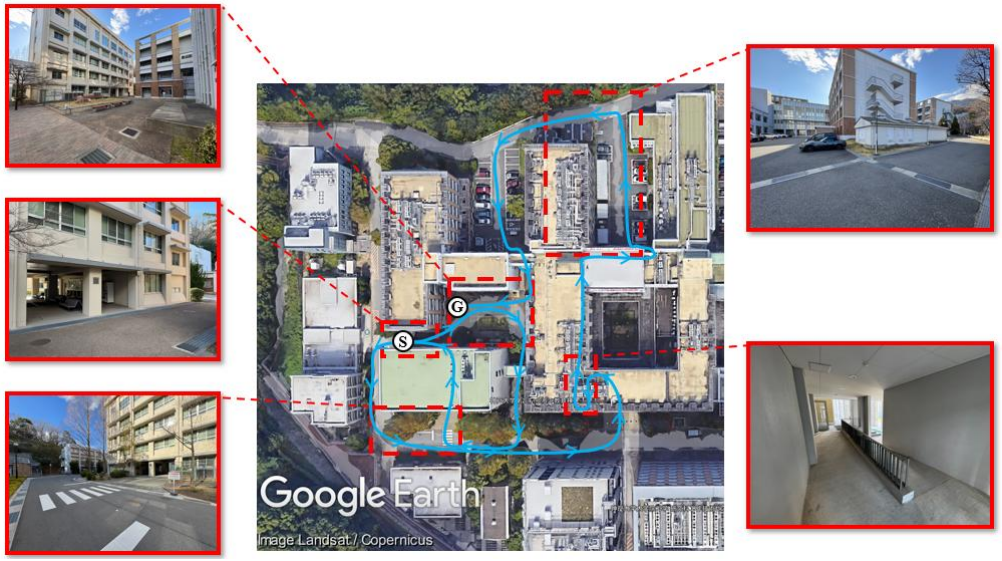
Polygonal Proximity Map [R. Nonomura et al., 2026]

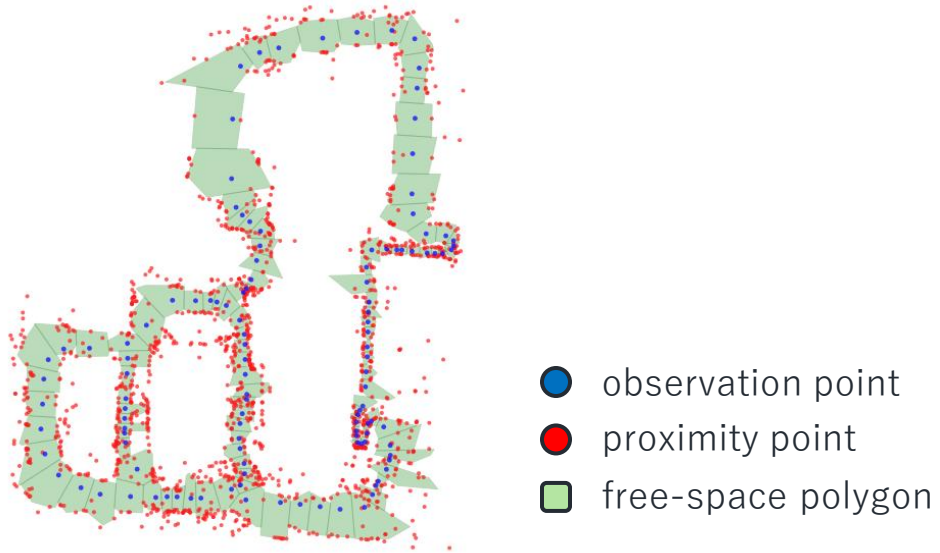
➢ **Polygonal Proximity Map:**
2D free space represented by convex polygons.

- At each observation point, intersecting the free half-spaces of all associated proximity points produces a convex polygon.
- Each observation point defines a convex free-space polygon; the union of these polygons represents the overall free space.
- Free-Space Membership in the Polygonal Map
  - Only the sign of a dot product needs to be evaluated.



➢ Polygonal Proximity Map in a Real-World Environment



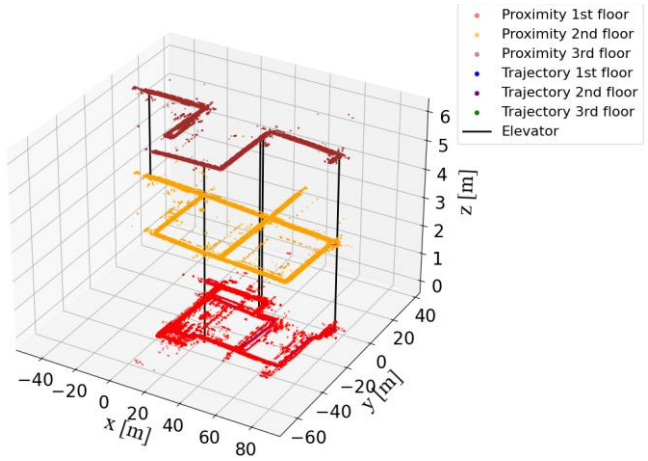


Real-World Experiments

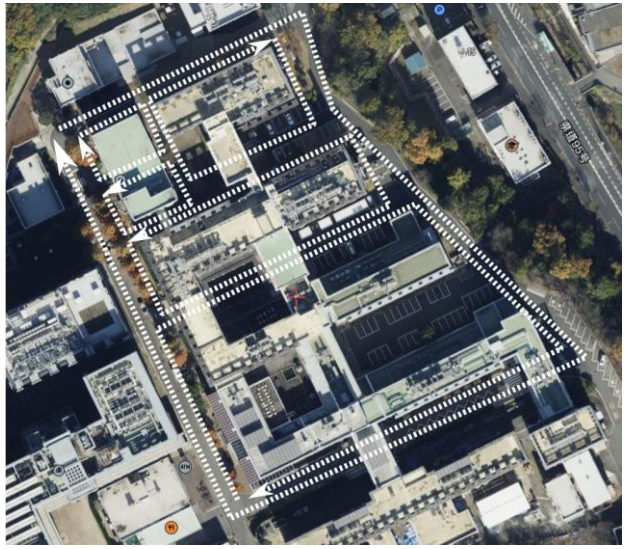


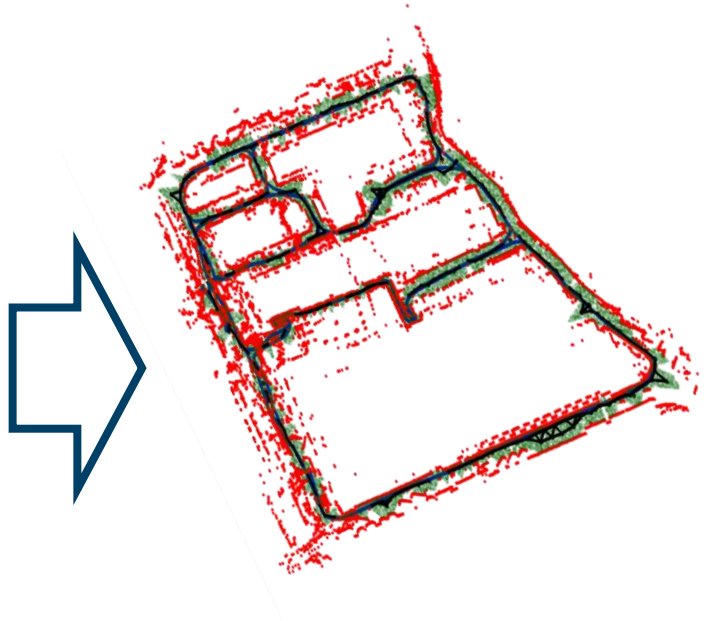
- **Nakanoshima Robot Challenge**
  - **Autonomous navigation in urban Osaka**
    At Nakanoshima Park and ATC

- **On-Campus Experiments**
  - Sensing and mapping inside and outside the Faculty of Engineering buildings



Multi-Floor Map





Polygonal Proximity Map