Robot Teknolojisine Giriş BLM4830

Öğr. Grv. Furkan ÇAKMAK

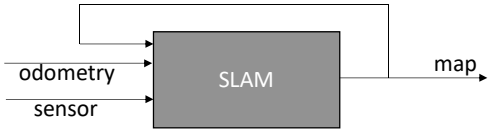
Ders Tanıtım Formu ve Konular

BLM4830 Robot Teknolojisine Giriş Hafta 5

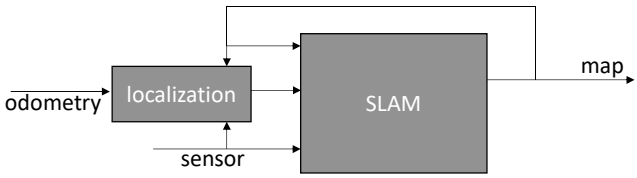
Hafta	Tarih	Konular
1	2.03.2022	Ders Tanıtımı, ROS ve Platform Tanıtımı, Robot Çeşitleri ve Robotik Konuları Başlangıcı
2	9.03.2022	Kinematik - Genel Tanımlar - Diferansiyel Sürüşlü Robot İçin Hesaplama Örnekleri
3	16.03.2022	Sensörler - Çeşitleri ve Çalışma Sistematikleri ve Uygulamaları
4	23.03.2022	Odometri ve Lokalizasyon Kavramları
5	30.03.2022	Haritalama Yöntemleri ve Uygulamaları
6	6.04.2022	Uygulama 1 (Laboratuvar) (Ödev İlanı)
7	13.04.2022	Navigasyon ve Keşif Yaklaşımları ve Uygulamaları
8	20.04.2022	Ara Sınav
9	27.04.2022	Uygulama 2 (Laboratuvar) (Ödev Teslimi)
10	4.05.2022	Tatil - Ramazan Bayramı Arifesi
11	11.05.2022	Robot Üzerinden Görüntü İşleme Teknikleri
12	18.05.2022	Robot Üzerinden Görüntü İşleme Teknikleri (Devam)
13	25.05.2022	3B Haritalama Yöntemleri
14	1.06.2022	Proje Sunumları

SLAM

- Simultaneous localization and mapping
- If odometry is perfect



- Since odometry is not perfect



Online – Full SLAM

- Online SLAM

$$p(x_t, m | z_{1:t}, u_{1:t})$$

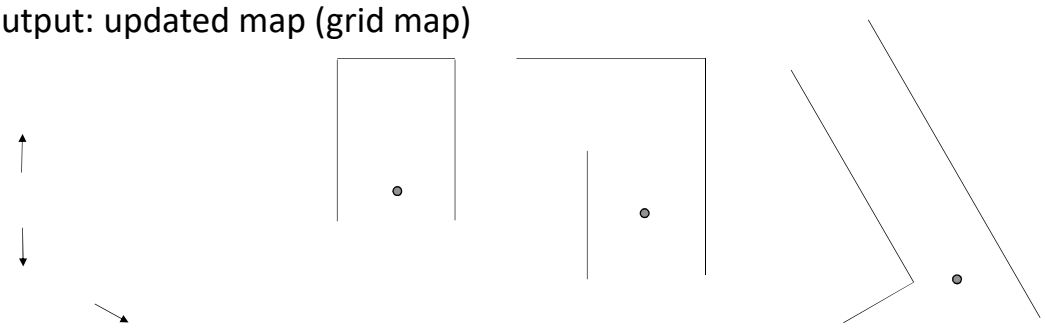
- Full SLAM

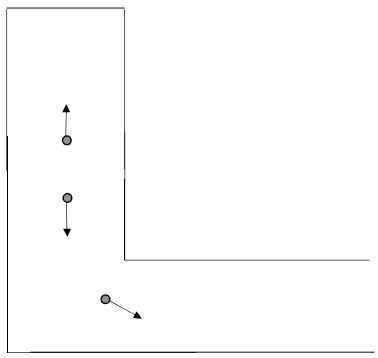
$$p(x_{1:t}, m | z_{1:t}, u_{1:t})$$

$$p(x_t, m | z_{1:t}, u_{1:t}) = \int \dots \int p(x_{1:t}, m | z_{1:t}, u_{1:t})\, d_{x_1} \dots d_{x_{t-1}}$$

Mapping with Perfect Odometry

- input: odometry (position, orinetation), sensor data (polar laser range), previous map (grid map)
- output: updated map (grid map)





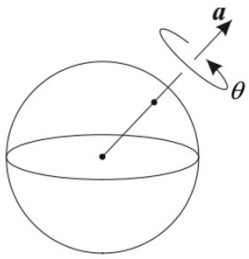
Quaternion – Orientation format

$$[w, x, y, z] = \left[\cos\left(\frac{\theta}{2}\right), \sin\left(\frac{\theta}{2}\right) \cdot nx, \sin\left(\frac{\theta}{2}\right) \cdot ny, \sin\left(\frac{\theta}{2}\right) \cdot nz\right]$$

(a is an arbitrary vector of rotation, nx, ny, nz components of normal vector a)

- For mobile robot travelling on XY-plane

$$[w, x, y, z] = \left[\cos\left(\frac{\theta}{2}\right), 0,0, \sin\left(\frac{\theta}{2}\right)\right]$$



SLAM Problem Statement

- Inputs:
  - No external coordinate reference
  - Time sequence of proprioceptive and exteroceptive measurements* made as robot moves through an initially unknown environment
- Outputs:
  - A *map** of the environment
  - A robot *pose estimate* associated with each measurement, in the coordinate system in which the map is defined

*Not yet fully defined

SLAM Problem -- Incremental

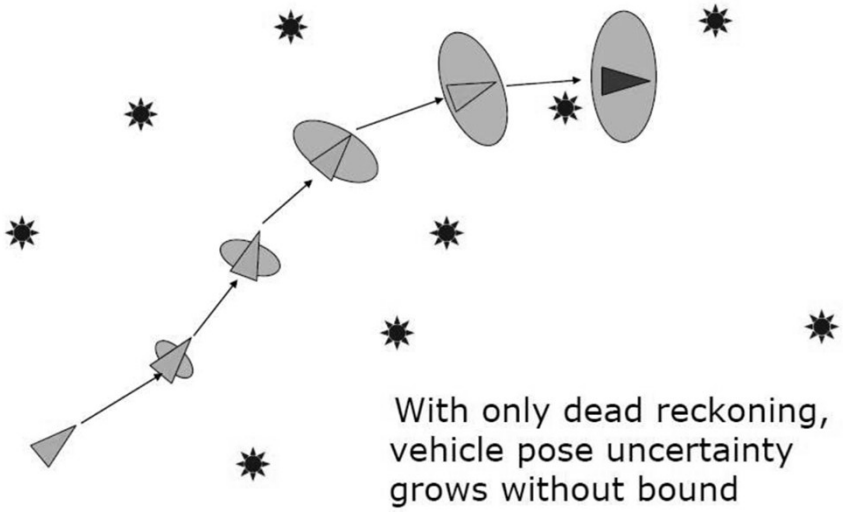
- State/Output:
  - Map of env't observed "so far"
  - Robot pose estimate w.r.t. map
- Action/Input:
  - Move to a new position/orientation
  - Acquire additional observation(s)
- Update State:
  - Re-estimate the robot's pose
  - Revise the map appropriately

SLAM Aspects

- What is a measurement?
- What is a map?
- How are map, pose coupled?
- How should robot move?
- What is hard about SLAM?

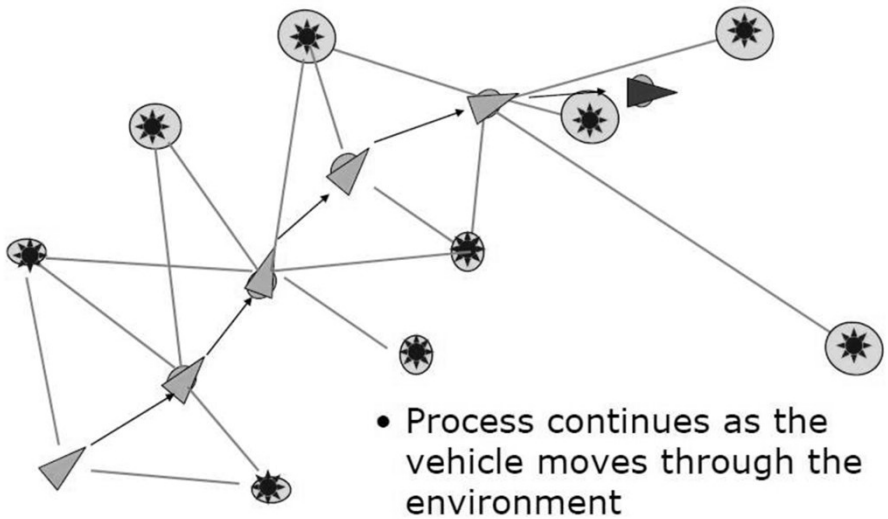
- But first: some intuition

Illustration of SLAM without Landmarks



With only dead reckoning, vehicle pose uncertainty grows without bound

Illustration of SLAM with Landmarks



- Process continues as the vehicle moves through the environment

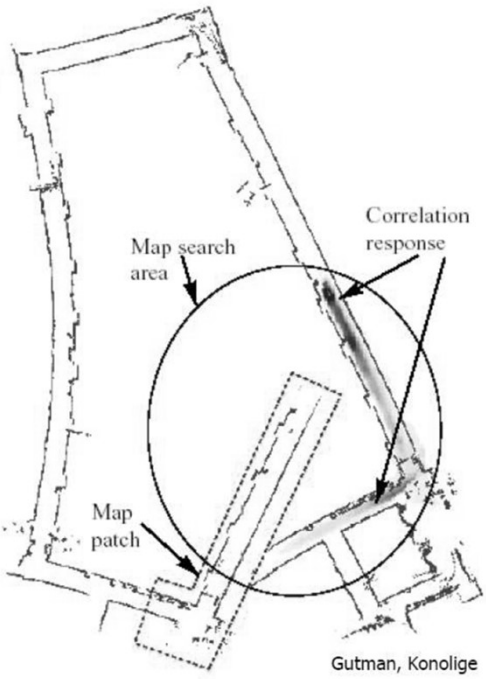
Why is SLAM Hard?

- "Grand challenge"-level robotics problem
  - Autonomous, persistent, collaborative robots mapping multi-scale, generic environments
- Map-making = learning
  - Difficult even for humans
  - Even skilled humans make mapping mistakes
- Scaling issues
  - Space: Large extent (combinatorial growth)
  - Time: Persistent autonomous operation
- "Chicken and Egg" nature of problem
  - If robot had a map, localization would be easier
  - If robot could localize, mapping would be easier
  - … But robot has neither; starts from blank slate
  - Must also execute an *exploration strategy*
- Uncertainty at every level of problem

Uncertainty in Robotic Mapping

Uncertainty: / Scale:	Continuous	Discrete
Local	Sensor noise	Data association
Global	Navigation drift	Loop closing

Loop Closing



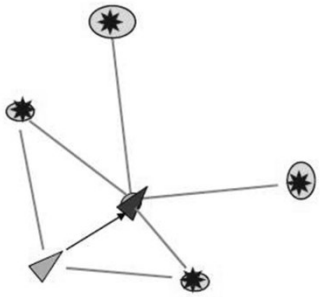
Gutman, Konolige

What is a map?

- Collection of *features* with some *relationship* to one another
- What is a *feature*? ← Uncertainty
  - Occupancy grid cell
  - Line segment
  - Surface patch
- What is a feature *relationship*?
  - Rigid-body transform (metrical mapping)
  - Topological path (chain of co-visibility)
  - Hybrid representation (geom. + topo.)

What is *pose* w.r.t. a map?

- Pose estimate that is (maximally) *consistent* with the estimated features observed from vicinity
- Consistency can be evaluated locally, semi-locally, or globally

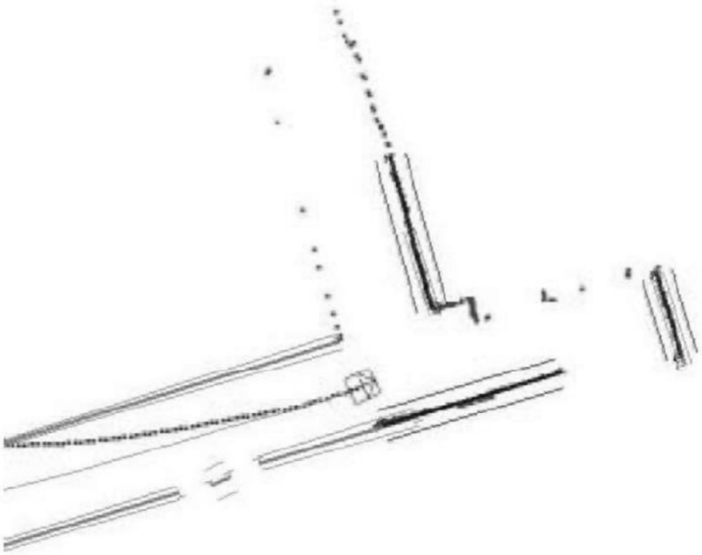


- Note tension between estimation *precision* and solution *consistency*

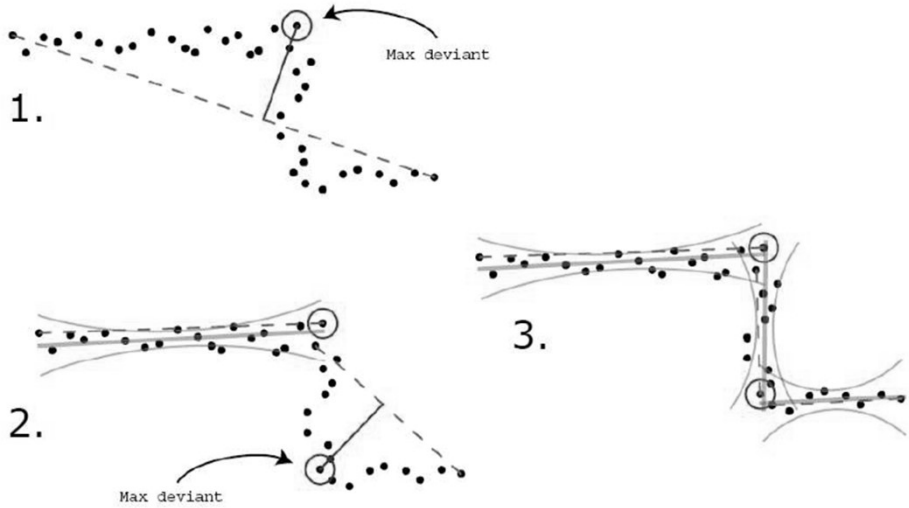
Example

- SLAM with laser scanning
- Observations
- Local mapping
  - Iterated closest point
- Loop closing
  - Scan matching
  - Deferred validation
  - Search strategies

Observations

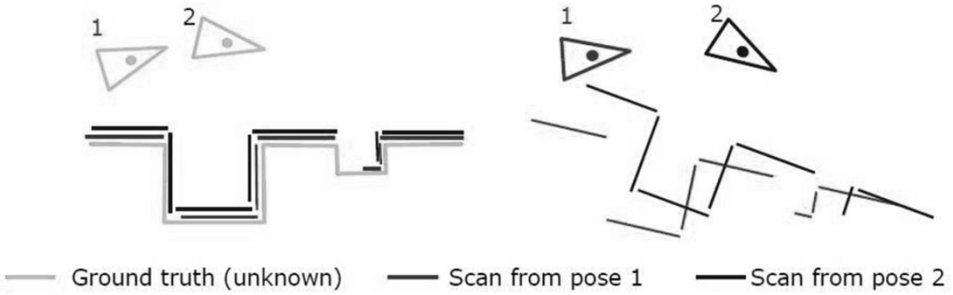


Observations



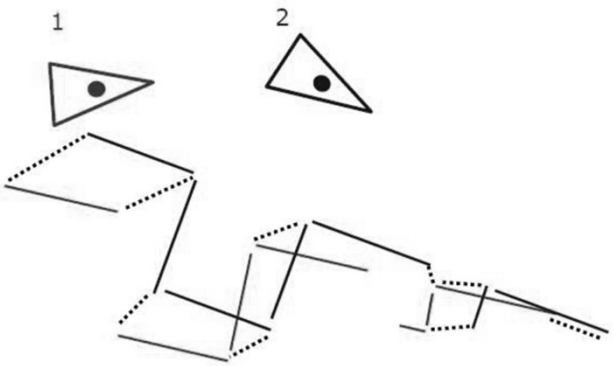
Scan Matching

- Robot scans, moves, scans again
- Short-term odometry/IMU error causes misregistration of scans
- *Scan matching* is the process of bringing scan data into alignment



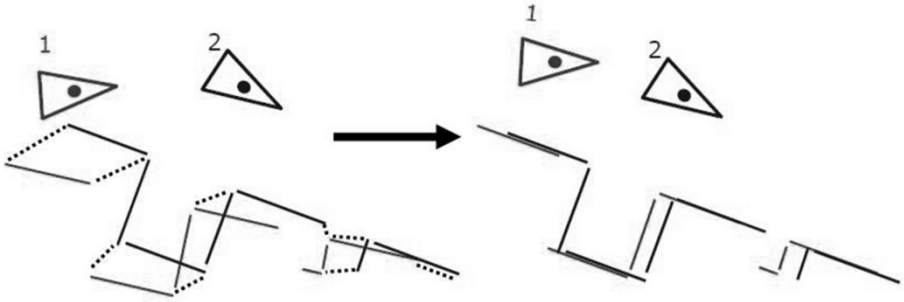
Iterated Closest Point

- For each point in scan 1
  - Find closest point in scan 2



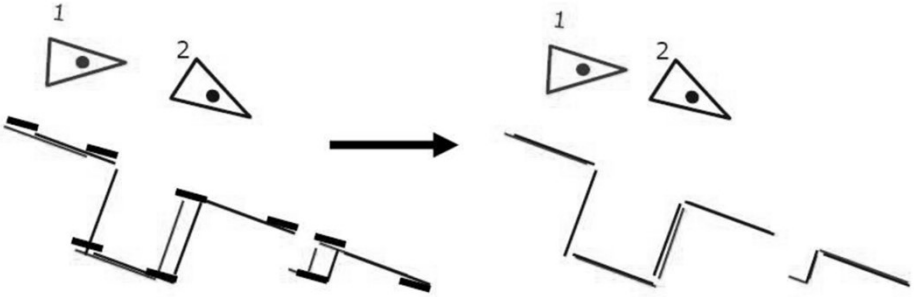
Iterated Closest Point

- Find the transformation that best aligns the matching sets of points



Iterated Closest Point

- … Repeat until convergence



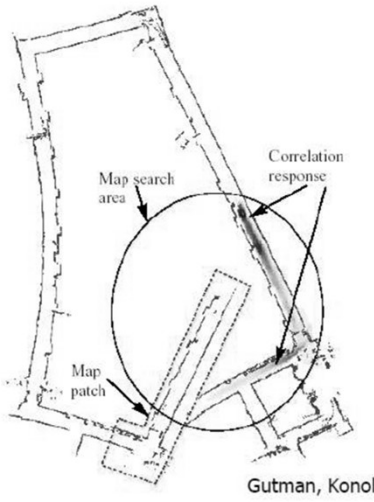
- Can ICP across scans, across a scan and a (sub)map, or even across submaps!

Limitations / failure modes

- Computational cost (two scans of size n)
  - Naively, $O(n^2)$ plus cost of alignment step
- False minima
  - If ICP starts far from true alignment
  - If scans exhibit repeated local structure
- Bias
  - Anisotropic point sampling
  - Differing sensor fields of view (occlusion)
- Lots of research on improved ICP methods (see, e.g., Rusinkiewicz)

Loop Closing

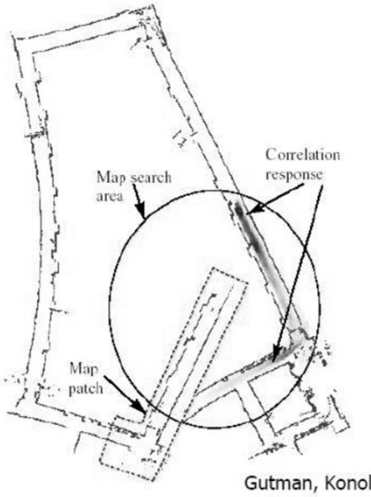
- ICP solves small-scale, short-duration SLAM fairly well
- But now, consider:
  - Large scale
  - High uncertainty



Gutman, Konolige

Loop Closing

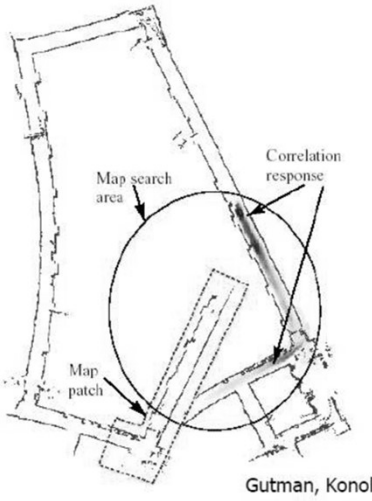
- Naive ICP ruled out:
  - Too CPU-intensive
- Assume we have a pose *uncertainty bound*
- This limits portion of existing map that must be searched
- Still have to face the problem of matching two partial scans that are far from aligned



Gutman, Konolige

Scan Matching Strategies

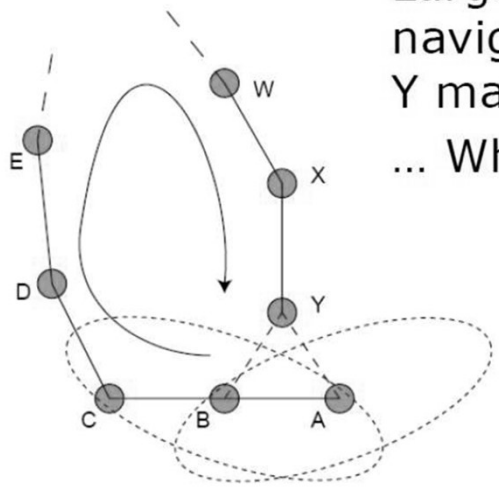
- Exhaustive search
  - Discretize robot poses
  - Find implied alignments
  - Assign score to each
  - Choose highest score
  - Pros, Cons?
- Randomized search
  - Choose minimal sufficient match, at random
  - Align and score
  - Choose highest score
  - RANSAC (1981)
  - Pros, Cons?



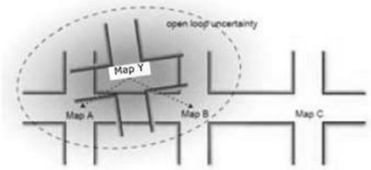
Gutman, Konolige

Loop Closing Ambiguity

- Consider SLAM state after ABC … XY

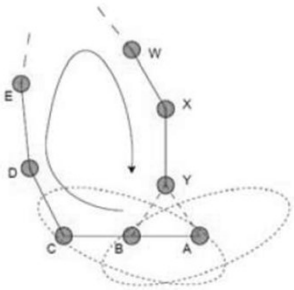


Large open-loop navigation uncertainty
Y matches *both* A & B
… What to do?



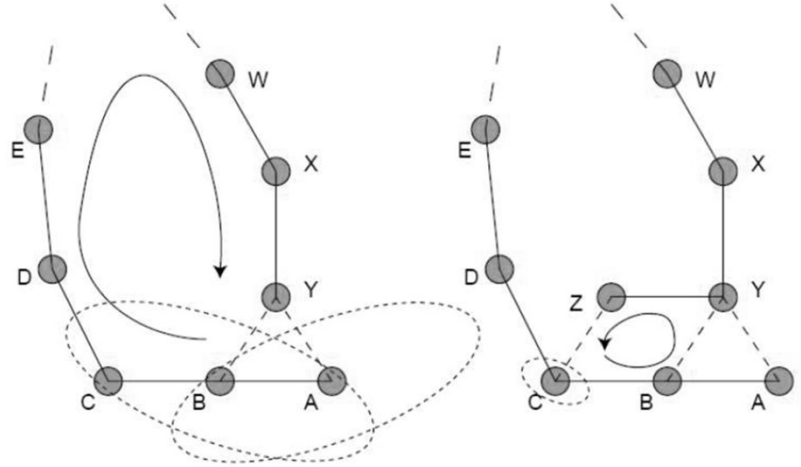
Loop Closing Choices

- Choose neither match
  - Pros, cons?
- Choose one match
  - Pros, cons?
- Choose both matches
  - Pros, cons?



Deferred Loop Validation

- Continue SLAM until Z matches C
- Examine graph for ~*identity cycle*



Occupancy Grid Map (OGM)

Maps the environment as a grid of cells

– Cell sizes typically range from 5 to 50 cm

Each cell holds a probability value that the cell is occupied in the range [0,100]

Unknown is indicated by -1

– Usually unknown areas are areas that the robot sensors cannot detect (beyond obstacles)

Occupancy Grid Map

White pixels represent free cells
Black pixels represent occupied cells
Gray pixels are in unknown state

Occupancy Grid Maps

Pros:

- Simple representation
- Speed

Cons:

- Not accurate - if an object falls inside a portion of a grid cell, the whole cell is marked occupied
- Wasted space

Maps in ROS

Map files are stored as images, with a variety of common formats being supported (such as PNG, JPG, and PGM)

Although color images can be used, they are converted to grayscale images before being interpreted by ROS

Associated with each map is a YAML file that holds additional information about the map

Map YAML File

```
image: map.pgm
resolution: 0.050000
origin: [-100.000000, -100.000000, 0.000000]
negate: 0
occupied_thresh: 0.65
free_thresh: 0.196
```

resolution: Resolution of the map, meters / pixel

origin: 2D pose of the lower-left pixel as (x, y, yaw)

occupied_thresh: Pixels with occupancy probability greater than this threshold are considered completely occupied

free_thresh: Pixels with occupancy probability less than this threshold are considered completely free

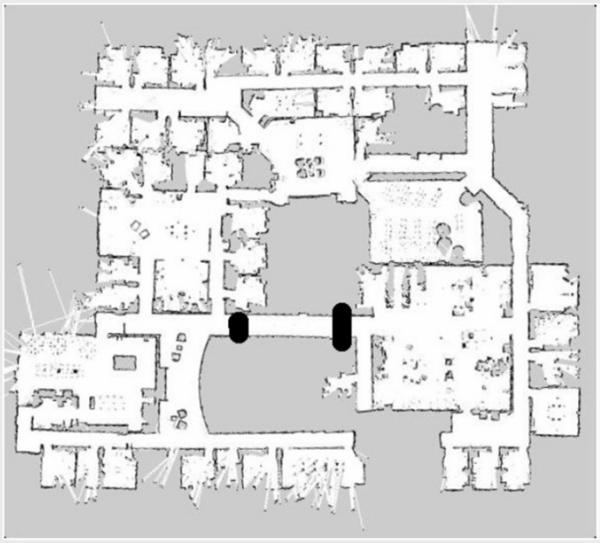
Editing Map Files

Since maps are represented as image files, you can edit them in your favorite image editor

This allows you to tidy up any maps that you create from sensor data, removing things that shouldn't be there, or adding in fake obstacles to influence path planning

For example, you can stop the robot from planning paths through certain areas of the map by drawing a line across a corridor you don't want to the robot to drive through

Editing Map Files



SLAM

Simultaneous localization and mapping (**SLAM**) is a technique used by robots to build up a map within an unknown environment while at the same time keeping track of their current location

A chicken or egg problem: An unbiased map is needed for localization while an accurate pose estimate is needed to build that map

Particle Filter – FastSLAM

Represent probability distribution as a set of discrete particles which occupy the state space

Main steps of the algorithm:

- Start with a random distribution of particles
- Compare particle's prediction of measurements with actual measurements
- Assign each particle a weight depending on how well its estimate of the state agrees with the measurements
- Randomly draw particles from previous distribution based on weights creating a new distribution

Efficient: scales logarithmically with the number of landmarks in the map

gmapping

http://wiki.ros.org/gmapping

The gmapping package provides laser-based SLAM as a ROS node called **slam_gmapping**

Uses the FastSLAM algorithm

It takes the laser scans and the odometry and builds a 2D occupancy grid map

It updates the map state while the robot moves

ROS with gmapping video

Sabırla Dinlediğiniz İçin Teşekkürler

BLM4830
Robot
Teknolojisine
Giriş
Hafta 5

Öğr. Grv. Furkan Çakmak