Markov Localization

(자율주행 핵심기술 SLAM 단기강좌)

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Maps

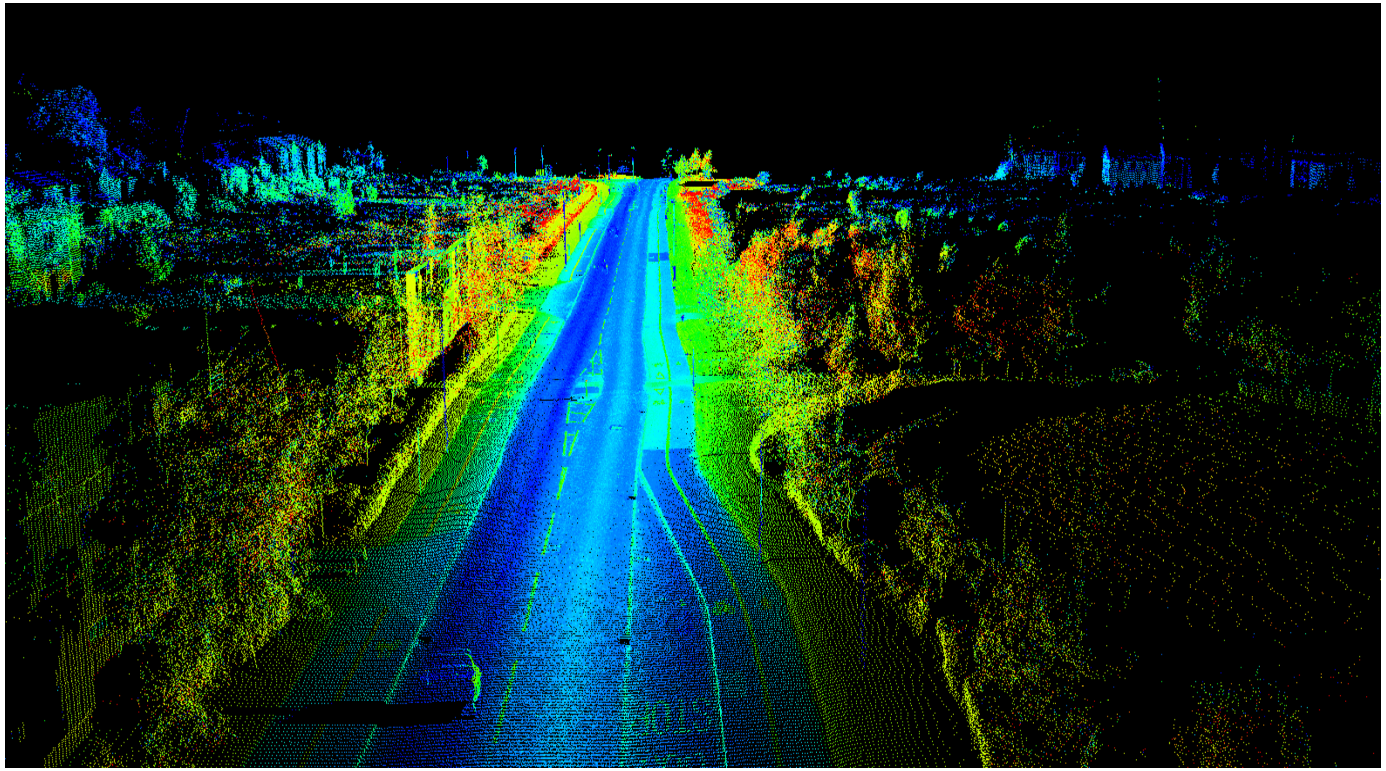
- Point-cloud maps
  – Maps based on a set of data points in the GIS
  – Vision-based sensors such as cameras, light detection and Ranging (LiDAR), radio detection and ranging (RADAR), and ultrasonic
- Planar maps
  – Rely on layers or planes on a geographic information system (GIS), e.g., high-definition (HD) maps
  – GPS-based systems

Point Cloud Map

- Point-cloud maps
  - Generated by 3-D scanners, such as Lidar sensors
  - Data are stored in x, y, and z format for each coordinate
- Localization
  - Performed using techniques such as Markov localization systems
  - Simultaneous localization and mapping (SLAM)

Point Cloud Map

- Point-cloud maps



[REF] https://www.geospatialworld.net/news/lizardtech-awarded-us-patent-lidar-point-cloud-compression-2/

Maps

- A map m is
  - a list of objects in the environment and their locations

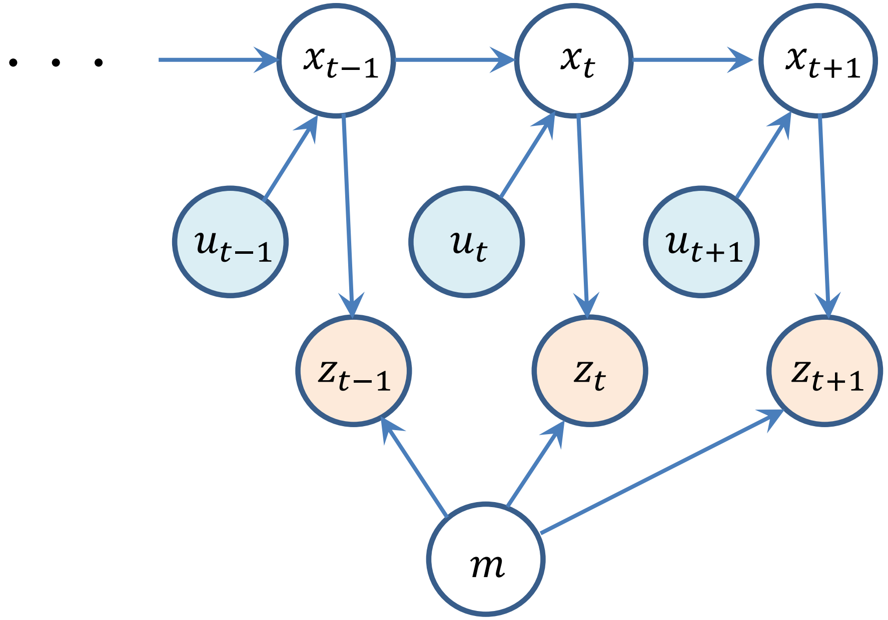
$$m = \{m_1, m_2, m_3, \cdots, m_N\}$$

N : number of objects

- Maps are indexed in one of two ways
  - Feature-based
    - The value of m_n is the Cartesian location of the feature
  - Location-based
    - The index n is a specific location. The element is often written as $m_{x,y}$

Mobile Robot Localization

- Graphical model of mobile robot localization
  - A map of its environment is given
  - The goal is to determine its position relative to the map



Markov Localization

- x_t : random variable for the state in the (x, y, θ) space of the robot at time t
- $P(x_t = l)$: the robot's belief that it was at location l at time t
- z_t : measurement (sensor information)
- u_t : movement action (odometry information)
- η : normalizer

Markov Localization

- Upon executing action u_t, Markov localization applies the following formula to update the belief

$$P(x_t = l) \leftarrow \sum_{l'} \underbrace{P(x_t = l | x_{t-1} = l', u_t)}_{\text{Action model}} \cdot P(x_{t-1} = l')$$

- Action model
  - Describes the probability that the robot is at location l upon executing action u_t at a position l'

Markov Localization

- x_t is updated whenever new sensory input is received

$$P(x_t = l|z_t) \leftarrow \eta \cdot \underbrace{P(z_t|x_t = l)}_{\text{Perception model}} \cdot P(x_t = l)$$

- Perception model
  - Describes the probability of measuring z_t at location l

Markov Localization

- The starting position of the robot $P(x_0)$ at time $t = 0$
  - Is set based on the knowledge
- If the position of the robot relative to the map is unknown
  - $P(x_0)$ is a uniform distribution
- If the initial position of the robot is known
  - $P(x_0)$ is a Dirac distribution centered at the known position

Markov Localization

Motion:

$$P(x_t = l) \leftarrow \sum_{l'} P(x_t = l | x_{t-1} = l', u_{t-1} = u) \cdot P(x_{t-1} = l')$$

Perception:

$$P(x_t = l) \leftarrow \eta \, P(z_t = z | x_t = l) \cdot P(x_t = l)$$

Markov Localization Algorithm

Algorithm Markov_localization($bel(x_{t-1}), u_t, z_t, m$):

for all x_t do

$$\overline{bel}(x_t) = \int p(x_t \mid u_t, x_{t-1}, m)\, bel(x_{t-1})\, dx$$

$$bel(x_t) = \eta\, p(z_t \mid x_t, m)\, \overline{bel}(x_t)$$

end for

return $bel(x_t)$

Markov Localization

- Example
  - (a) initial belief is uniform over all poses.
  - (b) the sensor notices the doors nearby and multiply it with the belief.
  - (c) as the robot moves, the belief is convolved with the motion model.
  - (d) the measurement is performed and is then multiplied with the current belief.
  - (e) the robot moves further.

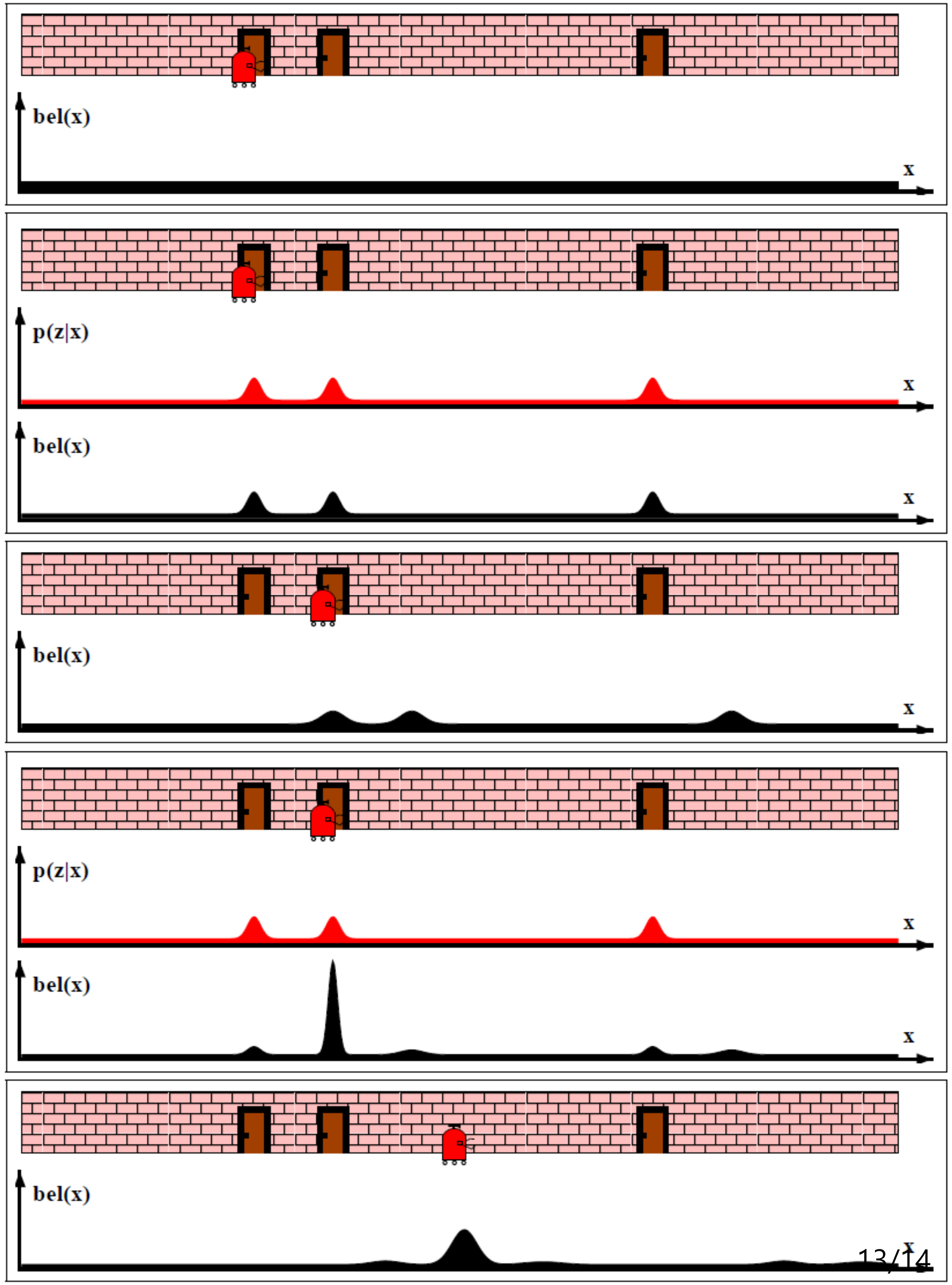
(a)

(b)

(c)

(d)

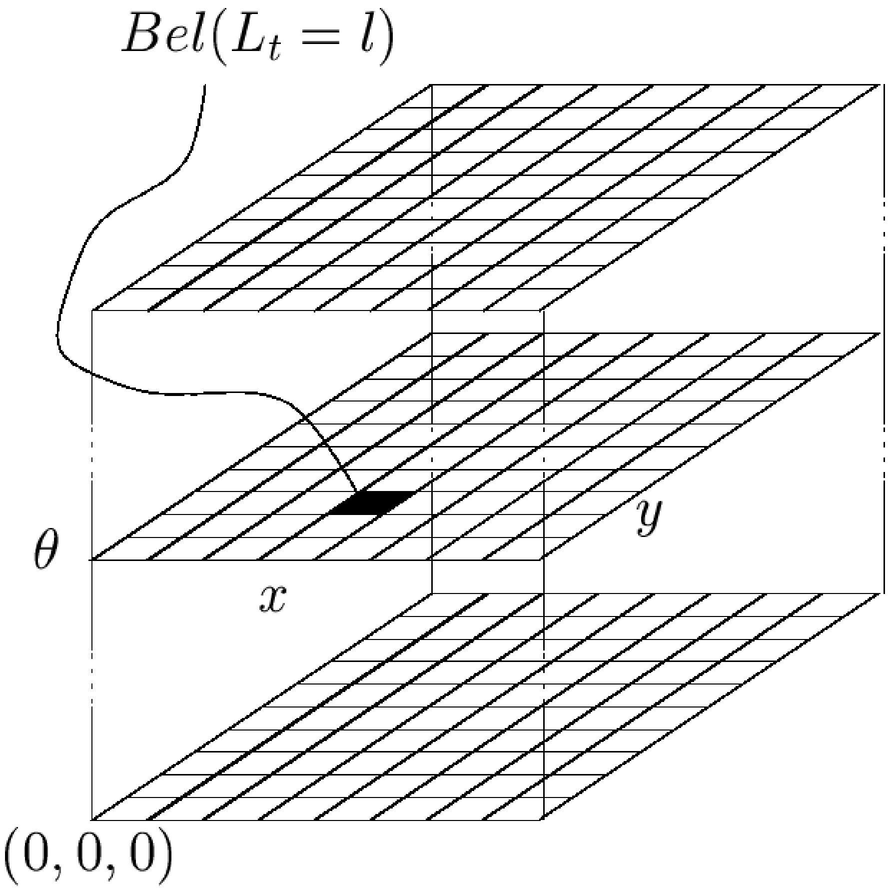
(e)



From Thrun Burgard Fox, Probabilistic Robotics, MIT Press 2006

Grid-based Markov Localization

- 3 dimensional grid over the state space of the robot



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