

AUTONOMOUS MOBILE ROBOTICS

ENVIRONMENTAL MAPPING AND LOCALIZATION

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ENVIRONMENTAL MAPPING AND LO- CALIZATION

- Simultaneous localization and mapping (SLAM) problem formulation



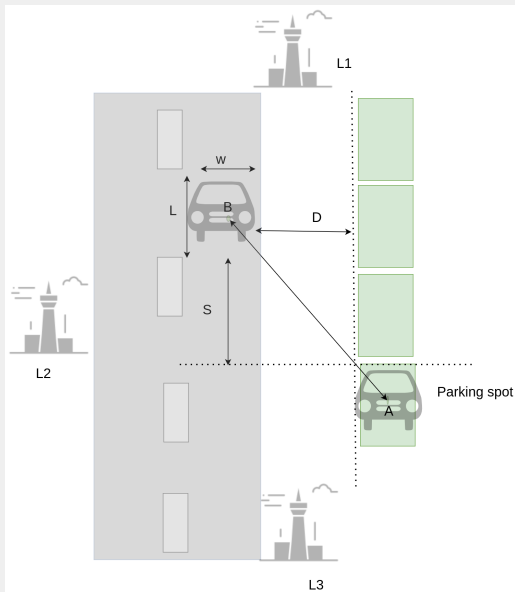
SIMULTANEOUS LOCALIZATION AND MAPPING (SLAM)



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Simultaneous localization and mapping (SLAM) is the problem of acquiring a map of an unknown environment, while simultaneously localizing the robot relative to the map. Why can't we rely on sensors' incremental egomotion for robot position estimation (e.g., odometry, inertial navigation) [2]? What is the main problem with these sensors?

PROBLEM DESCRIPTION



PROBLEM DESCRIPTION

- There are three landmarks: L1 (5, 30), L2 (5, -30), and L3 (-5, 0), which can be seen by the sensor attached to car. Sensor readings are obtained in the following way

$$\underbrace{\begin{bmatrix} r_k^i \\ \theta_k^i \end{bmatrix}}_{z_k^i} = \underbrace{\begin{pmatrix} \sqrt{(m_{j,x} - x)^2 + (m_{j,y} - y)^2} \\ \text{atan2}(m_{j,y} - y, m_{j,x} - x) - \theta \end{pmatrix}}_{h(x_{t,j,m})} + N(0, R) \quad (1)$$

, where $m_{j,x}$, $m_{j,y}$ denotes the coordinates of j th landmark detection at time t . The white noise of each sensor reading, the optimal robot current location estimation, and the

vehicle heading angle is given by $R = \begin{bmatrix} \sigma_r^2 & 0 \\ 0 & \sigma_r^2 \end{bmatrix}$,

$\mathbf{x}_{k,x}^- = x$, $\mathbf{x}_{k,y}^- = y$, and θ , respectively.

PROBLEM FORMULATION

1. Let's say we have n landmarks and now we need to incorporate those locations into the state vector (x_k)?

$$x_k = (x, y, \theta, m_x^1, m_y^1, \dots, m_x^n, m_y^n)^T \quad (2)$$

2. Design the system model (Φ_k)?
3. Can you derive the the general form of \bar{x}_k^- and P_k^- ?
4. When we perform the state prediction which part of the matrix (P_k^-) get updated?

PROBLEM FORMULATION

$$\underbrace{\begin{pmatrix} x \\ y \\ \theta \\ m_{1,x} \\ m_{1,y} \\ \vdots \\ m_{n,x} \\ m_{n,y} \end{pmatrix}}_{\mu} \underbrace{\begin{pmatrix} \sigma_{xx} & \sigma_{xy} & \sigma_{x\theta} & \sigma_{xm_{1,x}} & \sigma_{xm_{1,y}} & \dots & \sigma_{xm_{n,x}} & \sigma_{xm_{n,y}} \\ \sigma_{yx} & \sigma_{yy} & \sigma_{y\theta} & \sigma_{ym_{1,x}} & \sigma_{ym_{1,y}} & \dots & \sigma_{ym_{n,x}} & \sigma_{ym_{n,y}} \\ \sigma_{\theta x} & \sigma_{\theta y} & \sigma_{\theta\theta} & \sigma_{\theta m_{1,x}} & \sigma_{\theta m_{1,y}} & \dots & \sigma_{\theta m_{n,x}} & \sigma_{\theta m_{n,y}} \\ \sigma_{m_{1,x}x} & \sigma_{m_{1,x}y} & \sigma_{\theta} & \sigma_{m_{1,x}m_{1,x}} & \sigma_{m_{1,x}m_{1,y}} & \dots & \sigma_{m_{1,x}m_{n,x}} & \sigma_{m_{1,x}m_{n,y}} \\ \sigma_{m_{1,y}x} & \sigma_{m_{1,y}y} & \sigma_{\theta} & \sigma_{m_{1,y}m_{1,x}} & \sigma_{m_{1,y}m_{1,y}} & \dots & \sigma_{m_{1,y}m_{n,x}} & \sigma_{m_{1,y}m_{n,y}} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ \sigma_{m_{n,x}x} & \sigma_{m_{n,x}y} & \sigma_{\theta} & \sigma_{m_{n,x}m_{1,x}} & \sigma_{m_{n,x}m_{1,y}} & \dots & \sigma_{m_{n,x}m_{n,x}} & \sigma_{m_{n,x}m_{n,y}} \\ \sigma_{m_{n,y}x} & \sigma_{m_{n,y}y} & \sigma_{\theta} & \sigma_{m_{n,y}m_{1,x}} & \sigma_{m_{n,y}m_{1,y}} & \dots & \sigma_{m_{n,y}m_{n,x}} & \sigma_{m_{n,y}m_{n,y}} \end{pmatrix}}_{\Sigma}$$

The prediction state representation. Here, μ and Σ are equal to \bar{x}_k^- and P_k^- respectively

$$\underbrace{\begin{pmatrix} x_R \\ m_1 \\ \vdots \\ m_n \end{pmatrix}}_{\mu} \underbrace{\begin{pmatrix} \Sigma_{x_R x_R} & \Sigma_{x_R m_1} & \dots & \Sigma_{x_R m_n} \\ \Sigma_{m_1 x_R} & \Sigma_{m_1 m_1} & \dots & \Sigma_{m_1 m_n} \\ \vdots & \vdots & \ddots & \vdots \\ \Sigma_{m_n x_R} & \Sigma_{m_n m_1} & \dots & \Sigma_{m_n m_n} \end{pmatrix}}_{\Sigma}$$




The prediction state representation (more compact form). Here, μ and Σ are equal to \bar{x}_k^- and P_k^- respectively

PROBLEM FORMULATION

$$\underbrace{\begin{pmatrix} x \\ m \end{pmatrix}}_{\mu} \quad \underbrace{\begin{pmatrix} \Sigma_{xx} & \Sigma_{xm} \\ \Sigma_{mx} & \Sigma_{mm} \end{pmatrix}}_{\Sigma}$$

The prediction state representation (even more compact form).
Here, μ and Σ are equal to \bar{x}_k^- and P_k^- respectively

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