Ingeniería Eléctrica
FACULTAD DE CIENCIAS
FÍSICAS Y MATEMÁTICAS
UNIVERSIDAD DE CHILE

Thesis Defense

GraphSLAM Algorithm Implementation for Solving SLAM

Author: Franco Curotto
Thesis Adviser: Martin Adams
Commission Members: Marcos Orchard
Jorge Silva

March 5, 2016

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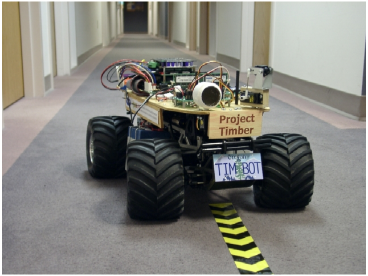
- You may be wondering what GraphSLAM and SLAM
- My work is ... in the field of robotics

Motivation

Robots Before



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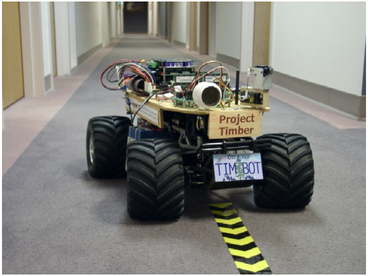
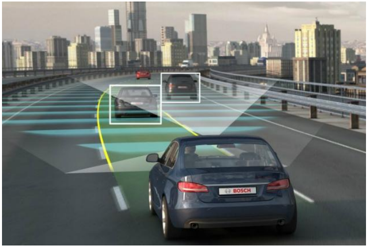
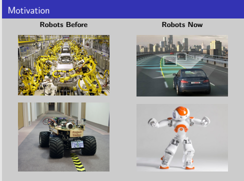


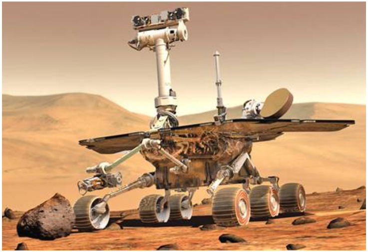
Robots Now

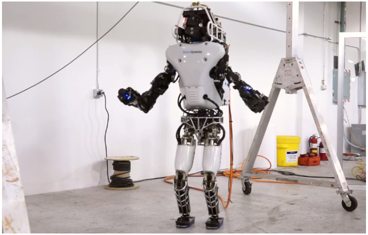




- Robots in the past were restricted to do simple, repetitive tasks, and were either stationary [reference photo], or had limited mobility, usually by following a reference [reference photo].
- Robots nowadays need to be much more versatile, autonomous and robust [reference photos].
- In particular robots must be able to move freely in an open environment.

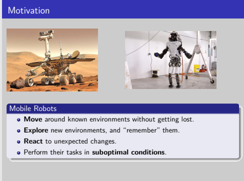
Motivation





Mobile Robots

- **Move** around known environments without getting lost.
- **Explore** new environments, and “remember” them.
- **React** to unexpected changes.
- Perform their tasks in **suboptimal conditions**.



- A robot must be able to identify where in the scenario he is standing on.
- For example if you buy a robot for your house, he never has seen your hous before, so he must be able to explore it and remember it for later use.
- For example when the environment changes, or when there is something moving on the room.

SLAM

Simultaneous Localization And Mapping (SLAM)

The problem were an agent must simultaneously estimate its current position (localization), and construct a map of its environment (mapping).

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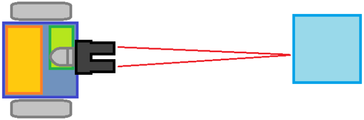
Odometry and Measurements

Sensors can be used to:

- Keep track of the robot movements (odometry)
- Sense nearby objects positions (measurements)

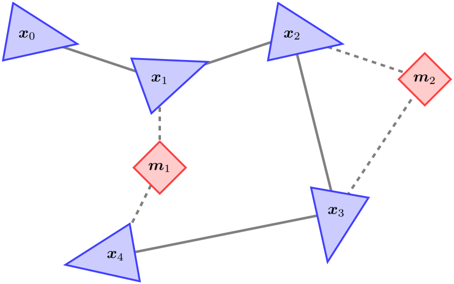
Sensors are noisy. We can use probabilistic methods to improve sensors estimates.



GraphSLAM

GraphSLAM translate the SLAM problem into a graph.

- Nodes represents robot **poses** or **landmarks**.
- Edges represents **robot** odometry or **measurements**.



Goal: Find the nodes positions that most accurately represents the sensors data (edges).

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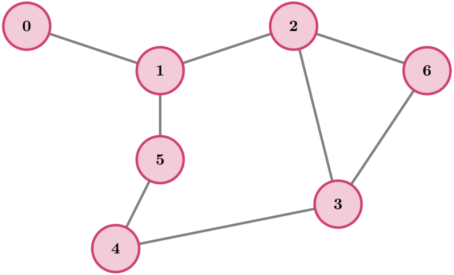

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Mathematical Formulation of GraphSLAM

We want to find the maximum likelihood of posterior probability:

$$p(\boldsymbol{x}_{0:k}, \boldsymbol{m} | \boldsymbol{z}_{1:k}, \boldsymbol{u}_{1:k})$$

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$$F(\boldsymbol{y}) := -\log(p(\boldsymbol{y}|\boldsymbol{z}_{1:k}, \boldsymbol{u}_{1:k})) = \sum_{\langle i,j \rangle \in \mathcal{E}} \boldsymbol{e}_{ij}(\boldsymbol{y})^T \boldsymbol{\Omega}_{ij} \boldsymbol{e}_{ij}(\boldsymbol{y})$$

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- $\boldsymbol{y}$: state vector (junction of robot poses and landmarks positions)
- $\boldsymbol{z_{1:k}}$: landmarks measurements
- $\boldsymbol{u_{1:k}}$: odometry measurements
- $\boldsymbol{e_{ij}}$: error function (difference between current estimate and data)
- $\boldsymbol{\Omega_{ij}}$: Information matrix of measurements

Mathematical Formulation of GraphSLAM

Gauss-Newton algorithm

- 1° order Taylor expansion around current estimate:

$$F(\breve{\boldsymbol{y}} + \boldsymbol{\Delta y}) = k + 2\boldsymbol{b}\boldsymbol{\Delta y} + \boldsymbol{\Delta y}^T \boldsymbol{H}\boldsymbol{\Delta y} \tag{1}$$

- Minimization of :

$$\boldsymbol{H}\boldsymbol{\Delta y}^* = -\boldsymbol{b} \tag{2}$$

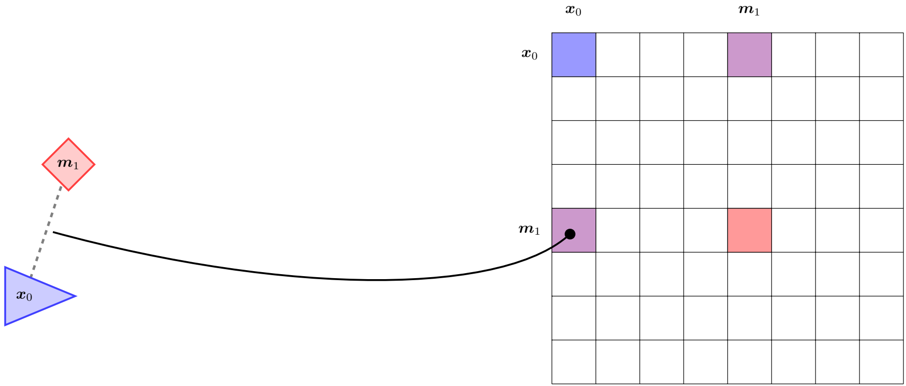
- Estimate update:

$$\boldsymbol{y}^* = \breve{\boldsymbol{y}} + \boldsymbol{\Delta y}^* \tag{3}$$

- $\breve{\boldsymbol{y}}$: current estimate
- $\boldsymbol{\Delta y}$: small disturbance around $\breve{\boldsymbol{y}}$
- $\boldsymbol{b}$: Information vector
- $\boldsymbol{H}$: Information matrix
- $\boldsymbol{y}^*$: New estimate

Structure of the Linearized System

Information matrix $\boldsymbol{H}$ is intrinsically ***sparse***.



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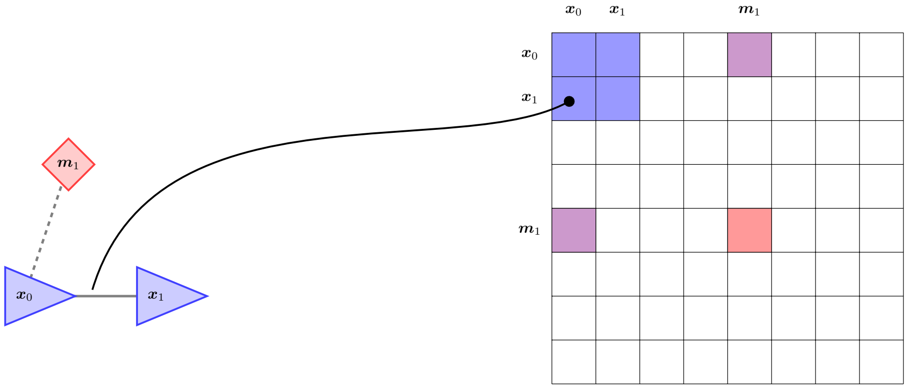

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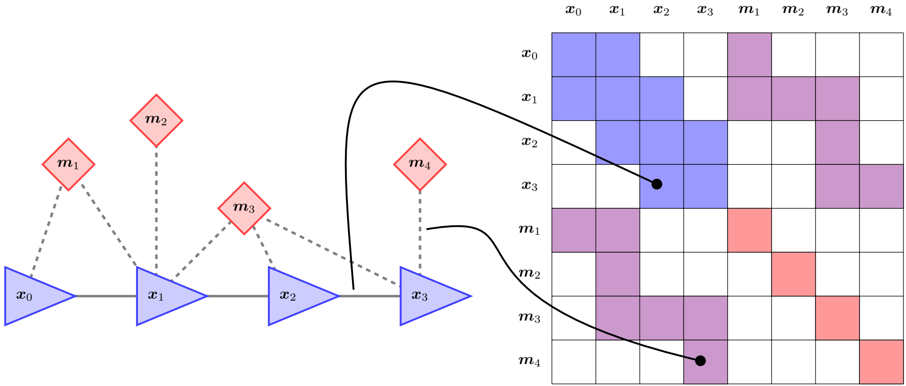

Implementation

Implementation details

Results

Conclusions

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