



Simultaneous Localisation And Mapping (SLAM) in a nutshell

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Autonomous Systems Perception and Interaction Control



What is SLAM ?



In robotic mapping and navigation, simultaneous localization and mapping (SLAM) is the computational problem of constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within it.

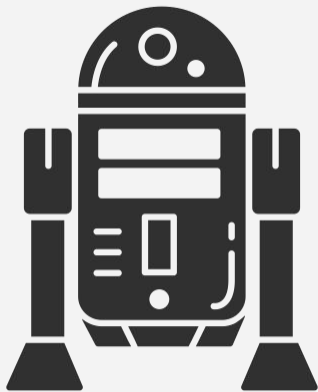


Over the last 30 years, SLAM algorithms are employed in self-driving cars, unmanned aerial vehicles, autonomous underwater vehicles, planetary rovers, newer domestic robots and even inside the human body.

Do we need SLAM ?
Is SLAM solved ?

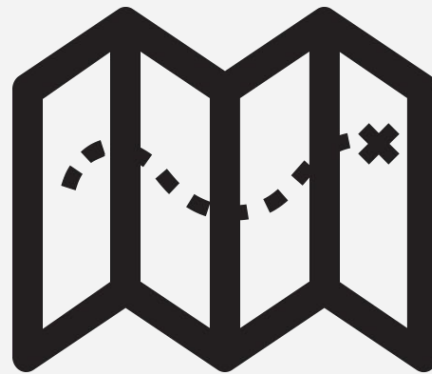


A robot



position
orientation
velocity
sensor biases
calibration

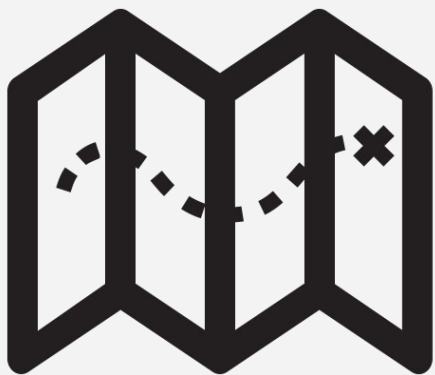
A map



points
landmarks
obstacles
graph



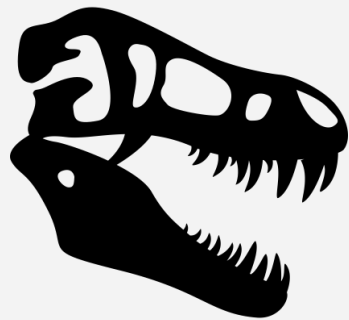
A map



Path planning
Visualization
Errors limitation (loop closure)
Prior Map
GPS / Indoor applications



The classical edge (1986-2004)



Probabilistic formulations:

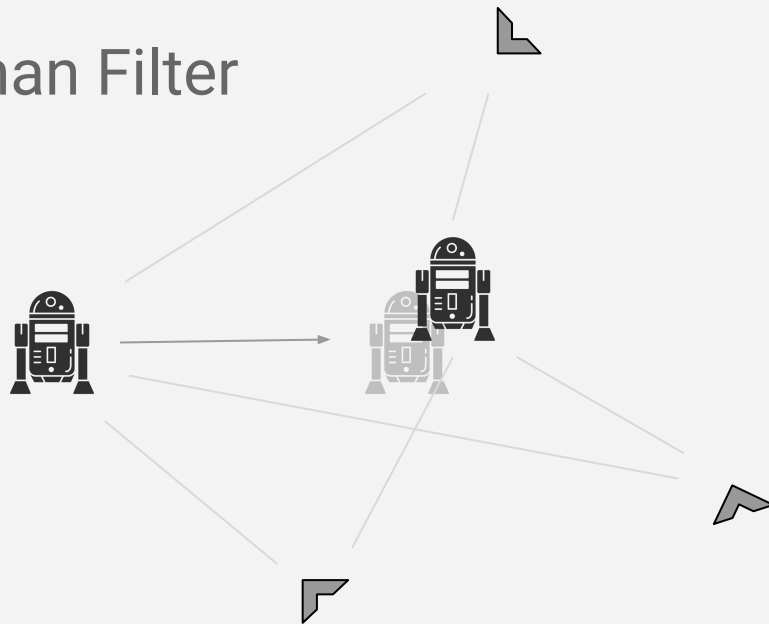
Extended Kalman filters

Particle Filters

Maximum Likelihood estimation

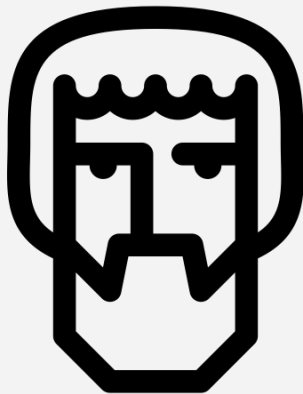


Extended Kalman Filter





The algorithmic-analysis edge (2004-2015)



Fundamental properties:

Observability

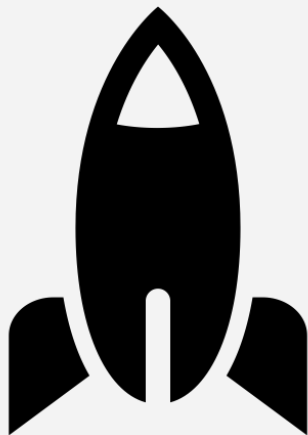
Convergence

Consistency

Open source



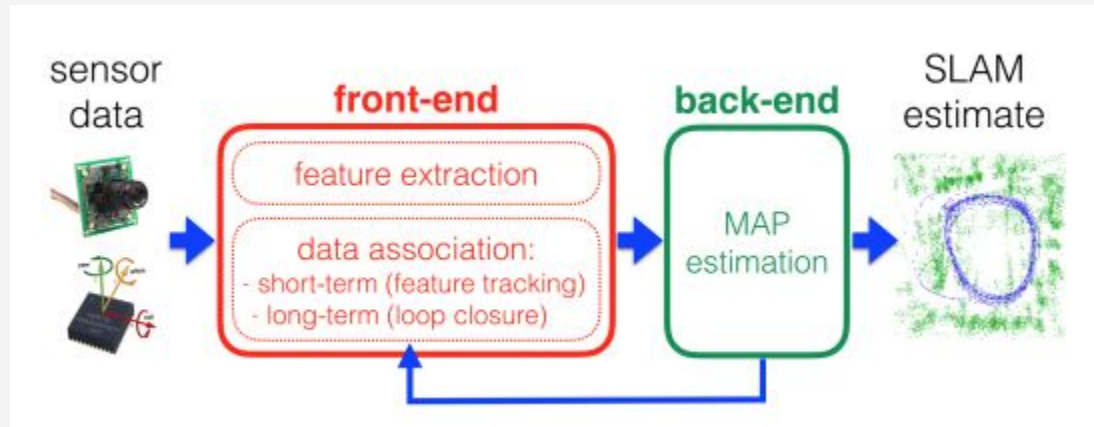
The robust perception edge (2016-20??)



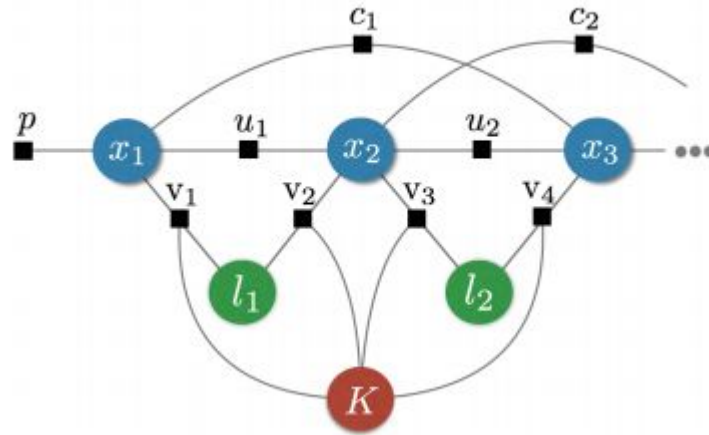
New requirements:

- Robust performances
- High-level understanding
- Resource awareness
- Task-driven perception
- Deep learning

The front-end and back-end in a typical SLAM system



Back-end: Maximum a posteriori estimation (MAP)



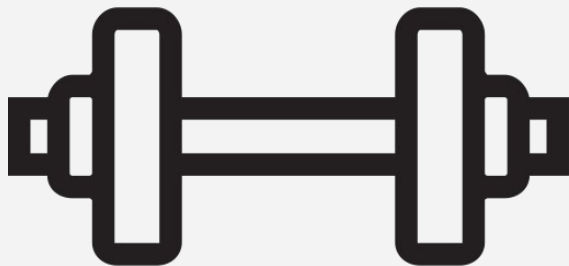


ORB-SLAM





Robustness



Main issues:

Many failures (algorithmic or hardware)

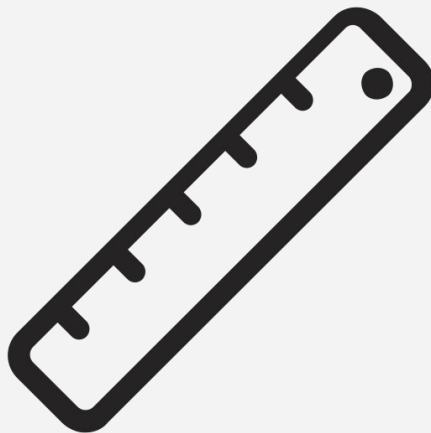
Data association

Static landmarks

Harsh environments (underwater)



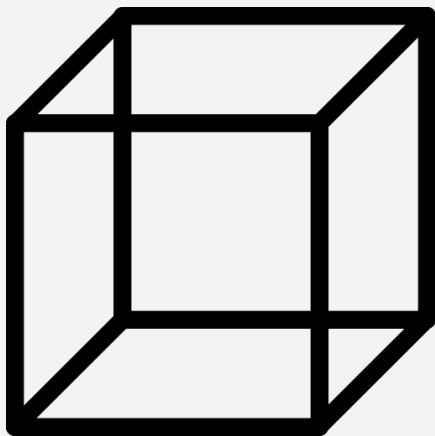
Scalability



Larger areas:
Unbounded factor graph
Quadratically growing



Metric Map Models



Different representation models:

Point Cloud

Parameterized primitive

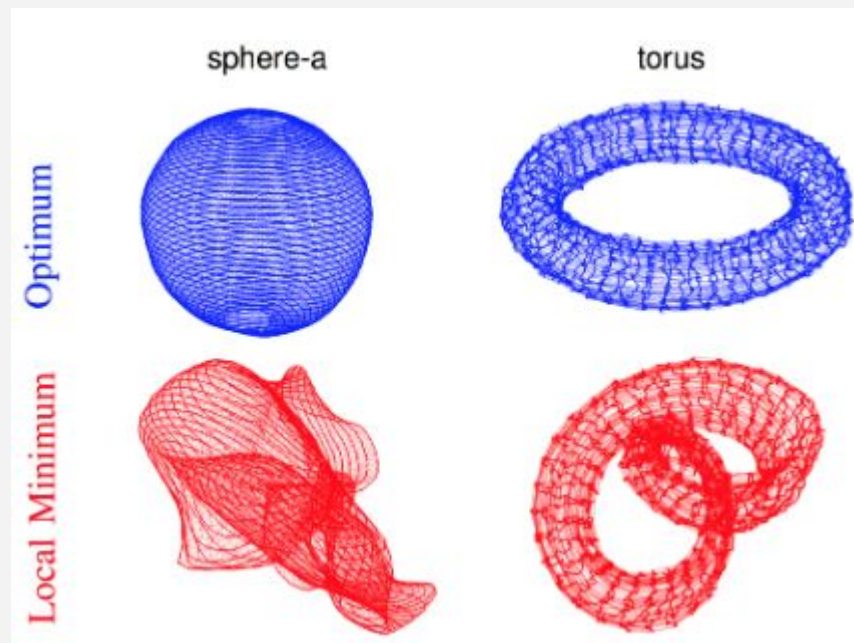
Sweep representation

Constructive solid geometry

Semantic maps



Local minimum failures





New Theoretical tools



Factor graph optimization:

- maximum likelihood estimation
- iterative nonlinear optimization
- convex relaxation
- suitable initialization
- resilience to outliers



Active SLAM

Leverage a robot's motion to improve the mapping and localization results.

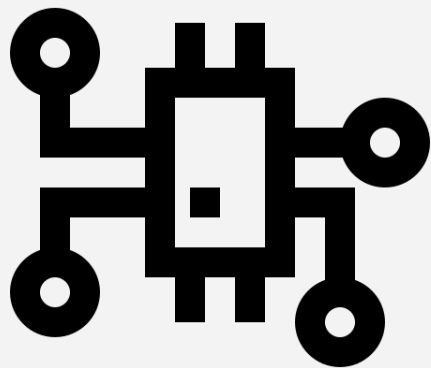
Random exploration.

Artificial Intelligence?

Theory of Optimal Experimental Design (TOED)



New sensors



Unconventional sensors:

Dominated by LiDAR and cameras

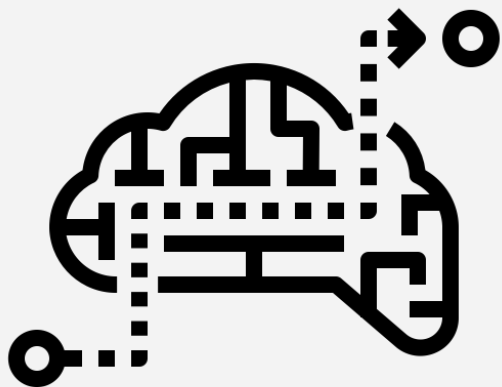
Light-field cameras

Event-based cameras

Inspired by animals



Deep learning



Regress the inter-frame pose btw 2 images
6DoF estimation
Depth of a scene from single camera



Conclusions

Do we need SLAM? **yes**
Is SLAM solved? **Not yet**