LARSyS Annual Meeting 2018

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SLAM in the quest for Autonomy

From Theory to Practice

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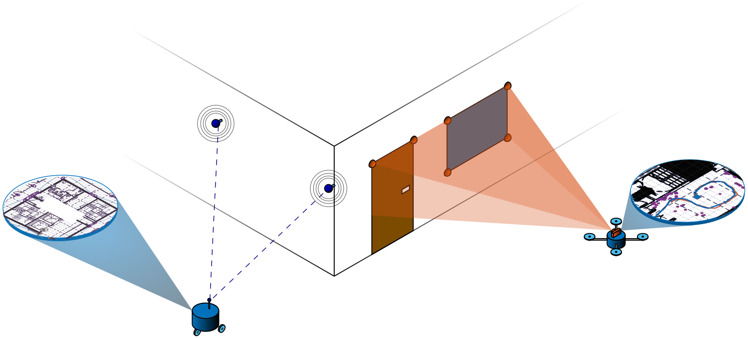
PRESENTATION OUTLINE

Introduction

- Motivation
- SLAM Formulations
- Main challenges
- Proposed Solution

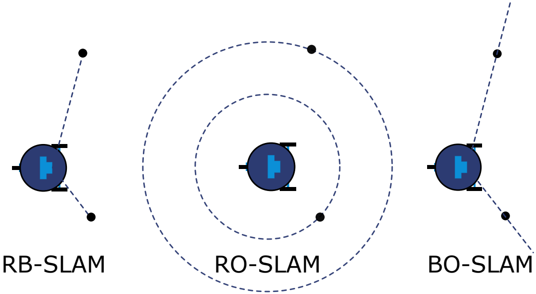
What is SLAM?

- Obtain a detailed map of the environment.
- Maintain an accurate estimate of the pose of the vehicle.



Why is it important?

- Missions with autonomous vehicles with no absolute positioning available
  - Surveillance, critical infrastructure inspection, among others
- Mission scenarios:
  - Indoors or outdoors, close to buildings or other infrastructure with (visual) marks



- Measurements with lower dimension than the mapped space:
  - Range-only SLAM
  - Bearing-only SLAM
- Measurements with fully observed space:
  - Range-and-bearing SLAM

On the technical side

- Computational efficiency
- Long range mapping
- Data association
- Loop closing

On the theoretical side

- Consistency
- Convergence
- Optimality
- **Undelayed** initialization

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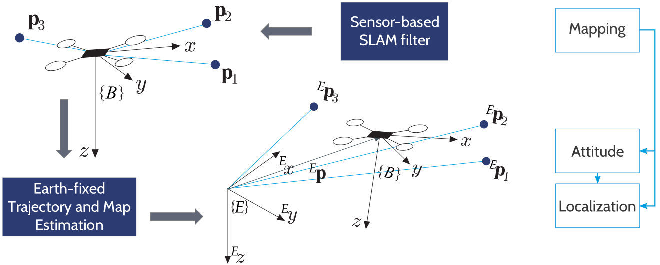
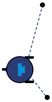
Separate SLAM in two problems:

- Mapping in a **relative** frame
- Attitude and position determination



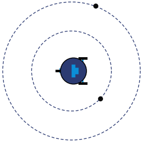
Sensor-based SLAM

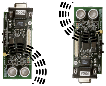
- Overview
- Observability & Convergence



Range-and-bearing

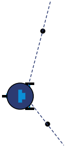
▷ Nonlinear dynamics





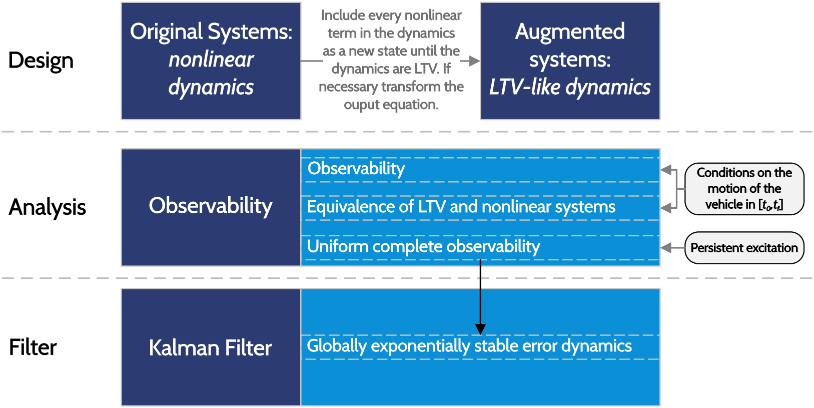
Range-only

▷ Nonlinear output



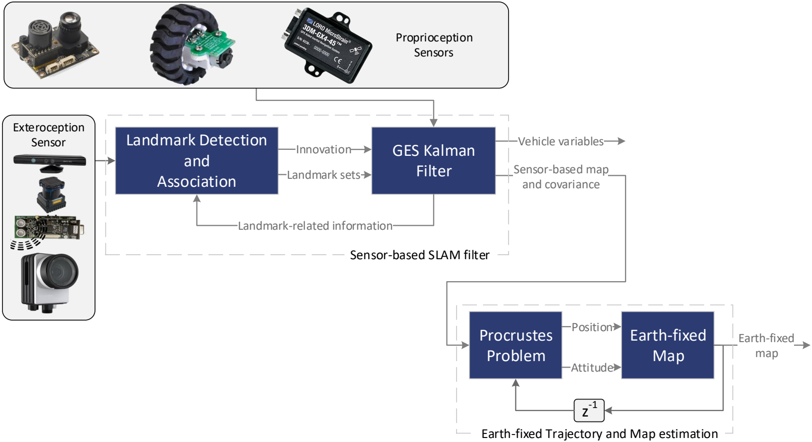
Bearing-only

▷ Nonlinear output


Design
Original Systems: *nonlinear dynamics*
Include every nonlinear term in the dynamics as a new state until the dynamics are LTV. If necessary transform the ouput equation.
Augmented systems: *LTV-like dynamics*
Analysis
Observability
Observability
Equivalence of LTV and nonlinear systems
Uniform complete observability
Conditions on the motion of the vehicle in $[t_o, t_f]$
Persistent excitation
Filter
Kalman Filter
Globally exponentially stable error dynamics

Earth-fixed Trajectory and Map

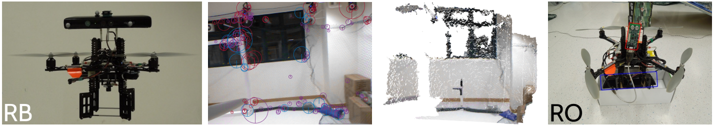
- Overview



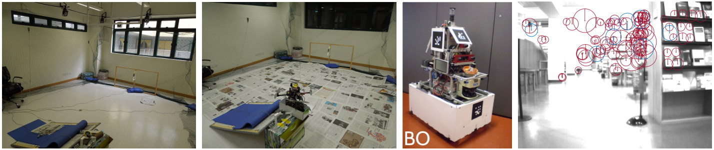
Proprioception Sensors
Exteroception Sensor
Landmark Detection and Association
Innovation
Landmark sets
GES Kalman Filter
Vehicle variables
Sensor-based map and covariance
Landmark-related information
Sensor-based SLAM filter
Procrustes Problem
Position
Attitude
Earth-fixed Map
Earth-fixed map
z^{-1}
Earth-fixed Trajectory and Map estimation

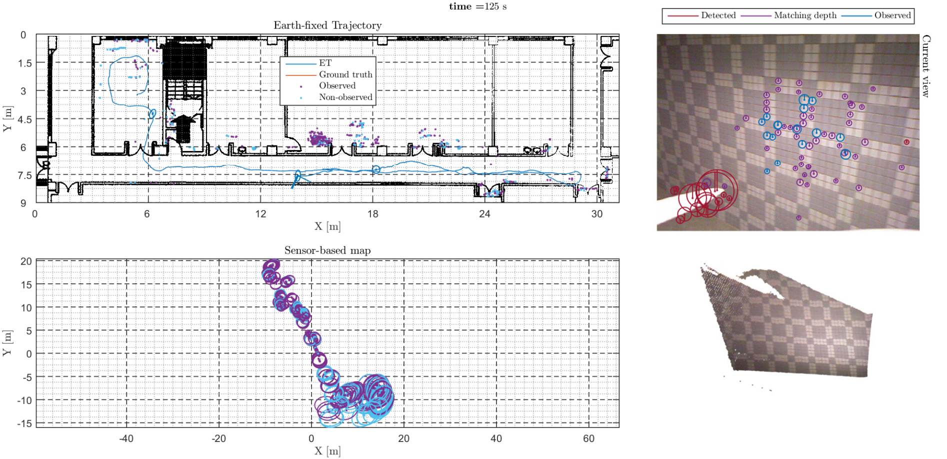
Practical examples

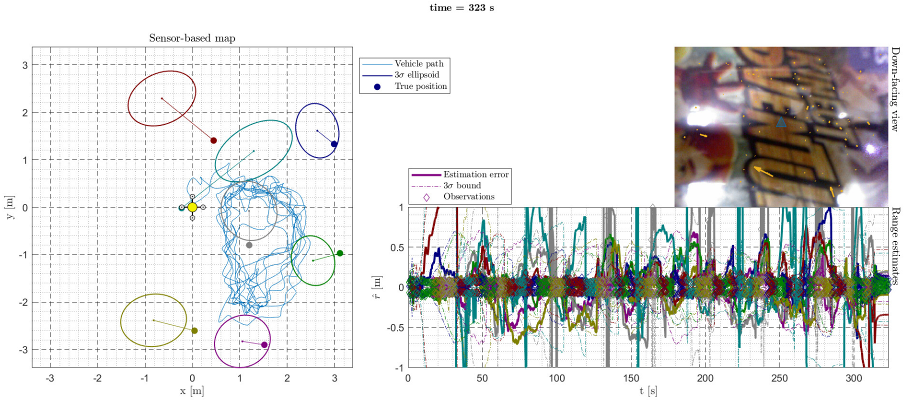
- Overview
- Range-and-bearing SLAM
- Range-only SLAM
- Bearing-only SLAM

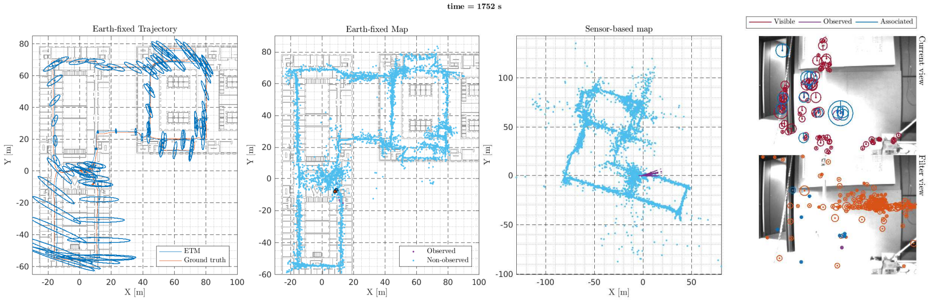


Quantities	Sensors
Landmark position	RGB-D camera (RB)
Landmark range	Radio/acoustic transceivers (RO)
Landmark bearing	Monocular camera (BO)
Linear velocity	Odometry (BO) / Optical flow (RO)
Angular velocity	IMU (RB,RO,BO)




time =125 s
Earth-fixed Trajectory
ET
Ground truth
Observed
Non-observed
Y [m]
X [m]
0
1.5
3
4.5
6
7.5
9
0
6
12
18
24
30
Sensor-based map
Y [m]
X [m]
20
15
10
5
0
-5
-10
-15
-40
-20
0
20
40
60
Detected
Matching depth
Observed
Current view


time = 323 s
Sensor-based map
Vehicle path
3σ ellipsoid
True position
x [m]
y [m]
Down-facing view
Estimation error
3σ bound
Observations
Range estimates
r̂ [m]
t [s]


time = 1752 s
Earth-fixed Trajectory
ETM
Ground truth
X [m]
Y [m]
Earth-fixed Map
Observed
Non-observed
X [m]
Y [m]
Sensor-based map
X [m]
Y [m]
Visible
Observed
Associated
Current view
Filter view

Conclusions

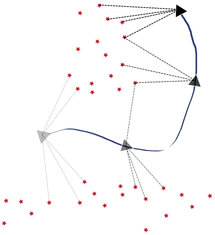
- Conclusions
- Future Work

CONCLUSIONS

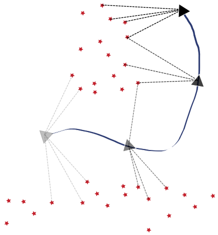
- Tools to tackle the **nonlinearities** of the **main** SLAM formulations were presented.
- A class of sensor-based simultaneous localization and mapping filters with **global convergence** guarantees was introduced.
- **Experimental** examples of practical implementations were illustrated.

- **Online** operation:
  - Prepare the algorithms for **real time** operation;
  - Refinement of associated algorithms: feature detection/data association, loop closing, etc.
- More **sensors**:
  - Altimeters, accelerometers, magnetometers.
  - Better estimates, new challenges (such as automatic calibration).

- The **idea** behind SLAM is: move to gain knowledge.
- The **problem** is: how to move?



- The **idea** behind SLAM is: move to gain knowledge.
- The **problem** is: how to move?
- **Solution: Active SLAM**



Complementary objectives	
Exploration	**Exploitation**
Visit new terrain	Revisit areas
Increase overall knowledge	Increase information gain.
Maximize explored areas	Minimize uncertainty

LARSyS
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and Engineering Systems

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Thank you. Questions?

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