PhD Open Days

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New design techniques for globally convergent simultaneous localization and mapping: analysis and implementation

PHD PROGRAM IN ELECTRICAL AND COMPUTER ENGINEERING

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Summary

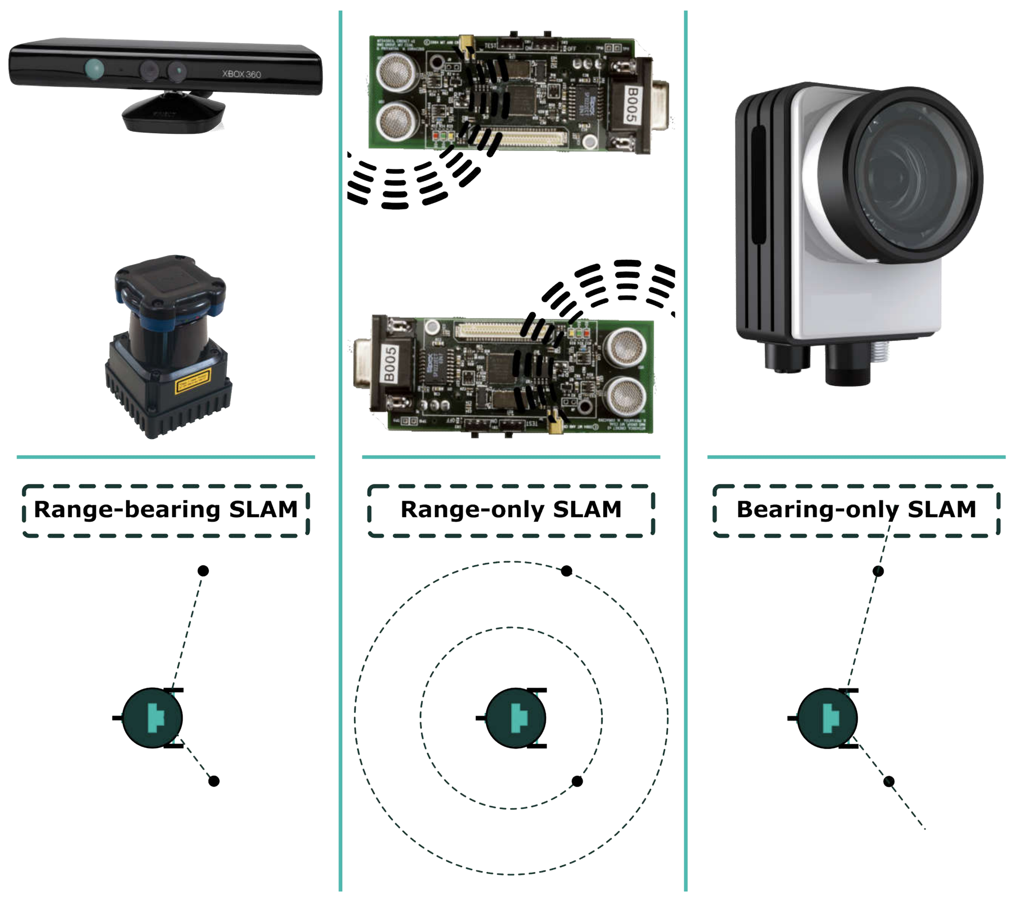
This work proposes novel techniques that can be applied to simultaneous localization and mapping in order to bypass the inherent nonlinearity of the problem and, ultimately, to design novel globally convergent filters. Algorithms for range-bearing, range-only and bearing-only frameworks are analysed and implemented with success in experimental settings.

I. SLAM: what is it for?

Navigate an autonomous vehicle in a new environment with no *a priori* info:

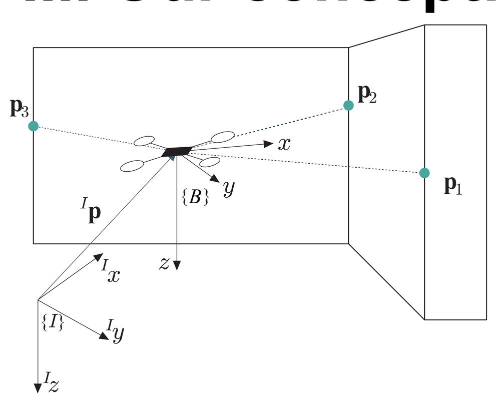
- Obtain a detailed map of the environment.
- Maintain an accurate estimate of the location of the vehicle.

II. What sensors can be used?



- **Proprioception**: motion sensors, e.g., odometry, rate gyros
- **Exteroception**: cameras, laser range finders, acoustic transceivers

III. Our concept: Sensor-based SLAM



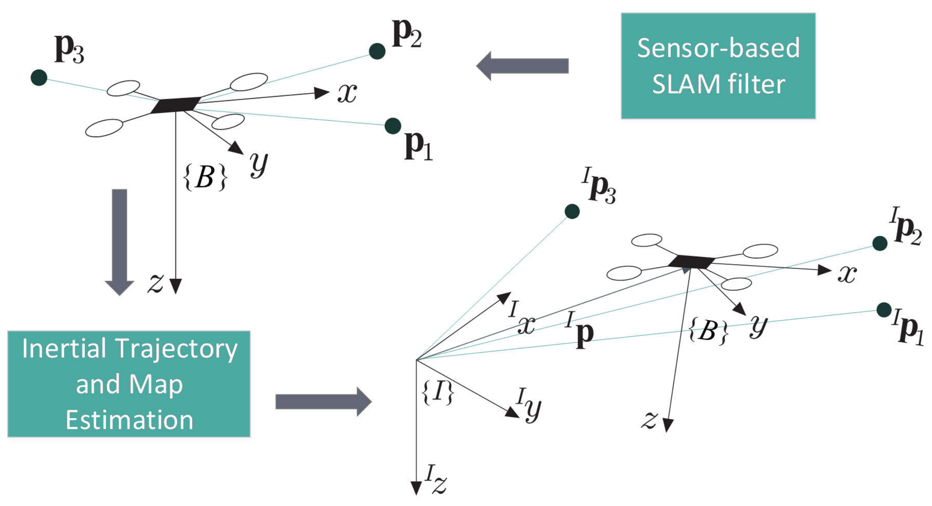
The **perception** of the environment by the vehicle is always **relative** to itself, due to the **sensors** involved. Exploring this idea, the algorithms we propose are designed in the space of the sensors.

Problems:

- The systems are **nonlinear**.
- There are no guarantees of **stability** or **performance.**

IV. Inertial Trajectory and Map [4]

The inertial pose of the vehicle is computed as the solution of an optimization problem, and the inertial map is updated accordingly.



[1] P. Lourenço, B. J. Guerreiro, P. Batista, P. Oliveira, and C. Silvestre, "Simultaneous Localization and Mapping for Aerial Vehicles: a 3-D sensor-based GAS filter," *Autonomous Robots*, vol. 40, no. 5, pp. 881–902, Jun. 2016.

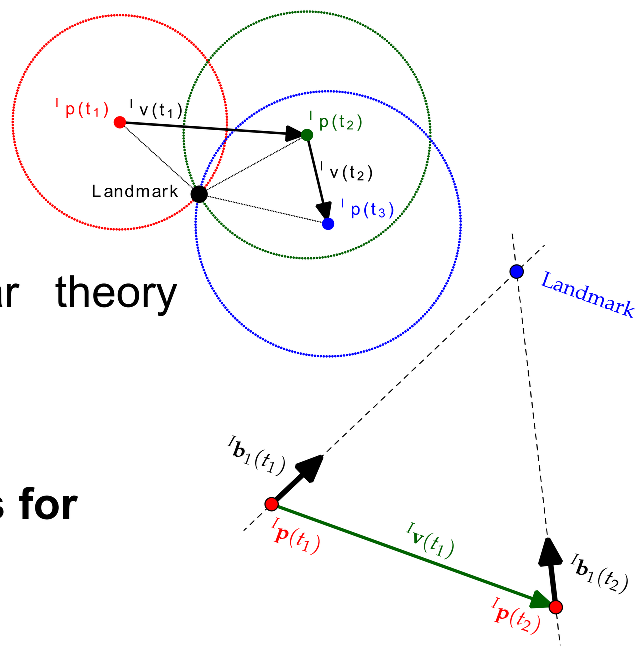
[2] P. Lourenço, P. Batista, P. Oliveira, C. Silvestre, and C. L. P. Chen, "Sensor-based Globally Exponentially Stable Range-Only Simultaneous Localization and Mapping," *Robotics and Autonomous Systems*, vol. 68, pp. 72–85, Jun. 2015.

[3] P. Lourenço, P. Batista, P. Oliveira, and C. Silvestre, "A Globally Exponentially Stable filter for Bearing-Only Simultaneous Localization and Mapping in 3-D," in *Proc. of the 2015 European Control Conference*, Linz, Austria, 2015, pp. 2817–2822.

[4] P. Lourenço, B. J. Guerreiro, P. Batista, P. Oliveira, and C. Silvestre, "3-D Inertial Trajectory and Map Online Estimation: Building on a GAS Sensor-based SLAM filter," in *Proc. of the 2013 European Control Conference*, Zurich, Switzerland, 2013, pp. 4214–4219.

V. Idea

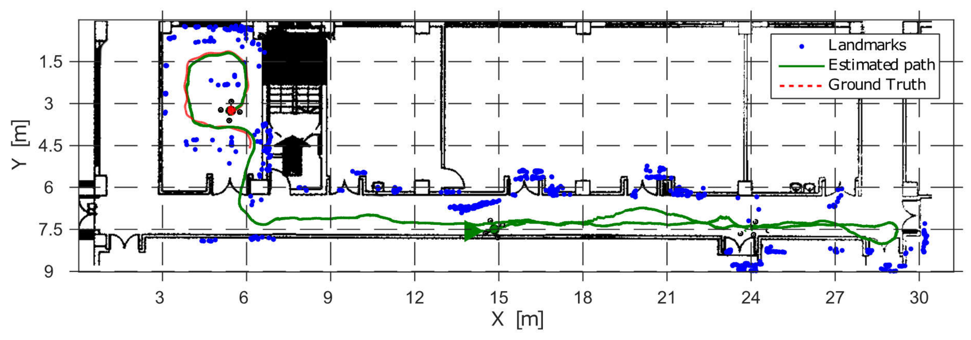
- **Transform** the measurements and **augment** the state depending on the specific nonlinearities involved.
- Obtain linear-like systems so that linear theory applies.
- Study the observability.
- Use a **Kalman** filter for **LTV** systems.
- Design an algorithm with **global guarantees for stability and convergence**.



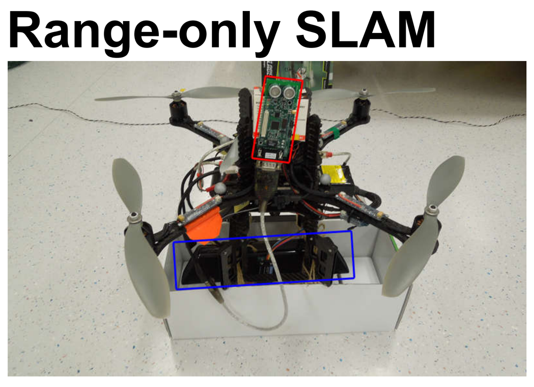
VI. Experimental results

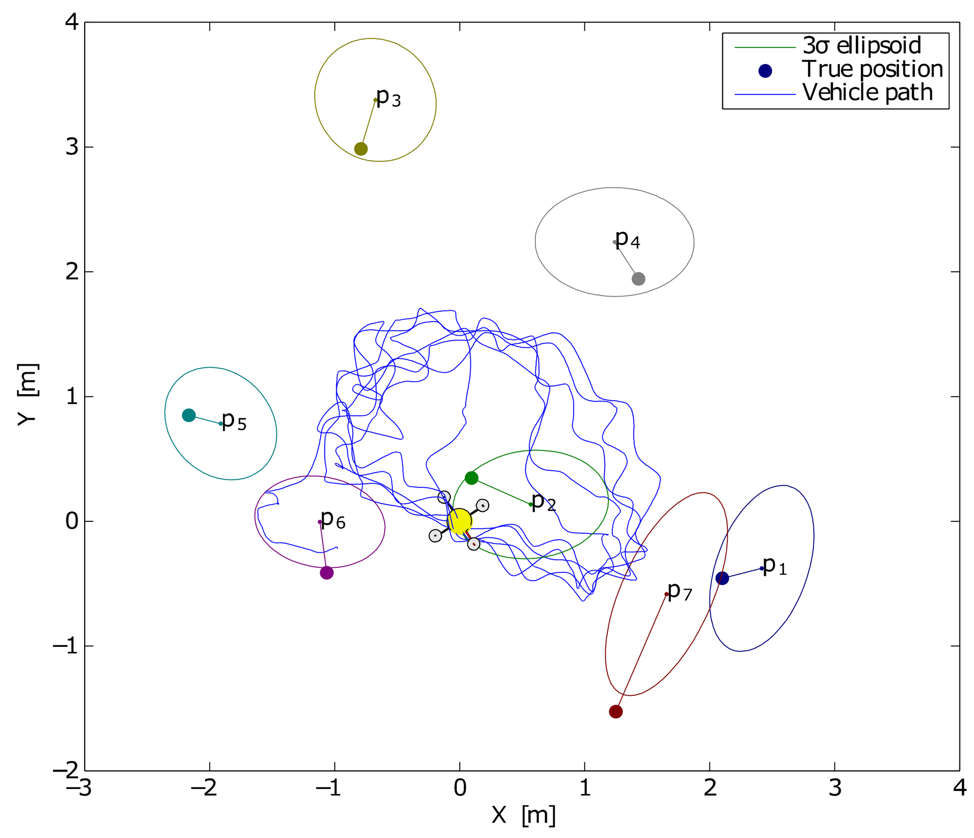
The proposed strategy was applied to the three SLAM varieties on the left: **Range-bearing** [1], **Range-only** [2], and **Bearing-only** [3] and the three resulting algorithms were tested in real conditions.

Range-bearing SLAM

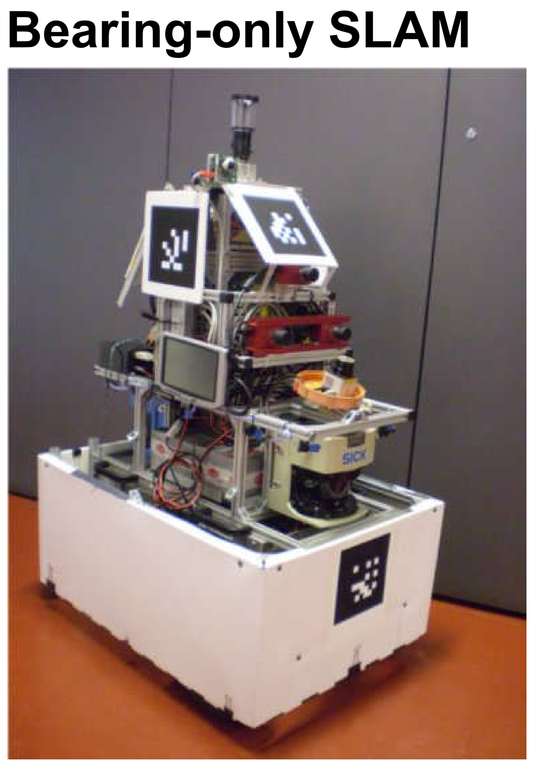


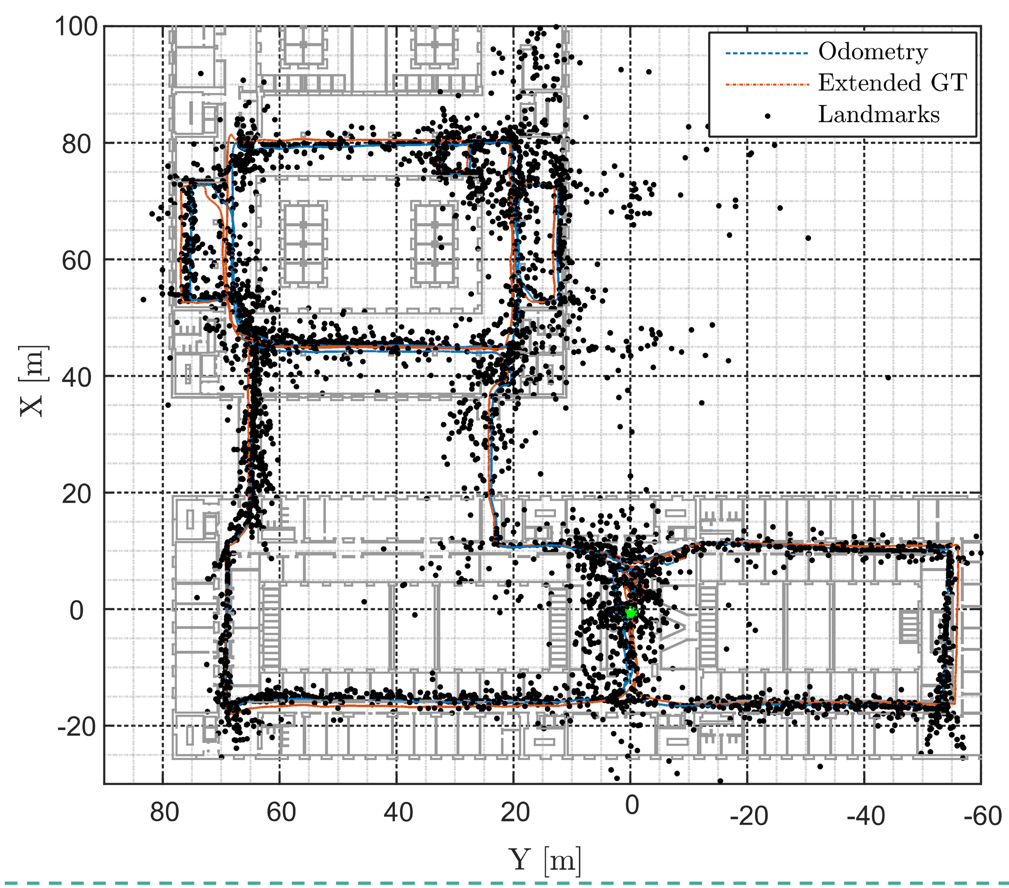
Range-only SLAM





Bearing-only SLAM





FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

This work was supported by the FCT [UID/EEA/50009/2013 and by FCT PhD grant SFRH/BD/89337/2012.

Supervisors: Paulo Oliveira, Pedro Batista e Carlos Silvestre

Phd Program in Electrical and Computer Engineering