Sensor-based Globally Exponentially Stable Range-Only Simultaneous Localization and Mapping

TÉCNICO LISBOA
ISR LISBOA
LARSyS Robótica e Sistemas em Engenharia e Ciência

Pedro Lourenço, Pedro Batista, Paulo Oliveira, and Carlos Silvestre

{plourenco,pbatista,pjcro,cjs}@isr.ist.utl.pt

Objective

Navigate an AV in a new environment with no a priori info:

- Obtain a detailed three-dimensional map of the environment measuring distances to landmarks
- Maintain an accurate estimate of the location of the vehicle

Design a RO-SLAM filter with global exponentially stable error dynamics

Major issues

Nonlinearity

- SLAM is an inherently nonlinear problem due to the necessity to convert relative measurements into global estimates.

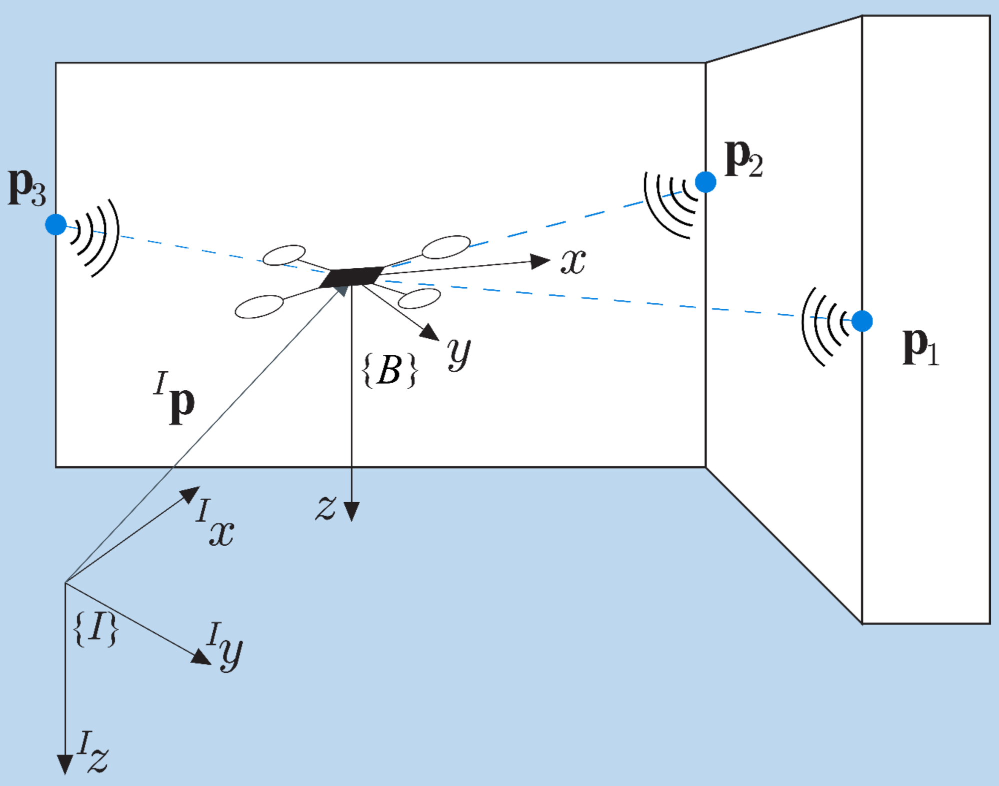
Partial observability / Landmark initialization

- In the particular range-only formulation, the range measurements are not enough to unambiguously determine a landmark

Idea

- **Sensor-based** formulation to eliminate the pose estimate from the filter
- **State augmentation** to obtain a **LTV-like** system
- Solve **initialization problem** by designing a filter with **global convergence** and **stability** guarantees

1 Sensor-based RO-SLAM filter



Mission scenario:

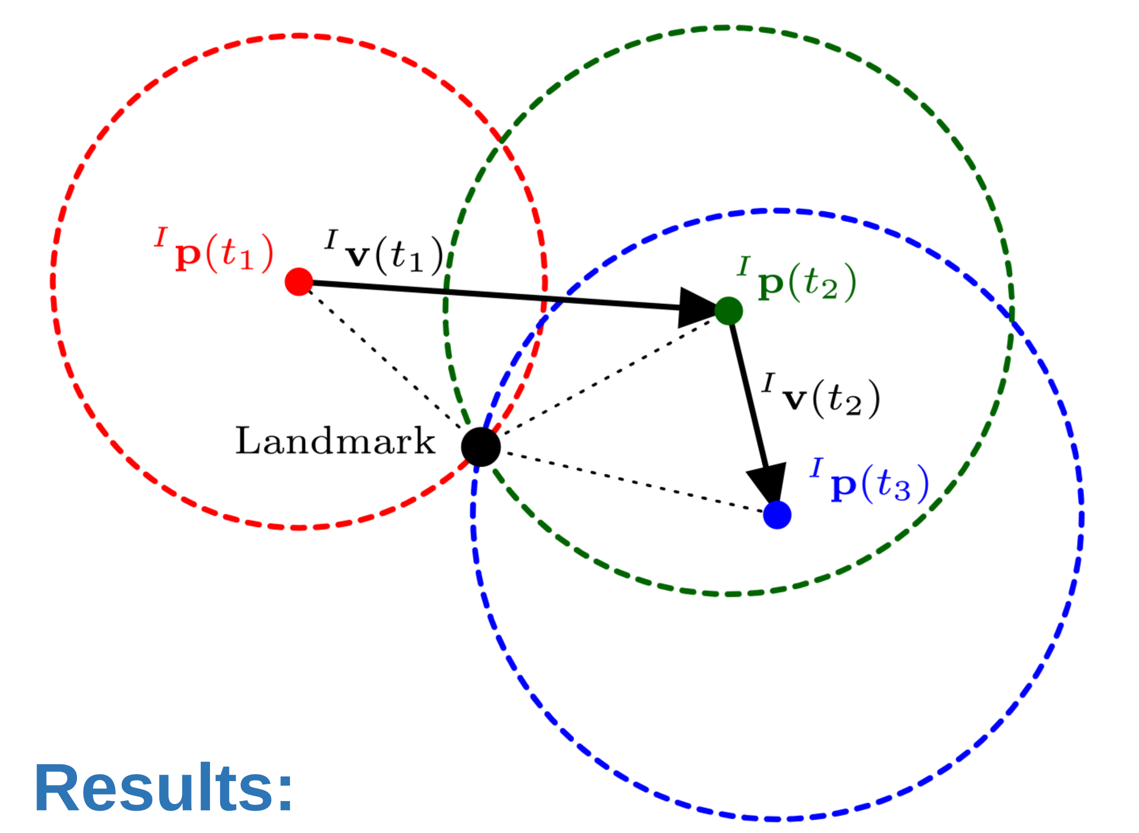
- Acoustic **beacons** are installed at unknown locations
- The vehicle measures **distances** to beacons
- The **linear** and **angular velocities** are available

System design:

- Sensor-based **landmark kinematics**
- **Range** measurement
- Result: system with **nonlinear** output

IDEA

- State **augmentation** → **linear** ouput, **nonlinear** dynamics
- Ranges to visible landmarks and linear velocity are outputs → system dynamics discarding non-visible landmarks is **LTV** for observability
- Linear theory applies → **LTV Kalman filter** is designed

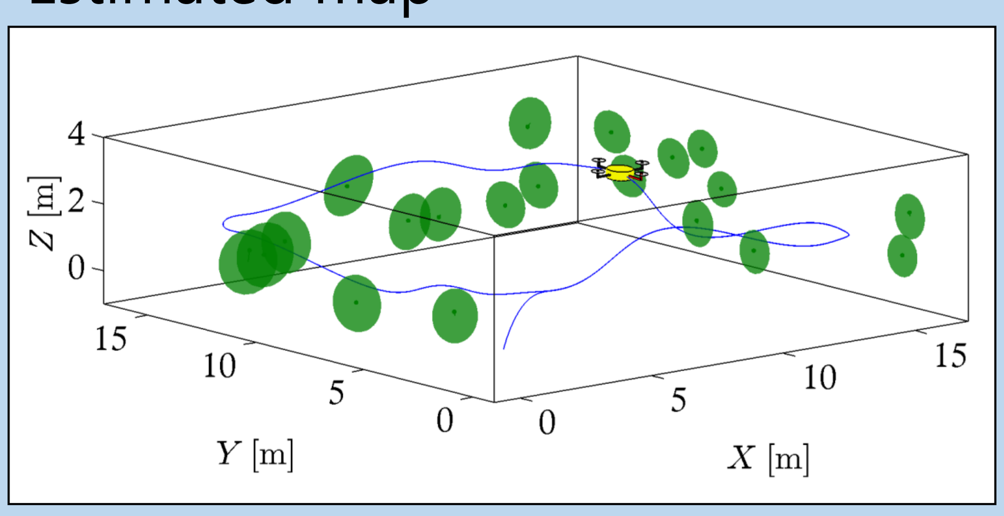


Results:

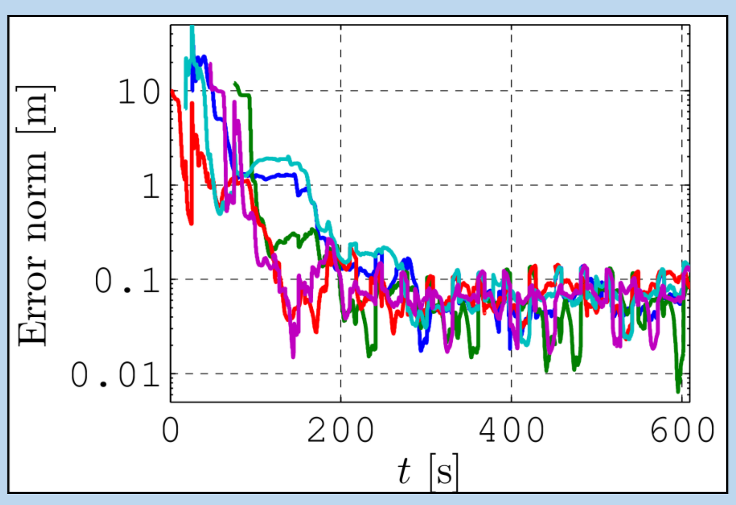
- LTV system is **uniformly completely observable**
- The designed Kalman filter has **globally exponentially stable** (GES) error dynamics

2 Simulation results

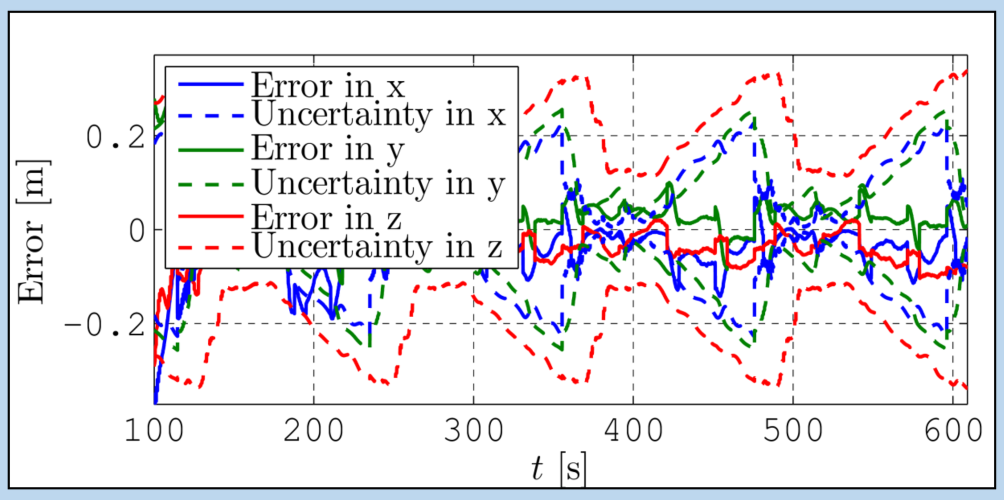
Estimated map

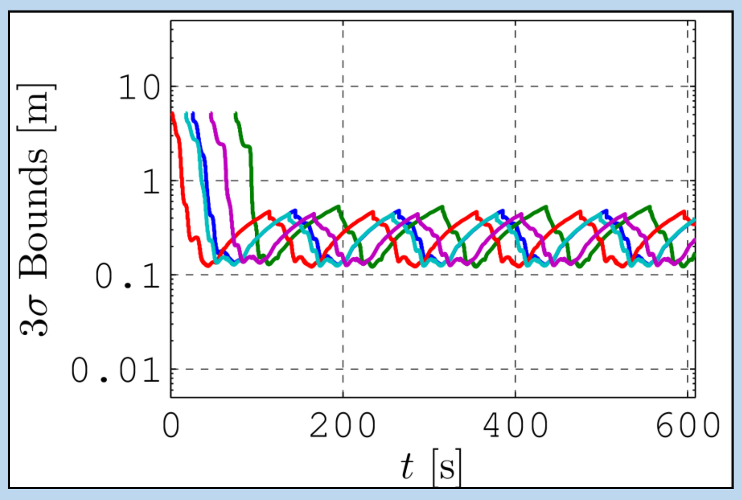


All landmarks



One landmark in detail

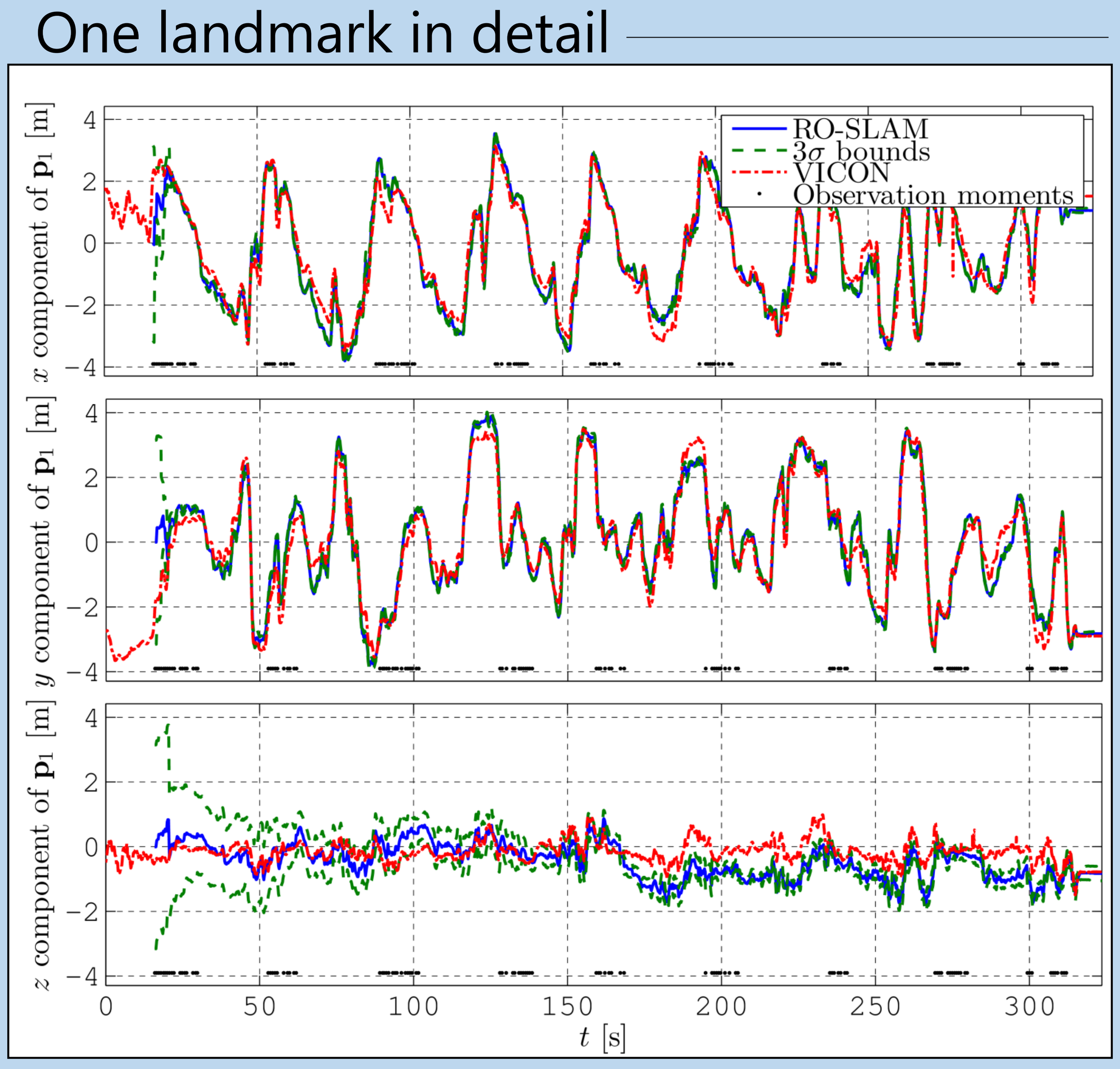




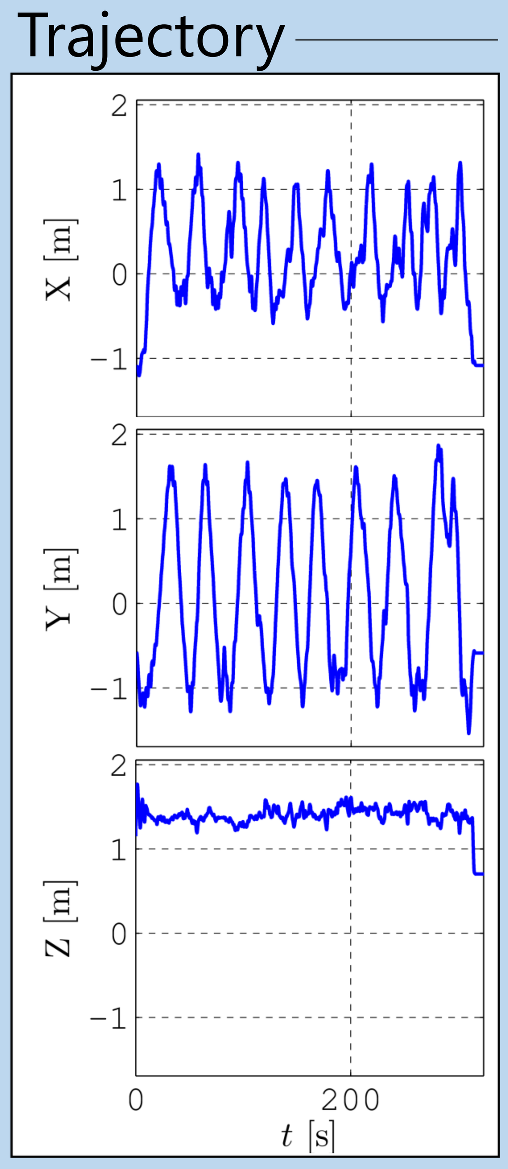
- Results confirm fast convergence of the estimation error for a trajectory sufficiently rich in all directions.
- In contrast with previous approaches to RO-SLAM, landmarks can be introduced in the filter when they are first observed, no triangulation or SoG is needed.

3 Experimental results

One landmark in detail



Trajectory



- Poor trajectory in the vertical direction precludes observability in that direction → slower convergence and higher errors
- Good performance, even with very noisy odometry

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

This work was supported by the FCT project PEst-OE/EEI/LA0009/2013. The work of P. Lourenço was supported by grant SFRH/BD/89337/2012 from FCT.