Distributed autonomous encirclement of a wheeled robot formation with collision avoidance

Castioni Edoardo

232250

edoardo.castioni@studenti.unitn.com

Pranzo Massimiliano

233174

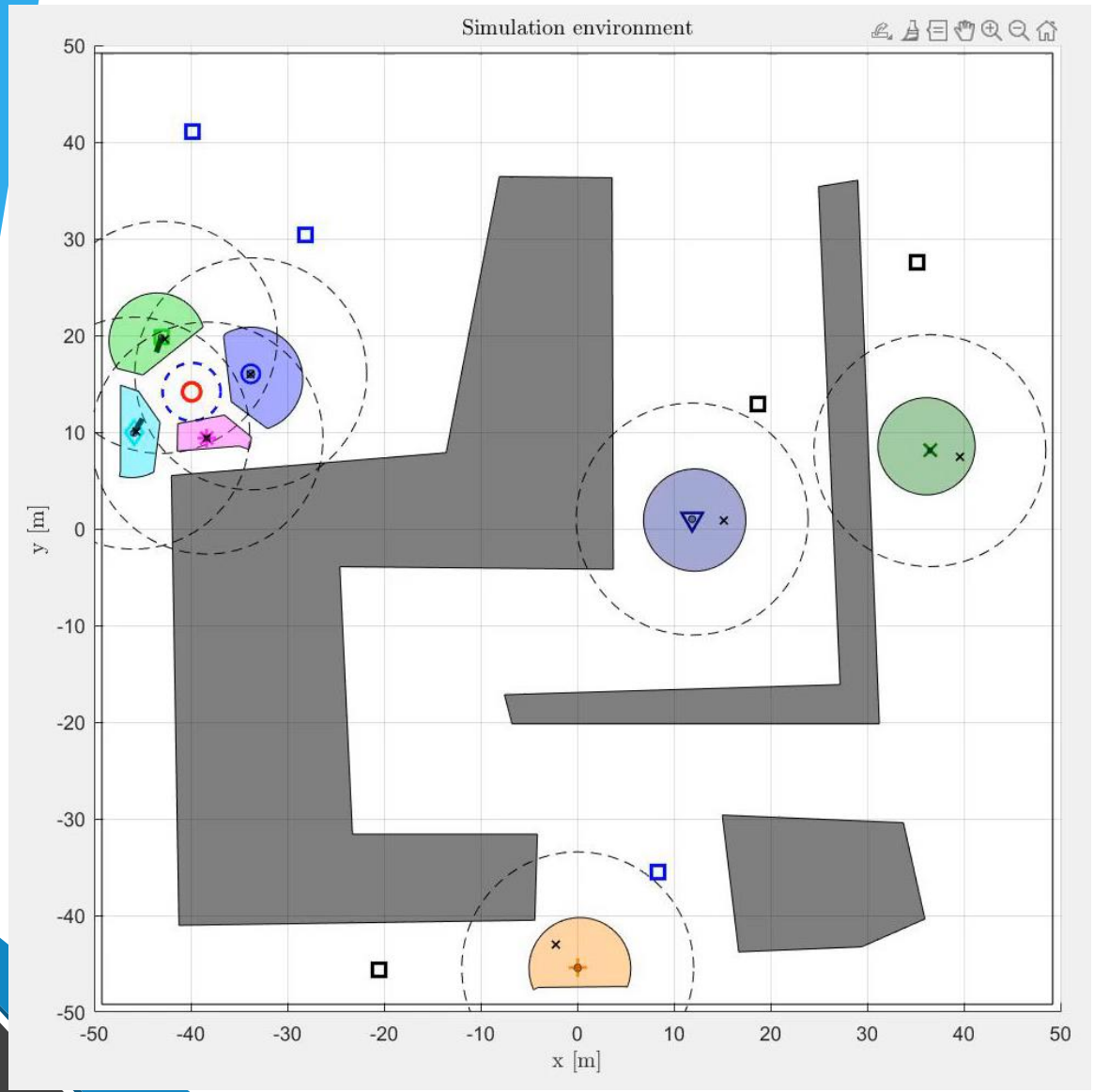
massimiliano.pranzo@studenti.unitn.com

Intelligent Distributed Systems
04 December 2023

UNIVERSITÀ DI TRENTO
Dipartimento di Ingegneria Industriale

Table of contents

Context and goal explanation



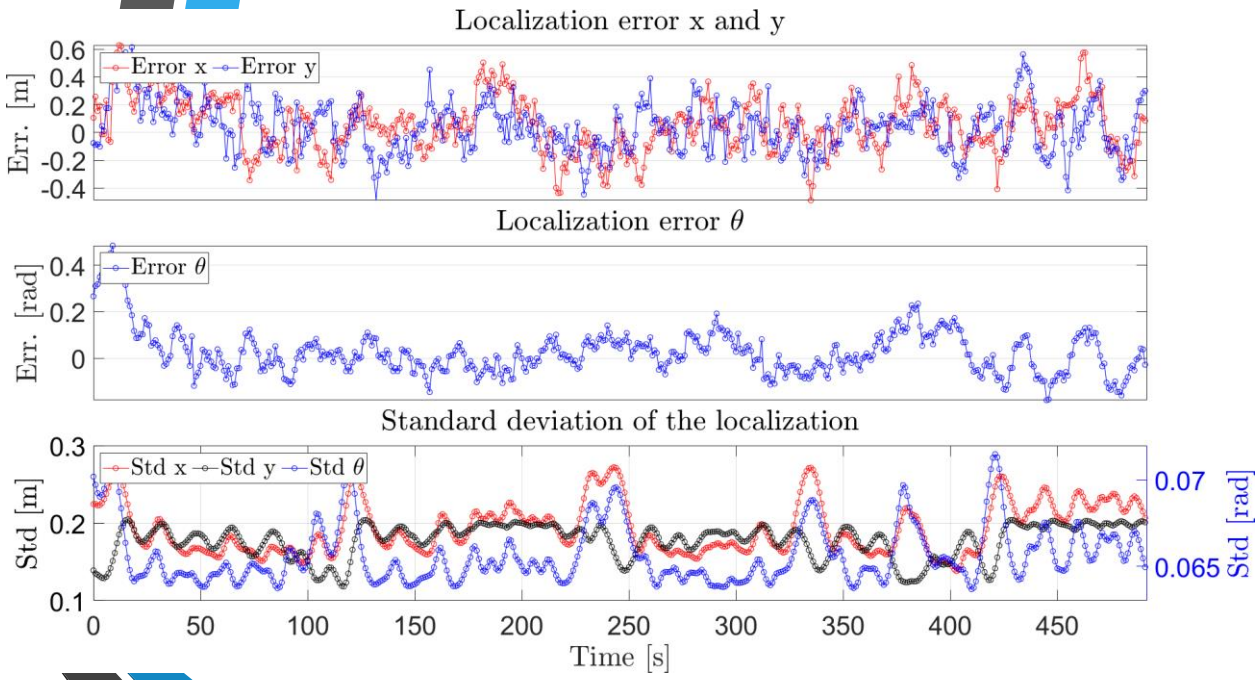
- Goal: Moving target encirclement
- Solution:
  - Localization
  - Exchange information
  - Motion control

Robot equipment

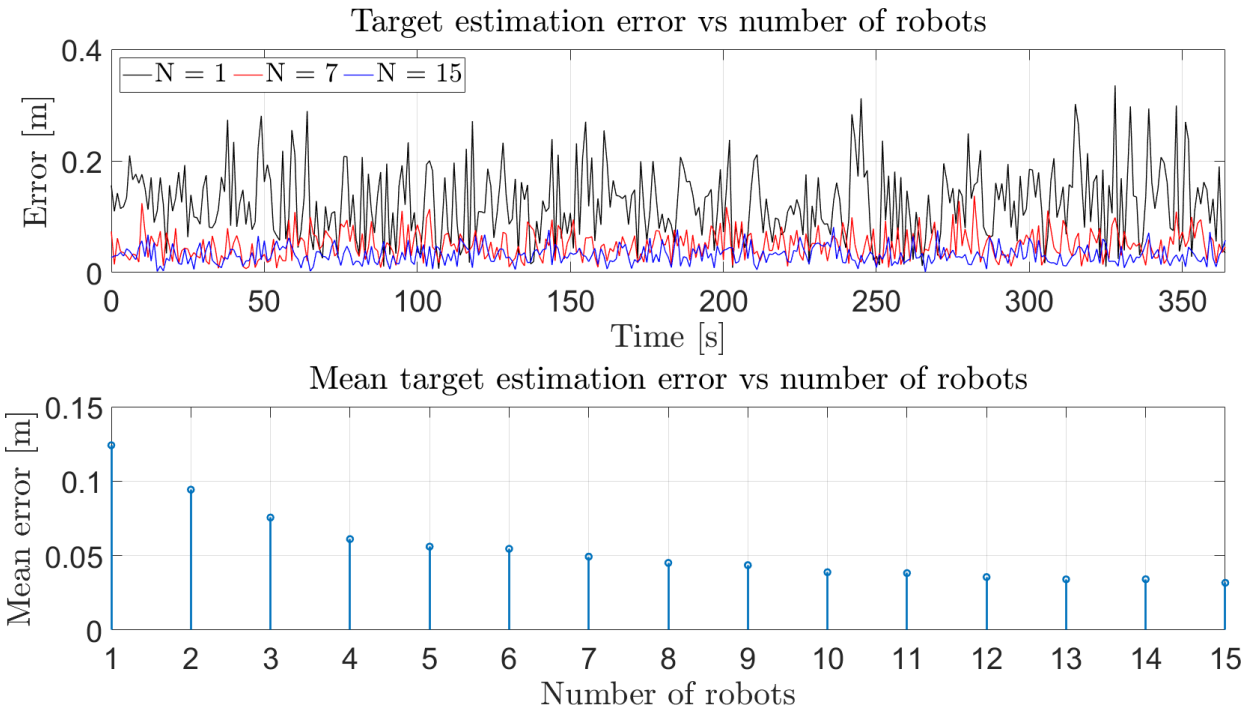
- Robot: moving circular entity with encumbrance δ
- Dynamics:
  - Linear $$\bar{x}_{R,i+1} = \bar{x}_{R,i} + \bar{u}_i + \bar{\nu}_i$$
  - Unicycle $$\begin{bmatrix} \bar{x}_R \\ \theta_R \end{bmatrix}_{i+1} = \begin{bmatrix} \bar{x}_R \\ \theta_R \end{bmatrix}_i + \begin{bmatrix} \cos(\theta_R) & 0 \\ \sin(\theta_R) & 0 \\ 0 & 1 \end{bmatrix}_i \bar{u}_i + \bar{\nu}_i$$
- Sensors:
  - GPS: $\sigma = 3\ [m]$
  - Stereo camera / Relative distance sensor: $\sigma = 0.3\ [m]$
  - $R_{com} = R_{cam} = 12\ [m]$

Robot localization

Extended Kalman filter



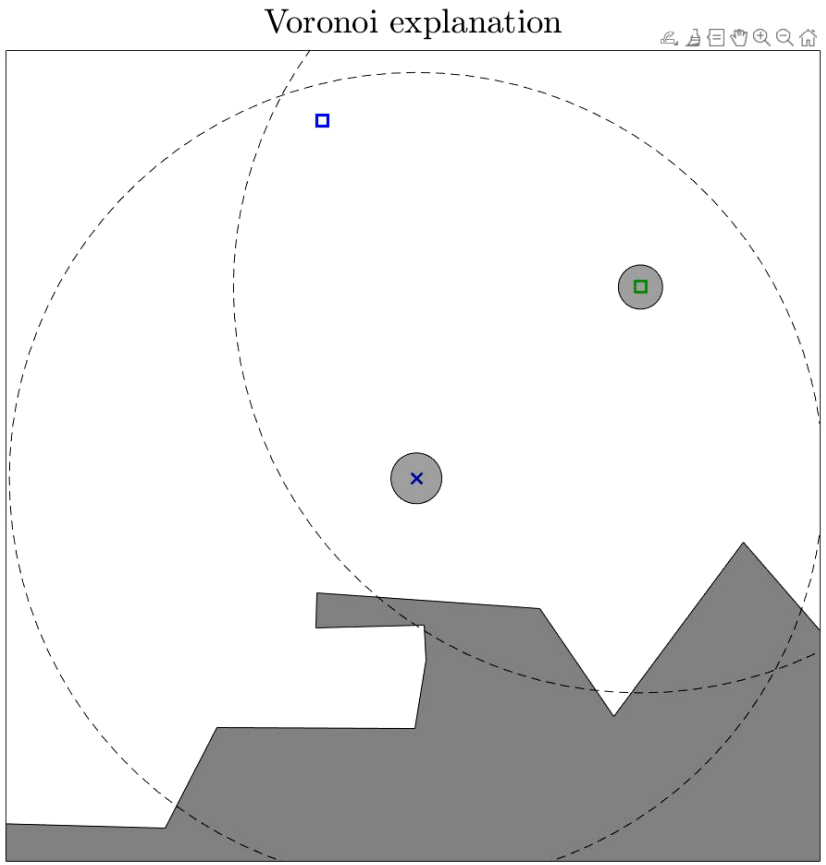
Distributed WLS

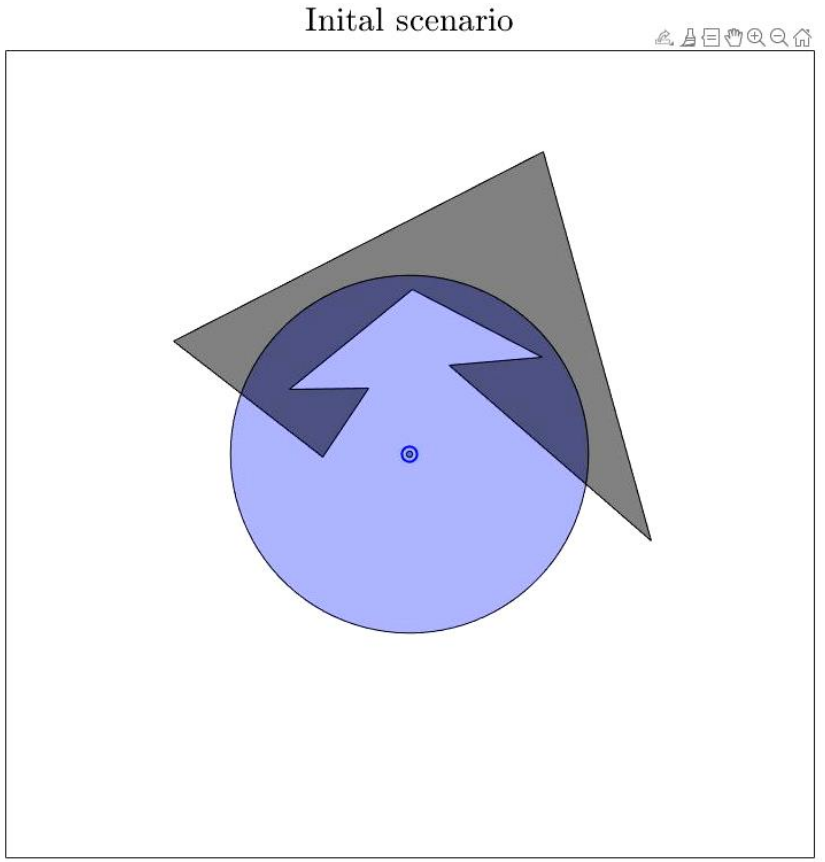


Voronoi tessellation

The voronoi cell considers:

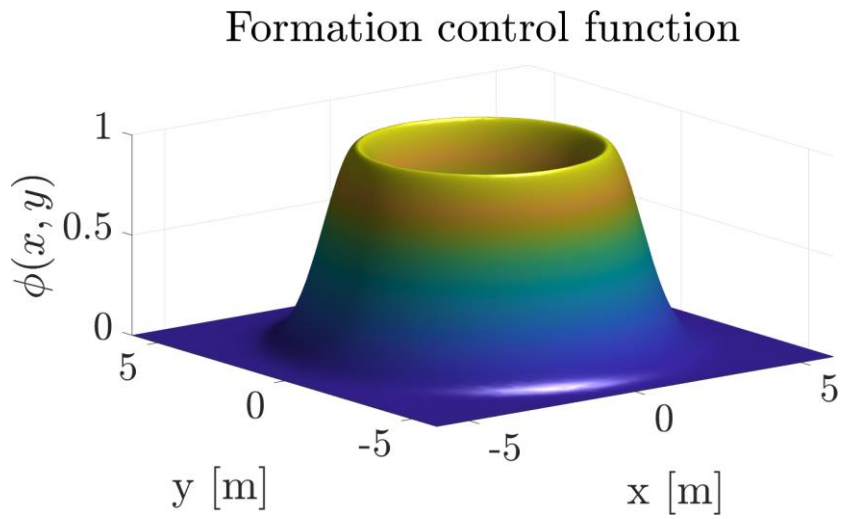
- Uncertainty on robot localization (self and reciprocal)
- Robot encumbrance

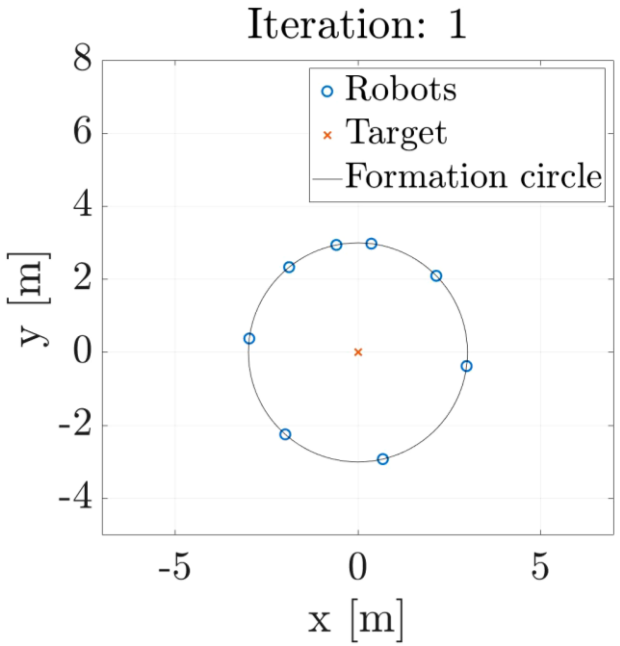




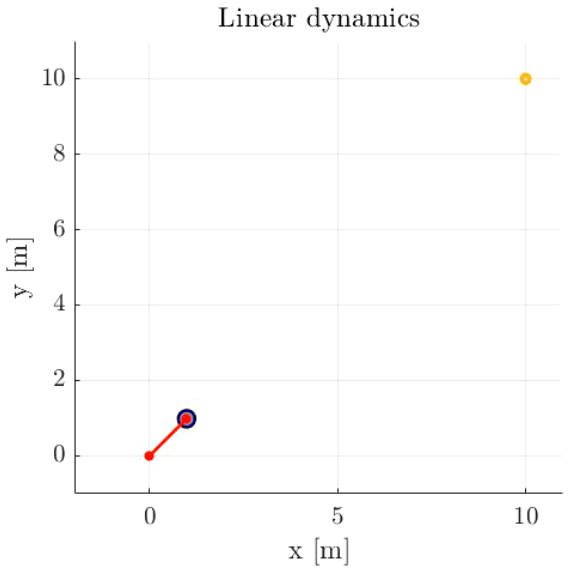
Motion control – High level

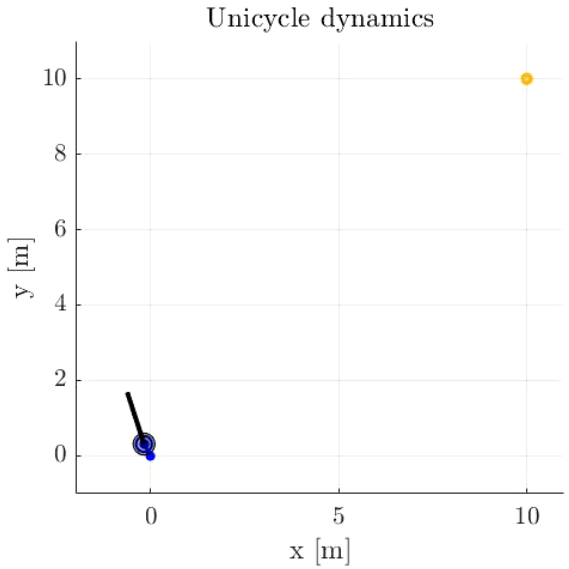
- It defines a goal position for the low level control
- Target search: random search of the target
- Target reaching
- Keeping equidistance

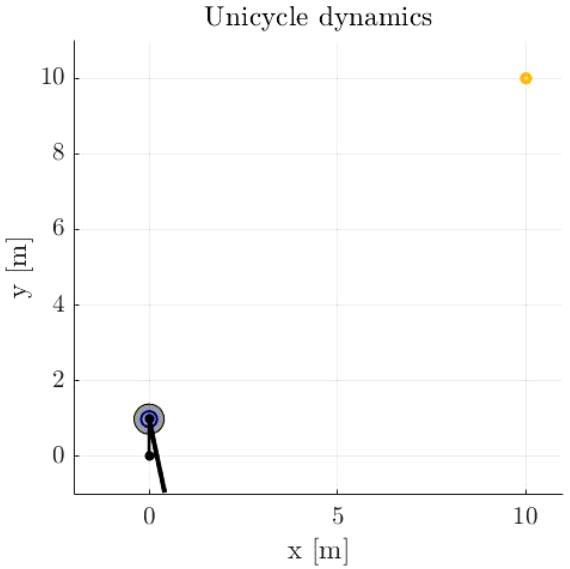




Motion control – Low level







Linear Dynamics

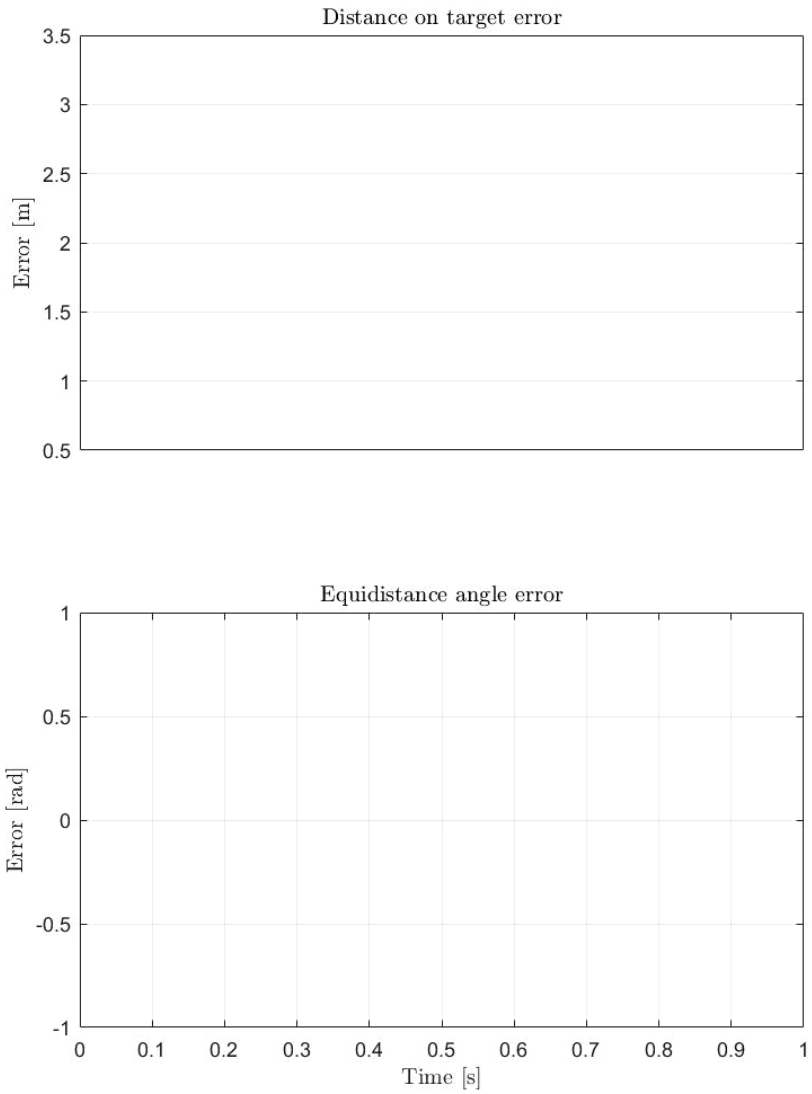
$$\bar{x}_{R,i+1} = \bar{x}_{R,i} + \min(k_p\,(\bar{x}_{R,i} - \bar{x}_D), v_{MAX})\,\Delta t$$

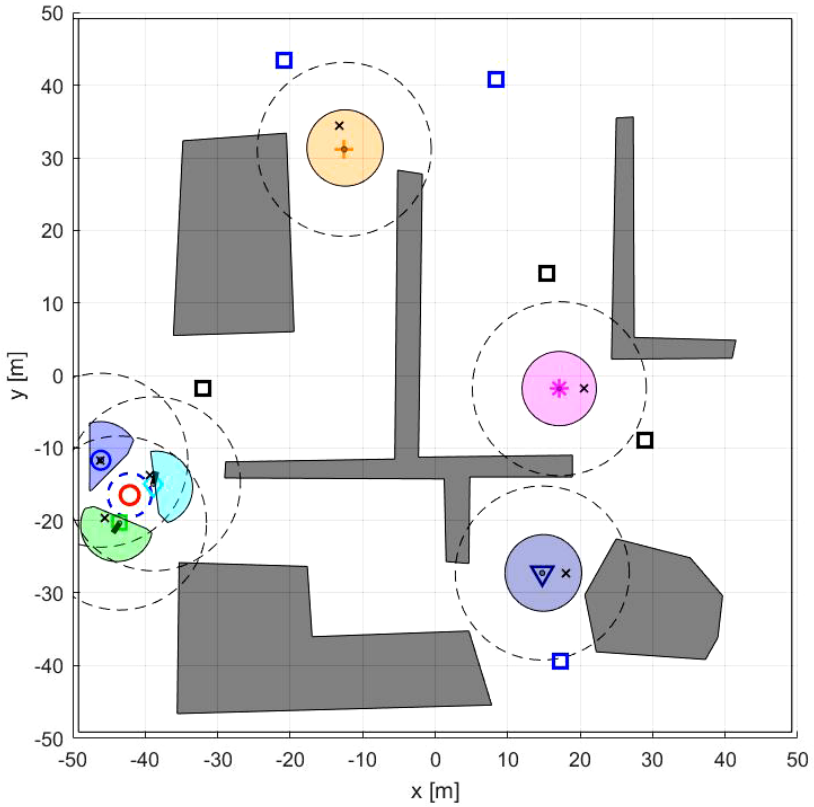
Unicycle Dynamics

$$v = \min(k_p\ \|\bar{x}_R - \bar{x}_D\|, v_{MAX})\ \cos(\gamma_m)$$

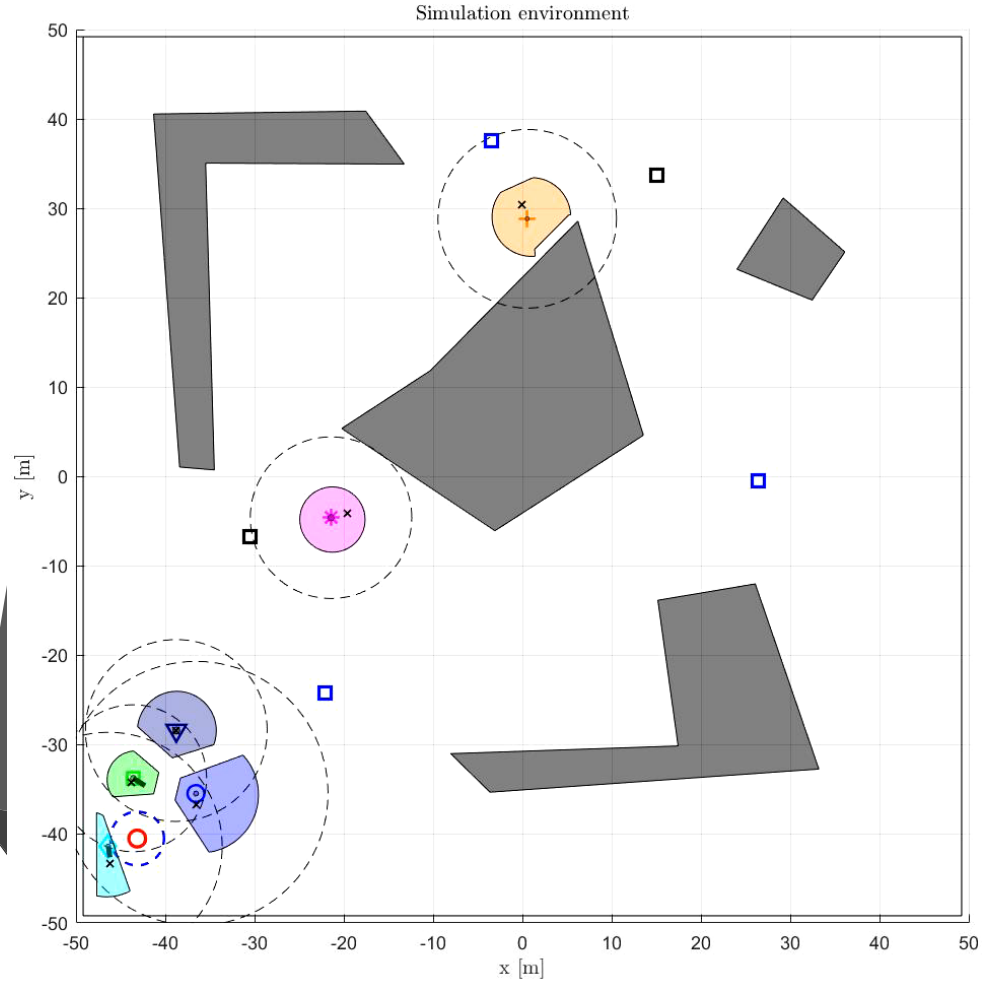
$$\omega = \min(k_p\,|\gamma_M|, \omega_{MAX}) \cdot \begin{cases} 1 & (\alpha_D \geq \theta_R \wedge \gamma_M < \pi) \\ & (\alpha_D < \theta_R \wedge \gamma_M > \pi) \\ -1 & \text{otherwise} \end{cases}_{\vee}$$

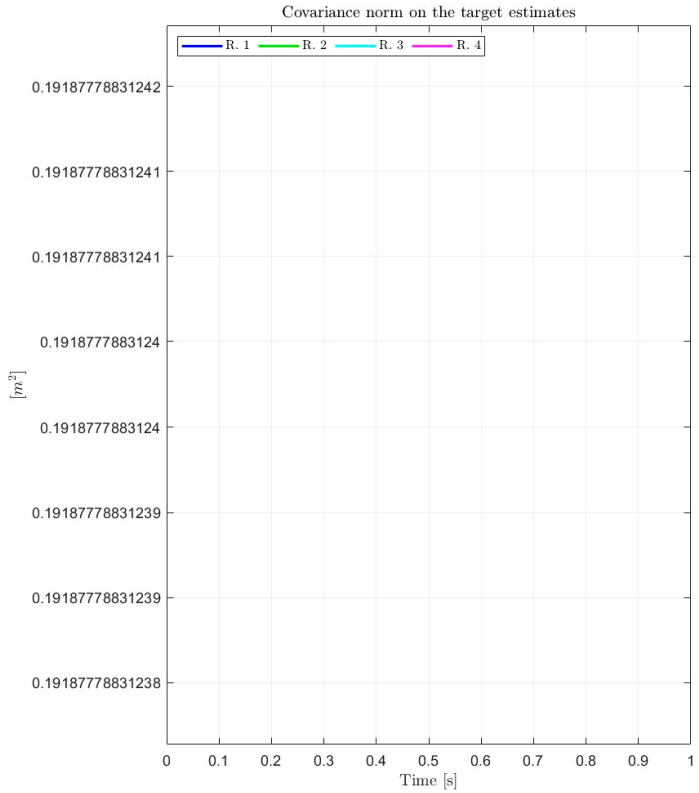
Final simulationand results

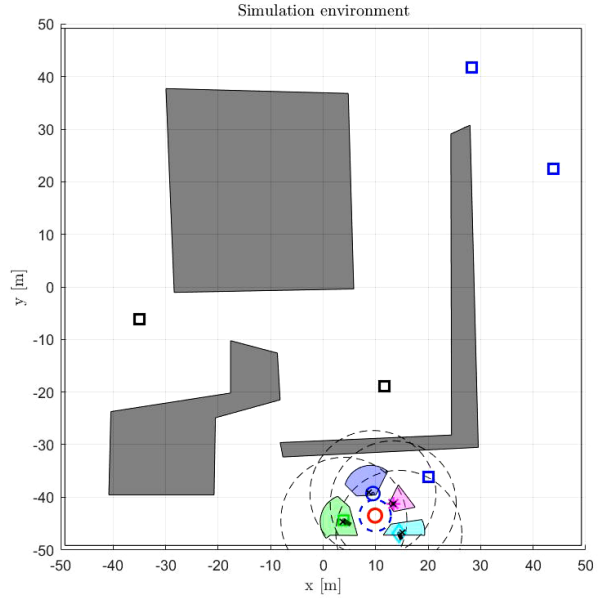




Extra results







Conclusions

- Performed tasks:
  - Localization
  - Information distribution
  - Voronoi tessellation and Motion control
- Improvements:
  - Increse localization accuracy with distributed SLAM
  - Model Predictive Control to enhance the non linear trajectory
  - Environment - adaptive formation function