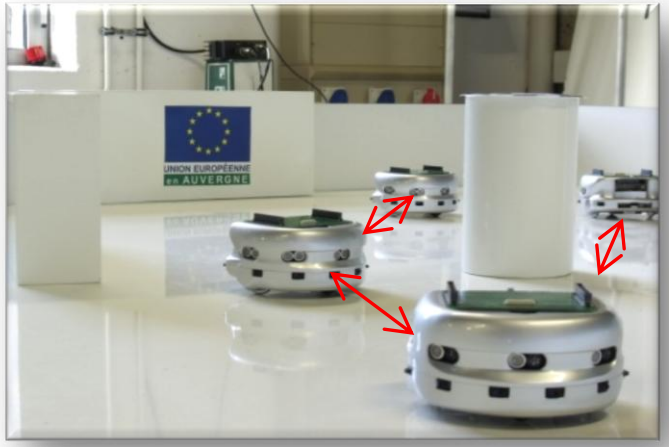
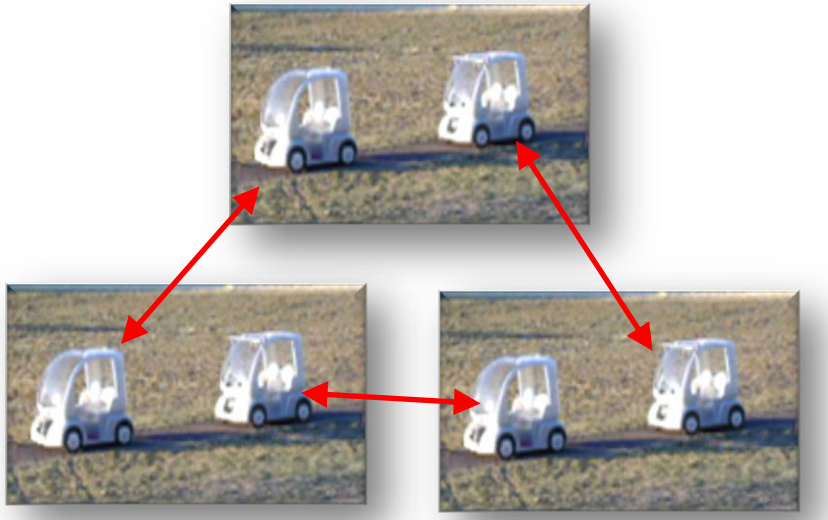
Distributed and Reactive Multi-robot Navigation in Cluttered Environment





Dr. Lounis ADOUANE

IAS'12 Congress (International Conference on Intelligent Autonomous System)

Workshop : **Personal Transport Service Robots – Jeju (Korea) – June 26, 2012**

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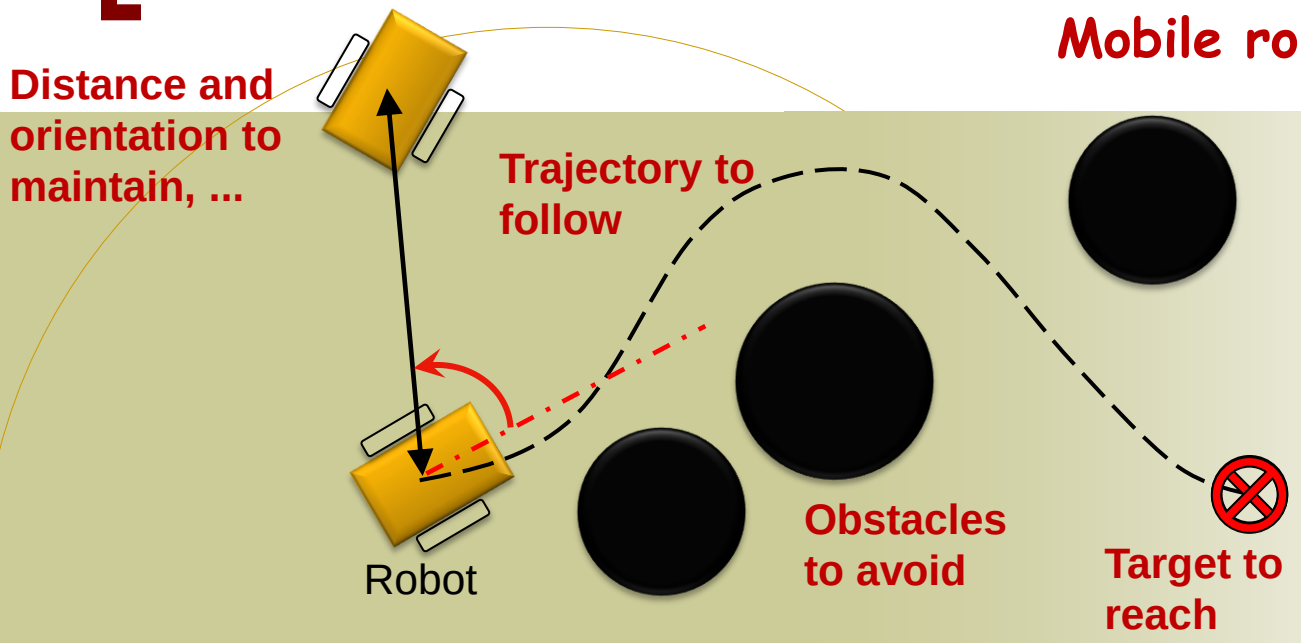
Mobile multi-robot navigation

Mobile robot navigation



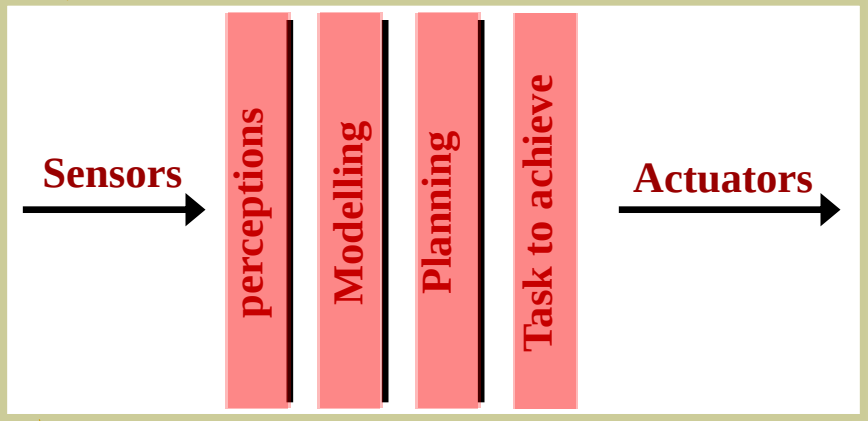
- Cluttered, uncertain and dynamical environment,
- A lot of subtasks to achieve,
- Multi objective constraints to guarantee (safety, flexibility, robustness, …).

Complex task ⟹ **Complex control**

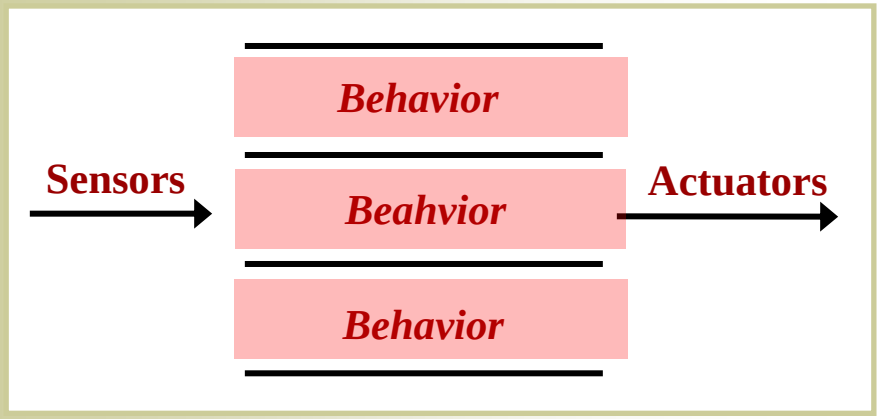
Mobile multi-robot navigation

Mobile robot navigation

How to control this kind of complex system?



Vertical decomposition

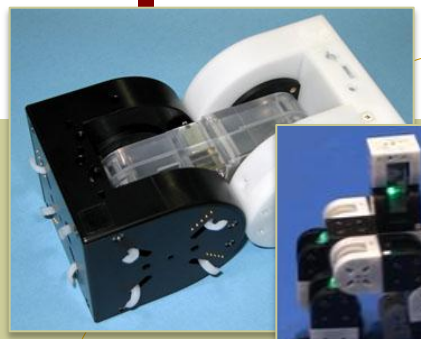


Horizontal decomposition (Brooks, 86)

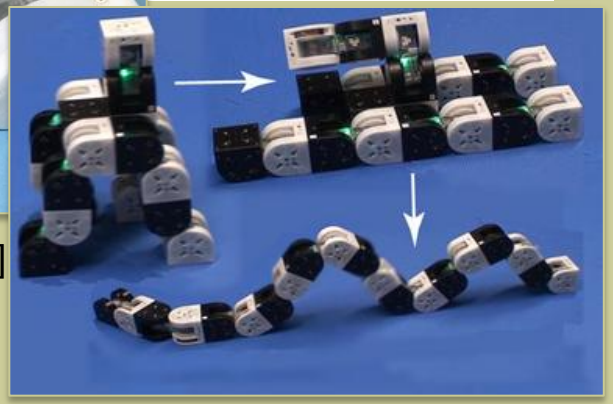
➢ **Bottom-up construction**

Mobile multi-robot navigation

Examples of cooperative tasks



[Kurokawa et al]



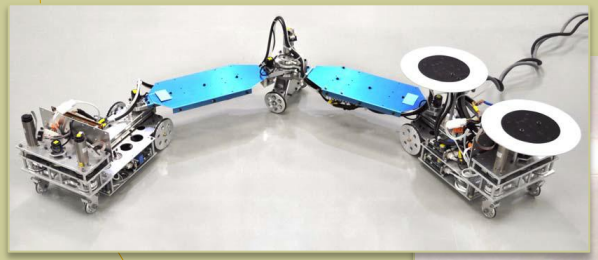
Modular robotics [M-TRAN project]

Earthquake intervention

[Khatib et al]

[Hirata et al]

Cooperative removal task using mobiles arms



[*Yamaguchi* et al]

Cooperative object displacement (physical link)

Mobile multi-robot navigation

Navigation in formation task

Agriculture
(Wheat Harvest)

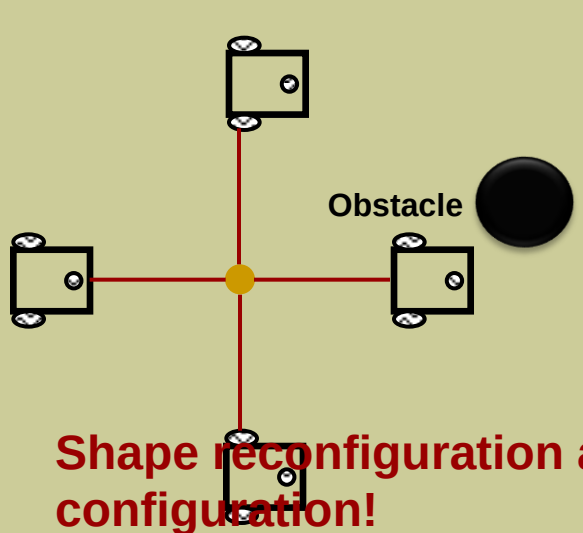
Road construction

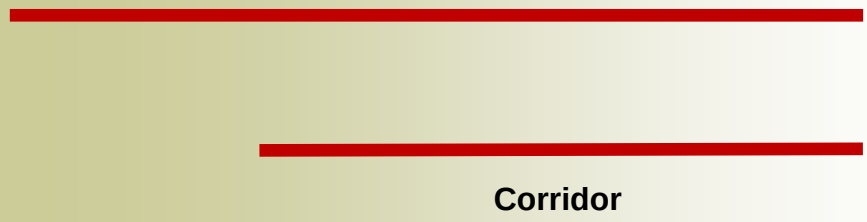
Military Transportation

Public Transportation

Mobile multi-robot navigation

Navigation in formation task (main functionalities)





Shape reconfiguration according to mission need and environment configuration!

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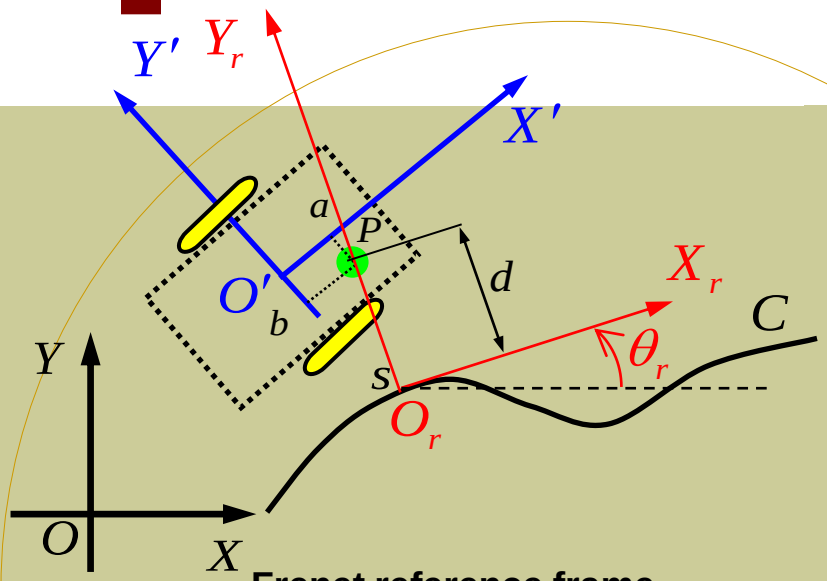
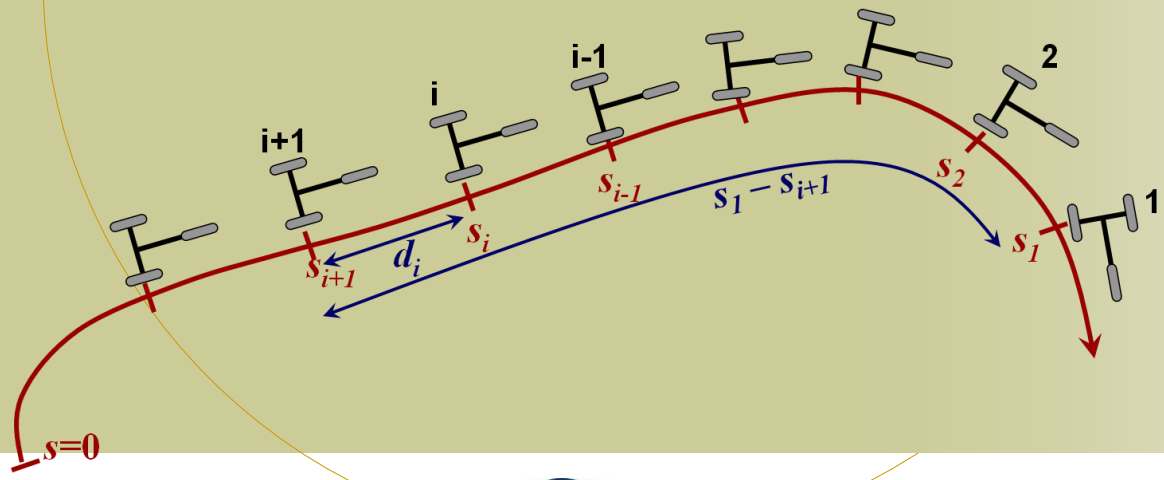
- Mobile multi-robot navigation (Introduction)
- **Strategies to control a formation**
- Distributed and Reactive control architecture
- Conclusion and future work

Strategies to control a formation



Frenet reference frame

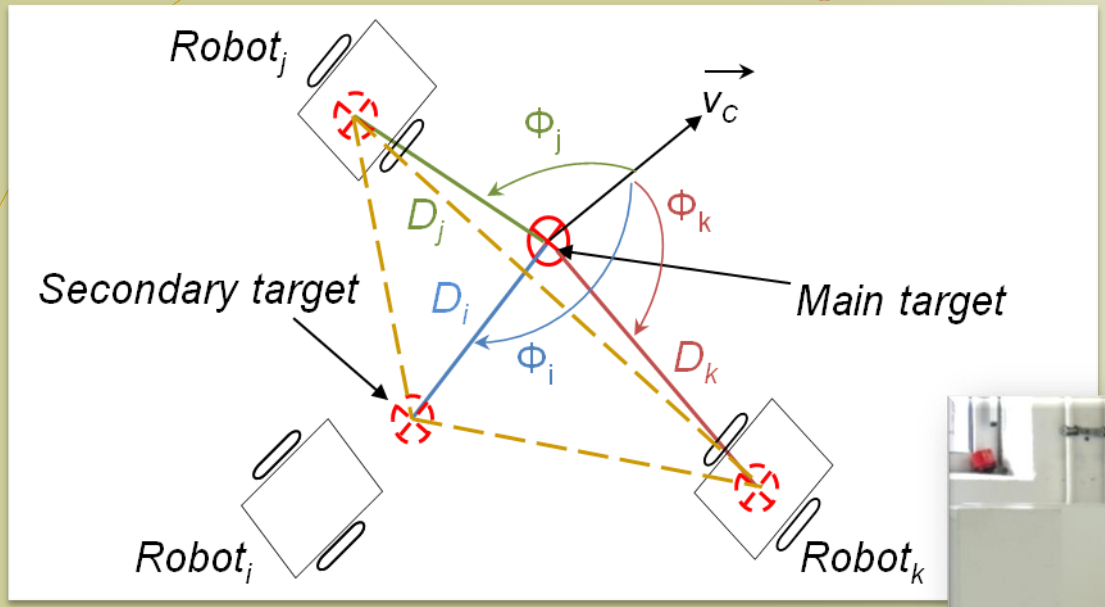


Based trajectory following [Bom et al. IROS 2005]

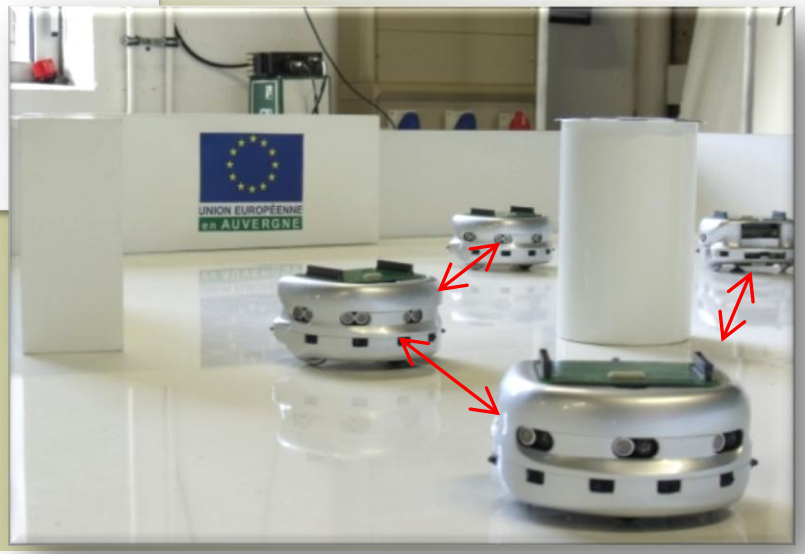
$$\begin{aligned} \dot{s} &= \frac{(v - b\omega)\cos\theta_e - a\omega\sin\theta_e}{1 - dc(s)}, \\ \dot{d} &= (v - b\omega)\sin\theta_e + a\omega\cos\theta_e, \\ \dot{\theta}_e &= \omega - \dot{s}c(s). \end{aligned}$$

Strategies to control a formation

Based targets following [Benzerrouk et al. IROS 2010]



Virtual structure



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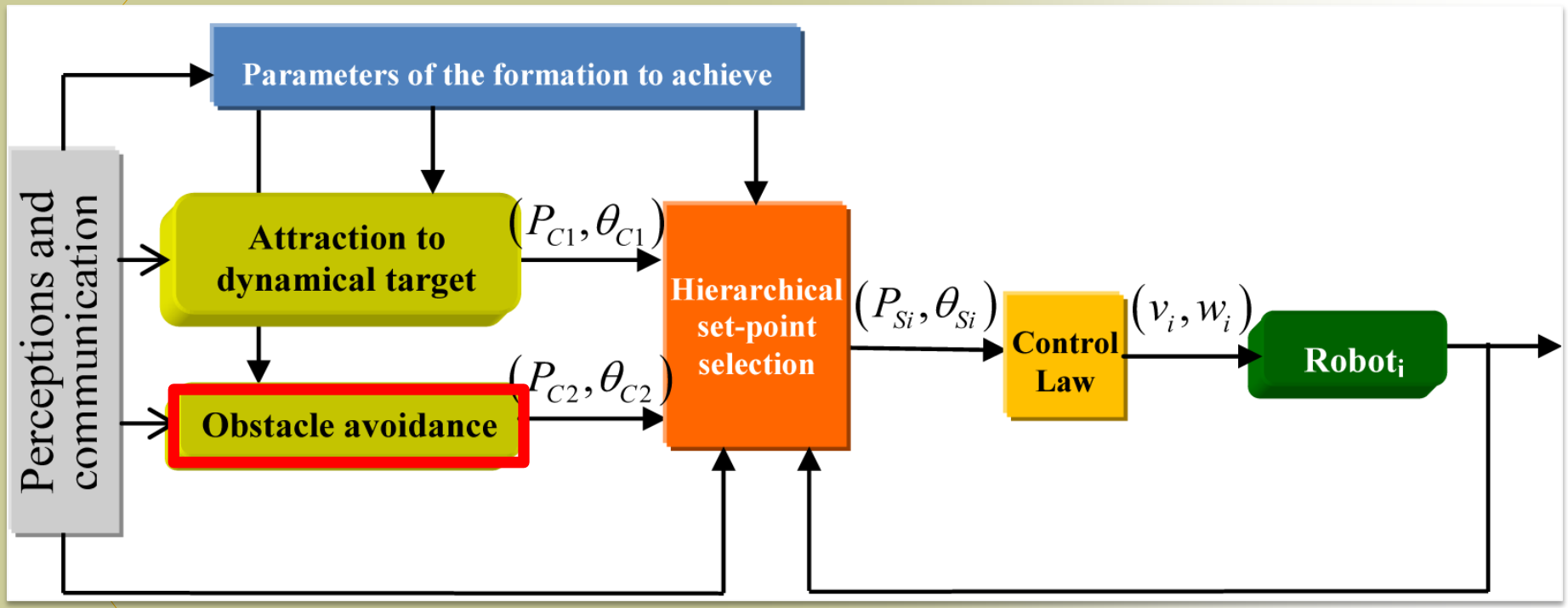
Distributed and Reactive control

Behavioral control architecture



Distributed and Reactive control

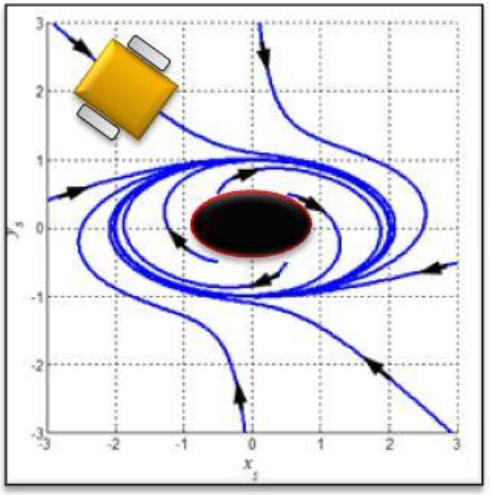
Obstacle avoidance

[Adouane et al. IFAC WC'11]

➢ Limit-cycles trajectories

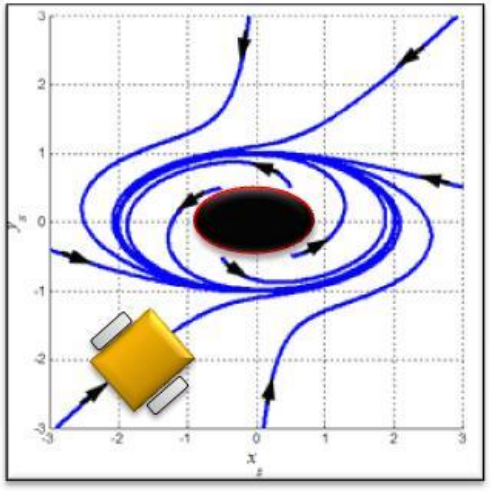
Clockwise trajectories

$$\dot{x}_s = y_s + \mu x_s(1 - x_s^2/A_{lc}^2 - y_s^2/B_{lc}^2 - cx_s y_s)$$
$$\dot{y}_s = -x_s + \mu y_s(1 - x_s^2/A_{lc}^2 - y_s^2/B_{lc}^2 - cx_s y_s)$$

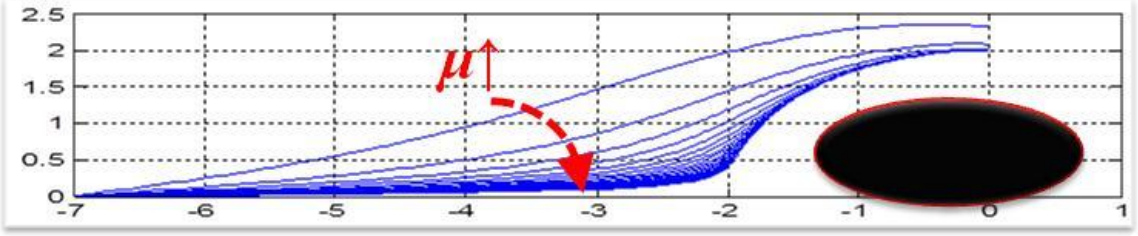


Counter-clockwise trajectories

$$\dot{x}_s = -y_s + \mu x_s(1 - x_s^2/A_{lc}^2 - y_s^2/B_{lc}^2 - cx_s y_s)$$
$$\dot{y}_s = x_s + \mu y_s(1 - x_s^2/A_{lc}^2 - y_s^2/B_{lc}^2 - cx_s y_s)$$

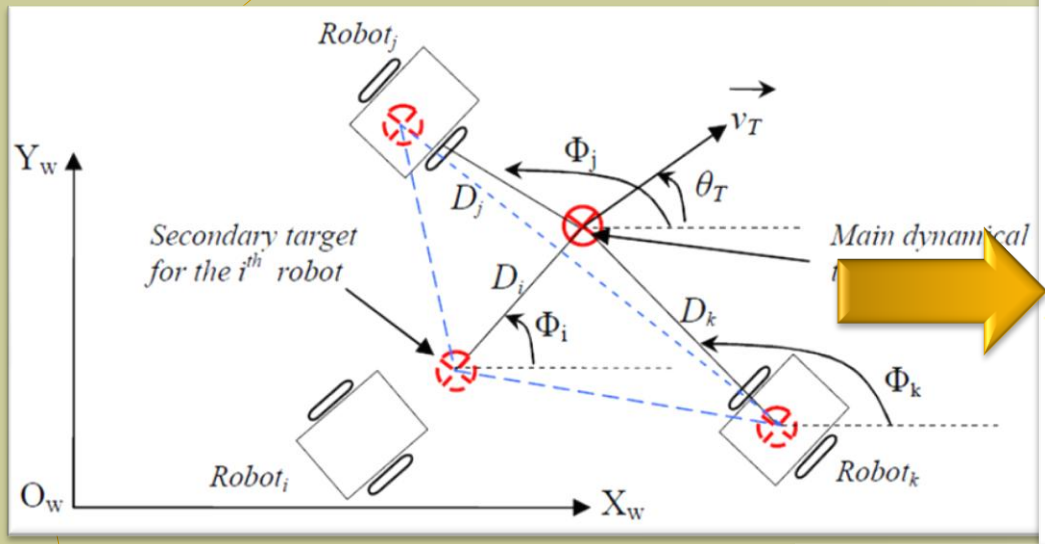


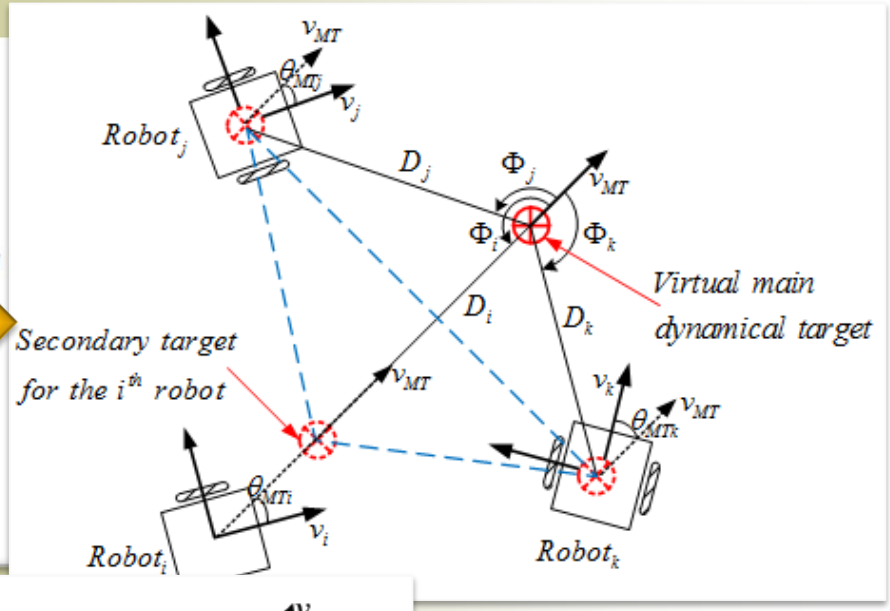
μ parameter



Distributed and Reactive control

From global frame to local one [Vilca et al, CAR'12]



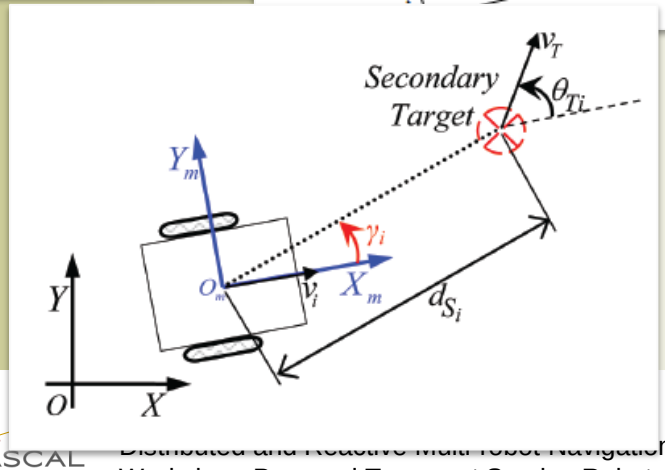


Control law

$$v_i = v_{max} - (v_{max} - v_{S_i})\, e^{-d_{S_i}^2/\sigma^2}$$
$$\omega = \omega_{S_i} + K_p \tilde{\theta}_i$$

Angular set-point

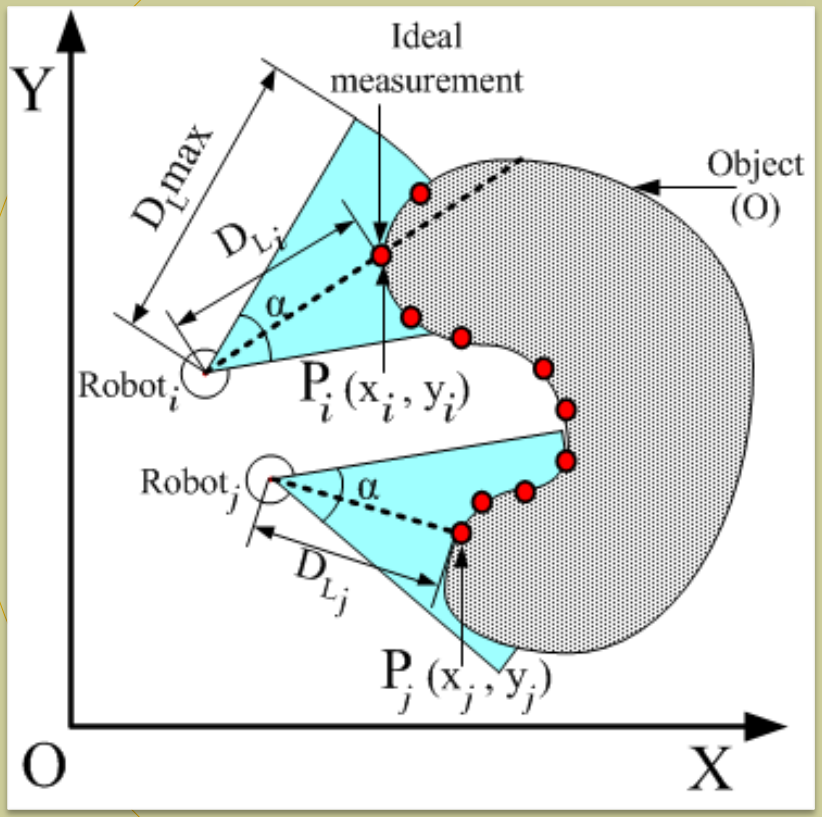
$$\theta_{SP} = \arcsin\left(\frac{v_T}{v_i}\sin(\theta_{T_i} - \gamma_i)\right) + \gamma_i$$

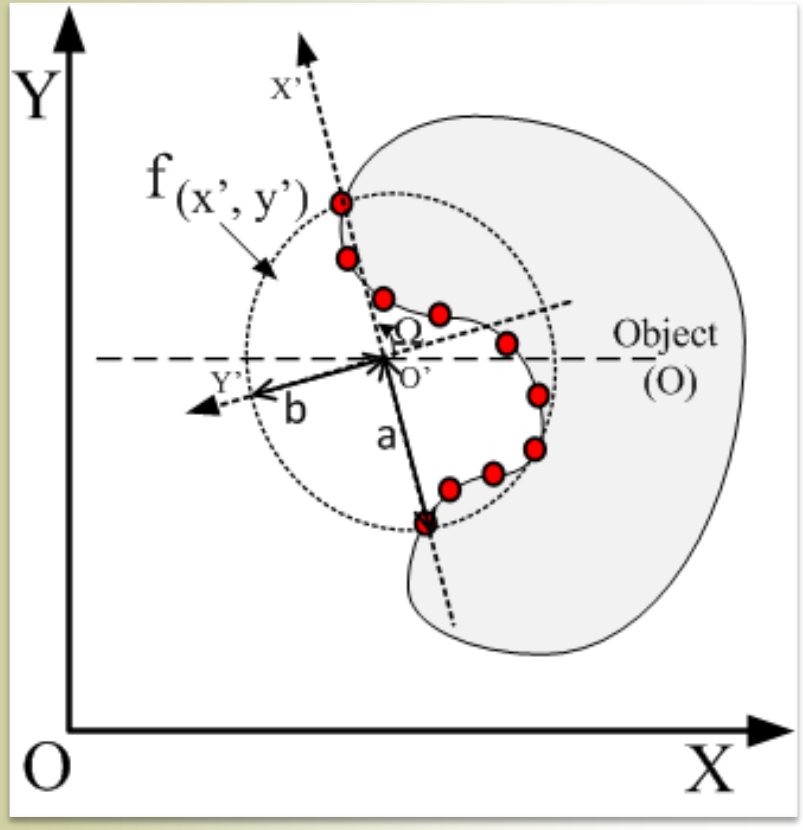


[Benzerrouk et al. IROS 2010]

Distributed and Reactive control

Enclosing data range with an Ellipse [Vilca et al. IAS'12]



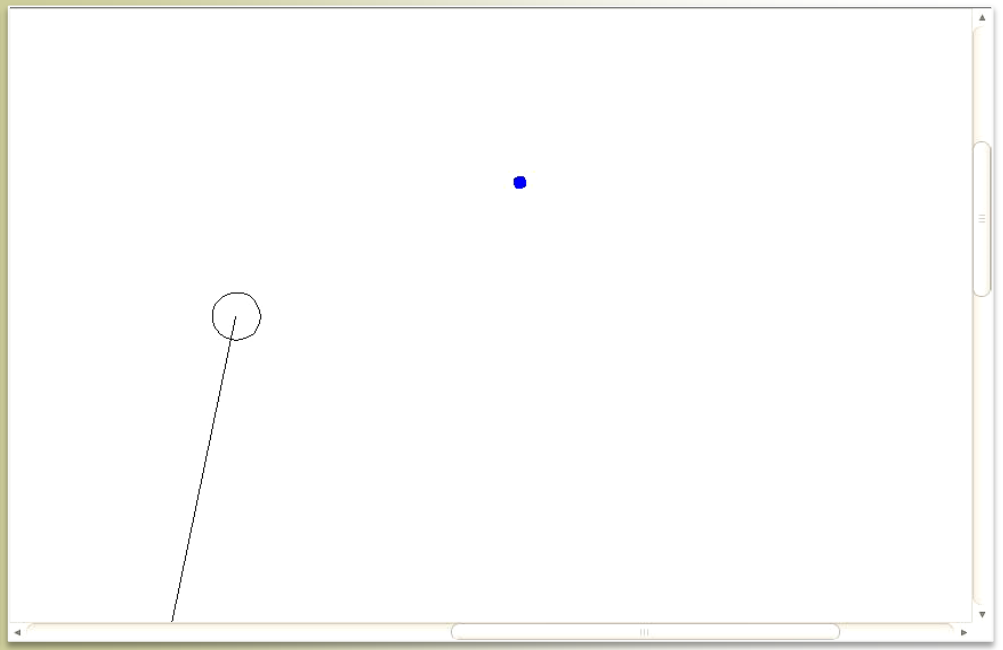


Heuristic approach using EKF

Distributed and Reactive control

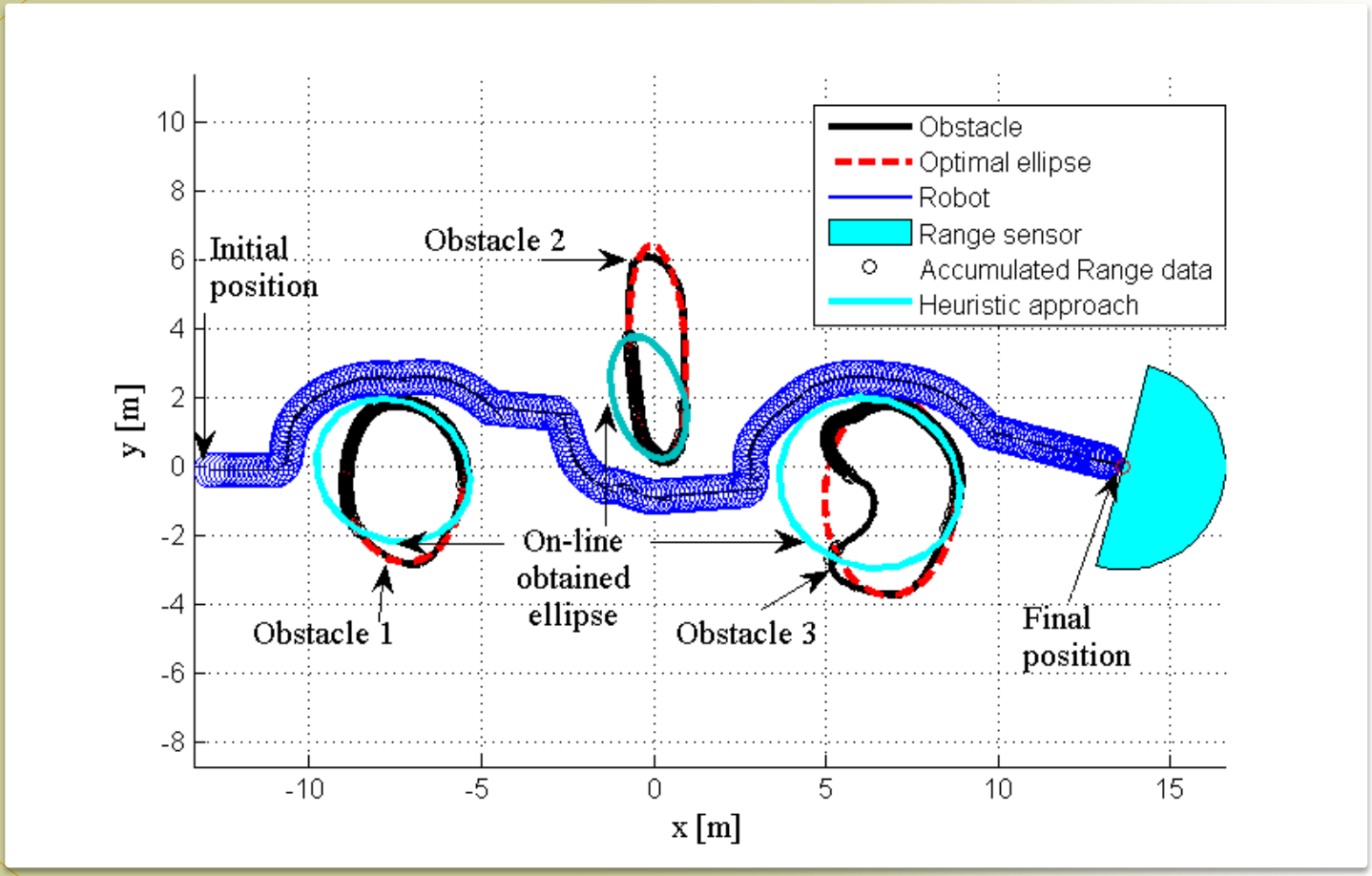
Enclosing data range with an ellipse

Khepera III mobile robot



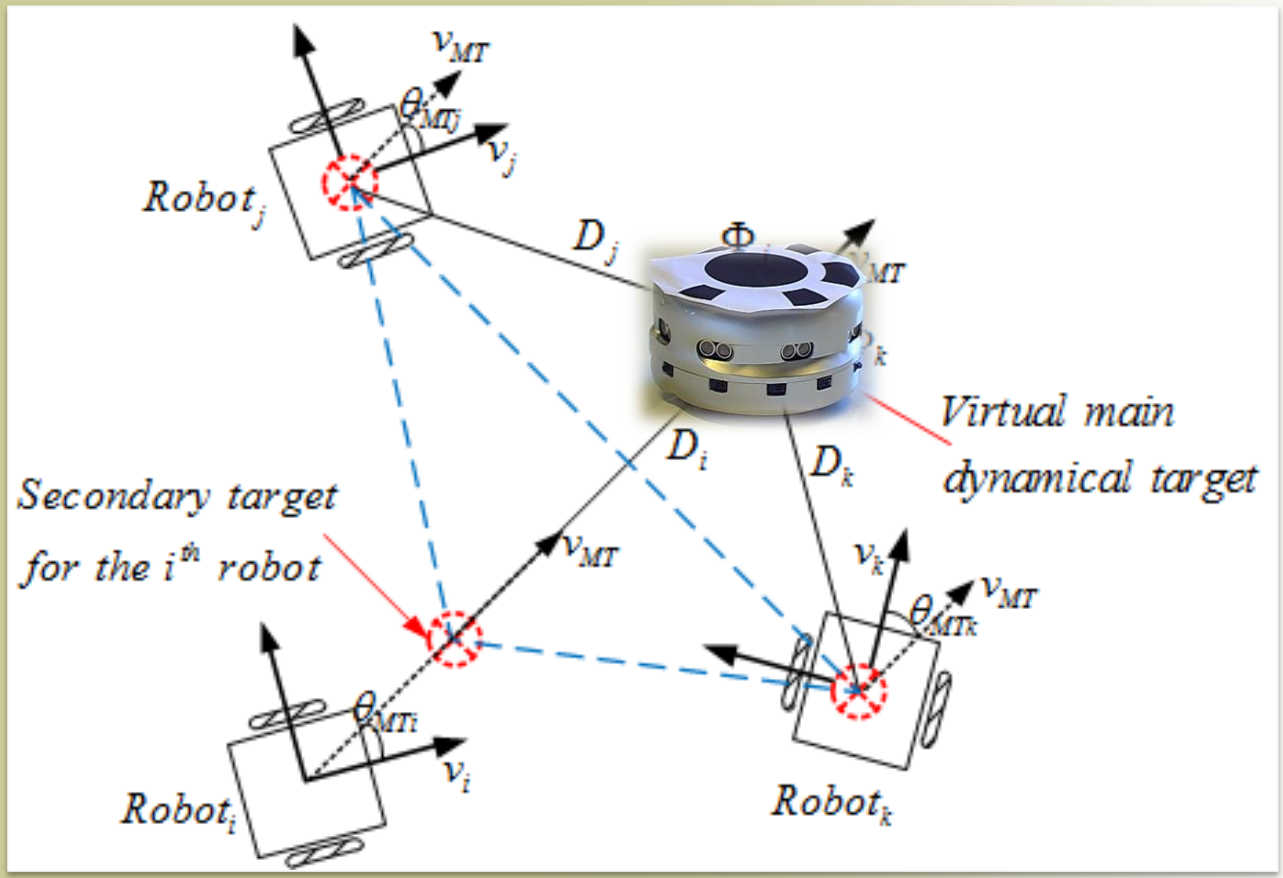
Distributed and Reactive control

Enclosing data range with an ellipse



Distributed and Reactive control

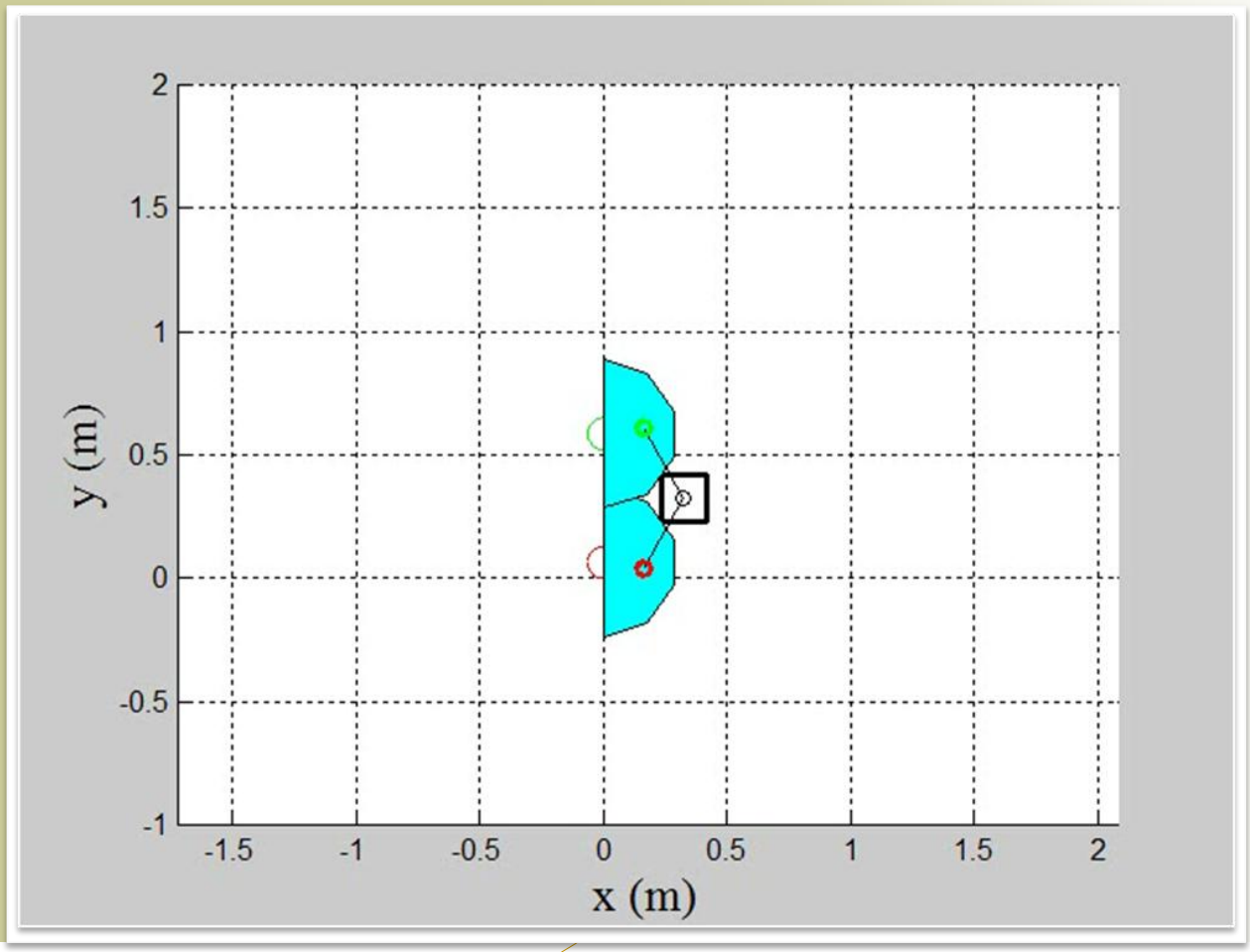
Toward Leader Follower approach



Distributed and Reactive control

Toward Leader Follower approach

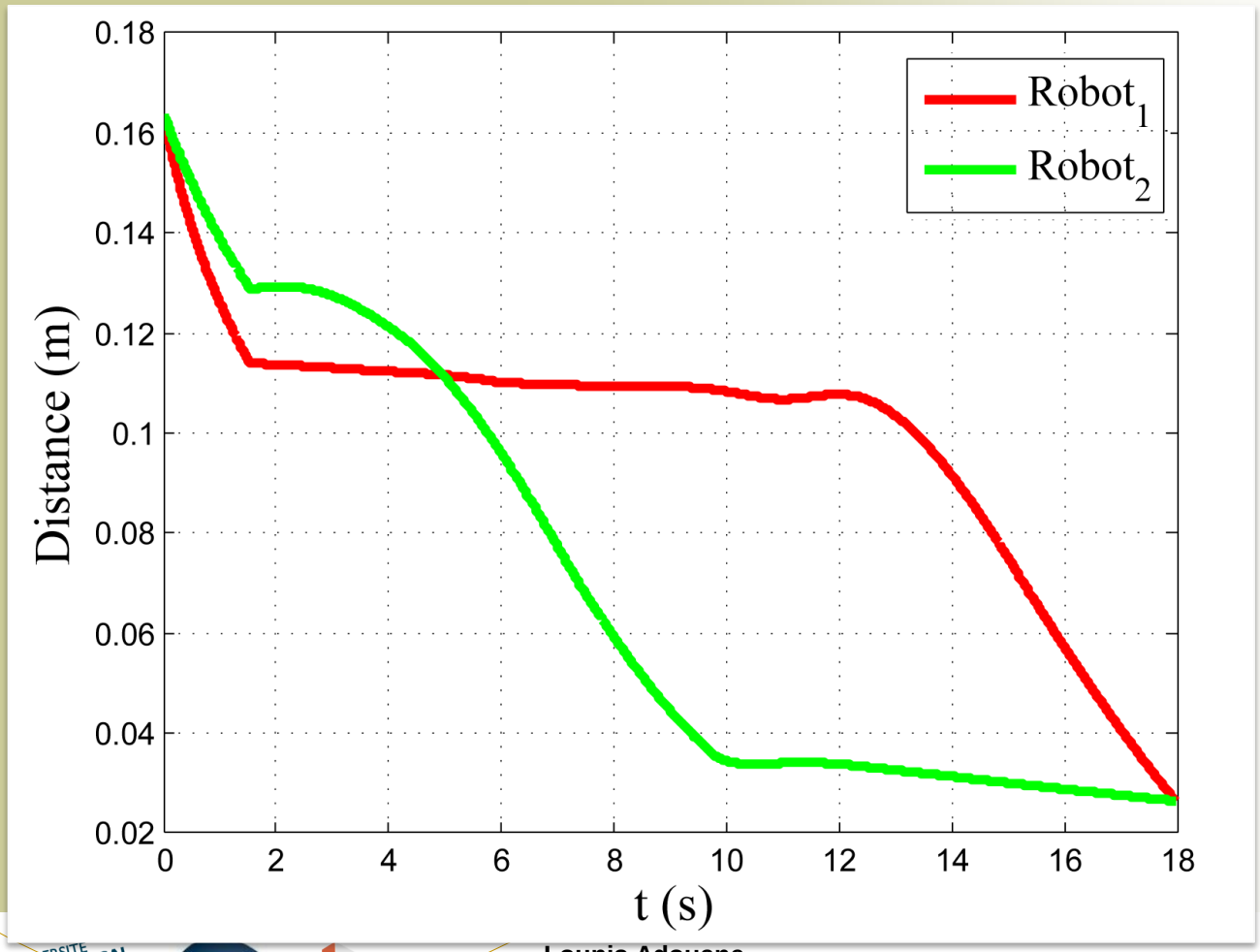
Each robot separately



Distributed and Reactive control

Toward Leader Follower approach

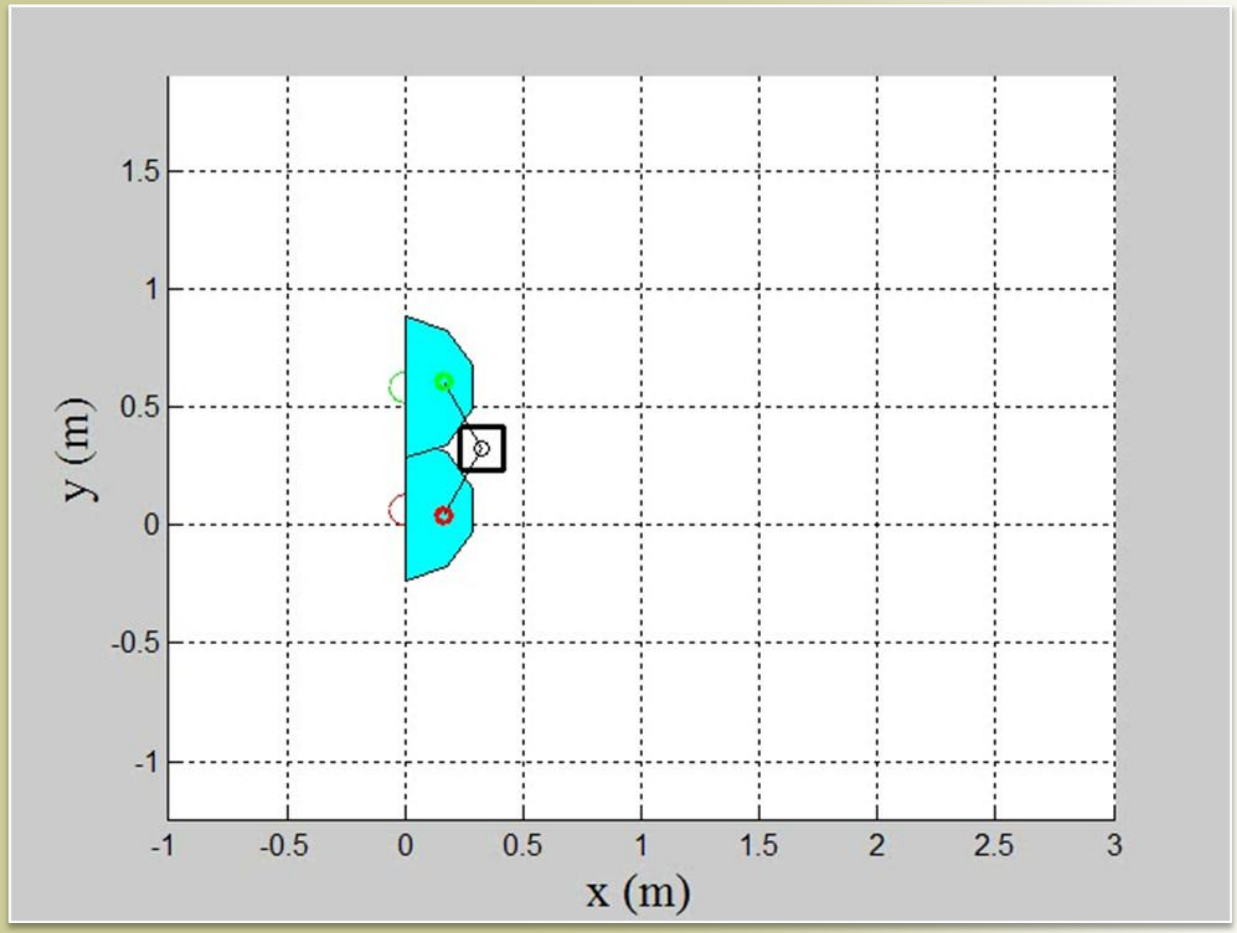
Mono-robot detction



Distributed and Reactive control

Toward Leader Follower approach

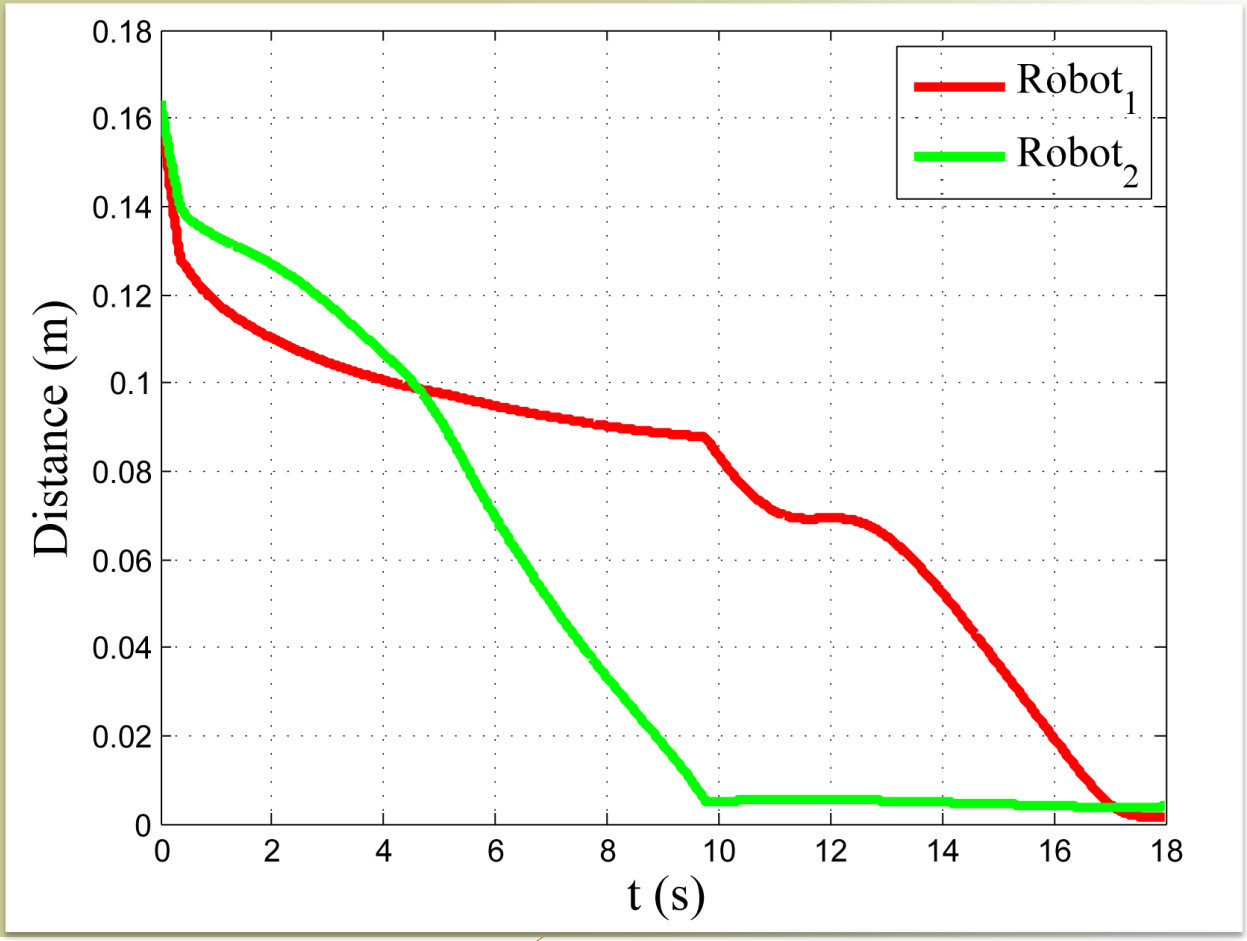
Cooperative detection



Distributed and Reactive control

Toward Leader Follower approach

Cooperative detection



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- **Conclusion and future work**

Conclusion and future work

➢Toward a Fully Distributed and Reactive Multi-robot Formation control

- ✓ Combination between: behavior based, dynamical virtual structure and leader-follower approaches,
- ✓ Only robot's locals frames were used to obtain the distributed control architecture,
- ✓ Efficient reactive navigation in environments with different obstacles shapes,
- ✓ Cooperative localization of the leader,
- ✓ **Future work:** dynamic obstacles, robust and on-line outlier detection, implementation on VipaLab vehicles.

Thanks for your attention!