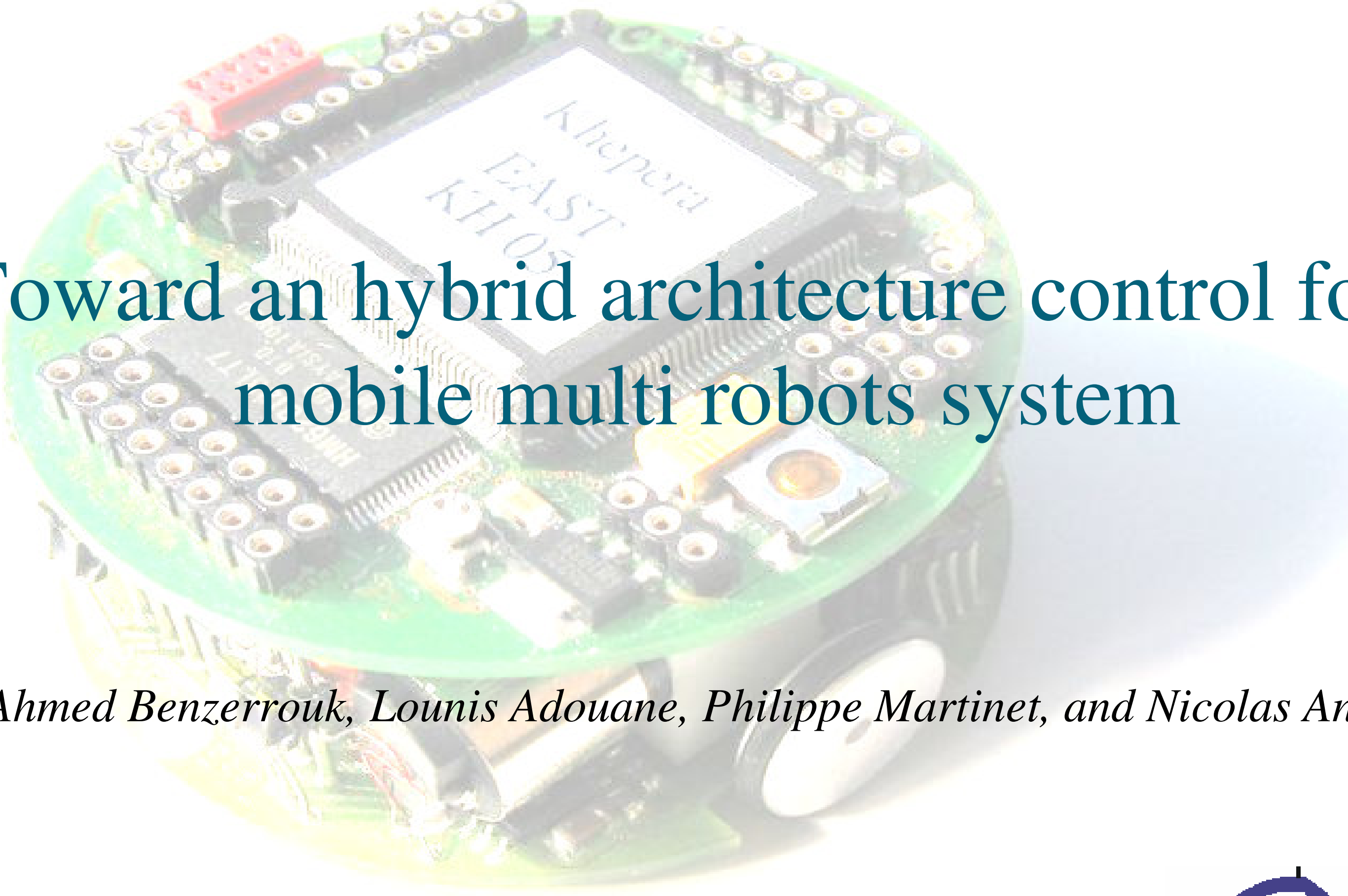

Toward an hybrid architecture control for a mobile multi robots system

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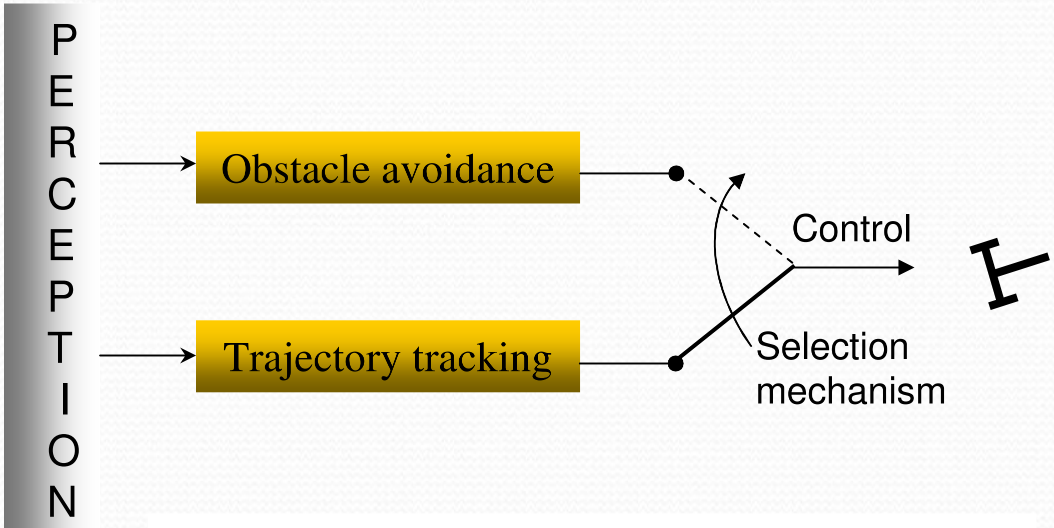
Content

Introduction

- Hybrid architecture control for a mobile multi robots convoy
  - ✓Open
  - ✓Robust
  - ✓Fullfill a lot of goals (safe navigation, velocity, convoy…)
- Navigation of a mobile robot



PERCEPTION

Obstacle avoidance

Trajectory tracking

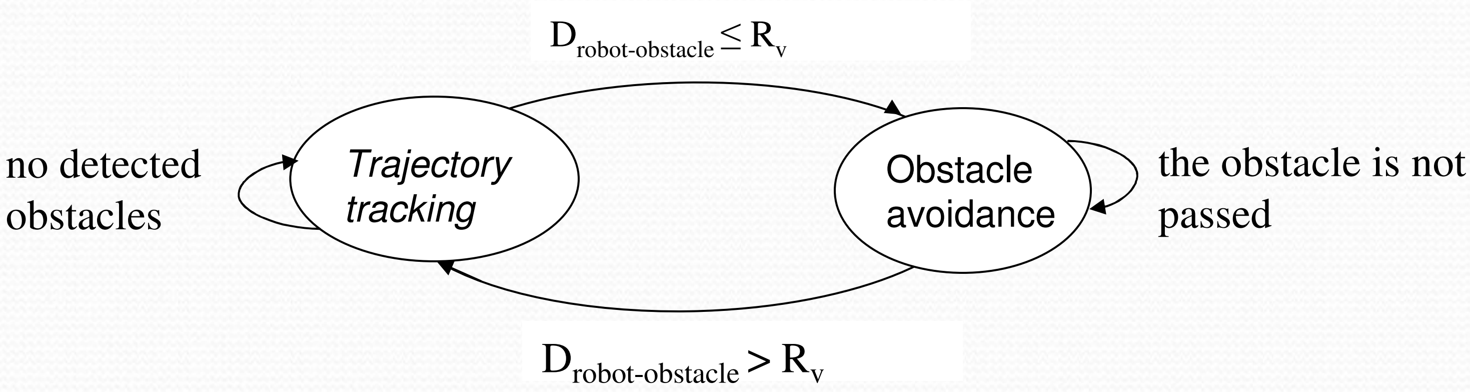
Control

Selection mechanism

FIG. 1 - Hybrid control architecture for trajectory tracking with obstacle avoidance

Introduction

- Hard switches



$D_{robot\text{-}obstacle} \leq R_v$

no detected obstacles

Trajectory tracking

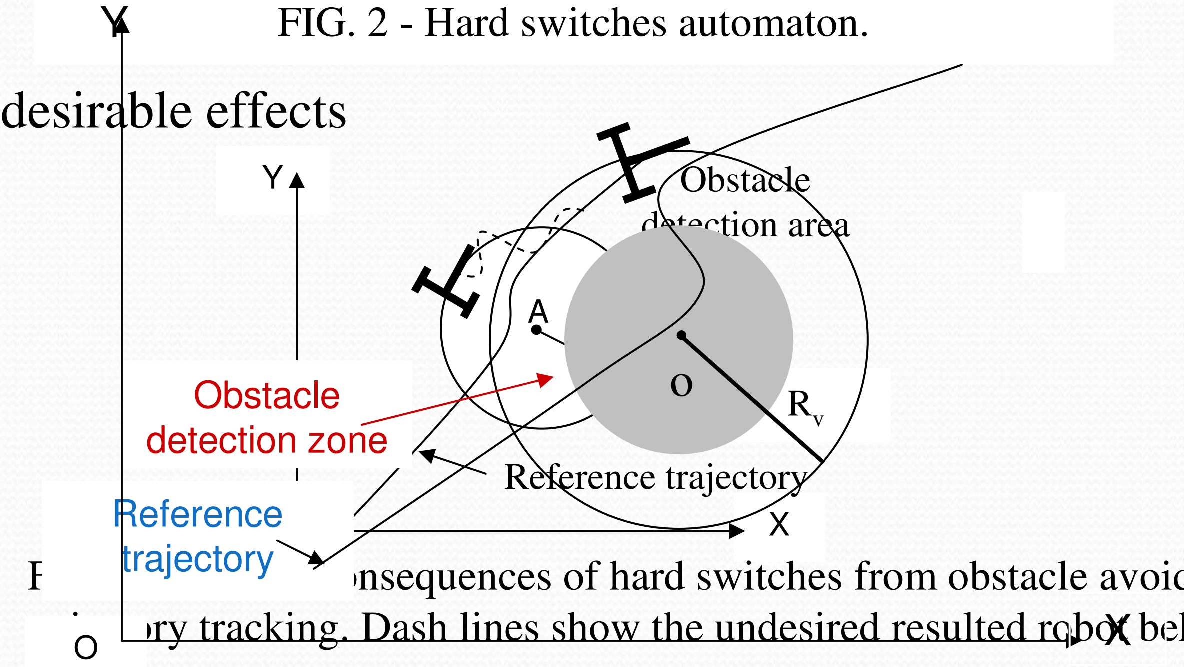
Obstacle avoidance

the obstacle is not passed

$D_{robot\text{-}obstacle} > R_v$

FIG. 2 - Hard switches automaton.

- Undesirable effects



Y

Y

Obstacle detection area

A

O

R_v

Obstacle detection zone

Reference trajectory

Reference trajectory

X

X

O

F nsequences of hard switches from obstacle avoidance to ry tracking. Dash lines show the undesired resulted robot behaviour.

Introduction

- ➢ Verification results of hard switches

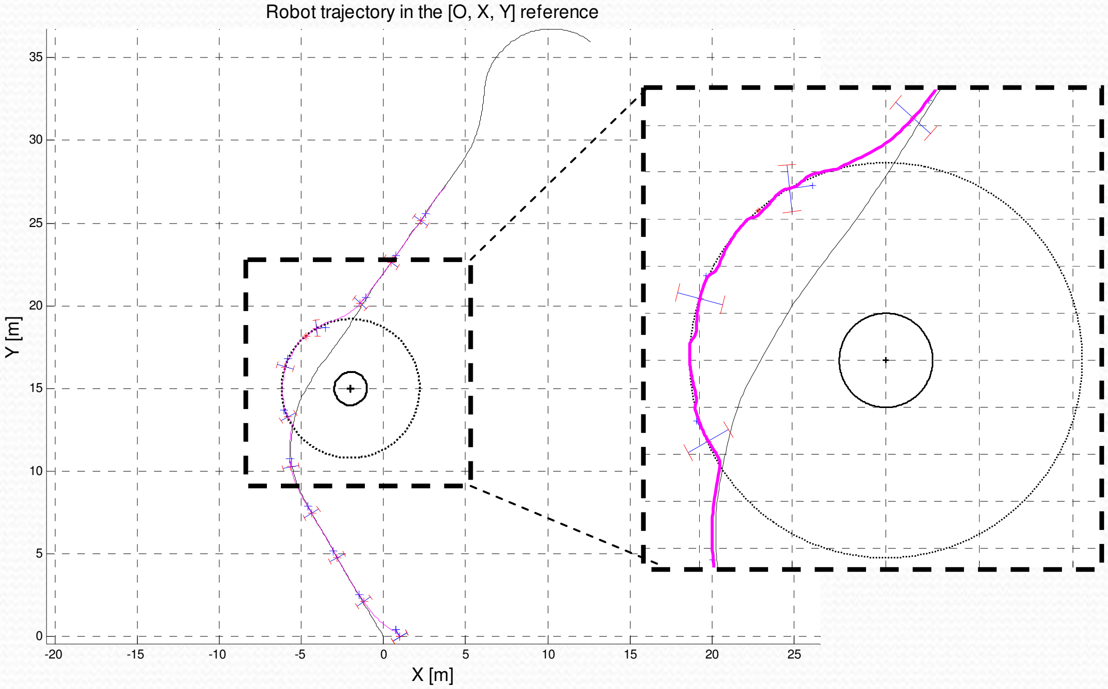


FIG. 4 – Real robot's trajectory controlled by hard switches.

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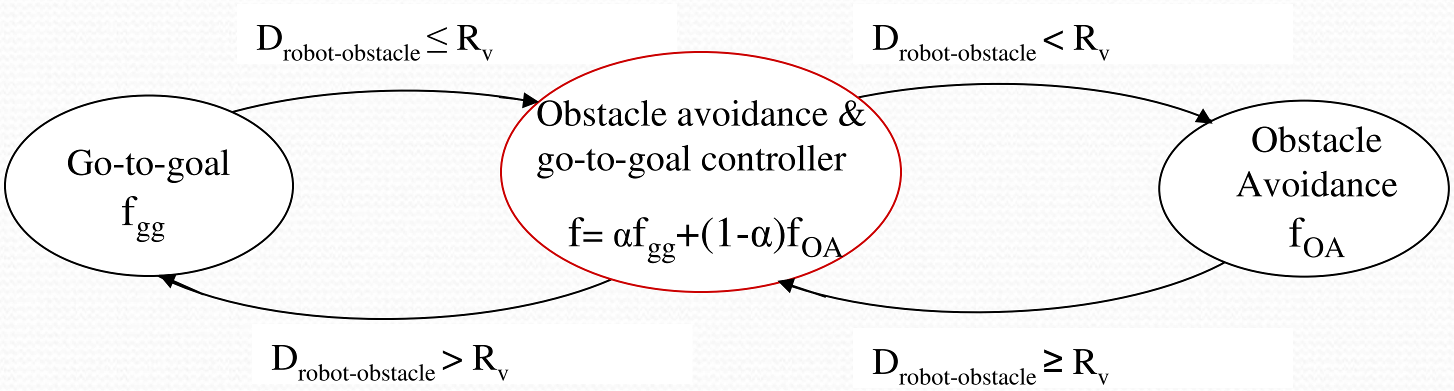
- Regularized Automaton
- The proposed architecture (1)
- Mobile robot control
- The proposed architecture (2)
- Simulation and results
- Conclusion and further work

Regularized automaton

- Egerstedt regularization (Egerstedt, 2001)



$D_{\text{robot-obstacle}} \leq R_v$

$D_{\text{robot-obstacle}} < R_v$

Go-to-goal
f_{gg}

Obstacle avoidance &
go-to-goal controller
$f = \alpha f_{gg} + (1-\alpha) f_{OA}$

Obstacle
Avoidance
f_{OA}

$D_{\text{robot-obstacle}} > R_v$

$D_{\text{robot-obstacle}} \geq R_v$

FIG. 5 – The regularized Automaton (Egerstedt, 2001)

Content

The proposed architecture (1)

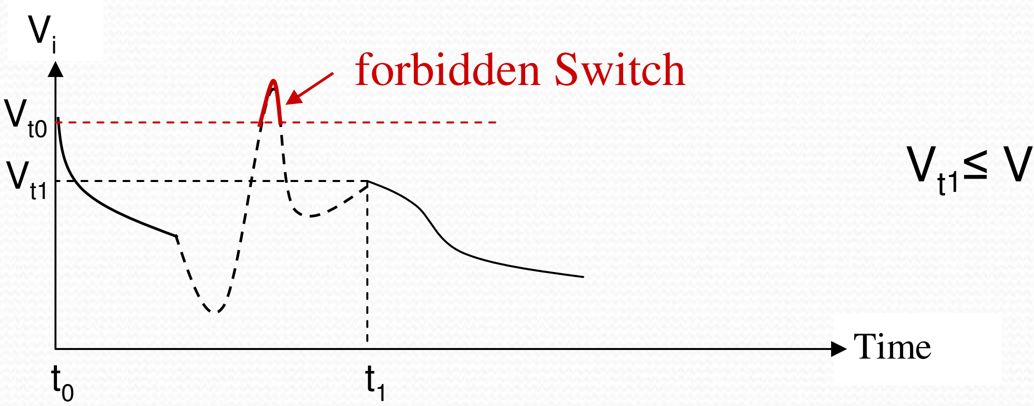
✓ Multiple Lyapunov function [Branicky, 1998]

N dynamical systems, $\Sigma_1, \ldots, \Sigma_N$, and N candidate Lyapunov functions, $V_1, \ldots, V_N$.

If {V_i decreases when Σ_i is active}

and {V_i (at the time when Σ_i switched in) $\leqslant$ V_i (at the last time when Σ_i switched in)}

Then the hybrid system is Lyapunov stable.



$V_{t1} \leq V_{t0}$

FIG.6 – Variation of the Lyapunov function for the "*i*" controller.
Solid lines indicate that *i* is active, dashed inactive.

The proposed architecture (1)

- The proposed architecture

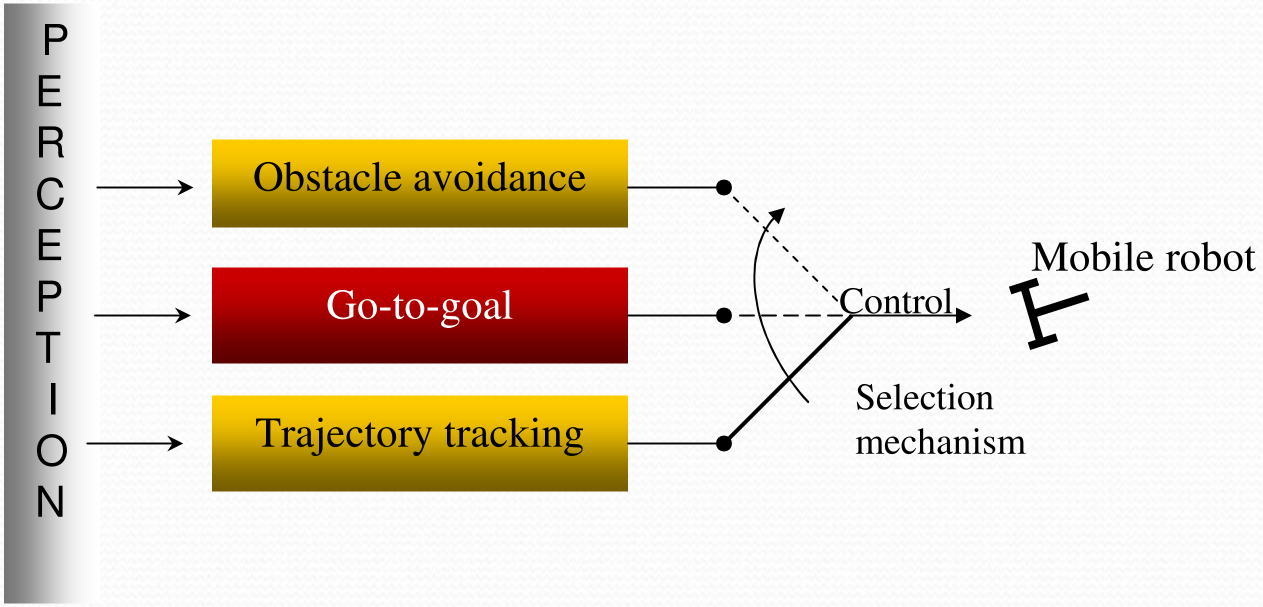


FIG. 7 – The proposed hybrid architecture of control

Content

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Mobile robot control

- Mobile robot model

$$\begin{cases} \dot{x} = v.\cos(\theta) \\ \dot{y} = v.\sin(\theta) \\ \dot{\theta} = u \end{cases}$$

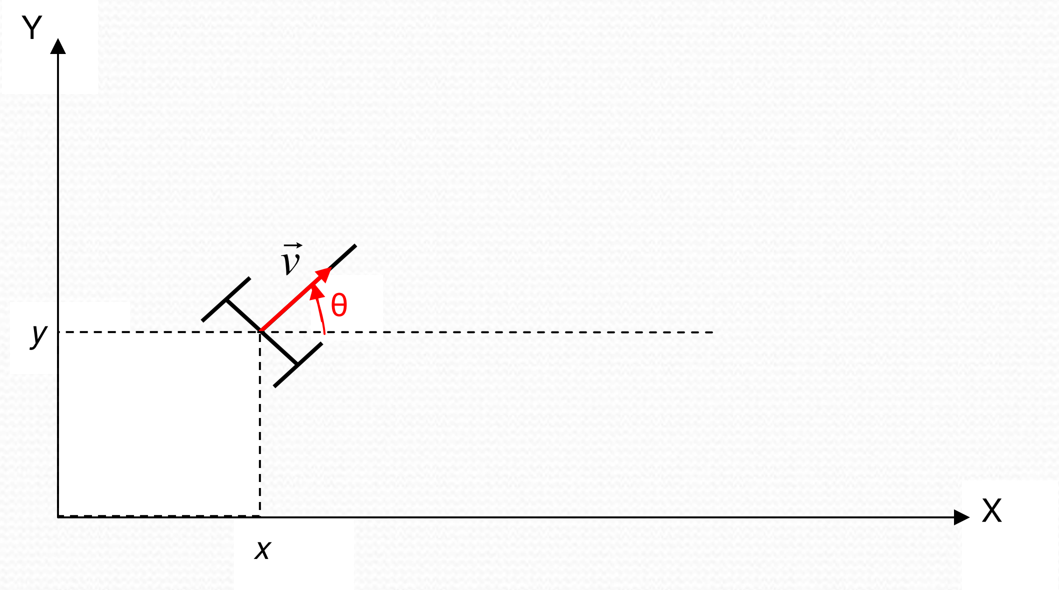


FIG. 8 – Unicycle mobile robot.

Mobile robot control

- Go-to-goal controller (Secchi, 1999)

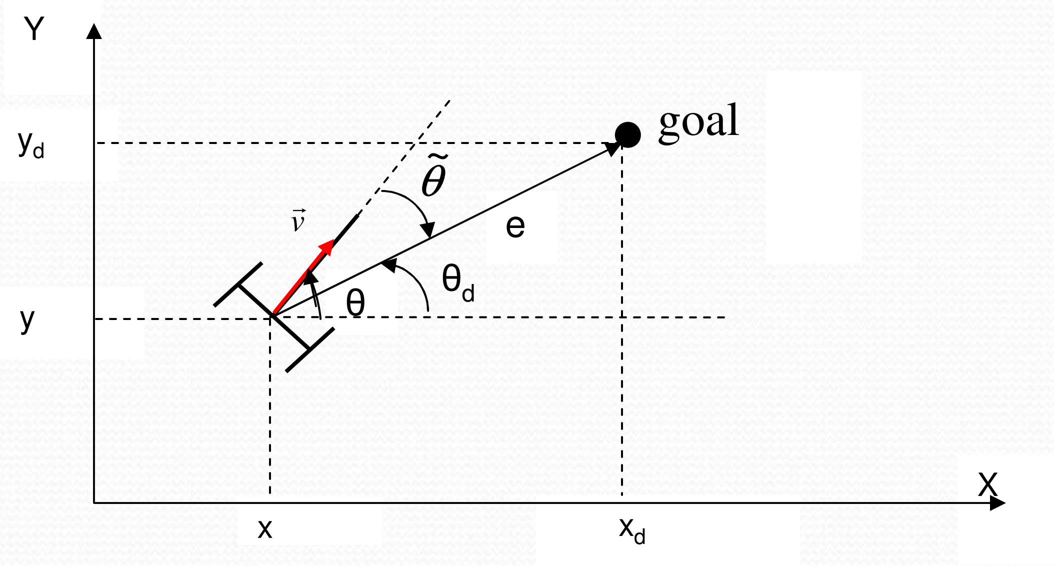


FIG 9 – Go-to-goal controller

$$\begin{cases} e_x = x_d - x \\ e_y = y_d - y \end{cases} \Longrightarrow \begin{cases} e = \sqrt{e_x{}^2 + e_y{}^2} \\ \tilde{\theta} = \theta_d - \theta = \tan^{-1}\left(\dfrac{e_y}{e_x}\right) - \theta \\ V = \dfrac{e^2}{2} + \dfrac{\tilde{\theta}^2}{2} \end{cases} \Longrightarrow \begin{cases} v = K_e . e . \cos\tilde{\theta} \\ u = K_e . \cos\tilde{\theta} . \sin\tilde{\theta} + K_{\tilde{\theta}} . \tanh(k_{\tilde{\theta}} . \tilde{\theta}) \end{cases}$$

Mobile robot control

- ➢Trajectory tracking controller (Canudas, 1996)

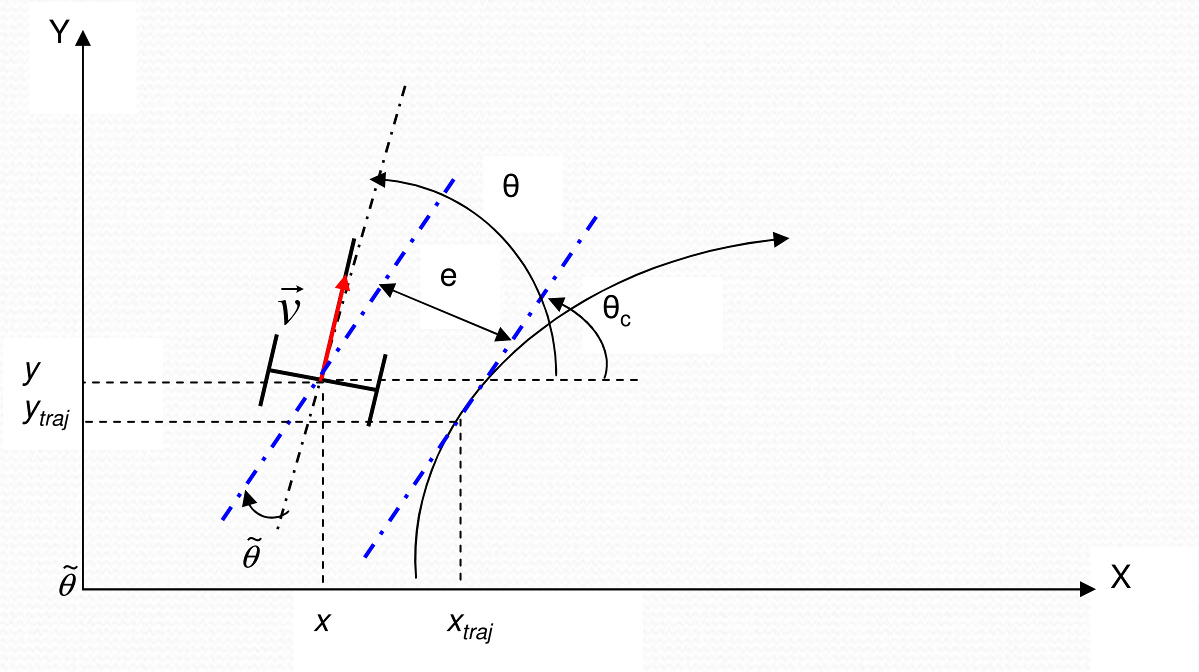


FIG10 – The mobile robot on the Frenet frame.

$$\begin{cases} e = (x_{traj} - x).\sin\theta_c - (y_{traj} - y).\cos\theta_c \\ \tilde{\theta} = \theta - \theta_c \\ V = k_1 \dfrac{e^2}{2} + \dfrac{\tilde{\theta}^2}{2} \end{cases} \Longrightarrow \begin{cases} \dot{e} = v.\sin\theta \\ \dot{\tilde{\theta}} = u \end{cases} \Longrightarrow \begin{cases} v = K \\ u = -k_1.v.e.(\dfrac{\sin\tilde{\theta}}{\tilde{\theta}}) - k_2.|v|.\tilde{\theta} \end{cases}$$

Mobile robot control

- Obstacle avoidance « limit cycle navigation » (Kim, 2003)

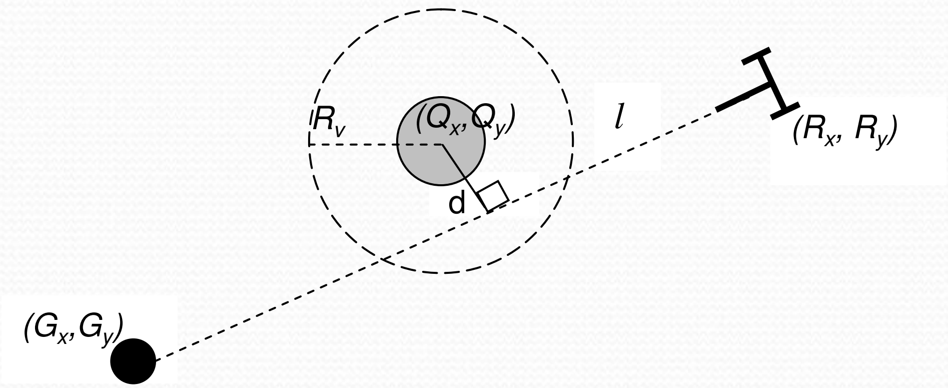


FIG 11 – Limit cycle navigation method

1) $(l): a.x+b.y+c = 0$

2) $$d = \frac{a.Q_x + b.Q_y + c}{\sqrt{a^2+b^2}}$$

3) $$\begin{cases} \dot{x} = \frac{d}{|d|}y + x(R_v{}^2 - x^2 - y^2) \\ \dot{y} = -\frac{d}{|d|}x + y(R_v{}^2 - x^2 - y^2) \end{cases}$$

Content

The proposed architecture (2)

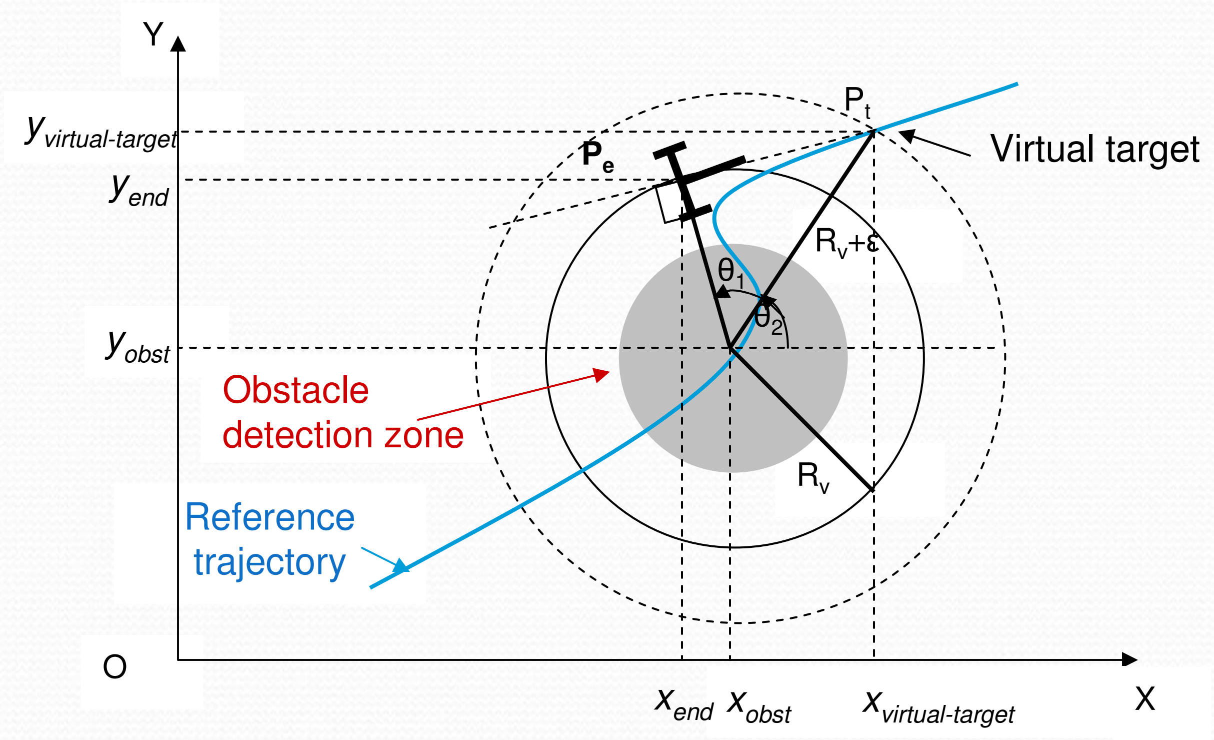
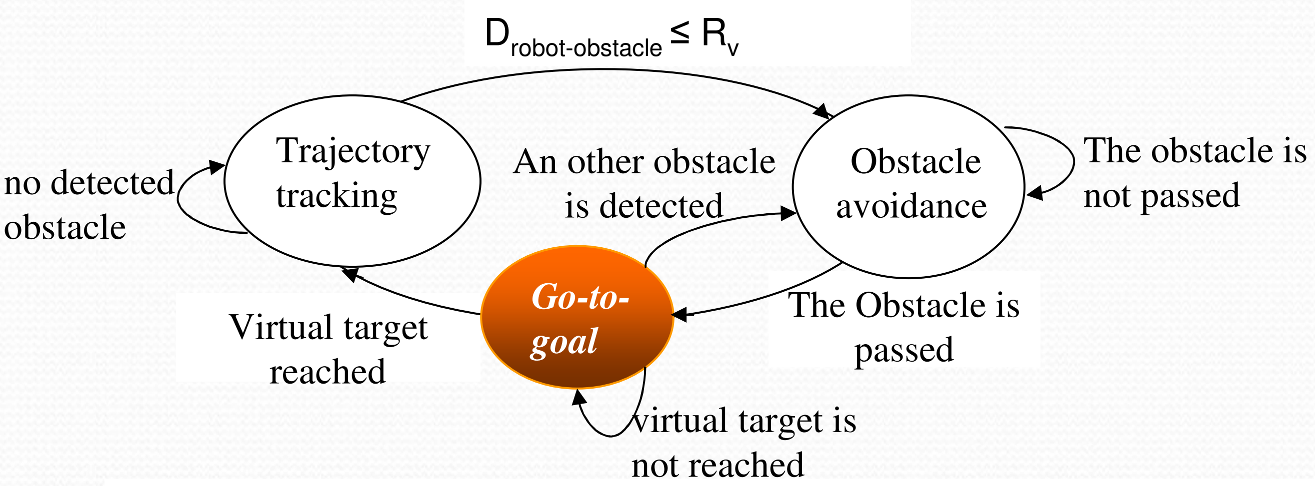


FIG 12 - Virtual target to reach before reactivating trajectory tracking controller. Here, the obstacle is clockwise avoided.

The proposed architecture (2)



$D_{robot\text{-}obstacle} \leq R_v$

no detected obstacle

Trajectory tracking

An other obstacle is detected

Obstacle avoidance

The obstacle is not passed

Go-to-goal

Virtual target reached

The Obstacle is passed

virtual target is not reached

FIG. 13 – The proposed automaton with an extra node corresponding to the go-to-goal controller.

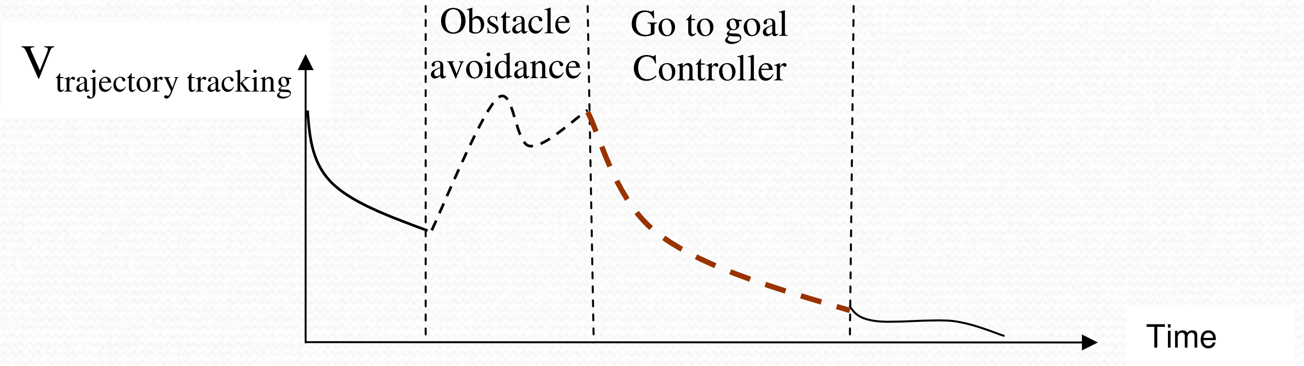


FIG.14 – Evolution of the Lyapunov function of trajectory tracking when go-to-goal controller is active. Continuous line means that trajectory tracking is active.

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Simulation results

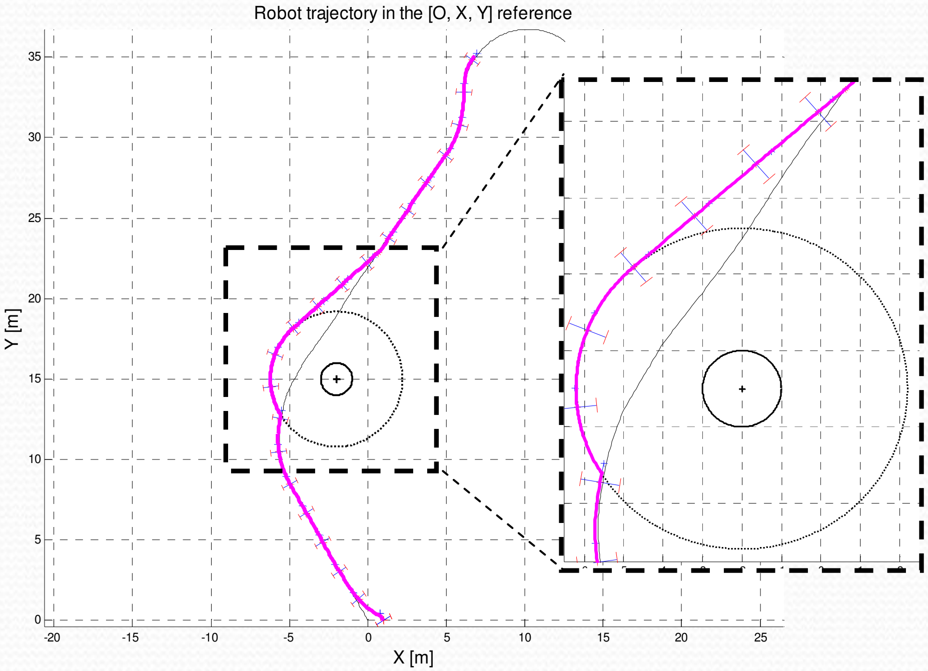

FIG 15 – Real robot trajctory when the proposed control architecture is used

Simulation results

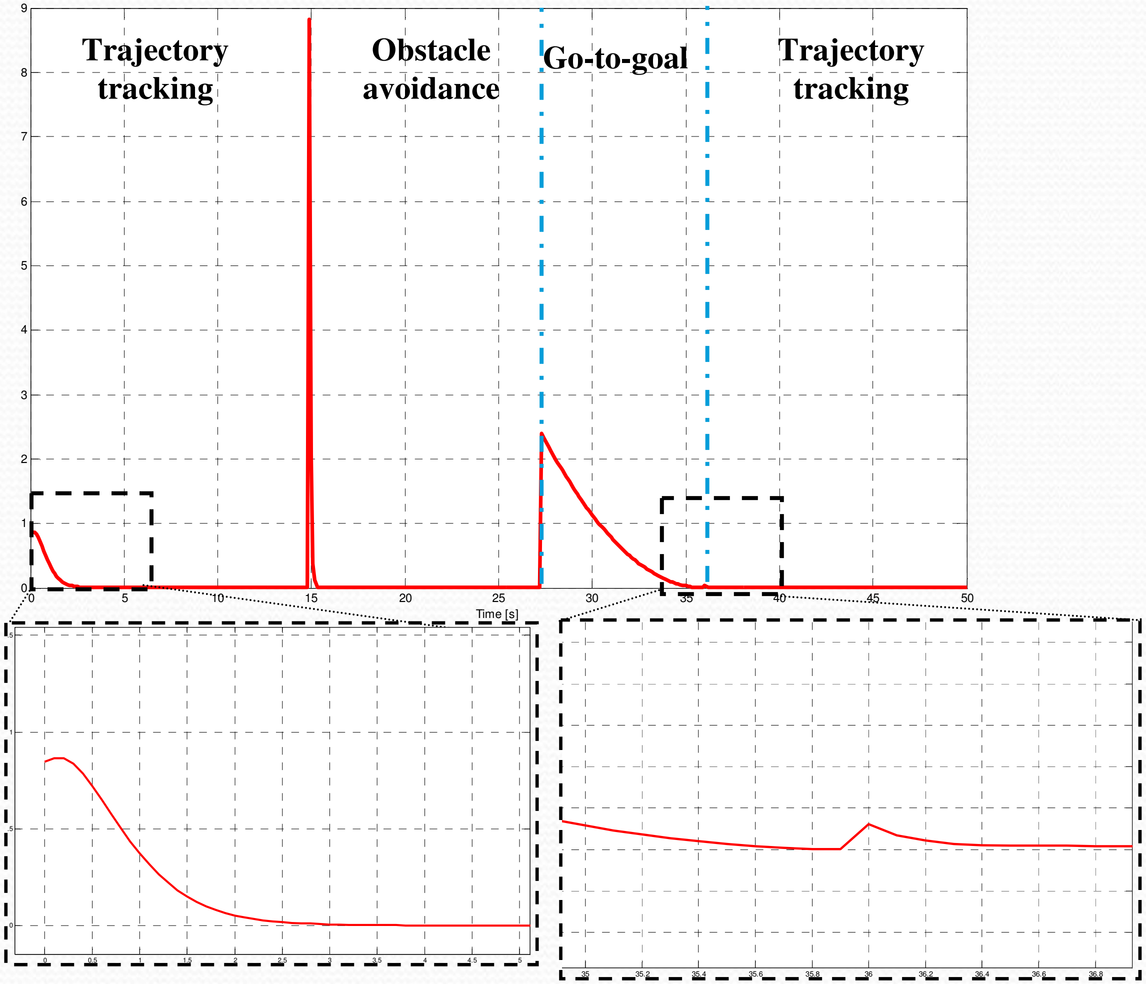

FIG 16 - Lyapunov variation functions of the proposed control architecture.

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Conclusion and prospects

- Stable hybrid architecture.
    - Based on Multiple Lyapunov Function theorem (MLF).
    - Introduction of a third controller to verify the MLF condition.

- Application on Khepera robots III (Infrared and ultrasonic sensors).
- Application to dynamical environments.
- Application to robots convoy.

Thank you!

Questions?