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Lieu de Formation d'Excellence à la Recherche et par la Recherche

Decentralized Control for Multi-Agent Systems (MAS) under Switching Topologies

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Introduction

A multi-agent system is a system composed of multiple interacting intelligent agents within an environment. It can perform a mission more efficiently than an individual agent, accomplish tasks not executable by a single one, increase tolerance to possible agent fault and provide flexibility during the task execution.

In multi–agent systems, the small embedded microprocessors form the computational core of the network. They are required to execute a variety of tasks including the relay of information packets, monitoring physical quantities from neighboring nodes and computation of feedback control laws.

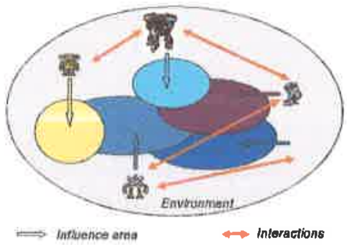


Figure 1: Multi-Agent System

Objective

To improve the navigation scheme of Multi-Agent Systems, while taking into account practical constraints

→ To design of cooperative controllers for each agent, in a fully decentralized way, while taking into account
- dynamic aspects (model, etc.)
- temporal constraints:
  - Fixed time convergence (importance of convergence rate)
  - Variable Sampling time (minimization of the information exchange)
- Possible switching network topology.

→ To implement the proposed controller on a team of robot

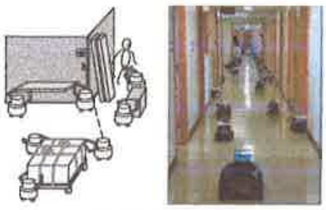
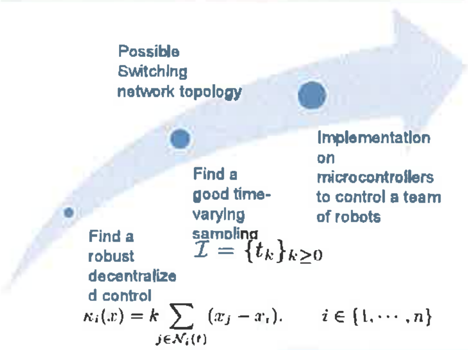


Figure 2: Implementation of MAS

Methodes



Fixed-time Convergence

To design a decentralized control protocol ui (i = 1, . . . ,N) for each follower, based on relative information, such that the fixed-time leader-follower consensus problem is solved.

$$\lim_{t \to T} \|x_i(t) - x_0(t)\| = 0$$
$$x_i(t) = x_0(t), \ \forall t \geq T$$

The fixed-time stabilization of the estimation errors

$$\tilde{x}_{k,i} = \hat{x}_{k,i} - x_{k,0} \qquad (i = \{1, \dots, N\}, \ k = \{1, \dots, 4\})$$

The the tracking errors

$$e_{k,i} = x_{k,i} - \hat{x}_{k,i} = x_{k,i} - x_{k,0} - \tilde{x}_{k,i}$$

$$(i = \{1, \dots, N\}, \ k = \{1, \dots, 4\})$$

The Settling Time

$$T_s = T_o + \frac{2}{\sqrt{\gamma_2}} + \frac{2}{\sqrt{\mu_2}} + \frac{2\sqrt{2}}{\sqrt{\gamma_1}} + \frac{2\sqrt{2}}{\sqrt{\mu_1}}$$

Numerical Results of Fixed-time

A numerical example is provided to show the effectiveness of the proposed fixed-time leader-follower consensus controller. The multi-agent system with N = 6 followers indexed by 1−6 and one leader indexed by 0.

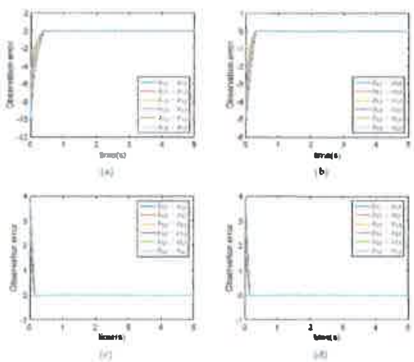


Figure 3: Evolution of estimation error

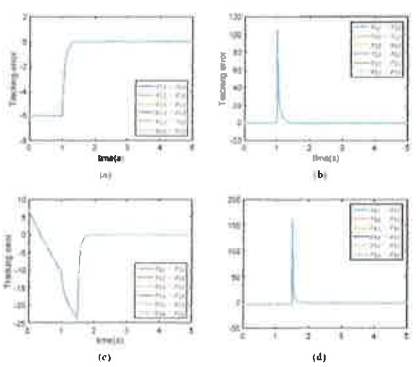


Figure 4: Evolution of the tracking errors between each agent and the leader.

Variable Sampling Time

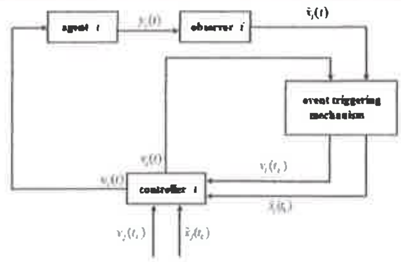
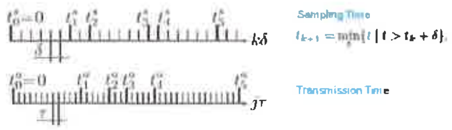


Figure 5: Event Trigger Control Schematic

Event–triggered control is a methodology where sensors send information to the controller when specific events occur, using a dedicated hardware.



Event-Triggered $t_{k+1} = \min_t \{t \geq t_k \mid |x(t) - x(t_k)| > \varepsilon\}$

Self–triggered control emulates event–triggered control without dedicated hardware. It uses the current sampled state to specify the next sampling time, through a scheduling procedure.

Validation in Practical

Mini-Lab Enova Robot is a mobile platform with two differential driving wheel. Mini-Lab is medium sized mobile robot optimized for indoor applications. Each wheel has a drive motor mounted on his axis. The wheels have been chosen to provide more accurate odometry localization. The robot can navigate autonomously or tele-operated using its camera, which transmits video in real time. The control architecture is open-source based on the Robot Operating System (ROS). ROS is a flexible framework for writing robot software.

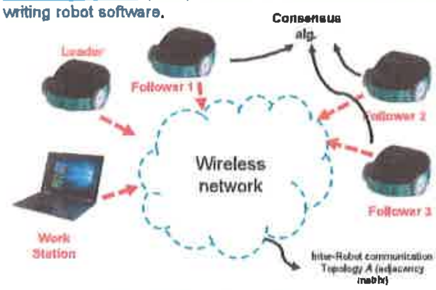


Figure 6: Description of the experimental environment

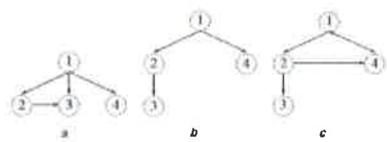


Figure 7: Communication Topology

Conclusions

Distributed observers have been designed to estimate the leader state in a prescribed time. Then, a decentralized switched control protocol, using the estimated leader state, has been proposed for each follower to solve the fixed-time consensus tracking problem.

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