Synthesis of Decentralized Supervisors for Cyber-Physical Systems

Text

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Introduction

- Uncontrolled system modeled as a DES: discrete state space; event-driven dynamics
- Higher level control logic in complex automated systems; Discrete abstractions of Cyber-Physical Systems, Hybrid Systems
- Need general synthesis methodology for decentralized supervisors under safety specifications

Decentralized Supervisory Control

- Limited actuation and sensing capabilities for each local agent (supervisor)

$$S_i: E_{o,i}^* \to E_{c,i}$$

- Plant is controlled by a set of local agents

$$S_{des}(s) = Fusion_{i=1}^{n} S_i(s)$$

- Controllablity and Coobservability Theorem [3]:

$$\mathcal{L}(S_{des}/G) = \mathcal{L}(H)$$

If event σ needs to be disabled, then at least one of the supervisors that can control σ must unambiguously know that it must disable σ.

- Goal: synthesize safe solution under the control and observation constraint, i.e.,

$$\mathcal{L}(S_{des}/G) \subseteq \mathcal{L}(H)$$

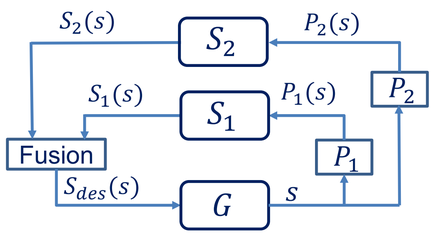


Figure 1. Decentralized control architecture.

Previous Works: [1],[2]

- A approach for synthesizing a *safe, non-blocking and maximally permissive centralized* supervisor. (first algorithm with such properties)

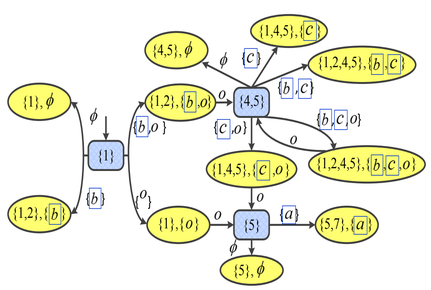


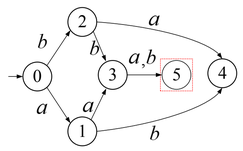
Figure 2.
All Inclusive Controller.

Challenges:

- Synthesis of safe and non-blocking solution is shown to be undecidable
- Even for safety, no general synthesis method exists
- Control, communication and estimation are coupled with each other

Proposed Research:

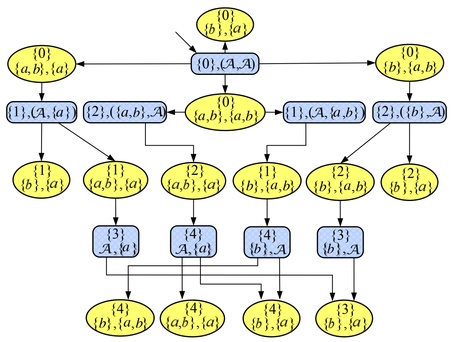
- Goal: synthesize safe (and deadlock-free if possible) solution for *decentralized* DES



- ❖ Agent 1: $E_{c,1} = E_{o,1} = \{a\}$
- ❖ Agent 2: $E_{c,2} = E_{o,2} = \{b\}$
- ❖ Goal: Avoid state 5

Figure 3. A Decentralized Control Problem

- A new game structure containing all information



- ❖ Centralized view
- ❖ Two layers:
  - control layer
  - observation layer
- ❖ Safe
- ❖ Control consistent

Figure 4. Illustration of the (Centralized) Information Structure

- Recursive projection to each local site

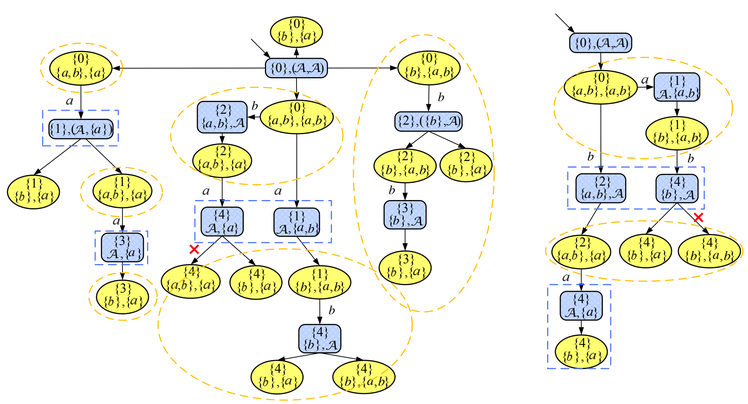
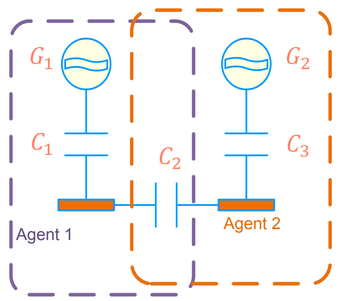


Figure 5. An illustration of Local Projection Step

- Communication layer, sensor activation layer or decision fusion layer

A CPS Case Study

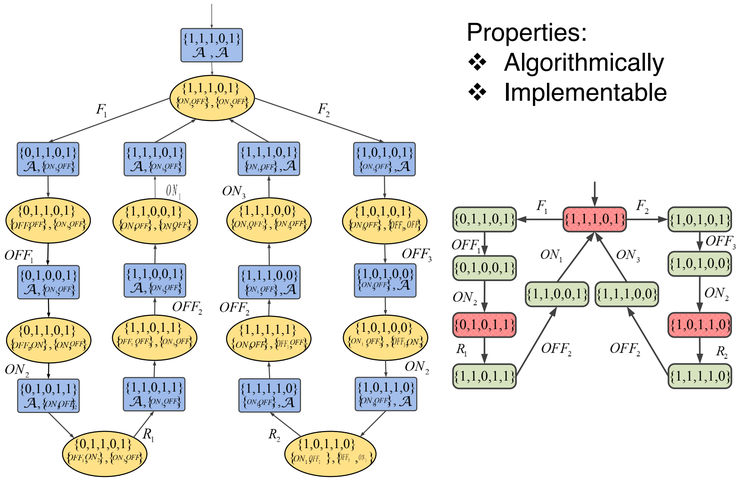
- Problem Statement



- ❖ Global specification
  - bus unpower &
  - generator parallel
- ❖ Limited local control and observations
- ❖ Fusion Rule:
  For C_2, if one say close, then it will close

Figure 6. EPS example

- Synthesis Approach



Properties:
- ❖ Algorithmically
- ❖ Implementable

Figure 7. The Decentralized All Inclusive Controller and the Solution for the EPS Problem

Acknowledgements

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References

1. Xiang Yin, Stéphane Lafortune. A General Approach for Synthesis of Supervisors for Partially-Observed Discrete-Event Systems. IFAC World Congress, 2014.
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3. Christos Cassandras and Stéphane Lafortune. Introduction to discrete event systems. Springer, 2008 (2nd Edition)