Multilevel discrete-event systems with a local bus architecture

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Introduction

Supervisor synthesis in large discrete-event systems (DES) is limited by high computational memory demand. As system size increases, the number of states to be handled grows explosively and synthesizing a **monolithic supervisor** becomes problematic, often resulting in out-of-memory errors. An effective approach, referred to as **multilevel supervisory synthesis** [1], decomposes the monolithic problem into subproblems, such as for each subsystem, and a supervisor is synthesized based on requirements for only that subsystem. The decomposition can be guided by a **Dependency Structure Matrix (DSM)** [2], which reveals the system structure based on the dependencies determined by requirements between components. While the current approach reduces complexity, not all resulting architectures provide substantial benefits.

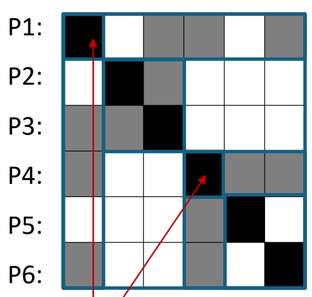
What control architecture and algorithmic strategies further reduce the controlled state space of the multilevel supervisors?

Proposed method

	R1	R2	R3	R4	R5	R6	R7	R8	R9
P1:	1	1	1						
P2:				1	1				
P3:	1			1	1				
P4:		1				1	1	1	1
P5:						1		1	
P6:			1				1		1

Domain Mapping Matrix (DMM) represents dependencies between the plant models and the requirement models.

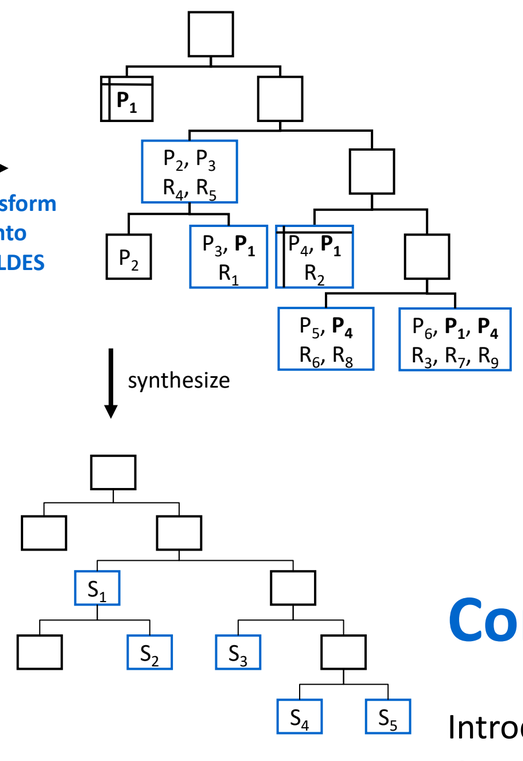
transform and cluster



DMM is transformed into a **Dependency Structure Matrix (DSM)** and subsequently clustered.

bus (recursive detection in clusters)

transform into MLDES

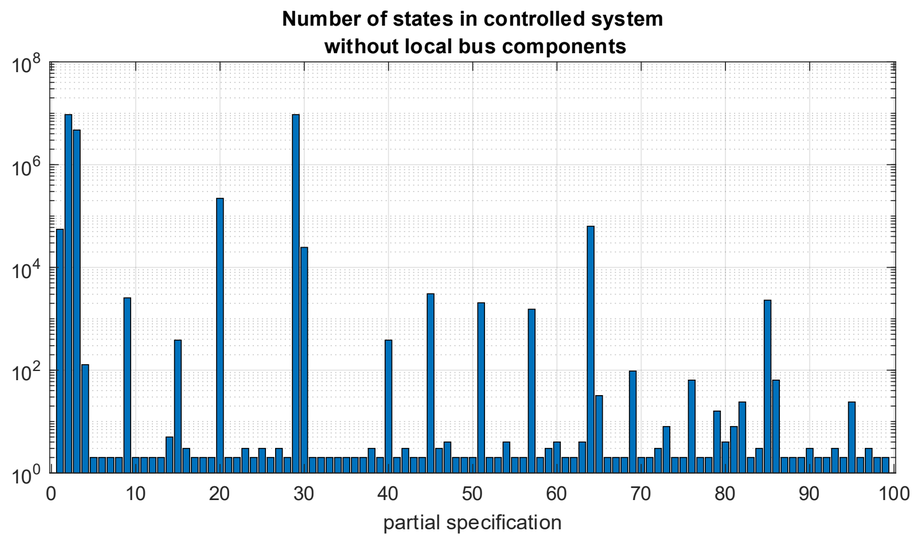


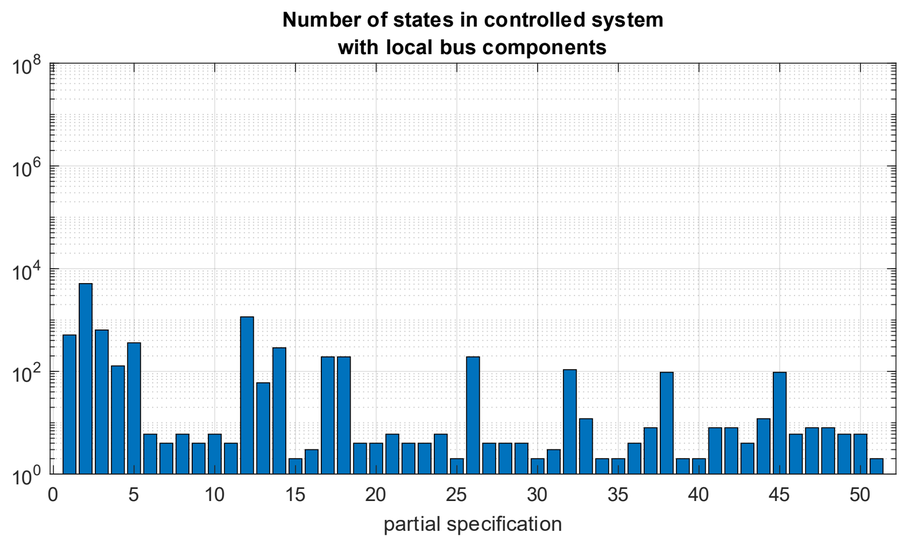
MLDES with local buses

- Multilevel DES (MLDES) tree structure is defined by the clustered DSM.
- Nodes are populated with plants and requirements, which together constitute synthesis subproblems.
- Bus components are placed at lowest possible nodes with the non-bus components that they are related to.
- Plant components may appear in multiple nodes.
- Requirements appear only once.

Case study: a production line (Festo)

The production line comprises 28 actuators and 59 sensors. The monolithic problem contains 198 control requirements and 77 plants, resulting in 2.22×10^{25} states in the controlled system.





Concluding remarks:

Introduction of **local bus detection** into DSM-based architectural decomposition and their distribution with the dependent plants in multilevel synthesis **reduces the memory** required to compute supervisors. On the production line system, the approach achieves up to a **1000 factor reduction** the controlled state-space size compared to the current approach without local buses.

References:

[1] J. Komenda, T. Masopust and J. H. van Schuppen, “Control of an engineering-structured multilevel discrete-event system,” WODES’16, pp. 103-108
[2] M. Goorden, J. v. d. Mortel-Fronczak, M. Reniers, W. Fokkink and J. Rooda, “Structuring Multilevel Discrete-Event Systems With Dependence Structure Matrices,” in IEEE Transactions on Automatic Control, vol. 65, no. 4, pp. 1625--1639, April 2020

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