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A Model Based Approach for Generating Modular Manufacturing Control Systems Software

Presented by:

Yassine Qamsane
Research Scientist, Siemens Technology-US
Automation Engineering Software

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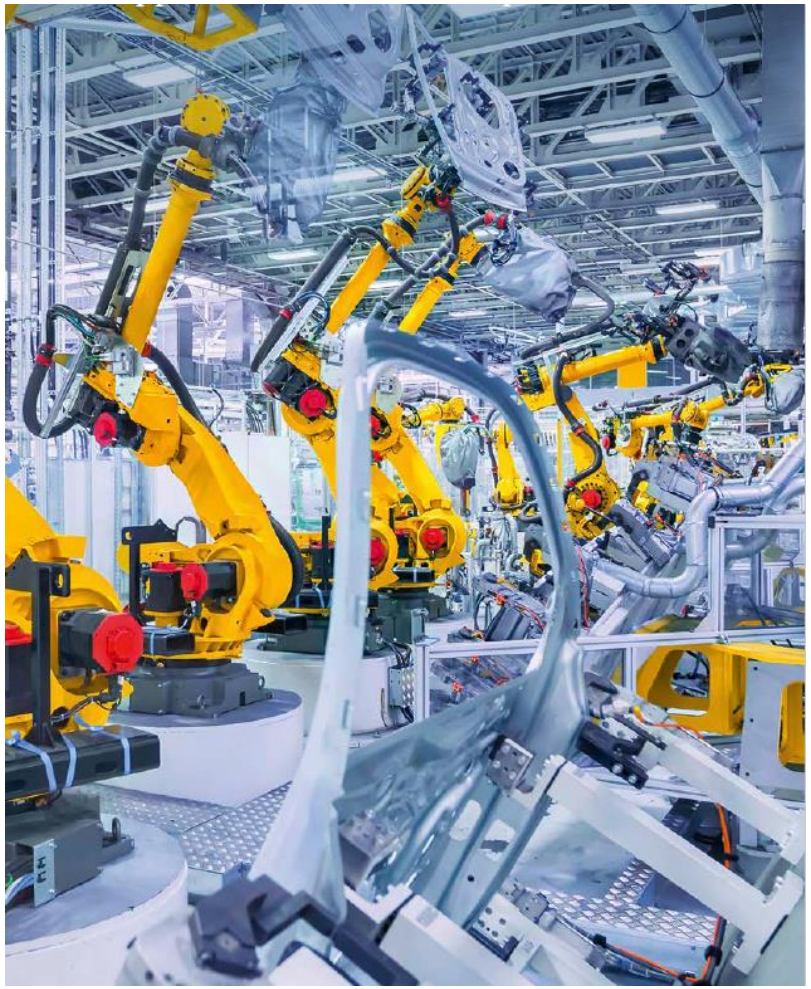
Why: Automation Engineering today is manual, time consuming, and expansive

Today's production lines

- The design of a new production line or reconfiguration to manufacture a new product variant implies a significant overhead in **manual** work
- Engineering activities are usually assisted by computer-aided engineering tools (e.g., TIA for the programming of PLCs)
  - However, the informal requirements are **manually** and **intuitively** transformed into control programs
- Manual workflows most often lead to:
  - **Deficient** documentation of the **sequential inter-dependencies** within the control program, and
  - **Additional costs** caused by **incorrect interpretation** of the textual requirements.

Need for algorithmic workflows to automatically and quickly derive control system software for flexible and adaptable production lines



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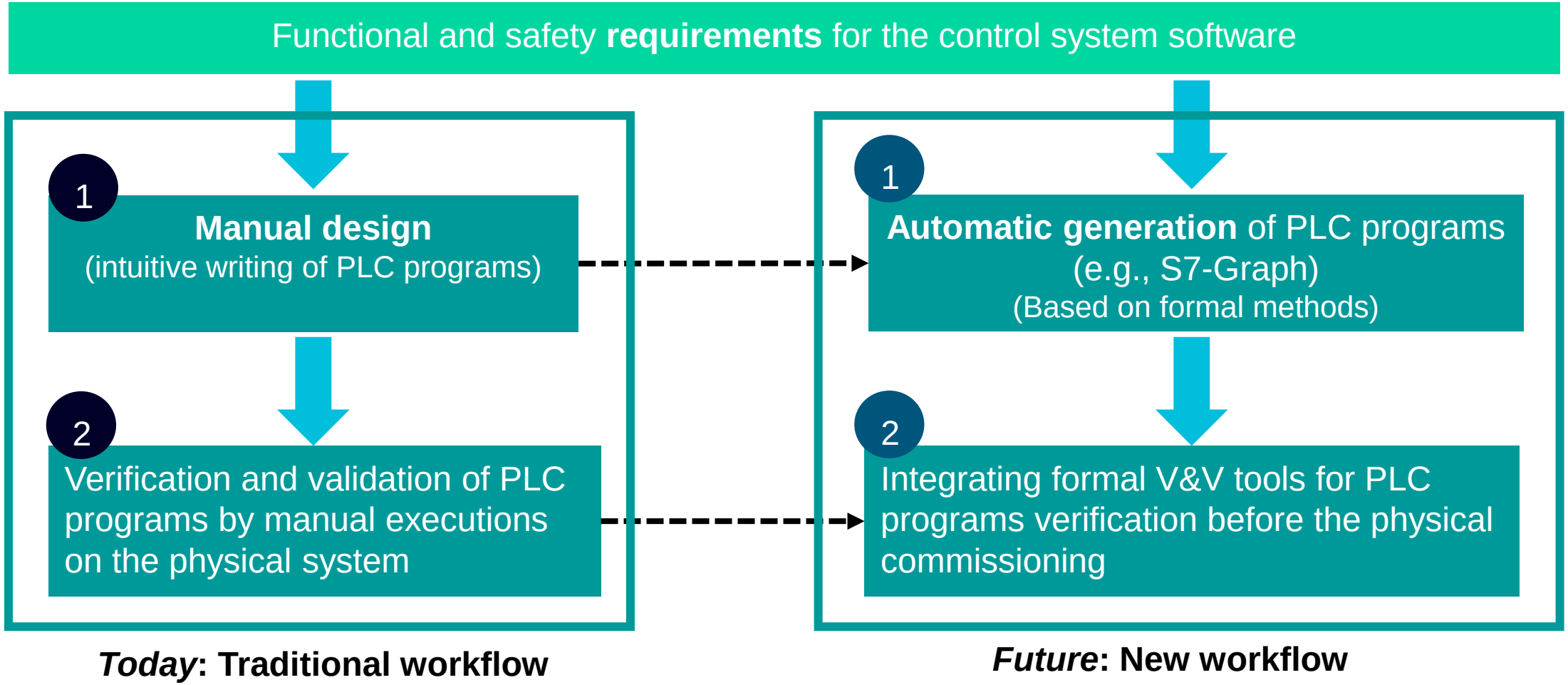
What: Traditional Workflow vs New Workflow



***Today*: Traditional workflow**

***Future*: New workflow**

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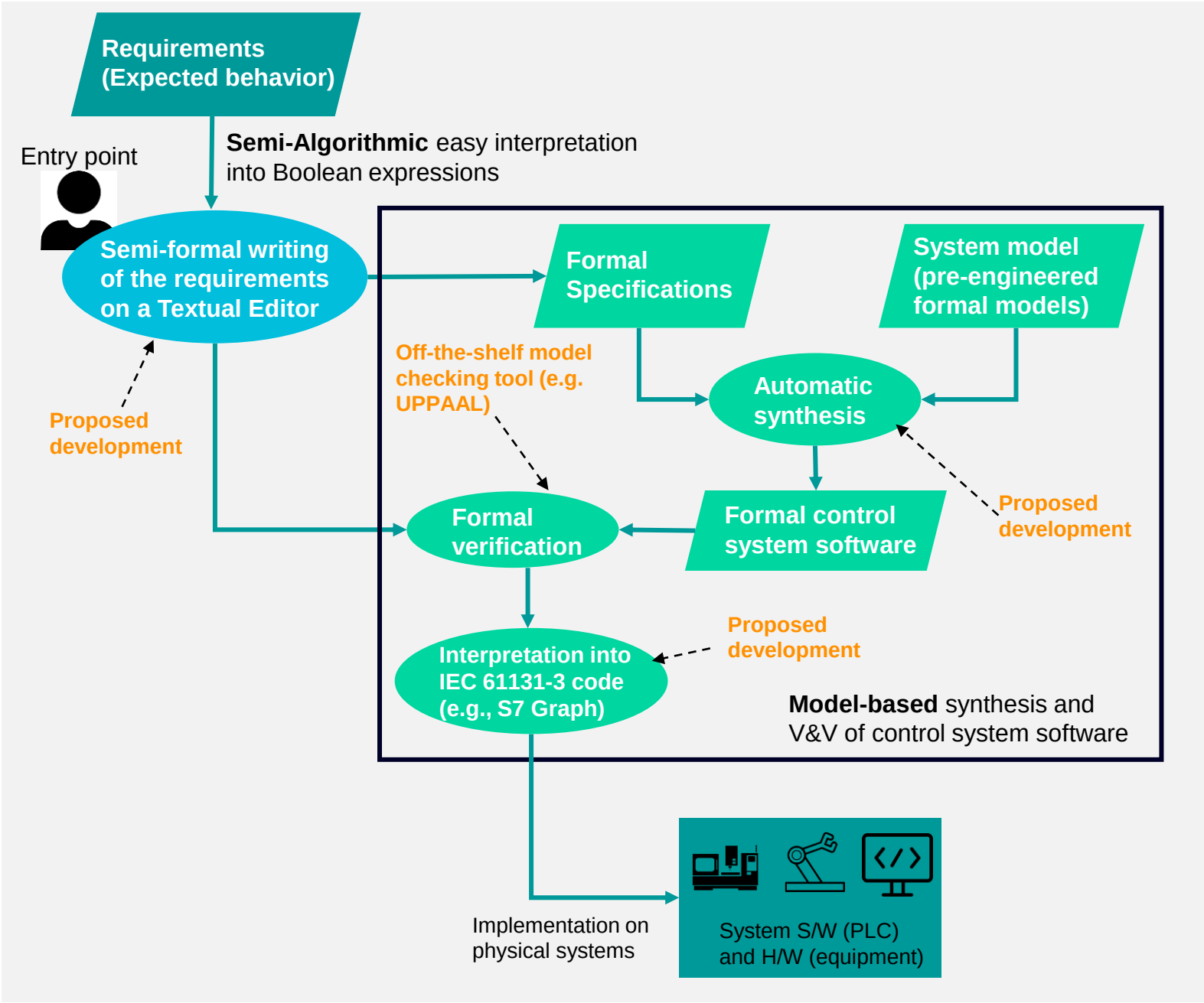
How: Proposed Approach

Model-based engineering of PLC programs

- Library of discrete-event models for the plant (templates for synthesis and V&V)
- Algorithms for the synthesis of PLC programs

Integrating off-the-shelf formal V&V tools

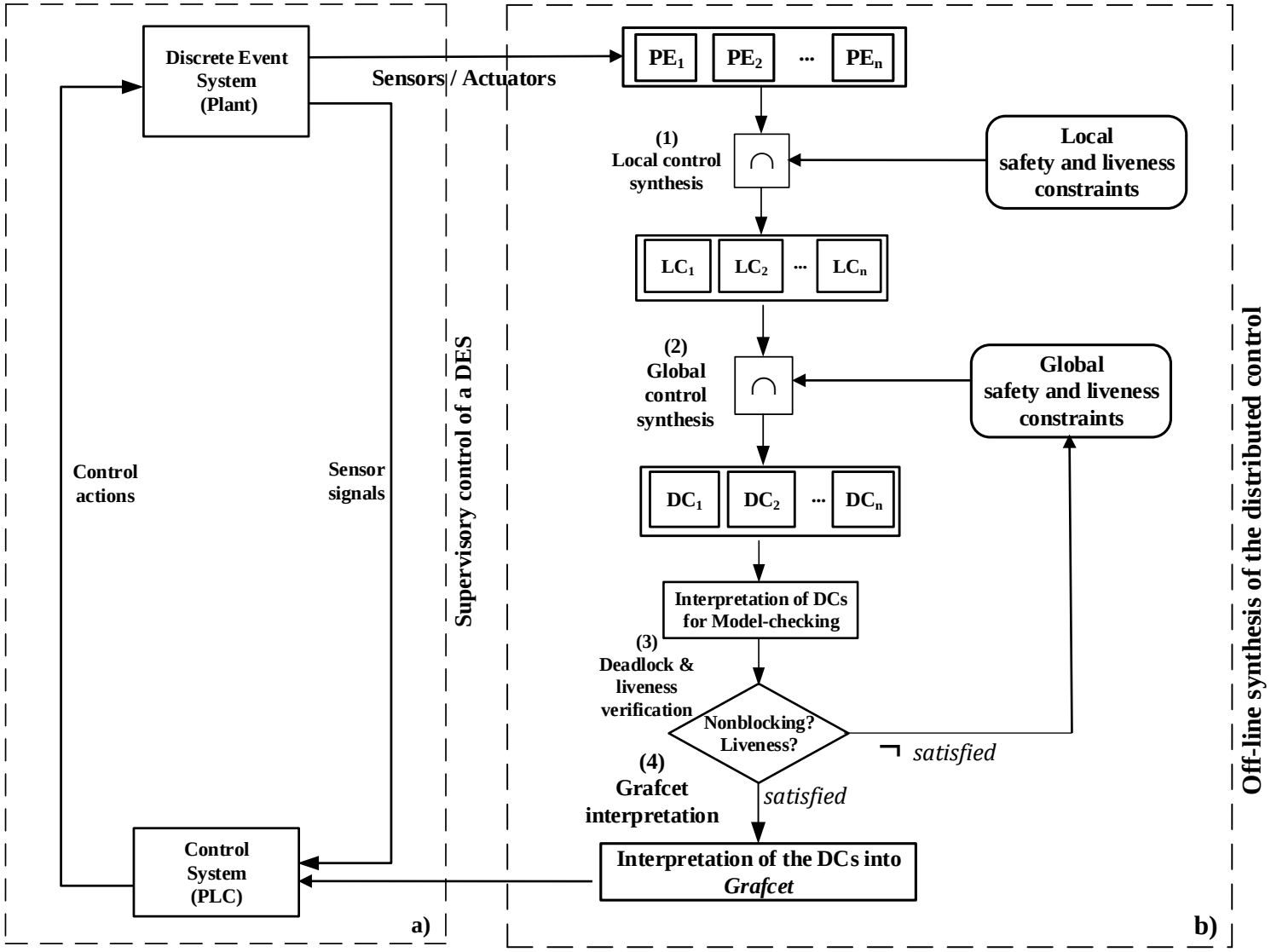
- Existing model-checking tools for formal V&V can be used for offline verification of PLC programs



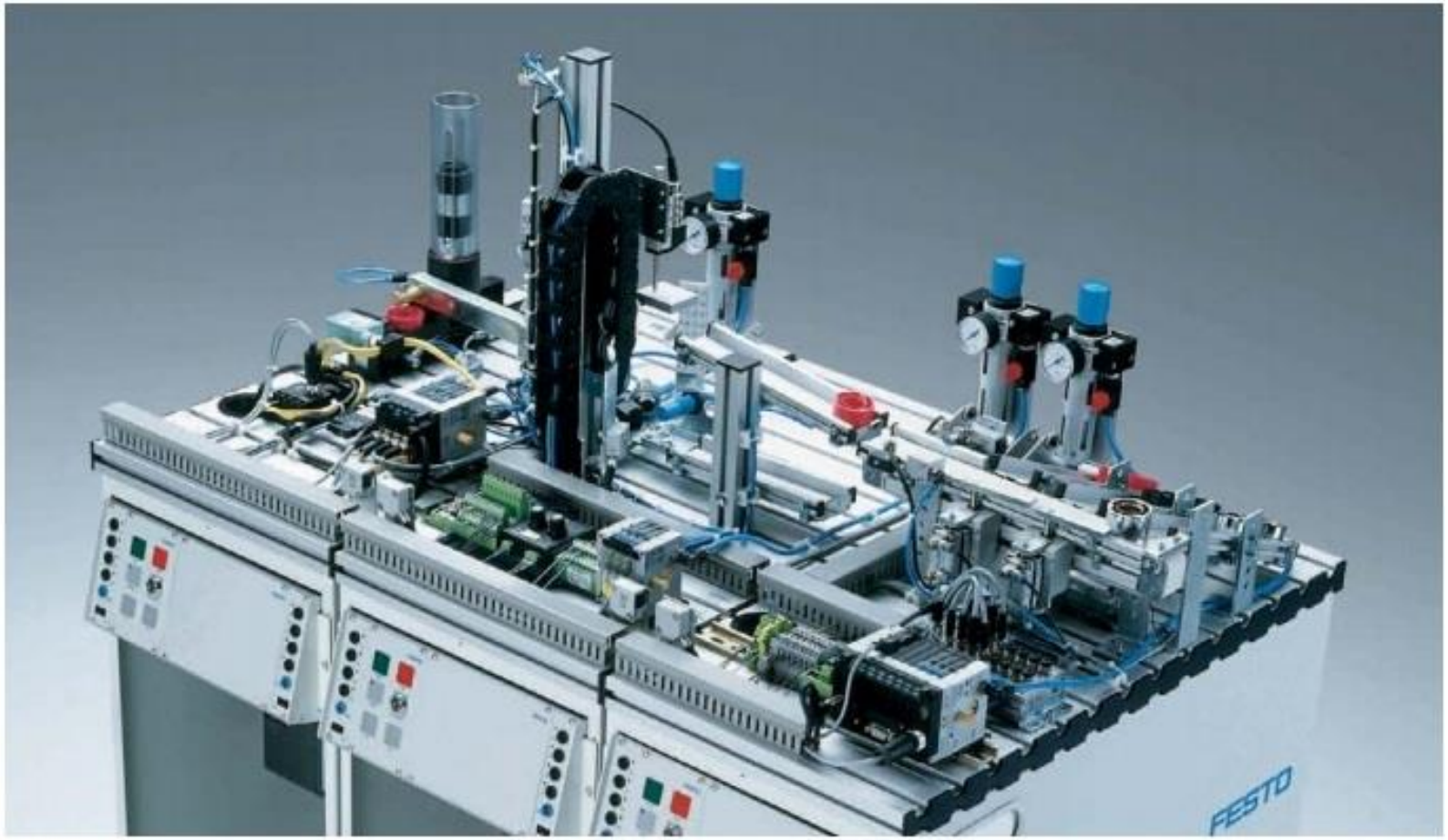
How: Proposed Approach

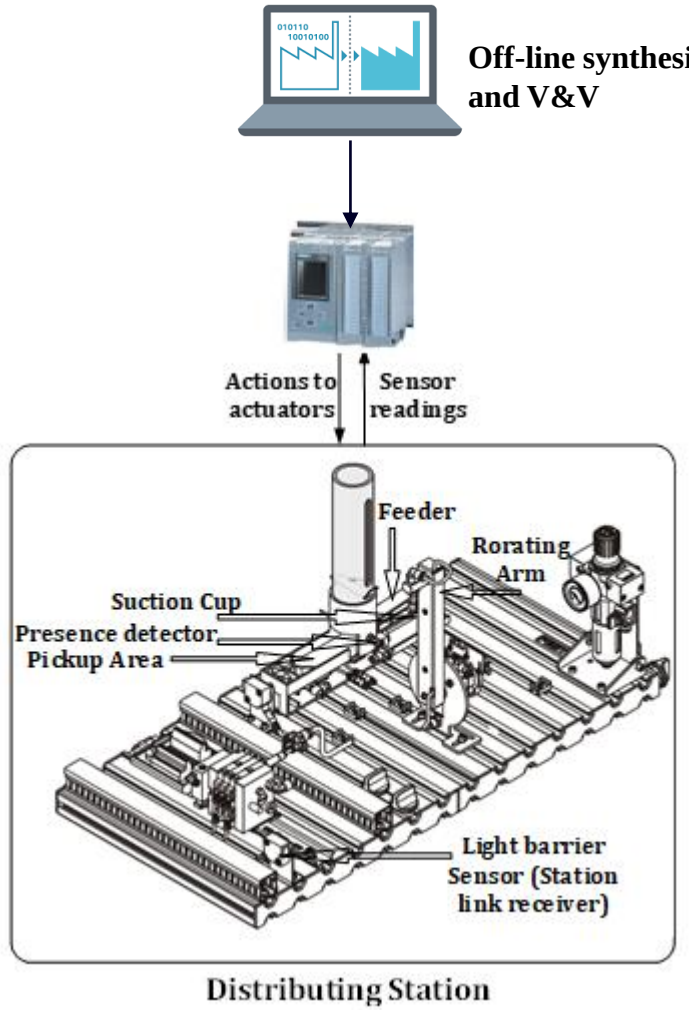
Modular and distributed for flexibility and reconfigurability

- Real systems are geographically or functionally distributed
- A monolithic system is decomposed into smaller subsystems that can be locally controlled with much less effort
- Reduced computational complexity: thanks to the design of small local controllers
- System modification can be made only on the corresponding subsystems in redesign



Application to a manufacturing system testbed





Synthesis of modular/distributed controllers

Informal specifications

(1) The rotating arm should not move to the "magazine" position unless a part is available in the pickup area.

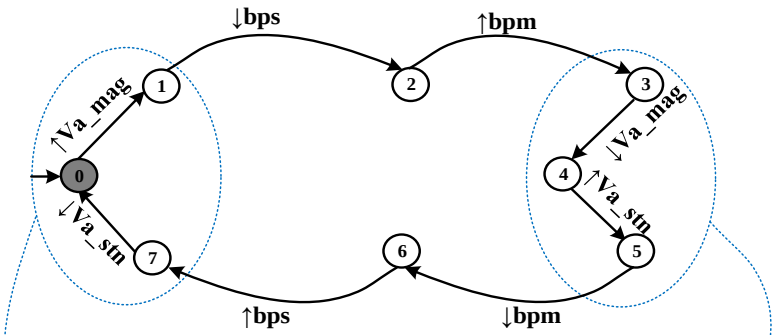
(2) Mutual exclusion between the activation of the suction cup and the movement of the rotating arm to the “magazine" position.

(3) The rotating arm should not move to the "test station" position until this is available, and the part is securely picked by the suction cup.

Formal specifications

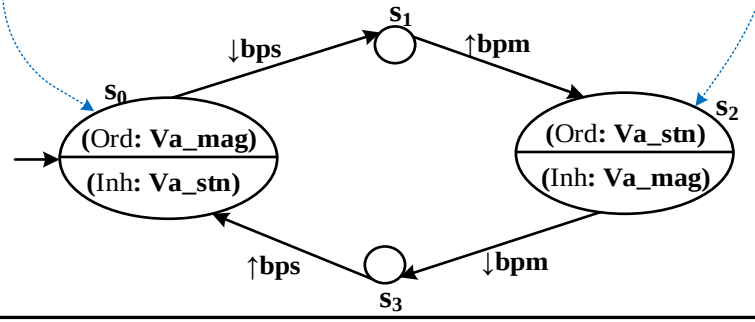
If	Then	
	Ord	*Inh*
¬pbf ∧ apa ∧ ¬Aspirer	Va_mag	
pbf ∧ stv	Va_stn	

Local Controller (LC)



LC aggregation

Aggregated Local Controller (ALC)

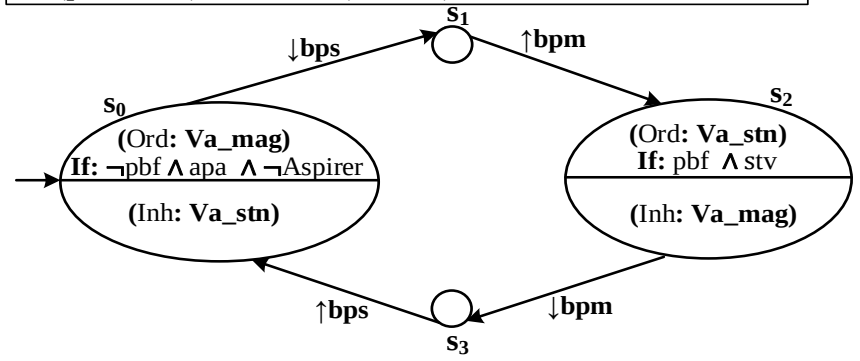


Consideration of the global constraints to the CLA

Global Constraints related to the Rotating Arm

If (¬pbf ∧ apa ∧ ¬Aspirer) **Then** Ord(Va_*mag*);
If (pbf ∧ stv) **Then** Ord(Va_*stn*);

Distributed Controller (DC)



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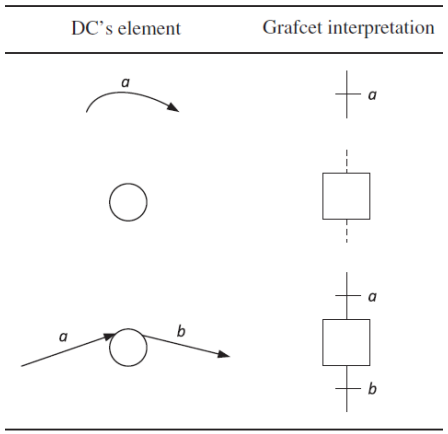
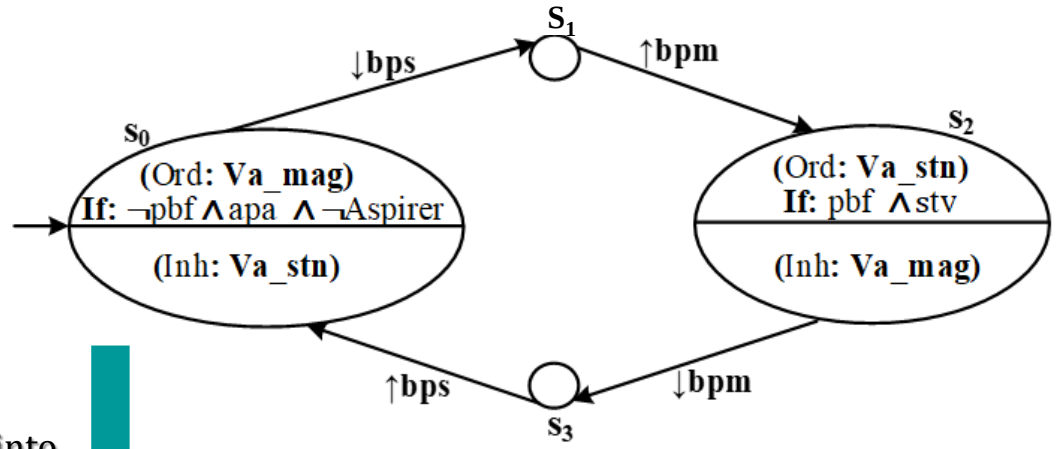
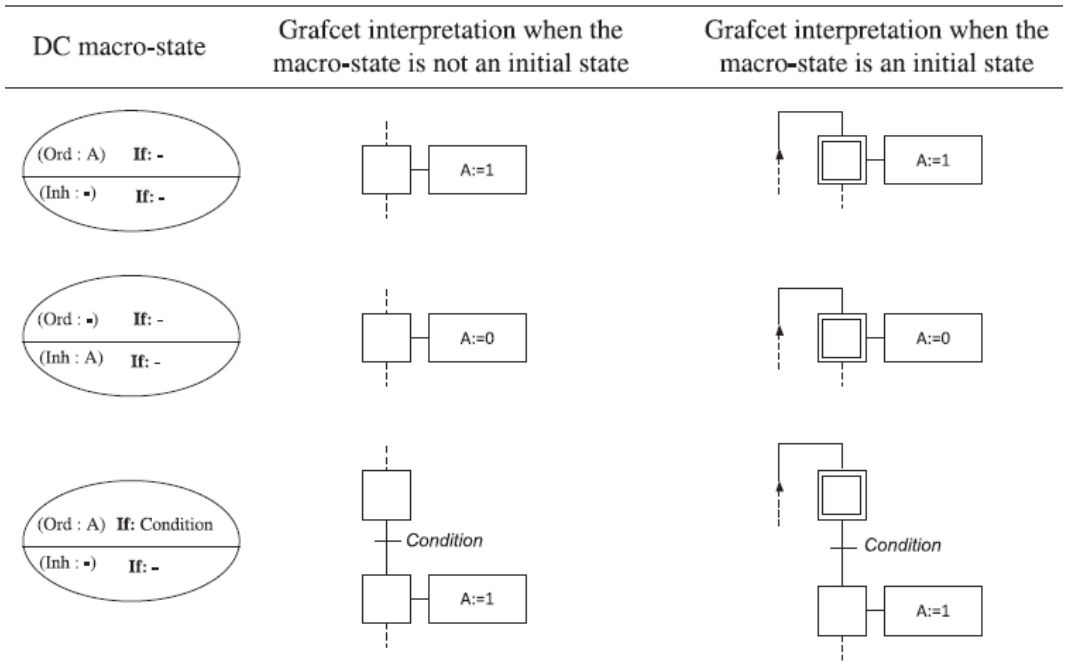
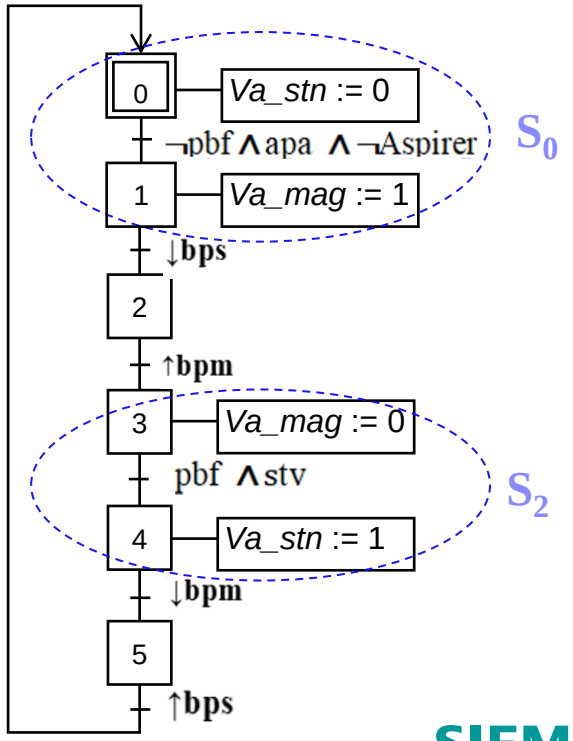
Implementation of the modular distributed control





Model to model transformation into IEC Standard 60848 [IEC 2013]





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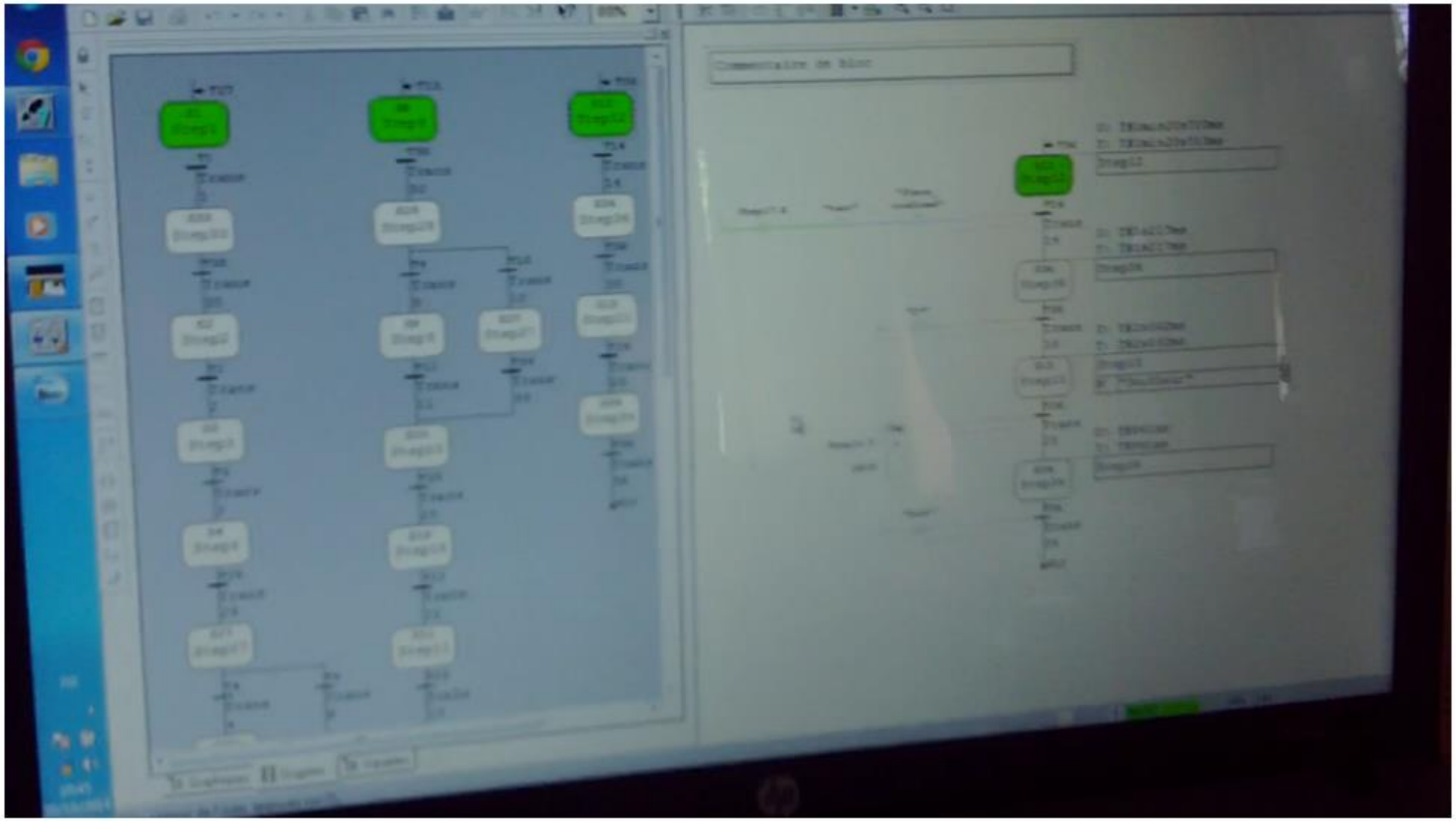
Demo video – deployment of the generated PLC code as S7 Graph



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Thank You!

Q&A

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Backup Slides

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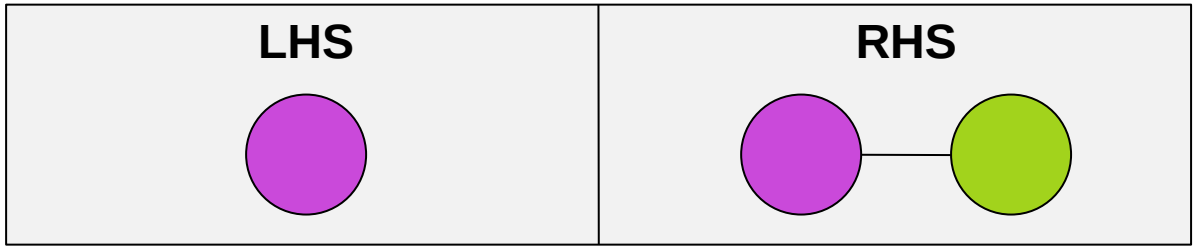
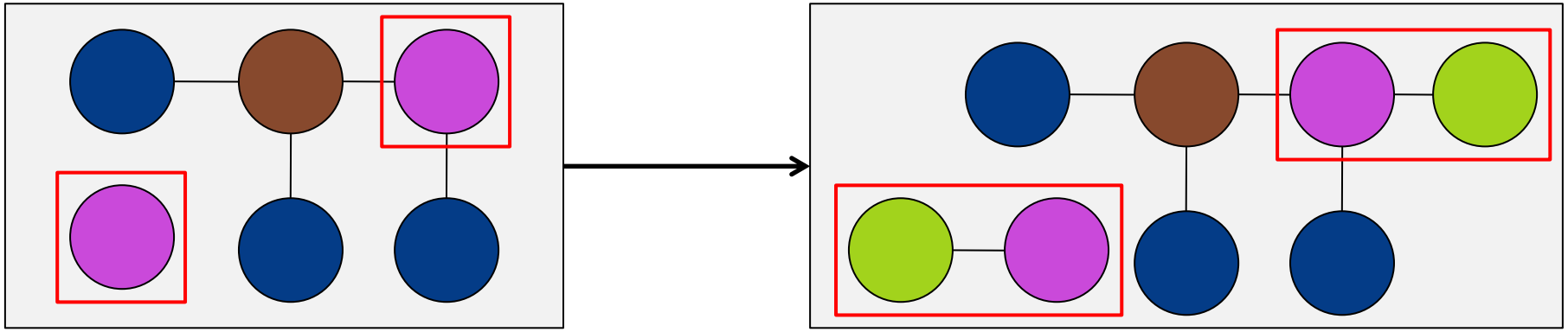
Graph transformations



Graph transformation rule



Source graph

Target graph

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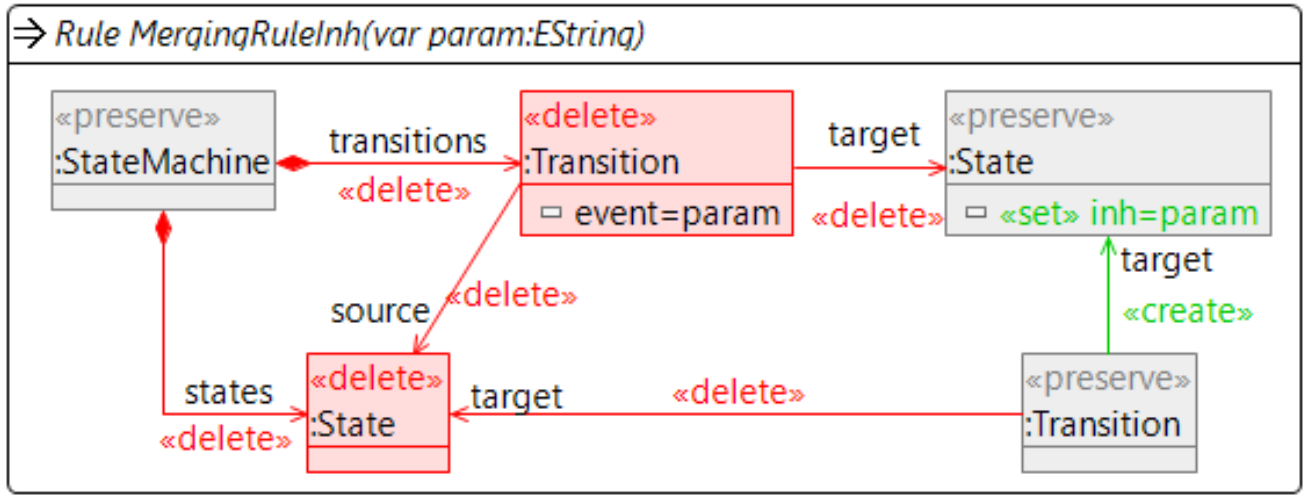
Graph transformations Tool

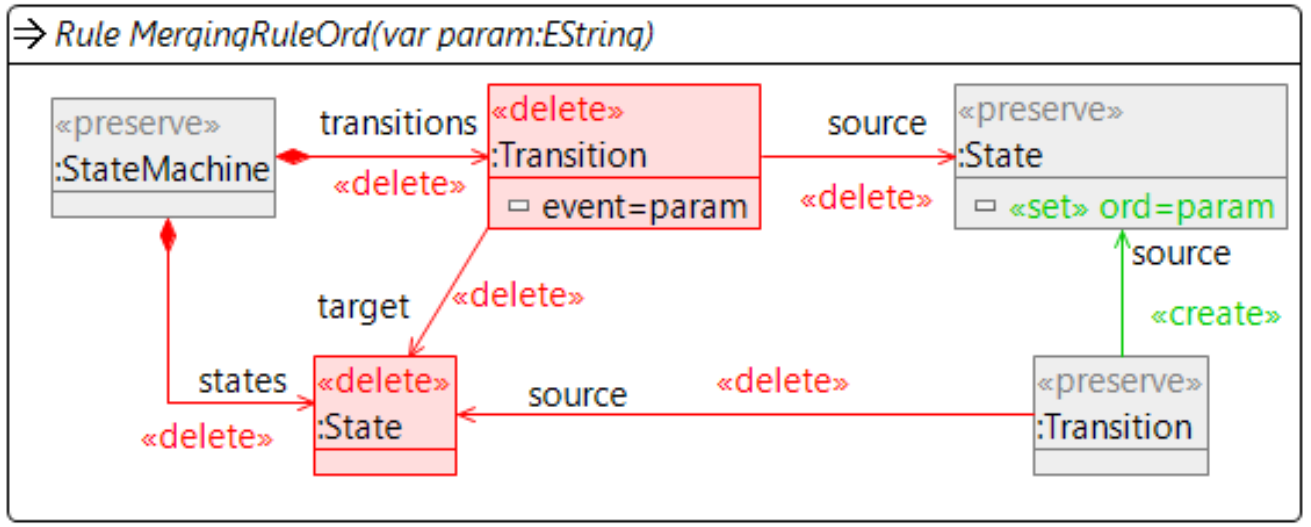
Henhsin is a graph transformation language and associated tool set for expressing graph transformations that operate directly on EMF models

- Possibility to specify a control flow of graph transformation by using graph transformation units
- Uses stereotypes to depicts the rule application semantic:

- ***Preserve***: specifies the elements to be sought to enable the rule application. Those elements will be copied in the resulting graph.
- ***Create***: it is used to describe the new elements to be added to the graph.
- ***Delete***: references the elements to be removed from the graph.
- ***Require***: allows expressing of the conditions necessary for the rule application.
- ***Forbid***: expresses a pattern that prohibits the rule application.

Aggregation transformations





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