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Faculty of Engineering

Petri net implementation in programmable logic controllers: methodology for development and validation

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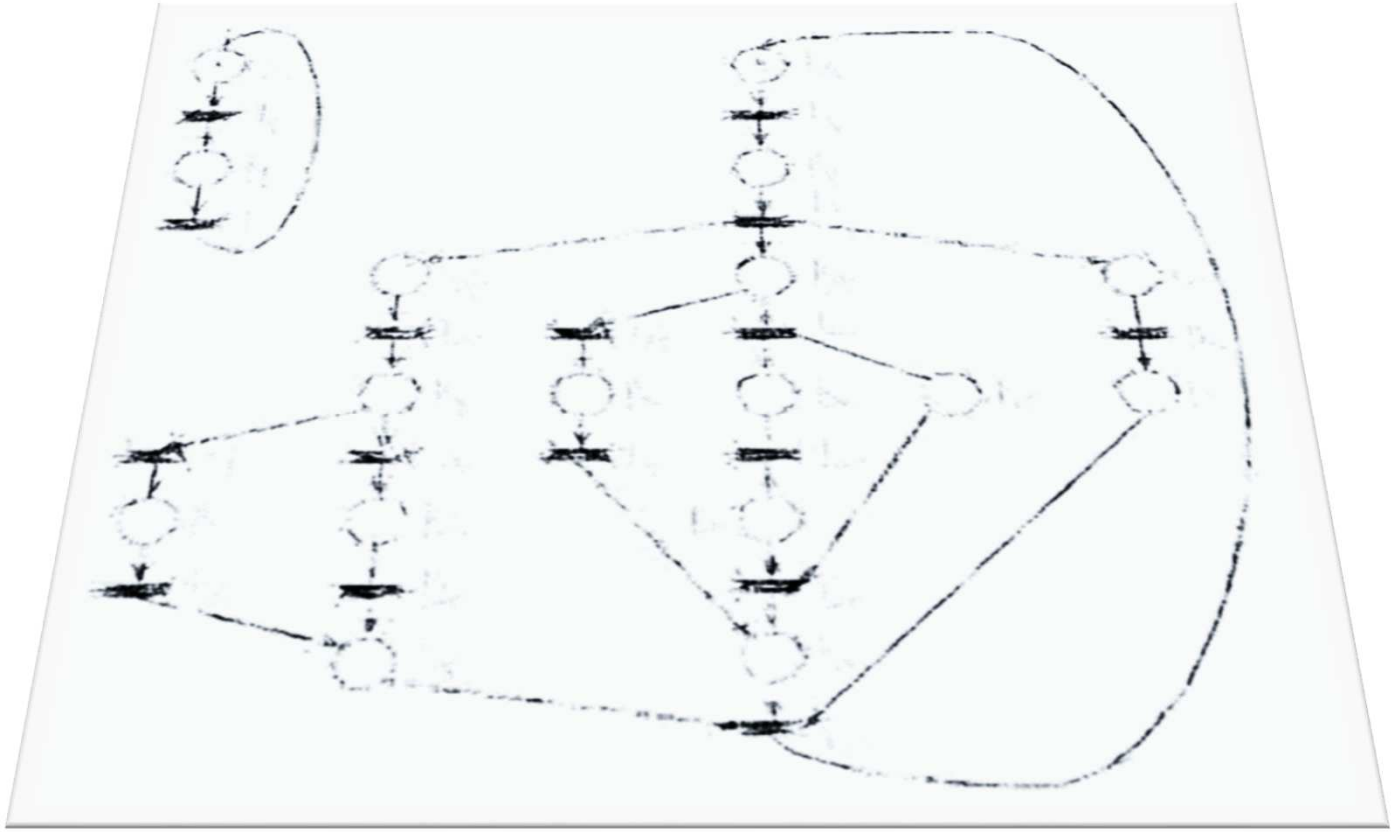

Introduction

Lead times, key for market positioning of manufacturers and integrators.

- Software validation during commissioning

Programmable logic controllers (PLC).

Code tested in the development environment itself.

Commissioning with the equipment already assembled.

Unforeseen events, extra costs, and downtime.

	Nombre	Tipo de datos	Dirección	Rema...	Acces...	Escrib...	Visibl...	Valor de observac...
1	MiCanalDeEntradas	Byte	%IB10		☑	☑	☑	16#02
2	Button	Bool	%I10.0		☑	☑	☑	FALSE
3	SensorClose	Bool	%I10.1		☑	☑	☑	TRUE
4	SensorOpen	Bool	%I10.2		☑	☑	☑	FALSE
5	MiCanalDeSalidas	Byte	%QB4		☑	☑	☑	16#00
6	MotorFwd	Bool	%Q4.1		☑	☑	☑	FALSE
7	MotorRev	Bool	%Q4.2		☑	☑	☑	FALSE
8	Light	Bool	%Q4.3		☑	☑	☑	FALSE

Fig.: Watch and force table for testing.

- Virtual commissioning (VC)

Emulation-based code testing, before commissioning.

Several benefits of using digital twins (DT).

Software-in-the-loop (SIL) and hardware-in-the-loop (HIL).

Coding remains a source of potential errors.

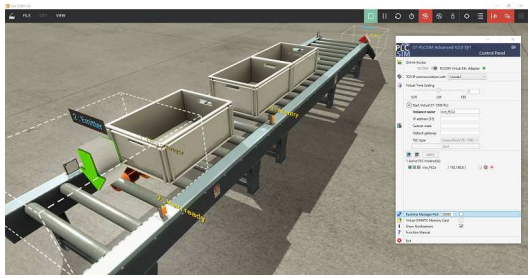

Fig.: DT-based virtual commissioning.

Introduction

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- How to generate programs with minimum errors?

Discrete event dynamic systems (DEDS) are modeled using GRAFCET.

GRAFCET is a particular case of Petri nets (PN).

Boolean variables / counters for each step ► Sequential function chart (SFC).

Approaches ►Programming workload, and nodifications affect the code.

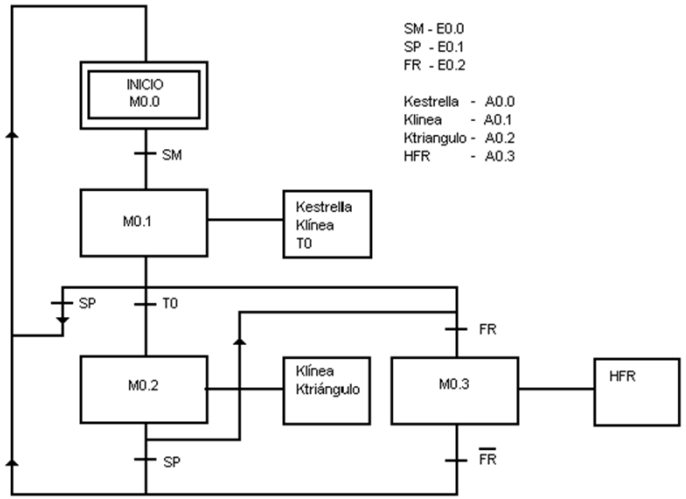
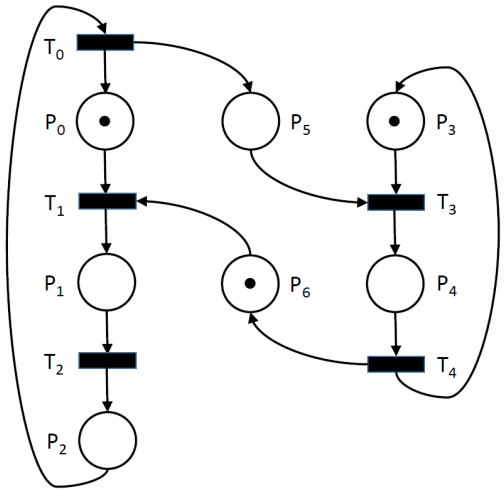


Fig.: GRAFCET (source: www.automatas.org)



Place	Action	Description
P_0	oCR	Red light for vehicles.
P_1	oCG	Green light for vehicles.
P_2	oCY	Yellow light for vehicles.
P_3	oPR	Red light for pedestrians.
P_4	oPG	Green light for pedestrians
P_5	-	Pedestrian green light enabling place.
P_6	-	Vehicle green light enabling place.

Transition	Condition	Description
T_0	tVY	Timed finishing for vehicle yellow light.
T_1	-	(TRUE)
T_2	tVG	Timed finishing for vehicle green light.
T_3	-	(TRUE)
T_4	tPG	Timed finishing for pedestrian green light.

Fig.: PN structure and interpretation.

Introduction

Focusing on PNs opens a new perspective.

- Matrix representation.
- Evolution rules.
- Model validation abilities are much more powerful.
- Wide theory for model structural analysis and property checking.

- What is proposed

A methodology for the development and commissioning of sequential systems controlled by PLC, based on a semi-compiled approach.

It manages evolution of any PN, based on its structure's matrix representation.

Reduced workload and error probability, combined with a virtual validation.

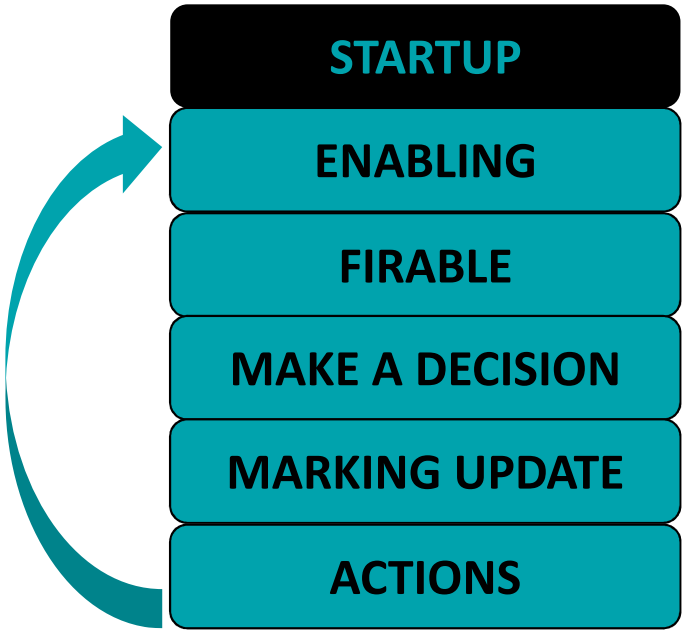
Methodology

- Algorithm for PN marking management

Transition firing and marking updating rules.

Net interpretation coding.

Structured language.



Methodology

- Phases

Conventional procedure	Proposed procedure
- Specifications.	- Specifications.
- Design of the GRAFCET diagram.	- PN model development (start of DT modeling). - PN structural analysis: graphic edition, simulation (movement of tokens around places), validation and matrix generation.
- Interpreted implementation of the GRAFCET diagram.	- Hardware and variable definition (internal and I/O). - Structure implementation: transfer of matrices data to PLC memory. - Interpretation implementation (end of DT modeling).
- PLC emulation in its development environment.	- Virtual commissioning.
- Wiring.	- Wiring.
- Commissioning.	- Commissioning.

Use case

- Process

Processing station (Festo Didactic).

Four modules which can work simultaneously.

Simple case to represent.

Emulator including a station's DT.

Fig.: Processing station (source: www.festo-didactic.com).

Use case

- Work to be done

Automation of the process, applying:

1) The most usual procedure: a fully interpreted GRAFCET diagram.
2) The proposed semi-compiled approach, supported by a DT.

- Resources

Siemens S7-1500 series PLC.

TIA Portal V15.1 and S7-PLCSIM Advanced V2.0 SP1.

PIPE2 online tool.

A propietary application for converting data from HTML to text format.

CIROS® Education 6.2 and EzOPC 5.6.

Use case

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- Conventional GRAFCET-based implementation

GRAFCET design.

GRAFCET implementation using a specific editor.

Software testing.

- Proposed PN-based approach

PN design and structural analysis.

PN implementation

- Structure transfer.
- Interpretation coding.

VC (SIL).

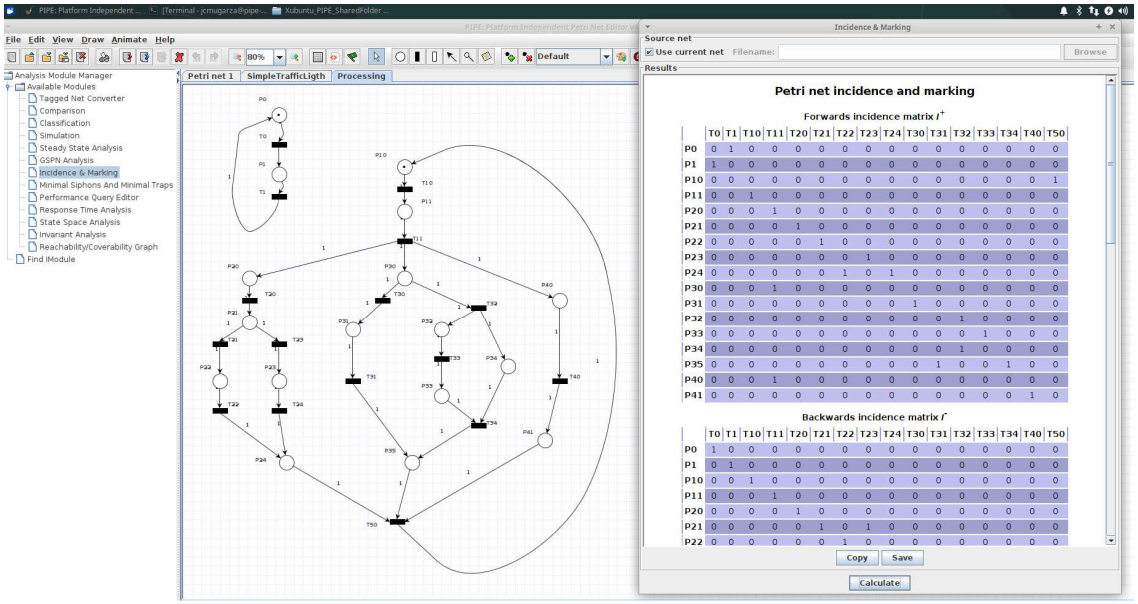

Fig.: PIPE2 tool for PN structural analysis and matrix generation.

Use case

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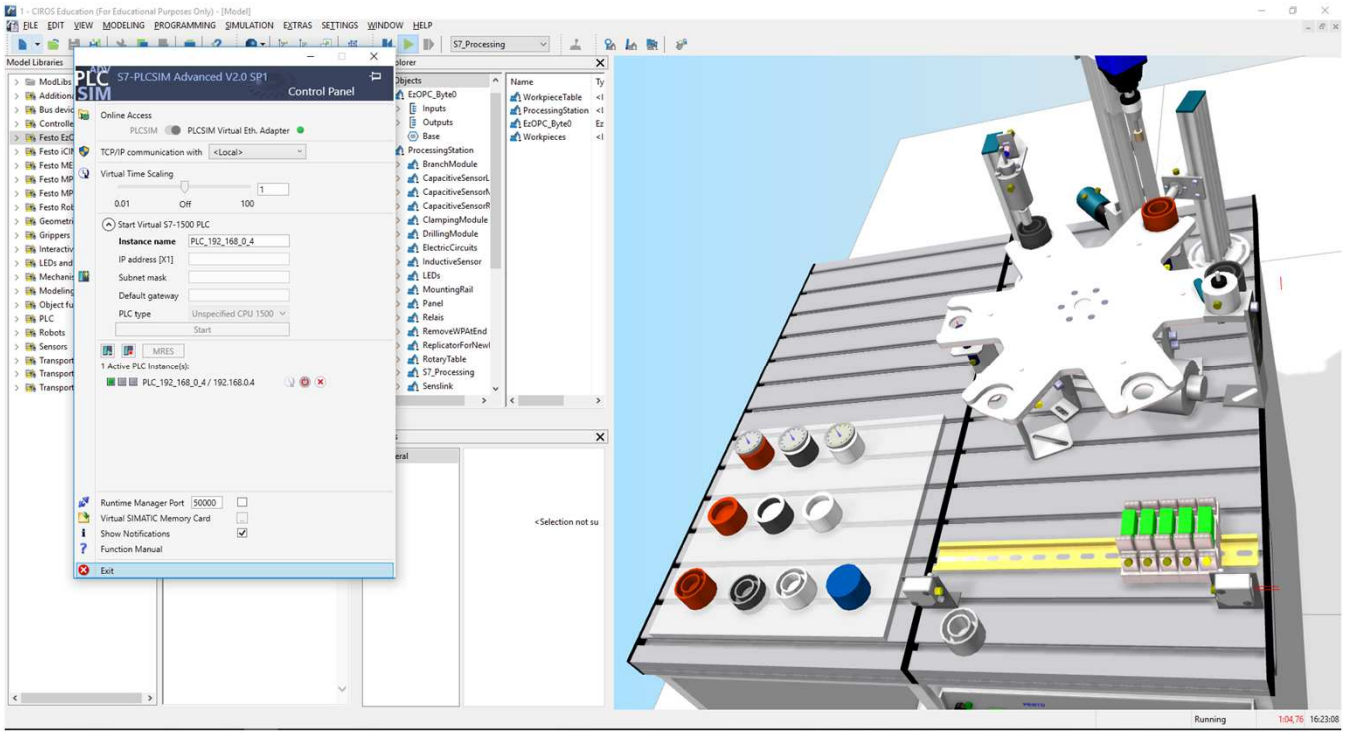

Fig.: Virtual commissioning (proposed procedure).

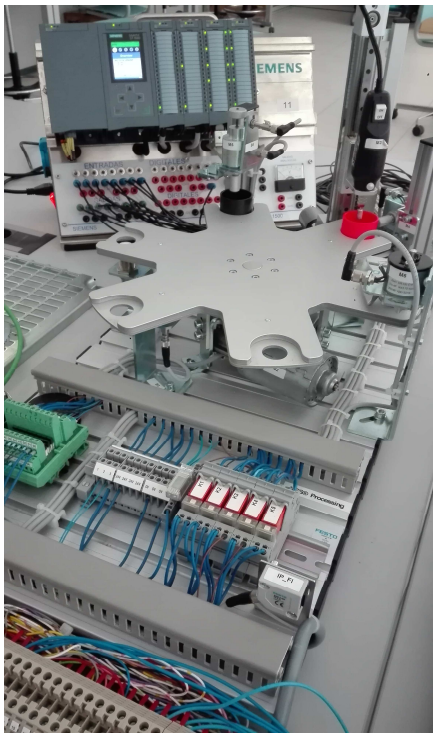

Fig.: Commissioning (conventional or proposed procedure).

Results

Error-prone points in coding

Manual addition of conditions and actions.

Minimal.

Paradigm shift related error-prone points

A PN needs to be set up.

As in GRAFCET.

Matrices need to be mapped with variables.

Automated.

DT design and communication.

Previous background.

Conclusions

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PN programming in PLC.

Use of any PLC and/or DT with OPC UA compatibility.

In more demanding applications (greater complexity or non-sequential):

- Advantages of this methodology over GRAFCET.
- Modeling effort, justified.

Several nets treatment.

Concept of hierarchy.

Customizable code block.

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Eskerrik asko
Muchas gracias
Thank you

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