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Petri Nets Modeling of a Flexible Manufacturing System

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Abstract

In a world where industrial mechatronic systems evolve daily, the intensity of these requirements influences the maximization of efficiency, the optimization of the safety of the working environment including humans, and the increase of the quality of services. This is why industrial computing is becoming a necessity for manufacturers and even researchers working on innovative and creative subjects. This paper deals with the analysis and the modeling of a flexible manufacturing system. Firstly, the study of the system engineering then presented the composition of the studied system. Second, we present an application of a modeling based on Petri Nets. Finally, the last present conclusion and future work.

Keywords: Flexible manufacturing system, modeling, Petri Nets

INTRODUCTION

Today the competition between companies and industrial companies is more and more fierce, which forces them to use new technologies to increase their productivity and diversify their products. For this reason, the model industries contain several components and equipment such as robots, PLCs, industrial networks and field buses, sensors, actuators, numerical control machines, among others. All this equipment's will generate a huge amount of data that we will have to manage to ensure a perfect and optimal functioning of the different workshops and automated systems of production and manufacturing. The tasks of management, supervision and real time control of these systems are ensured by SCADA supervision, control and data acquisition systems (Isermann, 2000), (El-Khalil et.al., 2019), (Zhiwei et.al., 2019). Among the challenges to be taken up during the modeling of complex systems, we can cite the design and implementation of test devices dedicated to the studied objects, the determination of the correct complexity of the models developed to meet the needs posed and the positioning of the research strategy between academic research and industrial constraints (Hardy, 2010), (Meyer, 2015), (El Khaldi, 2022).

An approach that brings together these different types of modeling is then required for it to be based on new representations of a real system, while taking into account instability, chaos, ambiguity, disorder, vagueness and paradox but which thus touch the creative side of development (Lakhoua, 2021), (Brams, 1983), (David et.al., 1992).

This study is divided into three workspaces; the first will be devoted to the study of mechatronic systems, through which we will present the field of mechatronics from different points of view namely mechanical, computer and electrical, and we will highlight the problematic considered through a case study detailed on the treated system and which presents a FESTO workshop flexible system. The second workspace presents the study of the modeling based on Petri Nets in which we will present the composition of the studied system.

MATERIAL AND METHOD

Presentation Of A Flexible Manufacturing System

The flexibility manufacturing systems aims to create an industrial revolution, since a flexible manufacturing system comprises several numerically controlled machines integrating various stations which are connected to each

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other by a Fieldbus system. They are generally characterized by reprogrammable machines.
Flexible systems are composed of complex and expensive machines, the number of which can be adjusted compared to other production systems. This allows a saving in cost and space of the order of 30% (Rohee et.al., 2009).
The figure 1 shows an example of type of mechatronic systems which is the flexible manufacturing system MPS 500 – FSM which will provide the axis of our study. It represents a multi-technological assembly owing to the merger and interactions between the different workspaces: mechanical, pneumatic, electrical, control and communication interfaces.
This manufacturing system has six stations linked together by a transport system, and presents a production chain organized as follows: a distribution station, a test station, a treatment station, an assembly station, a sorting and a storage station to manufacture cylinders with short strokes (Mlouhi et.al., 2022), (Balti et.al., 2023).

Figure 1. MPS 500 - FSM Station

MODELING BASED ON PETRI NETS

A Petri net is a graphic structure comprising a set of places and transitions, connected by oriented arcs, possibly carrying weights. These arcs are links between place and transition or between transition and place exclusively. In this structure move tokens (or marks) that appear in the places and are likely to cross the transitions according to certain criteria of crossability and crossing.

This network has interesting features such as parallel behavior modeling and visualization, synchronization, and resource sharing. In addition, their theoretical aspects have been widely studied and the theoretical results concerning it are very abundant.

It is a modeling tool generally used in the preliminary design phase of a system for its functional specification, modeling and evaluation. In this workspace, we will present the modelling of the six stations presented above in Workspace 2 as an application of Petri Nets modelling.

The test station

The figure 2 illustrates the modelling of the test station. It shows that after workpiece detection, the color and material of the inserted workpiece must be determined by sensors. Then the workpiece will be moved up to measure and compare its height. If the workpiece is compliant, it will be moved to the next station, otherwise it will be moved down and evacuated.

Legend:

P1: The presence of the workworkpiece

P2: Colour selector (Red or Black) and determine the material (Metallic or plastic)

P3: Comparator with a given height: Compare the height of the workpiece with a predefined height.

P4: Moving the workspace to the next station

P5: The work workpiece evacuation

T1: The entrance of the work workpiece

T2: Workpiece detected

T3: Move the workpiece up

T4: Conforming workpiece: The movement of the workpiece to the next station

T5: Not conforming workpiece: Moving the workpiece down for evacuation.

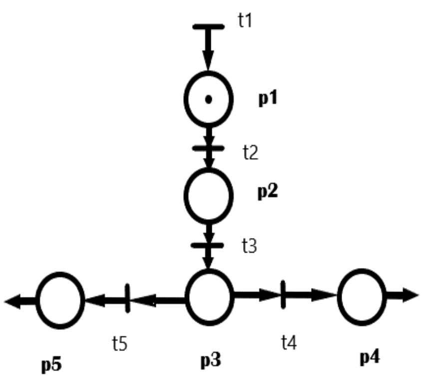

Figure 2. Petri Nets of test station

The treatment station

The figure 3 presents the modelling of the treatment station. The processing station allows the workspace to be drilled using a DC drill, this drilling action is carried out after using these different steps:

Firstly, the rotary table will take the workspace to the test module where it will check if the workspace is drilled or not (this is done with the help of an inductive sensor).

- If the workspace is not drilled, the rotary table takes the workspace to the drilling module where the workspace is clamped and drilled. Finally, the finished workspace is taken to the next station.
- If the workspace is drilled, the drilling module is passed and the workspace is fed directly to the next station.

Legend:

P1: The presence of the workspace

P2: The verification of the opening upwards

P3: Clamping station

P4: Drilling

P5: Transmission of the workspace to the next station

T1: Entry of the workspace

T2: Workspace detected + rotation of the table

T3: Workspace with opening upwards upwards + rotation of the table

T4: Clamping time elapsed.

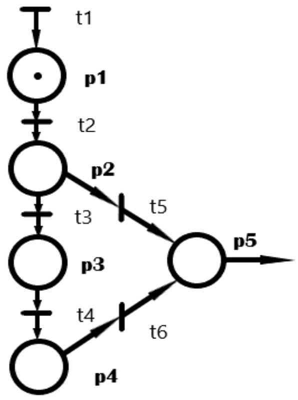

Figure 3. Petri Nets of the treatment station

The handling station

The figure 4 presents the modeling of the handling station. It shows that after the detection of the workspace, the advancement of the lifting cylinder and the closing of the clamp will be activated, in order to identify the color if it is black or not. Then, the recoil of the cylinder and the advance of the axis at station 1 or station 2 will be activated. Thereafter, the advance of the jack and the opening of the gripper will be actuated so that the black workspace is on the slide 1 and not black on the slide 2. Finally, the jack and the axis will be moved back to their initial positions.

Legend:

P1: The presence of the workspace

P2: Identification of the black or not black colour

P3: Station 1

P4: Station 2

P5: Lifting cylinder

T1: The entry of the workspace

T2: Hand of lifting cylinder holding the workspace

T3: Black workspace (transmit to station 1)

T4: Non-black workspace (transmit to station 2)

T5: Workspace in station 2: release the cylinder

T6: Workspace in station 1: release the cylinder

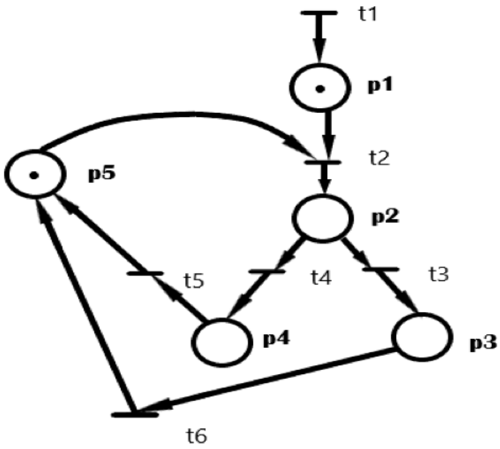

Figure 4. Petri Nets of the handling station

The sorting station

The figure 5 presents the modeling of the sorting station. The workpiece at the beginning of the conveyor belt, then the advancement of the stopper, and the starting of the engine will be activated only after the detection of the workpiece. Then it is made to be identified by its color and material whether it is black, red, or metallic. After the identification of the material and the color of the workpiece, the deflector will be selected and the cap will move backward and deflector 1 or deflector 2 associated with the red

or metallic workpiece respectively will retracted. If the workpiece passes through the associated conveyor belt the motor stops, the plug moves forward and deflector1 or deflector 2 moves back.
Legend:

P1: The presence of the workspace

P2: The identification of the colour and the material of the piece

P3: Central position

P4: Extremity

P5: Start

P6: Stock 1 Metal workspace

P7: Stock 2 black plastic workspace

P8: Stock 3 red plastic piece

P9: Deflector 2

P10: Deflector 1

T1: Entry of the workspace

T2: Detected workspace

T3: Metal workspace (transmit to central position then deflector 2 advance)

T4: Black plastic workspace (transmit to end position)

T5: Red plastic workspace (transmit to the start position and then advance deflector 1).

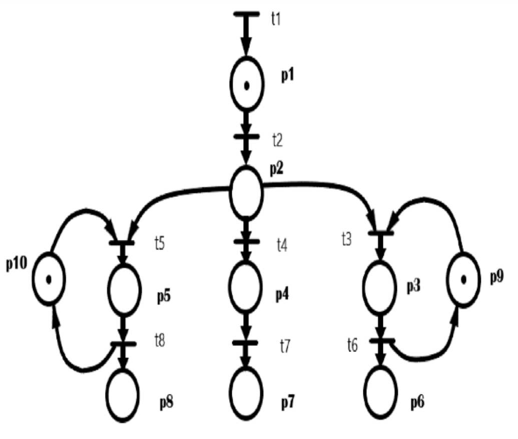

Figure 5. Petri Nets of the sorting station

The distribution station

The figure 6 presents the modeling of the distribution station. It shows that after the workspace is detected, the ejection cylinder moves forward to remove the workspace from the magazine. Then the cylinder moves back.

After the rotation of the arm to the magazine station, the vacuum is activated and the check whether the workspace is sucked in or not is activated. After the arm has been rotated to the test station, the vacuum is switched off and the workspace is released into the test station.
Legend:

P1: The presence of the workspace

P2: Ejection

P3: Workspace in the magazine to be sucked

P4: Workspace in the magazine sucked

P5: Ejection cylinder

P6: Vacuum

P7: Test station

T1: Workspace input

T2: Workspace detected + advance ejection cylinder

T3: Passing the workspace to the magazine

T3: Transmit the workspace to the magazine + move back the ejection cylinder + activate the vacuum

T4: Workspace sucked in

T5: Transfer the workspace to the test station

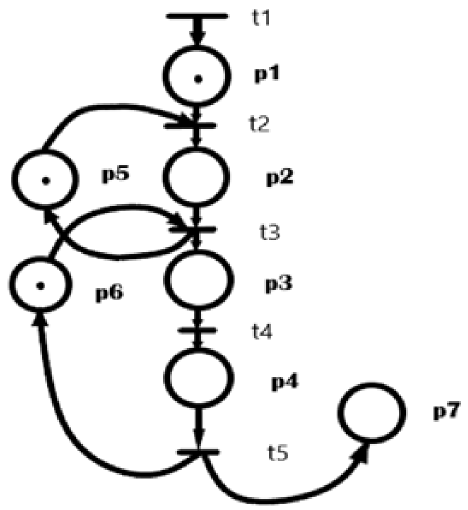

Figure 6. Petri Nets of the distribution station

The assembly station

The figure 7 presents the modeling of the assembly station. It shows that after the detection

of the basic body, the body rises. The body is transported and it is placed at the "clamp change" position. Then the color of the basic body will be detected.
If the color is black, the body will be picked up. Then the basic body is placed in the assembly position. After the metal plunger is picked up from the pallet, it will be inserted into the basic body.
If a spring is available, it will be picked up and placed on the piston. Then if a cap is available, it will be picked up and placed on the bolt. Finally, the cap will be rotated onto the body. The pneumatic cylinder is now assembled and can be placed on the rail.
Legend:

P1: The presence of the basic body

P2: Body in the assembly holding module, body in the clamp change position + determination of its colour

P3: Place the basic body in the "assembly" position, pick up the metal or black piston from the pallet and insert the piston into the body.

P4: Spring location in the piston

P5: Place the cap in the right direction on the body

P6: Piston present

P7: Spring present

P8: Presence of cap

T1: Enter the body

T2: body in position for clamp change

T3: A black or non-black basic body is picked up + piston is present

T4: The piston is inserted in the body + spring is present

T5: Spring is placed on the piston + cap is present

T6: piston is inserted

T7: Spring in

T8: Insert the cap

MATERIAL AND METHOD
In this paper, we modeled the different parts of a flexible manufacturing system using Petri nets.

IMPACT OF ACTIVITIES
Using Petri nets, we were able to graphically represent the components of our system as well as the transitions between states of the system. We also analyzed the dynamic behavior of the systems by examining properties such as liveness (the ability to reach certain states) and boundedness (the restriction on the number of tokens). All of this is extremely useful in system design and simulation, allowing us to test different configurations and control policies before actual implementation.

CONCLUSION
In this paper, we studied a FESTO flexible manufacturing system allowing manufacturing single-acting cylinders.
Uncovering the reality of a workspace of industrial computing has prompted us to find out how to use it to apply the methods used on complex systems that integrate dynamic components.
We therefore plan to find a solution to model the entire FESTO production line (the flexible workshop) which includes the different stations, based on the Petri Nets. Then, we will be interested in studying the exchange of energy flows between the different workspaces in order to supervise this data flow and test new supervision tools allowing to test the overall Petri Nets model of the system.

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