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PRODUCTION OPTIMIZATION USING PETRI NETS

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Abstract : The work finds purpose in the development of automating fibrous bag palletizing solutions. Using Petri nets, representation and studying of the entire process in a simple manner was possible, from bag apprehension until the final palletization of the filled bags – which allowed the analysis of system performance. Using PIPE, different process configurations were laid out and with FlexSim 2024 a virtual representation of the production line was made.
Key words : bag filling, automation, configurations, palletization, Petri, process.

1. INTRODUCTION

A Petri network is a graph type of mathematical model, used for the virtual analysis of distribution of system elements. It is made out of places and transitions interconnected through arcs which generate or consume a set number of tokens – these represent validation objects of the system conditions or, even the workpiece.[1]

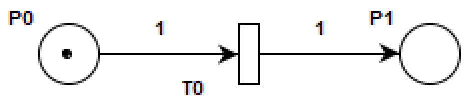

Figure 1 Petri network featuring 2 places and a transition [1]

Above (Figure 1), one can observe, in order, from left to right - an entry place P0 which contains a token, an entry arc with a weight of 1, a transition T0, an exit arc with a weight of 1 and an exit place P1.

Places represent discrete storage spaces for tokens and can serve as entry conditions, necessary storage space or necessary project resources, while a transition is characterized by the use of these tokens and generating them in the next places. Transitions are triggered when every entry place features at least one token – thus they can be representations of an event, a processing stage or a logical condition that must be fulfilled for completion of said stage. These rules of consumption/generation of tokens can be imposed through connection arcs by specifying the arc weight.

We can create logical blocks of place-transition for every process of product processing, thus characterizing the system from a functional point of view in an easy to understand way both by those responsible of process design during production but also by operators during training.[2]

In Figure 2, when we line up processes from the operational production chain that present a linear dependency (the only systems communicating are the ones before and after), we can represent them in a single block of place-transition and during our performance analysis they are represented strictly through their characteristic time parameters.

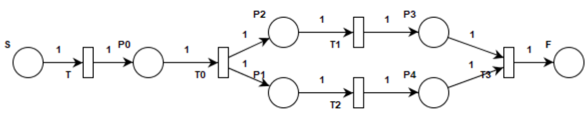

Figure 2 System with processes executed in parallel

When multiple places are connected to the output of a transition, in all the places tokens will be generated. This characteristic allows the representation of operations executed in parallel in an automated system when from a transition in series with a place P0, connected to the source S, are connected two ramifications or more, each with their own process required weight – thus, the branches created become independent of one another and, even though when a Petri net is simulated, they are triggered in a non-deterministic manner, the average of token distribution

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on every place becomes a parameter for system efficiency.[3]

Beyond what was previously mentioned, the concept of coloured Petri networks must be introduced, where tokens can be color-coded so that there can be a multitude of input and output conditions, handled by the arcs that enter and leave the transitions.[4]

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2. METHOD AND RESEARCH

2.1 The characteristics of manufacturing system:

Everything previously mentioned makes petri networks useful for conceptualization of systems in the field of production, their organization and increase in effectiveness of robots' coordination in various configurations in a short time.

The characteristic parameters of manufacturing systems are characterized by process execution time and the transfer time to the next process which is itself divided into execution time and dead time, respectively the effective transfer time and return time.

- The effective execution time (T) is the time in which, without stopping, the robot or the functional component executes a certain movement in the process.
- The dead time (t) is the waiting time between the moment when a manipulator of the system receives a command and the moment in which it executes it.
- The effective transfer time (T_t) is the time necessary for the transfer of the object destined for processing to the workspace of the next process.
- The return time (T_r) represents the time in which a manipulator travels to its initial position, ready to pick up the next product.

We can observe two aspects regarding the characteristics of the parameters listed above:

I. T and T_r are characteristic only to automated processes, systems containing hardware responsible for control and who account for their surroundings through programming. Thus, a system that is passively functioning can be characterized only through the other two parameters.

II. For the effectiveness of a manipulator to be dependent exclusively on the surrounding systems, its return time must be smaller than the characteristic execution time.

2.2 The structure of model system:

The system proposed for exemplification is made from a needle apprehension device 1 which picks up the empty bags from the source S, which are transported using the conveyor a, coordinated with a manipulator dedicated to the opening and positioning 2 (Figure 3). The bags are picked up by the two pallets of the manipulator, after which they are rotated 90 degrees to vertical position on a scale 3. The apprehension device and the manipulator return to their initial positions while the chute 4 fills the bag with flour, once the desired mass is reached, it continues down the line. In the next stage, the filled bags are moved using the conveyor b to the alignment rails 5, which straightens the edge of the bags and leads them to a tensioning area 6 where they are sealed by the sewing machine 7, so that they can then be palletized in the storage space F.

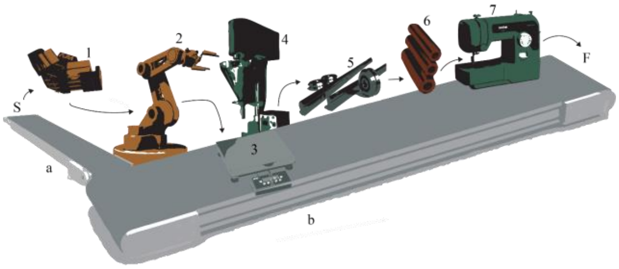

Figure 3 System used for the example
1 – needle apprehension device, 2 – manipulator robot, 3 - scale, 4 – bag filling machine,
5 and 6 – roller based tensioning system with guide rails,
7 – sewing machine.

It must be mentioned that the simulation time is independent of the actual execution time of the processes, but some results following the analysis of the system behaviour offer clues of system effectiveness. Because of this, when we wish to simulate the palletizing of processes, for example with 2 branches, the simulation time can be up to n times bigger. [4]

2.3 Case study:

Below, two studied cases can be observed, both with a number of 100 bags as input:

1. The system with all of the processes necessary for manufacturing being present in the minimum required amount(one type of process – one manufacturing stage, one machine for processing).
2. The system with the processes necessary to manufacturing laid out in parallel (two manufacturing lines in this case), for increasing effectiveness, the distribution and collecting being maintained as common (Figure 4).

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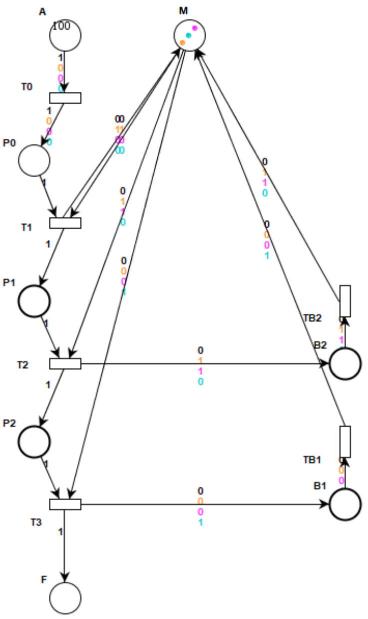
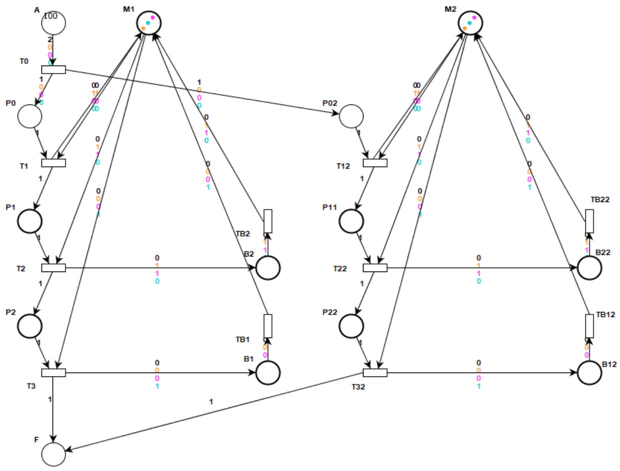


Case I



Case II

. Figure 4 Structure of the studied system

where

A – bag input area; T0 - transport of bags to collecting zone P0 through a conveyor belt; P0 – place designated for the bag pick-up using the needle apprehension device, whose presence is detected using an array of sensors; T1 – transport of the bags to a toppling area P1; P1 – the place in which the apprehension device coordinates with the robotic arm with pallets for opening the bag; T2 – the transportation to the weighing area; P2 – the logical place representative of the weighing, filling, distribution and sewing; T3 – the transitioning towards the palletizing area; F – collector. Palletization takes place here.

3. RESULTS OF SIMULATION

As the results of simulation we can observing following data (Table 1):

Table 1. The simulation results for case I and case II

Place	Average amount of tokens I	Average amount of tokens II
A, supply	16.16805	8.27949
P0	39.76539	21.58984
P02	-	22.46824
Palletized	42.9218	45.30853

Considering the nature of the studied system, the lower number of tokens in case II then in case I represents an increase in effectiveness, characterized through a ratio of places in case II over those of case I.

Based on this information, the production line was simulated using the Autodesk software FlexSim where we considered the same two scenarios as above (Figure 5).

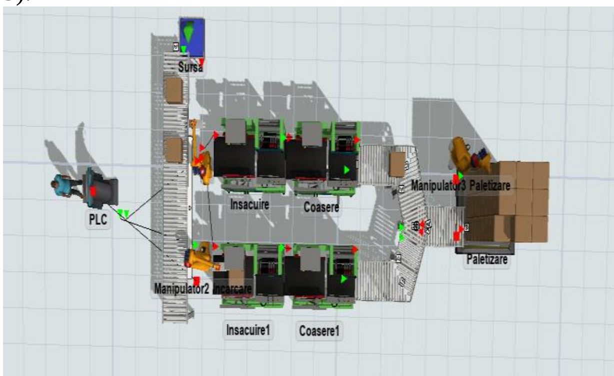


Figure 5 Second simulation

As result of the experiments the following were observed:

- In scenario I on a single branch, despite the generous arrival times of the bags, the lone manipulator is quickly overwhelmed, and the supply conveyor ends up being overcrowded and blocked, one can observe the large medium number of bags on the supply conveyor, the increased functioning time of the loading manipulator and the reduced productivity of the palletizing manipulator (Figure 6).

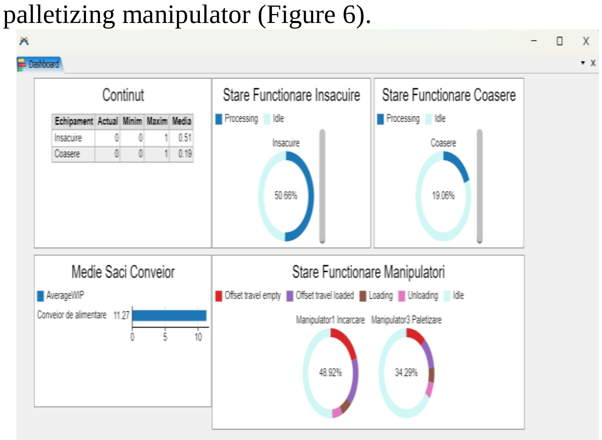


Figure 6 Scenario I, results obtained from single branch processing

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- In scenario II, with two branches, the system handles effectively the number of bags, succeeding in filling and palletizing 100 bags in 17 minutes (Figure 7). The increased efficiency is observed through the reduced medium number of bags on the conveyor and the increased functioning time of the palletizing manipulator which indicates an increase in productivity, meanwhile, the loading manipulators are used less.

Figure 7 Scenario II, the results obtained for two parallel branches

In principle, the single branch processing led to a disproportionate accumulation of bags in a single area of the manufacturing cell in direct correlation with the accumulation of tokens observed in the petri network, the adding of a second branch allowed the fluidization of the process and the prevention of excessive accumulations.[5]

This comparison between one branch and two branches can be easily scaled up to much greater and more complex systems making petri nets useful in production planning, especially when paired with simulation software.[6]

4. CONCLUSIONS

Petri nets are ideal for conceptualizing and easy organizing of factories, being an easy way of graphically interfacing in a logical way the elements responsible for process coordination as well as simple operators. They are also useful in increasing production effectiveness, thus directly increasing profits and motivating choices regarding investments in process automation.

Future research opportunities:

- The generation of formulas based on efficiency factors regarding time for the characterizing of each individual process.
- The conceiving of a specialized program which ensures communication between a live petri net and the robots of a factory.
- Increasing the range of applicability for coloured Petri nets.

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