Production Line Simulation to Sort the Product by its Quality Using Petri Net

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ABSTRACT

Due to the graphical and precise nature of the representation scheme for Petri net, this research uses the graphical tool of petri net which it is applicable for many systems because it is often easier to be understood and to analyze the behavior of the system. In addition to Petri net, a threshold is used to add some flexibility to the specifications of the products to distinguish high-quality product specifications from other products.

In this research, we describe the management of daily production line at lamps factory. A Petri net model was adopted to build a model to interpret the structure, function and workflow of this production line.

Threshold is used to treat some factors in lamp production like handle force helix, glasses thinness of and glasses color.

The structure of Petri net model describe the position of each part of the production line (place or transition) and how these parts will connect to each other. The function of Petri net depends on determining the conditions and the events of each place and transition, and the workflow of the production line that connects the structure to the function to achieve two requirements, the first, is verifying and packaging the lamps, the second, is factory workers financial consequences according to special daily conditions.

INTRODUCTION

Factory automation has been addressed at two very different approaches. The first approach is organizing of the production system, planning the workflow, scheduling the operations which are improved but the elementary operation are not necessarily automated. The second approach is the major part of the effort which is dedicated to the automation of the elementary repetitive sequences of the operations by
means of programmable logic controllers, while the management of production remaining largely based on human heuristic decisions.

The first approach deals with the overall model of the production process. What has to be improved and automated is the complex decision making system where human is present. The data are frequently imprecise; ill known information has to be taken into account. Not surprisingly, all available Artificial Intelligence techniques are typically used in this approach, including possibility theory.

In the second approach, the environment is generally well known, human is not included in the system to be automated. It is possible to formally specify the control/command sequences by means of Petri nets and to automatically derive programs for programmable logic controllers.

Petri nets are made up of places, transition and tokens. A state is represented by a distribution of tokens in the places (marking). Firing a sequence of transitions transforms the state and corresponds to a sequence of events. One of the major results in Petri net theory is that p-invariant is a sequence of events that remains constant whatever transitions are fired. An invariant is a sequence of events that can repetively occur i.e such that the system is cyclically passing through the same state [1].

M.D Zisman [2] has perhaps been the first one who pointed out that Petri nets can be considered as resulting from attempts in combining logic and theory. Peri net transitions could be interpreted as rules in specific production rule systems.

BASICS OF PETRI NETS

Here is the suggestion work as seen in figure (1) and some kinds of definitions for Petri nets, and Petri net model

![Figure 1: Suggestion for a Production Line](image)

Result: distinguished lamps packets and financial consequences for the workers in factory according to special daily conditions
1- FORMAL DEFINITIONS

Formal definition: A Petri net may be identified as a bipartite, directed graph

\[ PN = \{ P, T, F, W, M_0 \} \]

where:

- \( P = \{ P_1, P_2, \ldots, P_m \} \) is a finite set of places,
- \( T = \{ T_1, T_2, \ldots, T_n \} \) is a finite set of transitions,
- \( F \subseteq \{ P \times T \} \cup \{ T \times P \} \) is a set of arcs (flow relation),
- \( W: F \rightarrow \{ 1, 2, 3, \ldots \} \) is a weight function,
- \( M_0 : P \rightarrow \{ 0, 1, 2, 3, \ldots \} \) is the initial marking,
- \( P \cap T = \emptyset \) and \( P \cup T \neq \emptyset \).

A Petri net structure \( N = (P, T, F, W) \) without any specific initial marking is denoted by \( N \).

A Petri net with the given initial marking is denoted by \( (N, M_0) \) [5], [6].

Source transition: a transition without any place and it is unconditionally Enabled

Sink transition: a transition without any output place and it consumes tokens, but does not produce any [7].

2- PETRI NET MODELING

A Petri net is a particular kind of directed graph which is directed, weighted, and bipartite graph consist of two kinds of nodes, called places and transitions, where arcs are either from place to transition or from transition to place. Arcs have capacity 1 by default; if other than 1, the capacity is marked on the arc. Places have infinite capacity, while transitions have no capacity, and cannot store tokens at all. Some typical interpretations and their input places and output places are shown in table (1). A formal definition of a Petri net is given in table (1).

<table>
<thead>
<tr>
<th>Input Places</th>
<th>Transition</th>
<th>Output Places</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precondition</td>
<td>Events</td>
<td>Postcondition</td>
</tr>
<tr>
<td>Input data</td>
<td>Computation</td>
<td>Output Data</td>
</tr>
<tr>
<td>Input signals</td>
<td>Signal processing</td>
<td>Output signals</td>
</tr>
<tr>
<td>Resources needed</td>
<td>Task or Job</td>
<td>Resources</td>
</tr>
<tr>
<td>released</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td>Clause in logic</td>
<td>Calculation(s)</td>
</tr>
<tr>
<td>Buffers</td>
<td>Processor</td>
<td>Buffers</td>
</tr>
</tbody>
</table>

[3], [4].
3-PETRI NET FIRING RULES

The behavior of many systems can be described in terms of system states and their changes. In order to simulate the dynamic behavior of a system, a state or marking in a Petri nets is changed according to the transition (firing) rules:

1- A transition \( t \) is said to be enabled if each input place \( p \) of \( t \) is marked with at least \( w(p,t) \) tokens, where \( w(p,t) \) is the weight of the arc from \( p \) to \( t \).
2- An enabled transition may or may not fire (depending on whether the event actually takes place or not).
3- A firing of an enabled transition \( t \) removes \( w(p,t) \) tokens from each input place \( p \) of \( t \), and adds \( w(t,p) \) tokens to each output place \( p \) to \( t \), where \( w(t,p) \) is the weight of the arc from \( t \) to \( p \) [5].

FACTORY MODEL

In this section, we focus on three major things, the first, is the requirements functions of the proposed system, second, the model used to execute these function, third, determining factors used to distinguishing between the types of products.

1- ROLES TO ACHIEVE SIMULATION PROCESS

This model is designed to perform both purposes daily:

- Putting the lamps in the packet such that each packet contains twelve lamps. These lamps are verified before putting them in packets and assembles as packages.
- A daily reward is provided if one of the two conditions is achieved: the first condition is, if there is no defects in the production line. The second condition is, if the workers accomplished 50 packets of distance lamps per day, then the manager will pay the workers a daily reward.

2- PETRINET MODEL OF THE PROPOSED SYSTEM

Here is a Petri net model as shown in figure (2) for factory which produces lamps.

- \( P1 \): acts as condition place to determine whether the lamp is free of defects or not.
- \( P2 \): acts as a buffer.
- \( P3 \): acts as input signal to the inhibitor arc to control \( t6 \).
- \( P4 \): acts as a buffer, contains distinct lamps, and commercial lamps.
- \( P5 \): acts as input data (store) of packets.
- \( P6 \): has a conclusion whether the workers deserve a reward or not.
- \( t1 \): is a source transition to input the lamps of the factory in the Petri net model.
- \( t2 \): is enable and may fire when the lamp has no defect.
$t_3$: is enable and may fire when the lamp has any manufacturing defects.

$t_4$: is a threshold to verify the quality of the lamp.

$t_5$: is computation step, enable and may fire if $w(p4,t5) = 12$.

$t_6$: is connected with inhibitor arc, therefore $t_6$ is enable and may fire when there is no input signal in $p_3$.

$t_7$: is computation step, enable and may fire if $w(p5,t7) = 50$.

$T_{20}$: is computation step, enable and may fire if $w(p4,t_{20}) = 12$.

Figure 2: Petri net Model for Production line at lamps factory

3- THE FACTORS USED IN THRESHOLD

There are three factors were chosen to be used in lamps manufacturing in the proposed system.

- Handle force helix
- Thinness of glasses
- Color of glasses

The factors handle force helix, thinness of glasses and color of glasses are represented by the symbols $x_1, x_2$ and $x_3$ respectively.

There are two distinguishing groups to evaluate the quality of the lamps which are:
- Distinct lamps
- Commercial lamp

1- Distinct lamps: which is the first class industry
   The range of factors are as follows
   \[ 0.8 < x_1 \leq 1 \]
   \[ 0.7 < x_2 \leq 1 \]
   \[ 0.5 < x_3 \leq 1 \]
   \[ Y = 1 - (x_1 + x_2 + x_3) \]
   \[ \ldots \ldots \ldots \ldots \text{equation (1)} \]
   Where \( Y \) is the threshold of distinct group have the range \(-1 > Y \geq -2\), the member of distinct group, \( x_1, x_2 \) and \( x_3 \) are the handle force helix, thinness of glasses and color of glasses respectively.

2- Commercial lamps: which is the second class industry
   The range of factors are as follows
   \[ 0 < x_1 \leq 0.8 \]
   \[ 0 < x_2 \leq 0.7 \]
   \[ 0 < x_3 \leq 0.5 \]
   Apply equation 1 where \( Y \) is the threshold of commercial group have the range
   \[ 1 \geq Y \geq -1 \], the member of commercial group, \( x_1, x_2 \) and \( x_3 \) are the handle force helix, thinness of glasses and color of glasses respectively.

**SIMULATION FOR THE PETRI NET MODEL IN THE PRODUCTION LINE**

Figure (3) is illustrates the simulation for Petri net in the production line in the initial marking \( M_0 = (0, 0, 0, 0, 0, 0) \).
FACTORY MODEL ALGORITHM
Here is an algorithm which is used daily to assign the production line of the factory.
Begin of algorithm
for a day do
Begin (*for a day*)
packets =0; lampcounter =0; warddefect = false
Verify the lamp
If there is a defect then
warddefect is true
Else
Begin (** no defect in the product)
Read $x_1, x_2, x_3$
$Y = 1 - (x_1 + x_2 + x_3)$
If $-1 > Y \geq -2$ then

Figure 3: Petri Net Model of Production Line Simulation
Begin (** the product is distinct **)  
Add one to lampcounter  
Put the lamp in packet  
If lampcounter = 12 then begin  
Add one to packets  
Clear lampcounter  
End  
End (** the product is distinct **)  
(** The product is commercial **)  
End (** no defect in the product **)  
End (*for a day*)  
Print packets, warddefect  
End (*end of algorithm*)  
The outputs of this algorithm are used as inputs in award algorithm.

**AWARD ALGORITHM**  
Begin  
Read packets, warddefect.  
awarding1 = true; awarding2 = true;  
If warddefect is true then  
Awarding1 = false  
If packets < 50 then  
Awarding2 = false  
If awarding1 or awarding2 is true then  
(*put award in worker's accounts*)  
End.  
At the end of work time the algorithm above processed to determine if the workers deserve award or not.

**MATERIALS AND METHODS**  
In table (2), we give the three parameters redundant values in the ranges of both distinct and commercial groups as described in section (3). According to the result of Y parameter, it can be determined if this lamp is a distinct or commercial. The results as follows:
Table 2: Redundant Values of the Three Parameters to Apply Threshold

<table>
<thead>
<tr>
<th>X1</th>
<th>X2</th>
<th>X3</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>0.7</td>
<td>0.5</td>
<td>-1</td>
</tr>
<tr>
<td>0.5</td>
<td>0.6</td>
<td>0.4</td>
<td>-0.5</td>
</tr>
<tr>
<td>0.9</td>
<td>0.8</td>
<td>0.6</td>
<td>-1.3</td>
</tr>
<tr>
<td>1</td>
<td>0.9</td>
<td>0.7</td>
<td>-1.6</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-2</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The proposed model is a simulation of an industrial process which is affected by market factors, requirements and customer satisfaction. The ranges used for the factors is used to separate industrial lamps into two individual groups, so that, when the value of factors are increased within the range, the product is characterized as distinct lamp and when the value of factors are decreased within the range, the product is characterized as commercial lamp.

Petri nets are popular graphical modeling formalism that can help to ensure correctness and performance at design time. Petri nets theory has been widely used to implement a variety of modeling and evaluation tools. In future, we can use colored Petri net in the case study to enrich its power by associate weekly active machine, each day has special color as a stamp to compute 50 packet for each stamp color weekly. Here the system has to reset once weekly to compute the daily award for the workers. This will reduce the effect of repeating the daily routine of calculate award and to transform from daily to weekly job.

REFERENCES


