Intelligent system of coordination and control for manufacturing

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Abstract. This paper wants shaping an intelligent system monitoring and control, which leads to optimizing material and information flows of the company. The paper presents a model for tracking and control system using intelligent real. Production system proposed for simulation analysis provides the ability to track and control the process in real time. Using simulation models be understood: the influence of changes in system structure, commands influence on the general condition of the manufacturing process conditions influence the behavior of some system parameters. Practical character consists of tracking and real-time control of the technological process. It is based on modular systems analyzed using mathematical models, graphic-analytical sizing, configuration, optimization and simulation.

1. Introduction

Regarding production scheduling, is analyzed as an optimization process involved in allocating resources for limited production, is achieved through sequential activities.

By implementing intelligent manufacturing processes aims at increasing productivity with minimal staff involvement and implementation of process monitoring and control in real time, [5].

Intelligent systems are not exclusive to manufacturing systems. This is very difficult to achieve without using a dedicated algorithm and most times the computing time increases exponentially with the size of the problem. For this reason, use discrete event simulation systems modeled using Petri nets.

This paper uses the definition of Petri Nets type location / translation is of the form, [1] [2]:

\[ \sum = (P, T, F, W) \]  \hspace{1cm} (1)

The following descriptions and overviews:
- \( P, T \) are non-empty sets, with the property \( P \cap T = \emptyset \);
- \( F \subseteq (P \times T) \cup (T \times P) \) is the flow network, binary relation;
- \( W : F \rightarrow N \) of the network a share \( \sum (W(f)) \) - of the element a share \( (f) \).

This information should be considered for each subsystem modeling analysis.

2. Presentation of the System

Within manufacturing systems that are used the following types of handling systems:
- transfer linear automatic lines;
- conveyors;
- transfer pallets on machining centers;
- industrial robots for material handling.

Factors that influence the handling at all levels especially at the level of abstraction are [5]:
- amount of the material that can be small or large, continuous or discontinuous;
- the pace required by the material flow is determined by time, factor in establishing the architecture;
- the scheme material flow routes, aimed at the distribution, management and dispatching the materials transported;
- itineraries of transport, which defines each route of transport, including handling distance and time required.

The proposed system is relatively easy to use for detecting common problems that may occur, such as repair of processing equipment or varying times depending on the product.

The advantages of Petri nets modelling and analysis systems used in manufacturing are:
- explicit relationships between events;
- same modelling language can serve to describe abstract of the system on different levels;
- analysis of the properties of the system to validate the solution.

The transport system model can be assimilated to a discrete event system, forming a class of nonlinear dynamical systems and their use mathematical tools other than differential equations used in the theory and practice of automatically adjust.

For establish the total time of inactivity [5] of the equipment is based on the following considerations:
- is marked with I the total time from start the transition the first product on the equipment $M_1$ and end product equipment $M_p$, last the transition;
- establishing an arbitrary order crossing the products to all equipment;
- it is considered $X_{jq}$ the waiting between the end of product $P_{jq-1}$ the transition equipment $M_i$ and start to drive $M_i$ product the transition $P_{jq}$.

On the basis of the calculation to obtain the solution of the total time [6]:

$$ T = \sum_{r=1}^{n} A_{pr} + \sum_{r=1}^{n} X_{jr} \quad (2) $$

were $A_{pr} = t_{jr}$ it is time processing product $P_{jr}$ on equipment $M_p$. In view of the fact that the values for $A_{pr}$ are constants, for minimizing the time T function can be minimized:

$$ \sum_{r=1}^{n} X_{jr} \quad (3) $$

It is considered that the processing time of the product $P_{j1}$ on equipment $M_1$ is $A_{i1j1}$. On equipment $M_p$ the waiting time is given by the relation [6]:

$$ X_{j1}^{(p)} = A_{i1}^{(1)} + A_{j1}^{(2)} + A_{j1}^{(3)} + \ldots + A_{j1}^{(p-1)} \quad (4) $$

The waiting time $X_{j1}^{(2)}$, on equipment $M_2$, is calculated based on the relationship:

$$ X_{j1}^{(2)} = A_{i1}^{(1)} + A_{j1}^{(2)} - A_{j1}^{(2)} - X_{j1}^{(2)} \quad (5) $$

if

$$ A_{i1}^{(1)} + A_{j1}^{(2)} = A_{j1}^{(2)} + X_{j1}^{(2)} \quad \text{or} \quad X_{j1}^{(2)} = 0 $$

or

$$ A_{i1}^{(1)} + A_{j1}^{(2)} < A_{j1}^{(2)} + X_{j1}^{(2)} $$

For $M_p$ equipment the waiting time $X_{j2}^{(p)}$ is calculated based on the relationship [6]:

2
\[ X^{(p)}_{j_2} = A^{(i)}_{j_1} + A^{(i)}_{j_2} + \sum_{i=1}^{n-1} A^{(i)}_{j_2} - A^{(p)}_{j_1} - X^{(p)}_{j_1} \]  
(7)

if

\[ A^{(i)}_{j_1} + A^{(i)}_{j_2} + \sum_{i=1}^{n-1} A^{(i)}_{j_2} \geq A^{(p)}_{j_1} + X^{(p)}_{j_1}, \text{ or } X^{(p)}_{j_2} = 0 \]  
(8)

if \( A^{(i)}_{j_1} + A^{(i)}_{j_2} + \sum_{i=1}^{n-1} A^{(i)}_{j_2} < A^{(p)}_{j_1} + X^{(p)}_{j_1} \).

The above relations can write and form:

\[
\begin{align*}
X^{(2)}_{j_n} &= \max(\sum_{k=1}^{n-1} A^{(i)}_{j_k} - \sum_{k=1}^{n-1} A^{(2)}_{j_k} - \sum_{k=1}^{n-1} X^{(2)}_{j_k}, 0) \\
X^{(3)}_{j_n} &= \max(A^{(2)}_{j_n} + \sum_{k=1}^{n} A^{(i)}_{j_k} - \sum_{k=1}^{n} A^{(3)}_{j_k} - \sum_{k=1}^{n} X^{(3)}_{j_k}, 0) \\
&\vdots \\
X^{(p)}_{j_n} &= \max(\sum_{k=1}^{n} A^{(i)}_{j_k} + \sum_{k=1}^{n} A^{(i)}_{j_k} - \sum_{k=1}^{n} A^{(p)}_{j_k} - \sum_{k=1}^{n} X^{(p)}_{j_k}, 0)
\end{align*}
\]  
(9)

The total sum of idle time on \( M_p \) equipment noted \( X^{(p)} \) is:

\[
X^{(p)} = \max(A^{(i)}_{j_1} + A^{(2)}_{j_1} + \ldots + A^{(p-1)}_{j_1} + A^{(i)}_{j_2} + \sum_{i=1}^{n-1} A^{(i)}_{j_2} - A^{(p)}_{j_1} - X^{(p)}_{j_1}, \\
\sum_{k=1}^{n} A^{(i)}_{j_k} + \sum_{k=1}^{n} A^{(i)}_{j_k} - \sum_{k=1}^{n} A^{(p)}_{j_k} - \sum_{k=1}^{n} X^{(p)}_{j_k}, 0)
\]  
(10)

Analysing past relationships inactivity of the process technology, can process analytical interpretation of the whole technological process.

One gets:

\[
\sum_{r=1}^{n} X^{(p)}_{j_r} = \sum_{r=1}^{p} \sum_{l=1}^{n} X^{(i)}_{j_{l,r}}
\]  
(11)

The relationship represents waiting times as dependent relationships times working on machines.

The relationship has the minimum value when order processing is optimal, \( S: \left\{ P_{j_1}, P_{j_2}, \ldots, P_{j_m} \right\} \), [6].

\( D^{(p)}_u(S) \) total inactivity the time to machining work pieces in order \( S \), on equipment \( M_i \), defines the formula:

\[
D^{(p)}_u(S) = \max_{1 \leq r \leq S} \left( \sum_{r=1}^{n} \sum_{i=1}^{r-1} A^{(i)}_{j_{l,r}} - \sum_{r=1}^{n} \sum_{i=1}^{p} A^{(i)}_{j_{l,r}} \right)
\]  
(12)

\[
I^{(p)}_u = \sum_{r=1}^{n} \sum_{i=1}^{p} A^{(i)}_{j_{l,r}} - \sum_{r=1}^{n} \sum_{i=1}^{p} A^{(i)}_{j_{l,r}}
\]  
(13)

In this case the total inactivity times to processing may be expressed as follows:

\[
D^{(p)}_u(S) = \max_{1 \leq r \leq S} I^{(p)}_u
\]  
(14)

If we assume that is processed „n” on two types of products and choose any order products:

\[
S_i = \left\{ P_{j_1}, P_{j_2}, \ldots, P_{j_{k-1}}, P_{j_k}, \ldots, P_{j_m} \right\}
\]  
(15)
3. Architecture for intelligent control system

Is a line where the materials are manipulated using discrete entities for processing and assembly. The intelligent system is composed of discrete manufacturing systems, [2].

Intelligent completely is made up of:
- a set of flexible equipment;
- an automatic transmission;
- a sophisticated system of decision making both on transport and processing equipment.

Flexible the equipment’s have the ability to perform operations that are embedded in an automated system equipped with intelligent system processing program. The automatic transmission system is used to transport parts through intelligent activity to the next workstation.

System status is given by the total number of elements that are found at a given time in the system, the space is a lot of states.

It is considered flow line provided with asynchronous transfer system, some stations have the structure storage areas, others not. Storage spaces are determined by the processing time to the next stage. The preforms are inserted into workstations where they are processed and then transported at intervals measured in the factory, the following workstations.

Intelligent manufacturing control systems consist in using specialized programs, which are based on classical models of manufacturing for systems and where to get information about the behaviour of in different situations. The drawback is that its simulation results are obtained not accurate on the intelligent systems because systems are complex and require grouped activities ancillary which introduce unexpected errors from design stage.

The model presented is an interpretation of a set of cellule manufacturing system processes analysed. The processes are grouped based on their role and transportation systems.

For simulation used Pntool library of Matlab package. The simulation model chosen in Figure 1, consists of five processing centres. Handling is done with two robotic systems and transport conveyor belt. The processing 1 and 2 are coordinated robotic system 1. The processing 4 and 5 are coordinated robotic system 2. Between the two systems is positioned robotic processing system 3 where coordination is made with conveyor.

In preparing material for processing is arranged three rows warehouse management calling, checking materials resulting from the processing 1 and 2 and the intelligent positioning control, flow control and analysis.

In Figure 2 between the two robotic systems is a direct link, because the processing 3 is under repair because of defects detected by the intelligent control system.

In real applications, human operators may be replaced by semi-autonomous robots, as indicated in figure 1, 2.

The chosen system is grouped into three processes; these are the type of activity that takes place. Each of the three processes comprising the steps of: destination, process and momentum. For each process analysis with Petri nets it is important to determine the detailed analysis roles of. To define intelligent systems for each process is important and includes [3]:
- graphical analysis processes (detailed operation);
- incidence Matrix;
- analysis for the whole of the manufacturing invariants.

The results of simulations for figures 3 and 4 are relevant after more than 2.000 processing tracked and analyzed by intelligent control system.

To highlight diagrams in figures 4 and 5 must be analyzed variations that can occur and be identified following the analysis of intelligent control and monitoring system positioned between robotic systems in figure 2.
Robots have the capacity to maintain the network coverage for error detection and communication of information needed. Human errors that may appear have a significant influence on system reliability, sometimes more than technological failures. The research results indicate that the vast majority of industrial accidents are attributed to human error. According to the literature it is proposed a technique to design surveillance agents for the prevention of abnormal human operations. This control approach was applied on human-computer interactive systems. The control techniques which centralized oversight have been studied to overcome the inherent limitations of decentralized approaches, including lack of ability to provide fast and global solutions to be optimal.
4. Conclusions

The systems are used for drawing mathematical model, and the process under review.

Intelligent systems play an important role in the production of complex systems. Intelligent systems applications can create smart environments for increasing productivity.

Intelligent systems have an important contribution in improving control systems and manufacturing.

The graphical model is solved using:

- Non-timed Petri nets, where the use of tools available to provide information related to the mathematical model.

Pntool obtained using library tools development schedules while indicators Queue Length corresponding processing positions. It represents the current value by a continuous line and dashed line global value resulting from mediation between simulations.

Applying durations to the product manufacturing and journey times from measurement on site is obtaining charts that highlight the average lifetime of transport activity, but also the evolution of the average production based on the durations transport activities using as parameters batches of finished products.

Petri network as parameters are using the average value of the exponential distribution assigned position that shapes the transport availability. Obtained graphics on the evolution of the average time manufacturing, changes in the average length of employment of the machine is a graphical representation of the average transportation for individual carriers and plotting the average number of conveyor warehouse.

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