Aspects Regarding the Modeling of Intelligent Manufacturing Systems by Using Grafcet

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Abstract: - The implementing of a Flexible Manufacturing System in an integrate production system, represents an important result, which leads to the optimization of the entire material and informational flux of the enterprise. In this paper were developed management and control models of system in real-time, using artificial intelligence techniques. The simulation of the proposed manufacturing system using timed Grafcet provides the possibility to view the manufacturing process in time. Are described the applications of Grafcet to monitoring and control, knowledge-based applications. Aided by the simulation models designed one have studied: the influence of changes in the system structure on its behavior; influence of commands evolution and of system states on its output; influence of initial conditions or of some parameters on FMS behavior etc. Thus, we have been able to explore continuously ongoing operations, new operation procedures, decision rules, and information flows, material flows for the intelligent manufacturing system studied through simulation.

Key-Words: - intelligent manufacturing systems, modelling, discrete events, Grafcet

1 Introduction
The evolution of manufacturing systems has been motivated by two essential factors: productivity growth on the one hand and the growth of products types number which can be realised in the system (system flexibility), on the other hand. When the target is high automation degree in the domain of small and medium series products fabrication, there is necessary a compromise between the two contradictory requirements: high flexibility of equipment and productivity. A solution for this compromise is offered by the concept of flexible manufacturing system (FMS), which benefits from partial flexible automation. The notion of FMS is related to the new concept in manufacturing, which includes the components integration through the computer and flexible manufacturing. As it is stated in speciality literature, flexible manufacturing is represented nowadays by an area of dynamic research, which means a lot of research effort as “in the domain of mechanic technologies the future is represented by robotics, flexible automation and on this basis, technology is regarded as a system”, [2]. The concept of flexibility involves the complete study of manufacturing systems which can be performed only starting from the features of a complex system. The FMS concept represents a strong tool that maximizes and integrates automation on flexible cells, and a tool that designs Computer Integrated Manufacturing (CIM) oriented systems. The existence of asynchronous and concurrent events in a flexible manufacturing system made the number of modelling techniques of FMS to be reduced until now. Recent researches on the design and control of Flexible Manufacturing Systems were oriented towards the implementation of artificial intelligence (AI) techniques [1, 3, 4, 8]
These issues are receiving special attention from the artificial intelligence research community arising in a new, rich and rapidly expanding research area covering most of the aspects of manufacturing systems, such as intelligent product and process design, production planning and scheduling or systems engineering and architectures [5].

Graph theory is used successfully in flexible manufacturing systems optimization. It is useful in determining optimal trajectories of moving parts in the system and reliability FMS calculations.

In developing mathematical models were used concepts such as meshing, Petri Networks and theory of Grafcet and innovative concept of real-time modification of the production process [9]. PN graphically model: asynchronous / synchronous competing events, manufacturing processes, real time control systems, real time decision-making concepts. Pn can complement each other with modelling in closed network with queues. In addition to modelling and simulation of overall operation of flexible manufacturing systems, PN may also used in: modelling and simulation of FMS control; modelling and simulation handling within a FMS with generalized stochastic colored PN; modelling artificial intelligence (AI) by PN and Grafcet theory; modelling decision-making processes; modelling collision phenomena.

Grafcet and its international standard SFC (CEI/IEC 60848 revised in 2002) are used for the implementation of discrete events models for manufacturing systems and many programmable logic controllers use it as a programming language. The basic concepts of the grafcet are: the step, action, transition and its associated receptivity [5]. Therefore, the Grafcet notation and vocabulary were used to facilitate the understandability and the mapping between Grafcet models and the implemented software. As discrete event control is important and appears in many kinds of industries (manufacturing, automobile, chemistry, etc.), the pattern can be widely (re)used. When implemented, it is possible to achieve low level control, as well as supervision or fault diagnostics [6].

Actually Grafcet is becoming a means of communication between the developer and his customer, it is used as a tool for the specification of the sequence control systems. However one of the strong points of Grafcet is the easiness of passing from the model to the technological implementation thanks to the perfecting offered by the Grafcet. After being a language of specification, Grafcet becomes then a language of implementation of sequence control systems. One can speak today about: Grafcet according to an operational point of view, Grafcet according to a system point of view, Grafcet according to a sequence control point of view.

2 Sequential Function Charts

Sequential Function Charts (SFC) is a graphical language used to represent processes where a succession of steps can be identified. A SFC chart is a set of steps. Each step represents a well defined state of the process. Each step may be active or inactive. Transitions represent the conditions/events that move the activity from a step to another.

SFC should be used when you need to manage sequences of stable process states. Using SFC avoids complex switches and the declaration of multiple flags in programs. When you think: “when the process is in this situation…” then you should prefer the use of SFC.

2.1 SFC - Macro-steps

A macro step is a unique symbol that represents a group of steps and transitions in a chart. The body of the macro step is drawn separately in the same program. The body of a macro step must begin with a step and finish with a step and should have no links to the outside. Warning: a macro step is not a function intended to be instantiated several times.

In Figure 1 was represented: A: Main chart; B: Body of the macro-step; 1: Macro-step symbol; 2: “Begin” step; 3: “End” step.

A graphical language for depicting sequential is behaviour of a control system. It is used for defining control sequences that are time and event driven. This is an extremely effective graphical language for expressing both the high level sequential parts of a control program as well as programming low-level sequences, e.g. to program an interface to a device.

A high level textual language that encourages structured programming. It has a syntax that strongly resembles PASCAL and supports a wide
range of standard functions and operators. The
standard includes a formal syntax definition of ST is
presented in Figure 2 and Figure 3,[10].

```plaintext
IF Speed1 > 100.0 THEN
  FlowRate := 50.0 + OffsetA1;
ELSE
  FlowRate := 100.0;
  Steam := ON;
END_IF;
```

Fig. 2 Structured Text

A low level “assembler like” language that is based
on similar instruction list languages found in a wide
range of today’s PLCs.

```
LD R1
JMFC RESET
LD Press1
ST MaxPress
RESET:
LD 0
ST A043
```

Fig. 3 Instructions list

2.2 SFC – Application
Create a program that manages the mix of two
products in a tank with three parts (P).

```
1
bStart AND (Prod)
2
SP1:
Tank >= 20.0
3
GS3. T >= TH3a
4
SP2:
Tank >= 60.0
5
GS3. T >= TH3a
6
SP3:
Tank <= 0.0
104
GS104. T >= TH1a
```

Fig. 4 Sequential Function Charts. Application

- Wait for bStart value to be TRUE before starting.
- Note: P1: Fills the tank with Ingredient 1 P2: Fills
the tank with Ingredient 2 P3: Drains the tank

Solution of the problem is presented in Figure 4.

3 Grafset model to monitoring and
control of FMS

Real-time management systems primarily involves
the distribution to driving equipment of programs
necessary for accomplishment of activities assigned
by ordering, the execution of these programs, real-
time diagnostic equipment (locally) and monitoring
processes. The programs are usually automatically
generated for parts designing and they are stored in
specialized libraries. For FMS is used hierarchical
structure. At the lowest level is done real-time
management of equipment and transport system, as
the hierarchical level rise, the timeframe allocated
rise too, and frequency of control action decreases.
At the lower level is found not only computers, but
equipment CNC, PLC, e.a., for which must be
provided adequate equipment of communication and
data storage.

A major problem in the systems management is
storage and management of data necessary for each
level, [7]. Thus, these data can be grouped in two
categories:

a. Static data: NC software, fabrication task
(generalized references), generalized technological
sheet (group technology), production plans,
production capacities (number, type, placement);

b. Dynamic data: production diagrams, system
state variables, production capacities load and
current state. Interfaces of the management system
with driven equipment and human operators are part
of the management system. Management
implementing in real time involves a higher
difficulty degree because of information, operation
data complexity, heavy workload, and little work

time.

Therefore, distributed management architecture
is necessary, leading to advantages like: slight area
of interest at local level (cutting off data amount);
management system reliability increase, by its
reconfiguration. Another way to reduce work time
necessary to solve problems like diagnosis of
production process and authorizing is the use of
modern artificial intelligence techniques and
methods (fuzzy sets, neuronal networks).

3.1 Grafset model for real-time control

FMS management activities involve the existence of
two network types at the factory level:
informational network and fabrication activities network.

Cylindrical parts modularized system of manufacturing simulation has been designed, in general developing possibilities to change the technological flow according to essential elements: number and type of work stations and of machine-tools in the system; number and type of means of transport (conveyers) and transport speed; logistic subsystem type used; parts type, their technological stages; processing cycle time for each part type in each module of the flexible system; number of references simultaneously in process; fabrication series volume.

It were designed corresponding Graf-cet module, for example Figure 5 and Figure 6.

Transferring's Graf-cet from theoretical environment of graphical representation to the program module was carried out using the compiler Ladder, a modern programming language used in the study of FMS whose instructions are superior mathematical Boolean instructions (auto-tuning, loops) and better respond to problems arising in production planning processes.

Sequencing component states and their configuration was made through the discretization method. Logical associations made in a standard GUI environment, based on action and conditioning, was determined the system status. Each step was assigned a binary variable with values true and false logic based on active or inactive state of that step.
contacts and relays. A graphical language that is based on the relay ladder logic (a technique commonly used on current generation PLCs. However, the IEC Ladder Diagram language also allows the connection of user defined blocks and functions and so can be used in a hierarchical design.

3.2 Developed applications - software

Applications – software developed CCSV-1 – Control and Configuration of Technological Flow, MCIPPC-1 Application Soft – Monitoring, Control and Intervention in Cylindrical Parts Processing have been created out of the need to describe and study a real system behavior, for the future control and management of the system.

Aided by the simulation models designed one have studied:
- the influence of changes in the system structure on its behavior;
- influence of commands evolution and of system states on its output;
- influence of initial conditions or of some parameters on FMS behavior etc.

Thus, we have been able to explore continuously ongoing operations, new operation procedures, decision rules, and information flows, material flows etc. for the flexible manufacturing system studied through simulation.

It was designed and calibrated a data acquisition system through computer and sensors to make the driving process and feedback to optimize the design of flexible manufacturing system.

Applications development was based on OMRON software package which was used to build the program CCSV-1 - Technological flow control and configuration.

Compiler and interpreter Ladder is included in CX-Programmer application belonging OMRON software, used in making the source code from grafes to CCSV-1 program, used for the whole system that ensures the flow of manufacturing simulation (Figure 7) for cylindrical parts by PLC (Programmable Logic Controller). The command of the designed industrial system is maked by this computer (PLC) whose construction is based on a RISC (Reduced Instruction Set Computer) architecture. Microprocessor takes Ladder Logic instructions them submit to the entire system which is subordinated. Physical process and feedback control is performed using sensors and relays. That’s made: Testing of inputs (PLC scans input to establishing the state 0 or 1); The execution of the program (PLC executes a sequential program); Checking outputs (PLC check outputs); The cycle is repeated.

![Fig. 7 CCSV-1 program interface / CX-Programmer environment with the compiler Ladder open on screen](image)


114
4 Conclusion
The use of Grafcet for modeling and developing the proposed manufacturing system made it possible to create really flexible and reliable computer simulations. In developing mathematical models were used concepts such as meshing, Petri networks and theory of Grafcet and innovative concept of real-time modification of the production process.

By using Grafcet to model and study flexible manufacturing systems, it was possible to make system models that can be easily modified if needed. Also, from these models it was possible to developed computer simulation programs environment more easily and efficiently.

Grafcet, a standardized graphical language and a modeling tool that can be applied to describe the behaviors of discrete event systems, dynamic systems that evolve according to the asynchronous occurrence of events such as flexible manufacturing systems (FMS).

Benefits of using artificial intelligence such as Grafcet tools are:
• Provides a variety of languages for solving different types of industrial control problem.
• Encourages the development of quality software through well structured design, the use of encapsulation and information hiding.
• Its use will allow the same control software to be developed for different PLC products.
• Formalisation of re-usable software, especially function blocks should result in improving the productivity of system designers through the provision of off-the-shelf solutions.
• Programming tools are emerging that offer support for the complete PLC software life-cycle.

Further research will focus on developed applications to the construction and description of the Grafcet and software for simulation a dynamic system. The researches will be also extended in the domain of flexible manufacturing systems management and control in real and virtual environment. Will be developed aspects concerning programming with the aid of FMS virtual reality and it will open new directions of research, having as cumulative effect the decrease of the uncertainty degree which exists in the domain of flexible production.

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