A STOCHASTIC APPROACH FOR PERFORMANCE ANALYSIS OF PRODUCTION FLOWS

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Abstract: In our increasingly competitive world, today companies are implementing improvement strategies in every department and, in particular, in their manufacturing systems. This paper discusses the use of a global method based on a knowledge-based approach for the development of a software tool for modelling and analysis of production flows. This method will help promote the companies competitiveness by guaranteeing the efficiency of their production lines and, therefore, the quality and traceability of the manufactured products. Different kind of techniques will be used: graphic representation of the production, identification of specific behaviour, and research of correlations among events on the production line. Most of these techniques are based on statistical and probabilistic analyses. To carry on high level analyses, a stochastic approach will be used to identify specific behaviour with the aim of defining action plans, etc...

1 INTRODUCTION

The search for all the productivity sources makes necessary to improve the contemporary production systems. The production actors are, systematically and permanently, engaged in three stages: the audit, the diagnosis and the search for solutions to improve their production systems.

For the audit of production systems, recent Internet and Intranet technologies allow measuring and storing the state of the different production resources in real time.

From these data, and during the stage of analysis of production flows, the production personnel and the staff in charge must be able to find and formalize the problems inducing a faulty operation of the manufacturing system. Solutions must be imagined in order to increase the productivity at a given cost.

The stages of diagnosis and solution search are, nowadays, primarily instrumented by little formalized expert knowledge. This lack of formalism generates heavy development costs, does not guarantee reproducibility and does not support the necessary knowledge capitalization for the improvement of the production system within the same company. To solve these problems, a solution consists in formalizing the necessary knowledge to set and solve the problems related to that lack of productivity from the data collected during the audit stage. This formalization has to give birth to software tools for assisting the involved actors in a permanent and proactive way.

Several works have been carried out on the performance evaluation of unreliable production lines (Xie, 1993; Van Bracht, 1995; Tempelbeier et Burger, 2001). However, research on the simultaneous consideration of maintenance policies, production planning and quality improvement from an industrial point of view has still to be done.

Confronted with these industrial problems, there are two research lines. On the one hand, there is a great number of scientific works on the detailed modelling of production resources and activities. On the other hand, a much less developed research line is interested in the modelling of problem solving in production systems design. From these two work categories, our research group is interested in the understanding and modelling of the field experts reasoning during the stages of production flow analysis and solution searching and in automating this reasoning in order to bring proactive software assistance.

This article presents our approach for performance analysis of production flows. The approach is based on statistical and probabilistic

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methods and will be a new case of application of the stochastic approach (Le Goc et al., 2006). Section 2 presents the industrial context and describes the project. Section 3 presents the data graphical representation before setting the definition of phenomena in Section 4. Section 5 effectively presents the stochastic approch and finally, Section 6 states our conclusions and perspectives of future work.

2 THE INDUSTRIAL CONTEXT

This project is the result of the research collaboration between our laboratory and TECHNOVATION, a company specialized in the development and installation of applications that integrate the new information and communications technologies in industry.

2.1 The Project

Our project aims to define a global method based on a knowledge-based approach for the development of Pro@ctiF, a software prototype for the analysis of production flows, based on a TechnoFILER® solution already present at the customers' site (Zanni et al., 2007). This tool will allow the decision makers of the customer companies to have an analysis of their production lines flows. This analysis will consist in a general and by-workstation productivity evaluation, the main objective being the maximization of this productivity in terms of the number of produced parts in a given time window.

This diagnosis will be followed by an action plan for the improvement of the line, according to three criteria (quality, maintenance and yield) and a valorisation of the losses which could be avoided if the action plan was executed. The general idea is to maximize the productivity by improving the production cycle time and by reducing the workstations breakdowns / outages and the number of rejected parts.

2.2 The Indicators to be Measured

All the indicators to be measured come from the TechnoFILER® solution.

During the production stage, TechnoFILER® will detect if the part is good or bad and the times of:

- The arrival of the part to the workstation,
- The beginning of processing of the part,
- The end of processing of the part, and
- The exit of the part from the workstation.

In the case of a failure of a workstation, the indicators to be measured by TechnoFILER® are:

- The failure beginning time,
- The failure end time,
- The identification code of the failure.

TechnoFILER® will also provide other necessary information, in particular, the control parameters of the workstations, i.e., some workstation characteristics able to be measured by TechnoFILER® and which will be specific for each process plan, it will also provide maintenance data, information on production modifications, etc. The customer experts will have to decide which parameters to measure for each workstation, at the time of the modelling of their lines and processes, in order to obtain the more specific analysis. All these data are the input of the knowledge based system that we are building.

3 DATA GRAPHICAL REPRESENTATION

Data provided by TechnoFILER® can be analyzed with frequencies and sequential methods. Figure 1 presents a set of analysis which can be done.

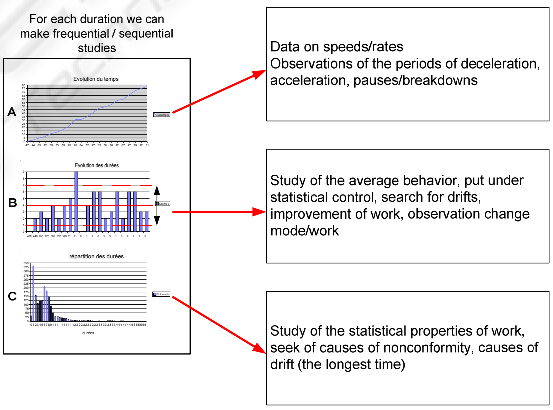

Figure 1: Graphical studies on data.

More precisely, studies of type A correspond to Poisson analysis. A Poisson process is a process of enumeration which describes the evolution of a "quantity" in time. In our study, it will be a question of tracing the evolution in time of durations (d1, d2,…). In the case of a perfect process, the Poisson curve is a line characterized by its slope λ (λ is a ratio number parts/time).

In real processes, we will observe various slopes which will make possible, for example, to determine the moments when the production is "faster", if there are moments of "tiredness", and to define ranges where the behaviour of the station requires a more thorough analysis.

Studies of type B are control charts derived from Statistical Process Control (Ishikawa, 1982). We trace the execution times of the tasks according to time. That will make possible to study possible drifts of the working station to check that the process is "under control", to identify the places where improvements could be made, to identify changes of rate/rhythm or raw materials, etc…

Studies of types C correspond to analysing properties of the distribution of duration. We trace the frequency of the durations to study the setting under statistical law of the station to consider.

From these curves a certain number of studies may be carried out: Study of dispersions, aberrant values, etc.

All these graphical representations of the production are a first method to have a better view of the reality, and to identify specific zones of bad behaviour or specific phenomena. It corresponds to the more specific level of abstraction. But to make better studies we need to build meta-data which will be associated to specific events or behaviours of the production that may indicate tiredness or lack of attention of the operators, for example. These behaviours can't be directly deduced from data.

A set of transformations has to be applied to obtain the expression of a certain behaviour under the form of a "phenomenon". The next section will define what we call a phenomenon before showing how we can compute phenomena from data.

4 PHENOMENA

A phenomenon is the expression of a particular behaviour which has a duration.

So a phenomenon will be described by a set of attributes, and at least (Le Goc, 2004):

- A name,
- A characterization of the location in the production line,
- Two dates:
  - A begin date
  - An end date

Therefore, we are able to build a sequence of phenomena, which contains more information than original data but lightest than original. Post analysis may be performed on each of these three sequences, by application of the stochastic approach in way to identify correlations which can exist between phenomena. Next subsection will show the method to determine phenomena from data on an example.

5 THE STOCHASTIC APPROACH: IDENTIFICATION OF FAULT MODELS

Once the log of phenomena obtained, new studies may be carried out.

New frequencies studies of the same type as described before may be made, but more especially we can carry out probabilistic studies, in order to identify if there exist correlations among phenomena, and the temporal constraints on these correlations.

The objective is to produce "fault models". These models may be used to perform real time diagnosis, but also to define action plans and corrections on the production line. Fault models will probably reveal implicit links among the workstations of the considered line.

With this objective in mind, we will apply the stochastic approach (Le Goc et al., 2006). This approach will permit the identification of sequential relations which can exist among phenomena and the computation of time constraints to label those sequential relations.

The stochastic approach is based on the representation of a sequence of discrete event classes in the dual forms of a homogeneous Markov chain and a superposition of Poisson processes.

The role of the BJT4S Algorithm (Le Goc et al., 2006) (BJT4S is the acronym of "Best Jump with Timed constraints For Signature") is to identify the most important sequential relations from the Markov chain model and to compute timed constraints on these relations from the Poisson process model. The union of sequential relations and timed constraints constitutes a "Signature"; it is an operational model of chronicle which anticipating ratio is equal to or higher than 50% (The anticipating ratio is a measure of quality of the model). A signature is a behavioural model representative of certain specific "situations".

The stochastic approach has been used to study the alarms or messages generated by a wide variety of systems like Sachem, for the diagnosis of blast furnace (Le Goc, 2004); Apache, for the diagnosis of a galvanization bath (Apache is a clone of Sachem) (Le Goc et al., 2006) or the supervision system of the production tools of the STMicroelectronics society (Benayadi et al., 2006).

In the context of Pro@ctif, we make the assumption that the stochastic approach will permit to define models like the one in Figure 2:

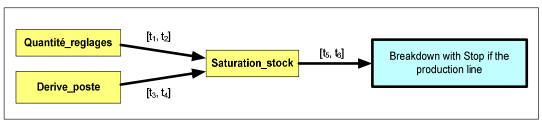

Figure 2 : Example of Breakdown Model.

This model may be read in the following way: If we observe an increase of the number of machine settings followed by a saturation of the stock in the time interval $[t_1, t_2]$, or if we observe a drift in the behaviour of the workstation followed by a saturation of the stock in the time interval $[t_3, t_4]$ then we have the risk to have a breakdown with the stop of the production line in the interval $[t_5, t_6]$.

The application of the stochastic approach corresponds to the generic level of analysis of our project. The stochastic approach produces behavioural models that, according to our experience, are realistic indeed and can be used to make prediction or diagnosis for example.

These models will be the base to the proposal of action plans to improve the performance of the production line in study.

They can also be used to make new studies, define new phenomena with high abstraction levels, etc. This phase will be described in more detail once the implementation of the algorithms for building phenomena will be achieved.

6 CONCLUSIONS

We have presented the results of our initial investigation into the application of knowledge-based techniques for the analysis of production flows.

To the best of these authors understanding, the reasoning on the number of produced parts and the recommendations according to the three criteria, quality, maintenance and yield, have not been fully addressed yet. Also, the generic vs. specific analysis approach will make the tool very flexible and available to use by the production staff on site (not necessarily at ease with other possible performance indicators) and decision makers.

We expect to detect, not only the evident causes of problems, such as breakdowns or outages; but also, more subtle aspects, such as fatigue or lack of training of an operator at a given workstation, and relations between phenomena with the use of the stochastic approach (Le Goc et al., 2006).

Today our works are mainly directed towards the knowledge acquisition stage at our industrial partner, an important automotive parts provider. We begin measuring the indicators described in section 3.1 for his production lines and we will be able, in the near future, to begin the validation of the knowledge bases we are building, and to progress into the definition of phenomena. These data will be used to implement the graphical tools and the algorithms for generation of phenomena (Zanni and Bouché, 2008).

This first step achieved we will apply a stochastic approach on logs of phenomena to obtain breakdown models and action plans.

Last step of the project will be the definition of a simulator used to compute the effects of the action plan, to search means to improve the production.

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