Grenoble INP – Génie Industriel

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MASTER Recherche 2ème année

Management, **I**nnovation, **T**echnologie

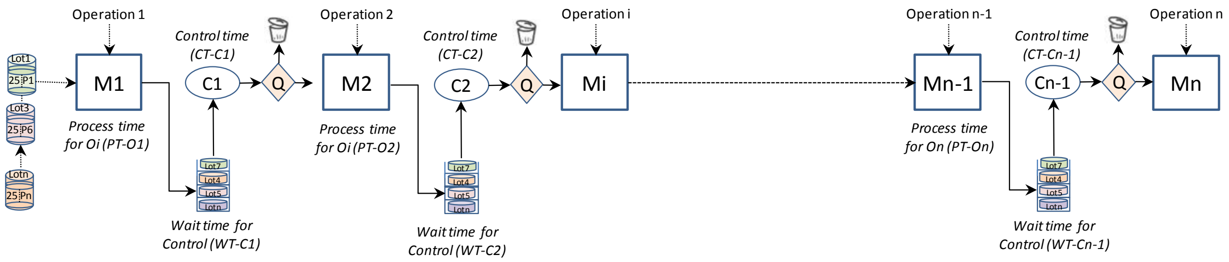
spécialité « **Génie industriel »**

Titre

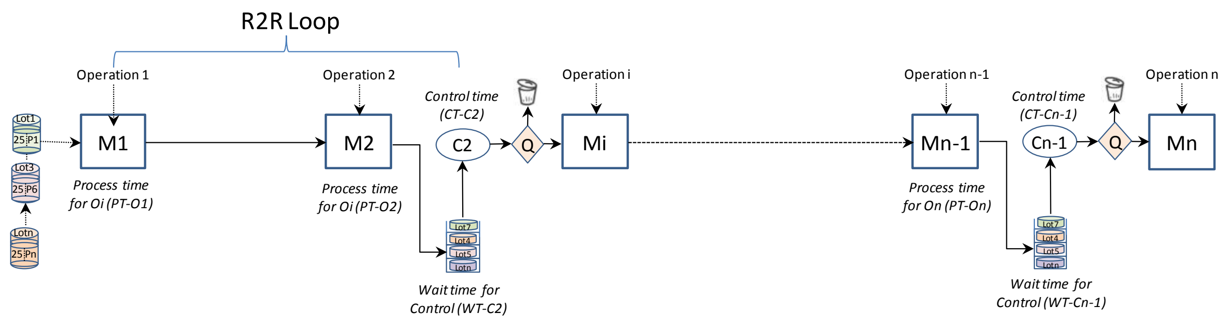
Optimize R2R (run to run) Loops to Reduce Cycle Time (CT) in Semiconductor Industry (SI)

Introduction:

The semiconductor industry (SI) is one of the most competitive and fragile manufacturing domain where increasing demand diversity and volume have resulted in a high-mix low-volume production with short product life cycles. The success in SI depends on our ability to reduce cycle time (CT) while ensuring product quality at reduced cost. In this competitive production line, more complex product designs with extended functionalities require rigorous controls during production steps that results in extended CT. This can be reduced by introducing R2R (run to run) loops where control on the product quality is carried out after multiple consecutive process steps. The problem context is presented in Figure 1 below. The Figure 1(a) depicts that, in semiconductor manufacturing, chips are fabricated on the silicon wafers of 300mm diameter. These are grouped in lots of 25 wafers of similar product and undergo 200+ operations with equal amount of metrology/inspection steps, in an ideal production line. The metrology/inspection capacity is low; therefore, we have a queue that adds waiting time followed by control time in the control machine. The cycle time for a product is the sum of all process times at each step, waiting time for each control and control time itself. This must be reduced to cope up with dynamically changing requirements of semiconductor production line.



(a) Semiconductor production line without R2R loop



(b) Semiconductor production line with R2R loop

Figure 1: Impact of R2R loops on CT of products in Semiconductor production line

Figure 1(b) presents the inclusion of R2R loops to reduce CT, while ensuring quality of the product. These loops are added only for the consecutive process steps where process drifts are minimum and is very well understood for the impact of variations on product quality. These loops can extend from two machines to many machines depending on our ability to master the process steps. The challenge with this approach is that once product quality drift is observed at the end of the R2R loop, we must quickly be able to localize the origin of the problem based on the monitoring of FDC sensors and other contextual and statistical information from production databases. The equipment is composed of multiple modules which are related to one another in parent child relation and have influence on the states of each other. So, as we increase number of equipment in R2R loop, problem to localize the origins along with causes diagnosis becomes huge in terms of workload of the computation. It is because of the fact that equipment sensor generate data at frequency of milliseconds and is installed with thousands of such sensors.

Existing approach:

(Nguyen et al., 2014a; Nguyen et al., 2014b; Nguyen et al., 2014c) have proposed a Bayesian based approach for diagnosis in the complex system with multiple failure sources. This diagnosis objective is first based on precisely and quickly locating faults that come from equipment and products (Duong et al., 2014). Moreover, it takes into account the different fault sources as recipes and human factors; and furthermore their correlations. This approach suits the context of complex manufacturing system that is characterized by multiple products, production lines, recipes and human factors e.g. SI where elements of system often change under flexible production activities. The proposed approach dynamically generates the structure of the BN and the associated probabilities. The Logical Diagnosis model (Eric and Deschamps, 2007) to significantly reduce the search space for suspect equipment in the given production flow. This reduced set of possible origins as directed graph provides the cause-consequent relation to simplify the failure model identification in learning phase of BN. In addition, the associated probabilities are computed by the BN model evaluate the suspect level of each member in the set of possible fault origins. This methodology has capacity to combine the advantages of both methods of Logical Diagnosis and BN. The proposed model dynamically locating the root causes, in less time and less workload to compute conditional probabilities. The diagnosis results support decision-making for corrective maintenance activities. The approach is presented below in Figure 2.

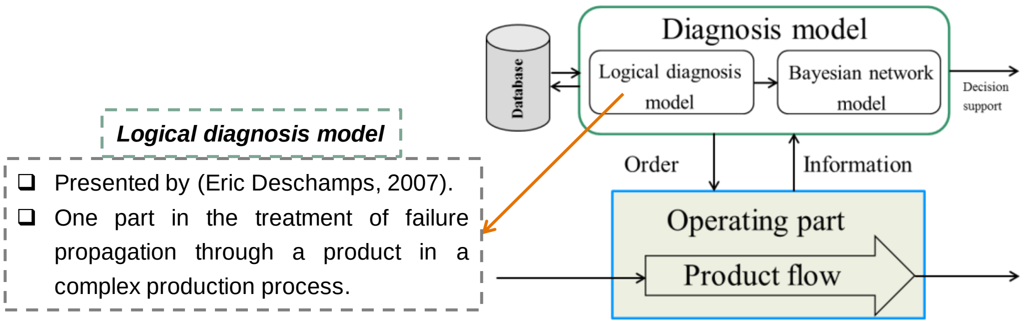


Figure 2: Bayesian based real time diagnosis in complex system

Problem context:

The semiconductor production line is presented in Figure 1 in its simplistic form; however, its more realistic representation is done in Figure 3, below. It can be seen that semiconductor production line follows a reentrant flow where same equipment is used multiple times for different process steps. Besides this, there are multiple types of equipment for similar process operations whereas each equipment can be used for multiple process operations. This situation results in a combinatory problem with huge workload as we increase the number of equipment in R2R loop. The objective of the semiconductor industry (SI) is to reduce the CT in order to be competitive while ensuring not only the product quality but to act quickly to diagnose the origin of problem equipment as well as likely causes. The computation time is highly critical when product quality is found as drifted and we are obliged to identify and localize the origins of problems. The objective is to quarantine this equipment so that it does not process any further lots until the equipment is fixed.

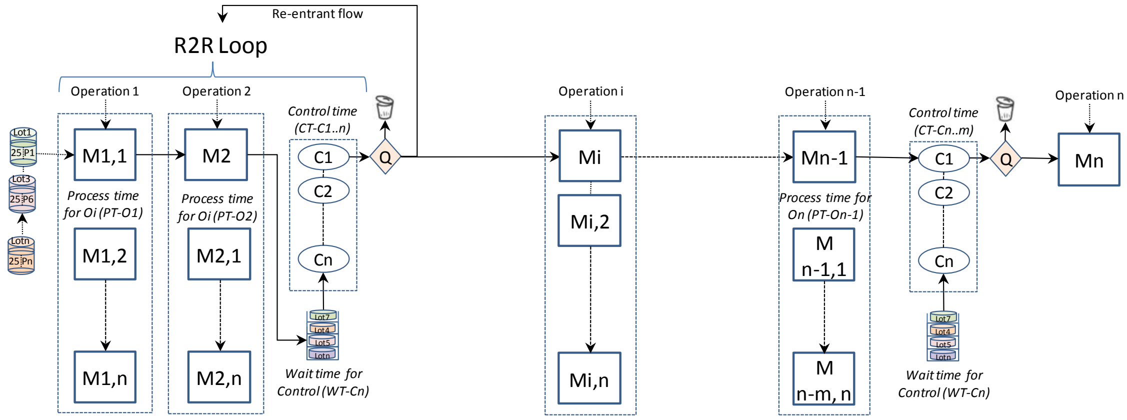


Figure 3: Complex semiconductor production line and R2R loop challenges

Awaited results from Internship:

This work is linked to the ongoing research for real time diagnosis in GCSP team at GSCOP. The awaited results are as under:

a) Develop an algorithm to compute time for learning of the logical diagnosis model (LDM) to reduce search space and Bayesian model for cause diagnosis, using real time databases (see Figure 4).
b) Use the developed LDM and Bayesian model to find optimal number of equipment in R2R loops (see Figure 4) and optimal number of R2R loops for a given product and technology.

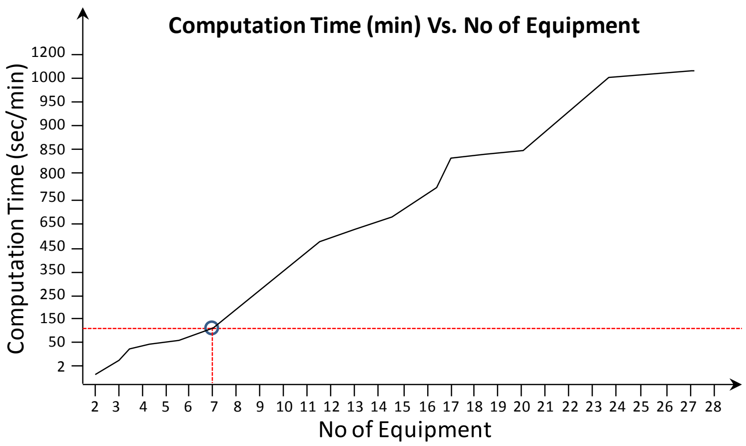


Figure 4: Computation Time for LDP + Bayesian Model against Equipment in R2R loop

c) Develop optimization algorithms (reduce computation time) in 'LDP + Bayesian' to extend the number of equipment in R2R loop and number of R2R loops with an objective to minimize the total number of R2R loops in the semiconductor production line, while minimizing the CT (see Figure 5).

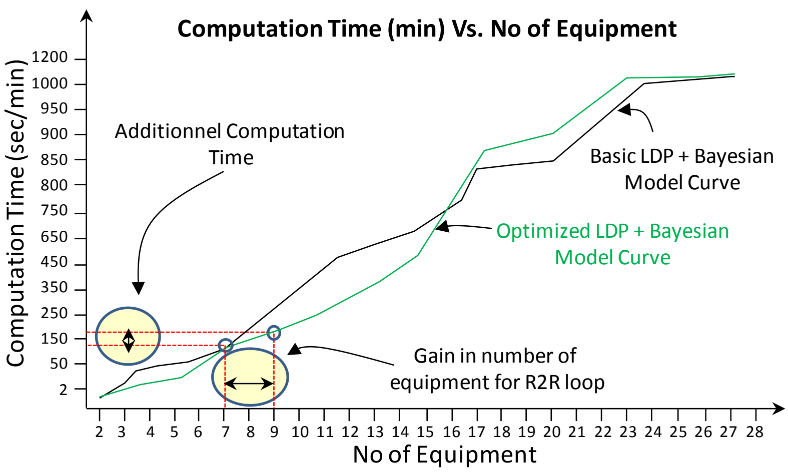


Figure 5: Gain in Equipment for R2R loop with Optimized LDP + Bayesian Model

Key References:

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