WHITE PAPER

SMART SCHEDULING TOOL

CASP S.A.

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EXECUTIVE SUMMARY

Maintenance tasks are an integral part of the manufacturing systems. They vary in complexity and require time and effort, thus leading to making the production resources unavailable for a significant period in time, while new customer orders keep arriving. For moderating this increase of the production downtime, there is a strong need in designing and implemented efficient solutions for integrated production and maintenance scheduling. This paper presents such a software solution for addressing the need of maintenance aware production scheduling and/or rescheduling taking into account the company's maintenance strategies as well as the machines remaining useful life gathered from monitoring and prediction components.

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INTRODUCTION

Intense global competition forces industries toward the maximal exploitation of their available resources, including personnel and equipment. However, the almost uninterrupted use of machine tools degrades their performances and leads to an increased insurgence of breakages and failures. In turn this leads to higher costs due both to machine tools unavailability and expensive repair interventions. The best solution to this problem would be to know at every time the real deterioration status of each piece of equipment. This knowledge would allow to select and schedule the best moment for maintenance, right before a component breaks or leads to unacceptable performance for the system it is part of. In addition, the definition of an advanced plant-wide integrated production and maintenance scheduling solution will determine substantial increases in economic performance and global competitiveness.

This paper presents a maintenance aware production scheduling approach implemented into a Smart Scheduling Tool which aims to retrieve the production data coming from company's ERP system as well as the maintenance data coming from external software tools regarding the resources' remaining useful life, their working hours and information regarding the optimal maintenance strategies. Through the proposed application, production and maintenance tasks will be automatically generated in order to produce a scheduling alternative that will include maintenance operations without disrupting the actual production. Section 2 includes the implementation, section 3 describes the interfacing with the ERP and other external tools, while section 4 describes the first prototype of the tool. In the last section, the business benefits and the future work are mentioned.

IMPLEMENTATION

For the implementation a web application has been developed. The application was developed using the Spring framework in Java. For the presentation layer Spring MVC alongside JSP, Javascript, ajax, CSS and Bootstrap technologies were used, adhering to the Material Design principles. For the data access layer Hibernate ORM has been used, with MySQL as underlying persistent storage. The interface services all are RESTful services with JSON formatted data.

Scheduling Algorithm

For the production scheduling a heuristic algorithm is used. The algorithm discretizes time into decision points (usually when a resource becomes idle), and at each decision point a number of alternatives are created and evaluated, which guides the algorithm to the next decision point until all tasks have been assigned to resources. The alternatives at each decision point are evaluated based on varying criteria: production task criteria such as time and cost, with maintenance related criteria on top of each production criterion - the latter has been implemented due to maintenance tasks needing specific evaluation. Each maintenance criterion evaluates the maintenance task at a specific point in time, taking into consideration the component RUL (Remaining Useful Life) and the component/resource criticality in the manufacturing process. These criteria values are normalized and an alternative utility value is generated taking into consideration the "weight" of each criterion. The algorithm chooses the alternative with the best utility value and continues to the next decision point.

The heuristic algorithm is governed by three parameters that affect the quality of the solution, as well as the performance of the algorithm in terms of time needed to find a suitable solution. These are the maximum number of alternatives at each decision point, the samples taken into consideration for evaluating the alternative, and the "decision horizon" parameter that controls how far into the future the algorithm should search for the generation of alternatives. These are set empirically in the begging of the installation, and, with a "trial and error" process, are fine tuned to fit each end user needs.

ERP Interfacing

An important functionality for commercial exploitation is that the system must be able to connect to end user's legacy systems, in order to automatically retrieve information regarding the production plan (what kind of products should be produced, at which quantities, and by what time), as this information is typically stored in each company's ERP system. Since there is not one single standard interfacing mechanism to connect to ERP systems, the reached compromise has been to create 'open' interfaces of the application, which can be used to connect to legacy ERP systems using secure data exchange standards, such as RESTful services over https exchanging information through neutral format models (JSON).

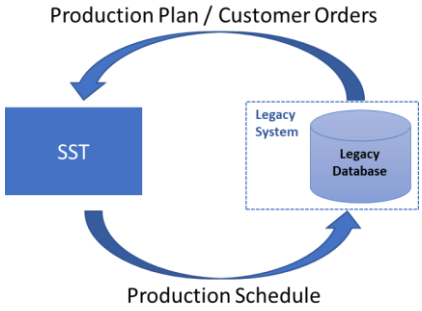

Figure 1: ERP Interfacing

The interfaces built for this are two-way ERP communication (Figure 1). First, the SST would require to get the production plan from the company ERP system, and then submit the generated production schedule. The information retrieved can be viewed and manipulated by the end user using the "Customer Orders" section of the Orders module. Then, after the schedule is created using the "Scheduling" section, it can be "persisted" and communicated back to the ERP system.

EXTERNAL INTERFACES

The Smart Scheduling Tool is developed in order to be easily integrated with external maintenance related modules. It obtains maintenance information in terms of optimized maintenance times from the Maintenance Strategy Optimization module, equipment RUL estimation (simulation and analytical) from the RUL calculation modules, monitored equipment signal data from the machine monitoring modules and accepts operator's requests for maintenance through the machine interface or the Maintenance Service Platform (MSP).

It can also provide the generated schedule as an output to whichever module is interested in it. The input and output flows are implemented as REST interfaces exchanging information in JSON format. An overview of the data exchange can be found at the table below.

Module	Input from SST	Output to SST
Maintenance optimization module (MSO)	Operator defined schedule	Optimized Maintenance Times KPIs of operator schedule
Maintenance Service Platform (MSP)	Scheduling of the proposed activities	Maintenance activities generated by a human operator
Machine monitoring tool		Machine usage times Robot usage times
RUL calculation modules		RUL values

PROTOTYPE

This section presents the first prototype of the Smart Scheduling Tool. First of all, the tool allows the user to view and edit the production data of the factory. The data are presented in the form of tables, while buttons for adding, editing and deleting each entry are also included.

The user is able to read, edit and delete the entities of the production line. This includes the workstations of the production line, the resources as well as the workload. Apart from viewing and editing the product types, it also allows the user to list the bill of process for each product type as well as editing the suitability for each process. This means that the user can define which resources are able to execute which process, also setting the time needed for the execution.

The maintenance tasks are displayed in a separate screen (Figure 2). This is a read only screen as the user can only view the maintenance tasks and their details (date, duration, recurring time) as these are coming from the external maintenance related tools and not being created manually by the users.

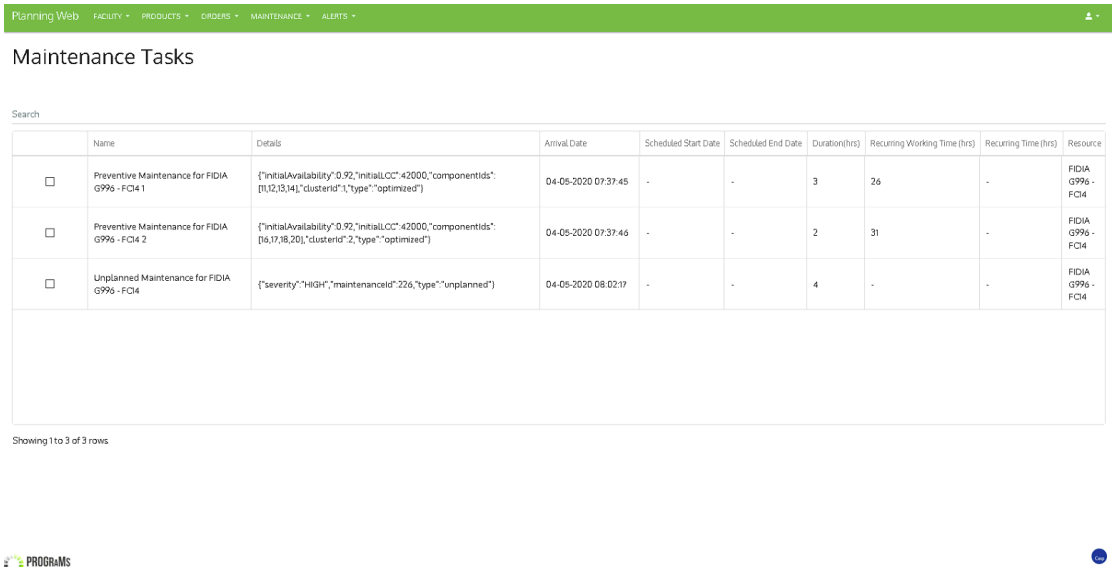

Figure 2: Maintenance tasks screen

The outcome of the SST is the integrated schedule (Figure 3). Pressing the 'Reschedule' button tool will automatically retrieve the production and maintenance data and feed the scheduling algorithm. After the algorithm returns the planning output, the production tasks (orange) as well

as the maintenance tasks (red) are displayed for every resource inside a Gantt chart. The KPIs of the generated schedule are also being automatically calculated and displayed to the user.

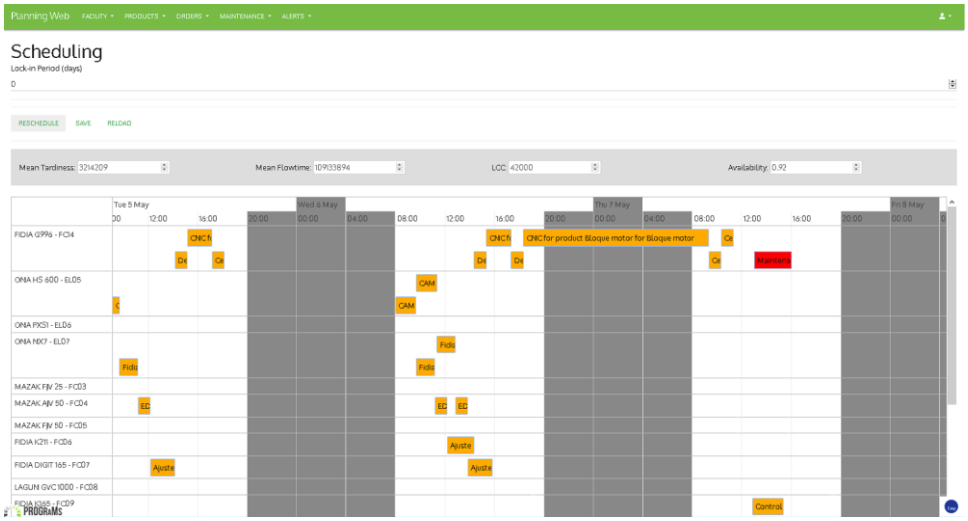

Figure 3: Scheduling screen

BUSINESS BENEFITS

There is no solution for planning, scheduling and rescheduling of production jobs, other than the rough, manual prioritization of the jobs in progress. Once a job is close to completion, or finished on a specific resource or department, a decision is made by senior engineers about which job is going to be processed next. Priority conflicts are daily resolved informally on a personal level or with short meetings of every stakeholder involved, while adaptations are being made constantly.

The automated scheduling of the production and maintenance tasks of a company allows the customer to:

- reduce the delays in orders delivery,
- maximize the utilization of resources,
- minimize the time spent in manual prioritizing and scheduling of tasks and
- satisfy company's maintenance policies

SST aims to minimize the time spent in non-added value activities by the engineers. There will be no need for manual scheduling of either production or maintenance tasks. Moreover, there will be no wasted time in learning the tool; the simple and friendly user interface will guide the user through the tool without any further training needed.

SST will make the life of the customers easier by decreasing any extra working hours spent on scheduling/rescheduling, maximizing machines' utilization by the effective scheduling of maintenance tasks and minimizing orders' delays and missing deadlines. Furthermore, the easy integration with any existing ERP system is a feature that will benefit the company in terms of time and cost. Apart from the aforementioned advantages, the heuristic way the SST uses in order to generate a solution allows the user to have an integrated production-maintenance schedule in a really short time in comparison to the existing solutions.

DISCUSSION AND CONCLUSIONS

The Smart Scheduling Tool first prototype is tested in terms of data exchanging with the external modules and in terms of actual generation of production and maintenance schedule. Further developments that are going to make the tool more ready for the market by applying parameterization and friendliness measures are ongoing. In the near future these developments will be implemented and included in the final prototype of the SST.

ACKNOWLEDGEMENTS

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