
pSci
from data
to knowledge
Marcin Zientara
Description of IT tool:
The Job Shop Scheduling Algorithm
Advanced Planning and Scheduling
AI4IN4
AI for INDUSTRY4.0
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Additional information

Substantive information and explanations regarding described IT tool are provided by Marcin Zientara Ph.D. marcin.zientara@psci.eu.

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I. Introduction

This brochure includes short information about IT tool offered by **pSci Marcin Zientara** company for a resolving and an optimization of the Job Shop Scheduling Problem.

The **Job Shop Scheduling Algorithm (JSSA**) is an IT tool designed to optimize tasks series on production / technology lines. The Algorithm solves the Job Shop Scheduling Problem against the given optimization criteria, based on data from MRP/ERP and MES systems. The Algorithm is the core of the system performing the functions of **APS (Advanced Planning and Scheduling)** class systems. The tool can be used both on production lines in factories and in office processes for optimizing of an work of RPA class systems.

II. About company

pSci Marcin Zientara is R&D company. Informal beginnings of the company date back to 2010 and in a formal way it has been operating since January 2015. The company was founded by a physicist, PhD Marcin Zientara, a long-term research worker of Polish and German scientific institutions. pSci creates advanced algorithms for analysis and modeling of data, phenomenon and processes. In the own work pSci applies Big Data, Artificial Intelligence and Data Science methods. The company products are the result of own R&D work and modern scientific knowledge in the field of physics, mathematics and related natural sciences (more details www.psci.eu/en/).

III. Description of the JSSA

The Job Shop Scheduling Algorithm (JSSA) is a set of original programming libraries that uses the genetic algorithm to optimize the production task series - it performs APS functions. It solves the problem of arranging and optimizing of the order queue for a system consisting of: N - executive stations, K - technological lines composed of the above-mentioned N stations, M - resource groups serving the above-mentioned N stations and L - SKU units implemented on K lines. To obtain optimal solutions, the Algorithm uses technological data describing production processes, including tables of task completion times at positions, matrices of conversion / reloading times, matrices of minimum and maximum inter-station transfer times, stations interchange matrices, competence matrices and tables characterizing time criteria for timely implementation of available tasks / orders. To optimal operation the Algorithm also requires delivery of calendars for the availability of stations and resources. As a result of the action, the Algorithm calculates the optimal precise plan of order execution, which contains detailed time schedules of all orders for all executive stations with the necessary resources assigned to their implementation - solves the problem of Job Shop Scheduling for a given production system. The Algorithm can be used both for current planning work and for simulation of plans to identify bottlenecks, the degree of utilization of production lines, providing information on current production capacity, etc. Thanks to the development of an original way of recording information about production plans in the genetic algorithm chromosomes, the analysis is simultaneously performed for entire network of connections in the production system and not individual for subsequent elements of this

structure. This approach allows you to get the maximum efficiency at the minimum cost. The JSSA functionality fits perfectly into the concept of Industry 4.0 and the Smart Factory.

The current form of the JSSA algorithm allows:

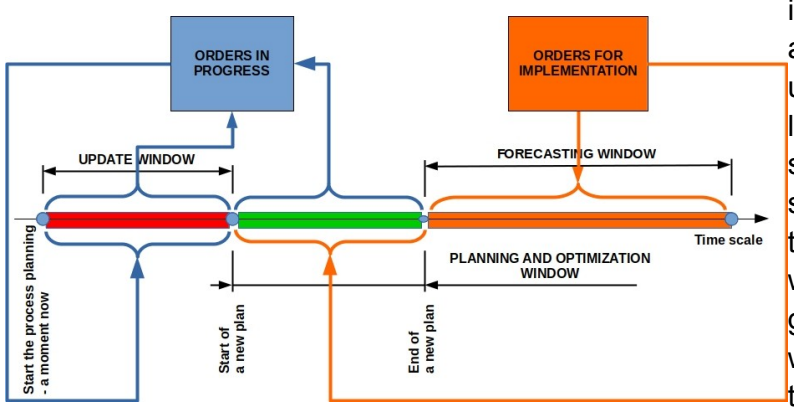
- generation of accurate production plans / activities for different time horizons - solution to the Job Shop Scheduling Problem;
- assessment of the current production capacity of individual SKUs and their transfer to interested factory operating cells - assessment of timely execution of orders (Capable to Promise);
- assessment and estimation of production delays;
- assessment of the amount of resources in time necessary to complete the portfolio of orders;
- OEE forecasting;
- analysis of bottlenecks of the production process;
- plan vs. performance evaluation execution;
- optimization functions for RPA systems.

Other functionalities of the Algorithm can be implemented by modifying the algorithm and the objective function.

IV. The Job Shop Scheduling Algorithm applications

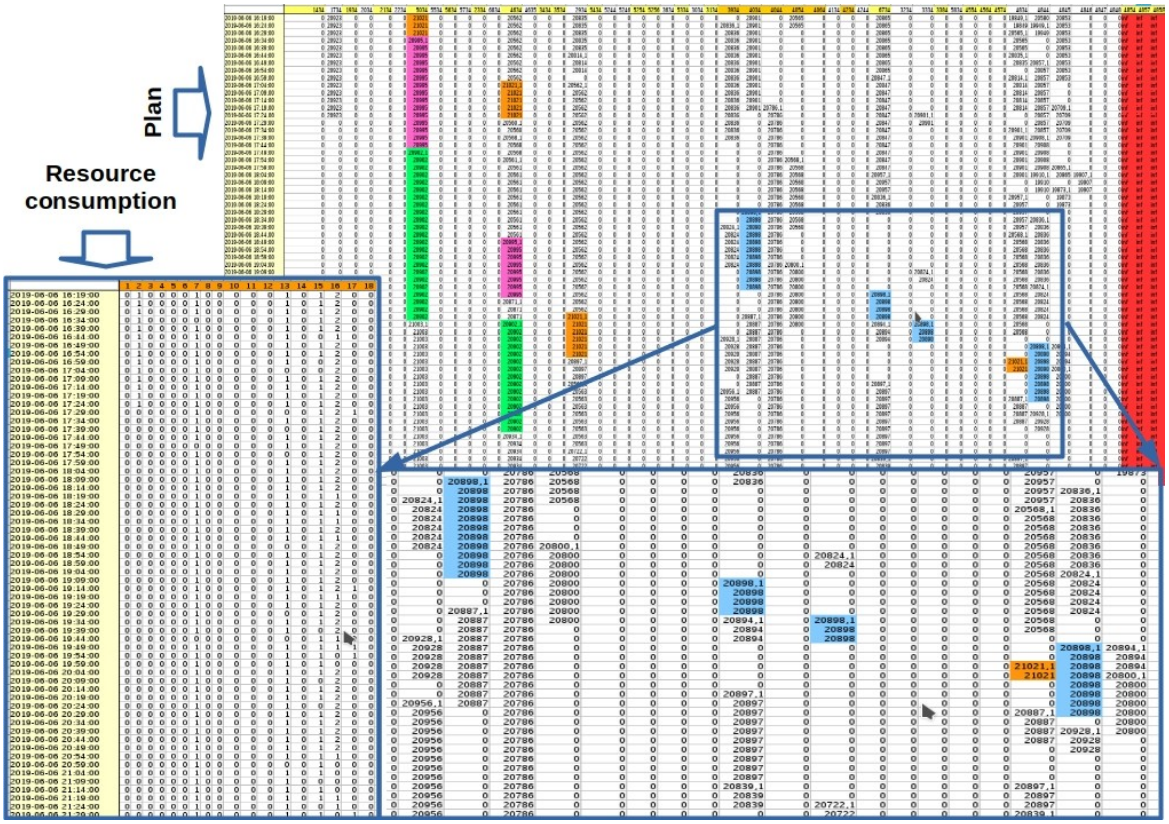
JSSA can be used in current operations to plan production and optimize the series of tasks as well as to analyze its production capacity with a given set of tools and resources.

In the first case, based on the JSSA algorithm, one can create a system that will generate and manage a production plan. On the basis of the input data provided to them, it will generate, refresh the plans with a given frequency, reacting each time to changing current and future production conditions - incoming new orders, emerging machine downtimes, resource constraints, etc. An example of the time schedule of such the system is presented in the drawing below. An operation of the system are divided into time windows in which subsequent situations appearing in the respective time windows are analyzed, optimized and simulated. In the first window, the so-called the update window the production plan being implemented now is currently analyzing and, if necessary, is updated with delays on the lines and unplanned shutdowns of machines. In the second window, the so-called the planning and optimization window, the new plan is generated and optimized, which will be implemented in this time interval for given production conditions - a set of tasks to be carried out in



Time schedule of operation of the planning and optimization system

this time interval, availability of stations and resources in this time interval. In the last time window, the forecasting window the preliminary plans for the remaining production orders, whose urgency does not require implementation in the optimization window, is generated. With such a set of plans, for subsequent time intervals, one can effectively manage production, react in advance to emerging critical situations, and effectively evaluate your production capacity, which allows you to increase the level of punctuality of your work in relation to the customer. The shown working diagram is just an example. A similar flowchart can be imagined for office applications and optimal use of RPA systems. Thanks to the versatility of JSSA and the open architecture of the system, it is adapted to the needs of the user with each implementation.



The result of the planning and optimization system – sample screenshots. Time axis is vertical and stations axis is horizontal.

In the second case, the JSSA algorithm and the related system can be used to simulate the loads of your production lines under given production and technological conditions, e.g. to optimize the set of your work stations and the resources support them, identify bottlenecks, forecast the theoretical value of the OEE indicator, assess timely delivery, etc.

Finally, it is worth emphasizing that such **tools as described here will be indispensable in the quickly era of personalized, short-series products, where the portfolio of existing orders will be characterized by diversity and high dynamics of change. Automatic, optimal planning of the series of carried out tasks will be necessary to effectively use modern means of production and to rationalize the costs of their operation both on the production line and in the office.**

Thanks to the flexible way of recording the Algorithm's chromosome and its logical structure, it can be easily adapted to the implementation of various other optimization sentences, extending its functionality and optimization criteria.

V. Who can use the JSSA

The JSSA Algorithm can be used by both manufacturing and service companies. Production companies can use it to perform the functions of advanced planning and scheduling ASP production tasks, while service companies (telecommunications, telemarketing) can use it to optimize their office processes or optimize the operation of RPA class systems.

This tool is particularly useful for companies implementing dynamically changing short-series production, performed on collated production lines (the need for frequent retooling) from their own park of executive stations.

VI. Input and output data of the JSSA

Input data to the JSSA:

- table characterizing the orders carried out: technology, technological times, delivery date, etc.;
- table of order completion dates: contains dates when a given order should be in a given position - if required;
- three-dimensional matrices of conversion / reloading time;
- three-dimensional time matrices of transition between stations for minimum and maximum times;
- interchangeability matrices of production stations;
- stations availability calendar;
- resources availability calendar;
- three-dimensional competence / resources matrix.

The basic result of JSSA's activity is the detailed plan of implementation of individual production tasks, written out for time and for the stations. This plan or family of plans provides the basis for further analysis to obtain useful data on the production process (see Chapters III and IV).

VII. The most important features of the JSSA

Main advantages of the JSSA:

- the ability to work in two modes: 1. ongoing production management; 2. simulation of production plans to estimate process parameters;
- the ability to integrate with local MRP/ERP systems;
- simple data structures necessary for the operation of the Algorithm;
- the ability to monitor relationships: plan vs. its implementation;
- the ability to run JSSA as a separate client application or in the cloud (recommended);

- possibility of cooperation with Maintenance Forecasting and Capacity Planning class systems and MES class systems;
- possibility of cooperation with Statistical Process Control class systems;
- open form of JSSA, in the form of computational libraries, allowing to provide a user interface in accordance with the needs of the customer - **the system adapts to the customer's needs and not the other way around**.

VIII. Algorithm implementation

The implementation of the system based on the JSSA Algorithm is done by connecting it specially created interface for data exchange with the local ERP. The system itself can operate both locally and in the cloud

IX. Tests of the JSSA

The Algorithm's practical tests were carried out in one of the medium-sized production plants characterized by high dynamics of order portfolio volatility.

The algorithm after integration with the local ERP system enabled the generation and optimization of production plans for different time horizons. The obtained plans allowed to identify bottlenecks of the production process, at the overall level and to manage resources more efficiently in order to implement production tasks and avoid / minimize delays

X. Summary

The JSSA Algorithm presented briefly above allows you to effectively plan and optimize production. Thanks to the flexible logical structure and the original and innovative recording of plans information, it can be easily adapted to various optimization tasks related to current production management as well as its quantitative and qualitative analysis. The system based on the JSSA Algorithm together with Maintenance Forecasting and Capacity Planning and Statistical Process Control systems is very effective tools for controlling the production process, both quantitative and qualitative.

By implementing our solution, you are able to solve current optimization problems as well as, what is very important, you will be prepared to solve problems that will occur in the future in the age of robotization and human-machine cooperation.

It should be remembered that the production task implementation plans generated by JSSA are model constructs that should be approached in everyday practice to achieve the assumed and calculated goals. Therefore, they should be treated as references allowing for rational and close to optimal production management and relationship control: plan vs. its implementation.

Created by *Marcin Zientara, Ph.D.*