Use of Simulation and Visualization in Multi Criteria Scheduling Optimization with Genetic Algorithms

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Abstract: An approach to the use of simulation and visualization of discrete event oriented simulation models for multi criteria scheduling optimization with genetic algorithms is described. A simulation model was used for fitness function computation of genetic algorithms' results as well as for visual representation of process behavior of the chosen schedule after genetic algorithm optimization. In this way, with the help of simulation and visualization, an additional verification of schedule's suitability was done on results of the optimization. Described methodology provides the planner with a quick and efficient scheduling method and enables them to experiment and decide which of suitable solutions will become the production plan.

Keywords: genetic algorithms, scheduling, optimization, simulation, visualization

1 Introduction

Most of the real life optimization and scheduling problems are too complex to be solved completely. Complexity of real life problems often exceeds the ability of classic methods [1]. In such cases decision-makers prepare and execute a set of scenarios on the simulation model and hope that at least one scenario will be good enough to be used as a production plan. A long time goal for scheduling optimization research has been to find an approach which will lead to quality solutions in a relatively short time.

Simulation is a strong interactive tool which helps decision-makers to improve efficiency of enterprise actions. Ability of simulation to show real process on the computer with consideration of uncertainty is a big advantage for analysis of system behavior in complex situations. In some situations system behavior can be accepted as optimal not just in the case of minimal make span, but also when risk of decision does not exceed defined point etc. In practice most of decision-makers pay attention to specific limitations (law, social, performance) of the system, which in the future can lead to unstable system behavior.

Development of decision-making methodologies is currently headed in the direction of simulation and search algorithms integration. That leads to a new approach, which successfully joins simulation and optimization. The proposed approach supports man-machine interaction in operational planning. A group of widely known meta-heuristic search algorithms are genetic algorithms (GA). With computer imitation of simplified and idealized evolution, an individual solution-chromosome represents a possible solution of our problem. Chromosome fitness is calculated with a fitness function. After evaluation with fitness function each chromosome in population receives its fitness value. Optimal fitness values depend on the problem. E.g. for a maximization problem the values should be maximal and for minimization problem they should be minimal. The final evolution step to be transferred from the world of biology to idealized evolution in the scheduling problem solving is data transfer from database to the GA computer program. Data are presented to GA in the form of chromosomes.

Although there is considerable work devoted to study of combining simulation and GA methodology, there is a lack of its application in practice, especially in small and medium-sized companies. The reason probably lies in the lack of suitable methodologies for knowledge transfer to enterprises, and not in the methodology itself [2].

The article describes the methodology and procedure of implementation of simulation and GA methods in solving the order-scheduling problem in order to improve the production operation planning. System behavior is studied on a discrete event simulation model, which helps understand the consequences of a chosen production plan. The system is based on the GA [3] for scheduling optimization and on discrete event simulation model built with the method of Petri nets [4].

2 Method

The discrete event simulation and genetic algorithms were used for multi criteria scheduling optimization

because of transparency and holistic approach. Scheduling optimization with GA and visual simulation are just parts of entire system, which should be in conjunction with complete enterprise activity. Figure 1 shows master data and information streams, which are needed for scheduling and decision support system implementation.

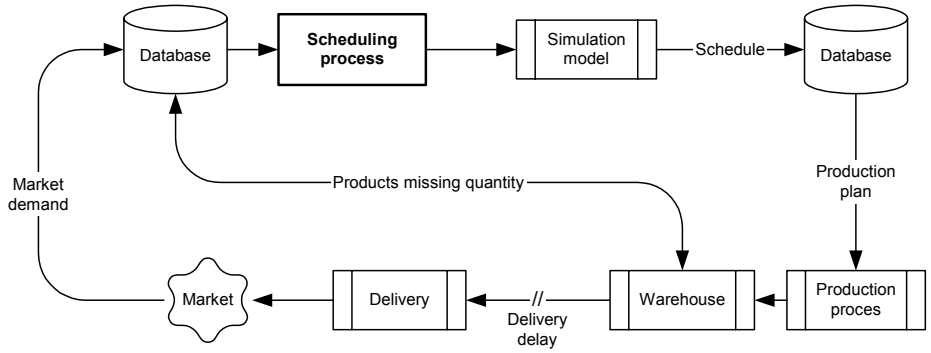

Fig. 1: Diagram of data and information streams for scheduling optimization

Market with its demand for chosen products or services launches processes in the enterprise, which represent market demands for production process. Required numbers of different products are stored as market demands in the database. According to market demands and quantity of different products in warehouse, the quantity of products to be produced is calculated. After that step, the planner prepares schedules according to the defined criteria. The most suitable schedule becomes production plan. Scheduling with GA and simulation is a complex process and is showed on Figure 2. Simulation of the real process is conducted in the GA scheduling process

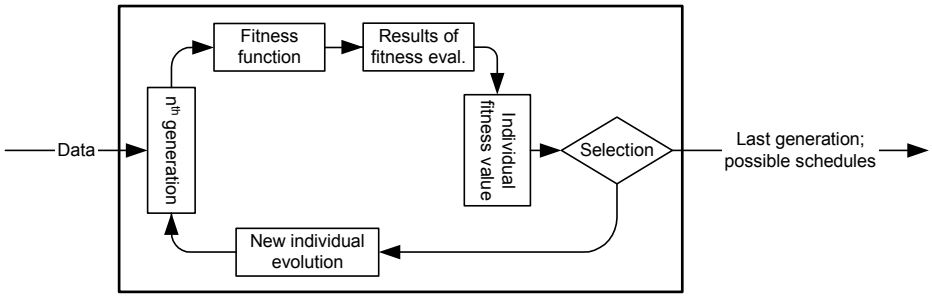

Fig. 2: Genetic algorithms and simulatio evaluation in the process of scheduling

and is used for fitness function. Each schedule represents possible schedule-production plan.

After completion of scheduling process most suitable production plans are simulated on the visual model of the system. With process animation using chosen parameters and according to defined criteria, the decision-maker is motivated to search for results which will have most advantageous influence to whole production process. The schedule which is selected after simulation on the visual simulation model becomes the production plan and is written to the database. That production plan will be completely carried out if there will be no urgent demands from market in the process of production plan execution. In the case of urgent demands from market, scheduling process with visual simulation is repeated. Newly selected production plan should fulfill urgent demands, as less important tasks are scheduled at a later point in time.

Programs for scheduling and visual simulation model are integrated into decision support system, so that planner can quickly and efficiently search through possible schedules. Figure 3 shows process of scheduling and decision making for production plan selection.

Simulation and visualization of possible schedules on the simulation model also helps to better understand the process and in that way contributes to quicker decision-maker response in the case of unpredictable events that influence the system.

2.1 Problem Definition

Due to increased demand for the products and higher quality requirements an enterprise has encountered the problem of production system utilization in some parts of the production process, especially of its main and most expensive parts. So, there are occasional bottlenecks which are mainly the result of unsuitable, "not good enough" production schedules. The enterprise's management decided that production planners and decision makers should be assisted in planning and schedules preparation with a system for scheduling optimization. With system's help they should be able to search for optimal scheduling of ordered parts into production process while spending a minimum amount of time and money. The system should consider all or at least most of process restrictions e.g. production capacity, quantity of materials on stock and products delivery time. Criteria used in this research project were: task priority, minimizing makespan, money spent for the process completion and finishing all jobs before the deadline. For the optimization of the complex stochastic systems, simulation models are often used as a form of

fitness function [5]. To consider all of the restrictions and criteria GA, the fitness function is represented in the form of discrete event simulation model.

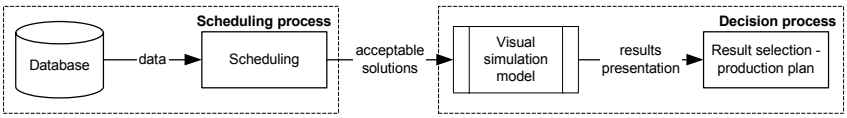

Fig. 3: Scheduling and decision process for production plan selection

2.2 Genetic Algorithms

Of all the evolutionary techniques, the GA are best known and widely spread. They have been used successfully to solve continuous functional optimization problems [6]. GA use operators of selection, crossover and mutation. They combine survival of the fittest in the series of structures with structured, but still random information exchange in the form of search algorithms [7]. GA represent solutions of the problem in the structures named chromosomes. In our case a chromosome is represented as a list of ordered products, which production should be scheduled according to prescribed criteria and restrictions in the production process. As stated before, simulation model was used for fitness function, so each chromosome gets its fitness value. Model of the process for evaluation of solution quality is often used in complex organizational processes where both randomness of the process and restrictions should be considered. So it is suitable to be used in production processes [2], logistics [8] and elsewhere.

From the database, data for scheduling optimization are prepared. GA program on the base of extracted data prepares a starting population of chromosomes. Each population has a limited, fixed size and is called a generation. With the help of fitness function, represented with simulation model, chromosomes in each population are evaluated. Selection of chromosomes is used to choose which chromosome from generation will survive to the next generation. Evolution on the survived chromosomes is executed according to the genetic operators such as crossover and mutation. So the new generation of chromosomes is evolved. Process of evolution is repeated as long as the stopping criteria are not satisfied. Last generation of chromosomes represents a number of suitable plans. Chromosomes with better fitness value are then simulated on visual simulation model. Planner can therefore choose the most appropriate – optimal plan. With visual simulation and optimization integration into the system for production planning decision support it is possible to decide easier and quicker, which plan is the most appropriate according to the current data.

The whole program for scheduling optimization with GA was developed with the C++ programming language. In the early stage of the research, fitness function was represented with the model, developed in simulation tool ExSpect. But it was quickly obvious that simulation time is too long for evolution with GA. Because of excessive length of evolution time, it was decided that fitness function implementation should be quicker. So the model was rewritten from ExSpect to C++. This way the model is implemented in the same language as GA, and the entire evolution of solutions has become very fast. ExSpect's simulation model is also used for visual simulation.

2.3 Visual Simulation

Simulation model with process visualization and animation is developed in applicative simulation software ExSpect [9]. ExSpect is a powerful business-modeling tool giving organizations the ability to model and analyze their business processes effectively and efficiently. With the support of ExSpect current and future business processes can be modeled and then subjected to computer analysis. This enables trying out "what-if" scenario's before introducing them into practice.

Visualization and animation of an ExSpect model is supported automatically. The animation offers planner facilities to follow its business processes in a step-by-step mode as well as a continuous simulation. To overview the performance of business process ExSpect offers a so-called dashboard. The dashboard is in fact both a dynamic report which updates itself on the fly and a medium in which planner can enter parameter values. The ExSpect dashboard shows information about studied business processes in a desired format. Simulation model (Figure 4) is used for animated simulation, which helps planners to figure out properties of each appropriate plan and helps them to find the best plan [10].

3 Results and Discussion

Research was conducted in a middle size factory which produces concrete goods, where the problem of scheduling to production process has occurred, and that lead to uneven utilization of production capacity, prolonged delivery time due to increasing demand in seasonal deviations. Performance of the process, which was described and discussed in details in [2], is studied on the described visual simulation model. In the first stage of research, simulation was conducted in ProModel simulation tool, but in the further research

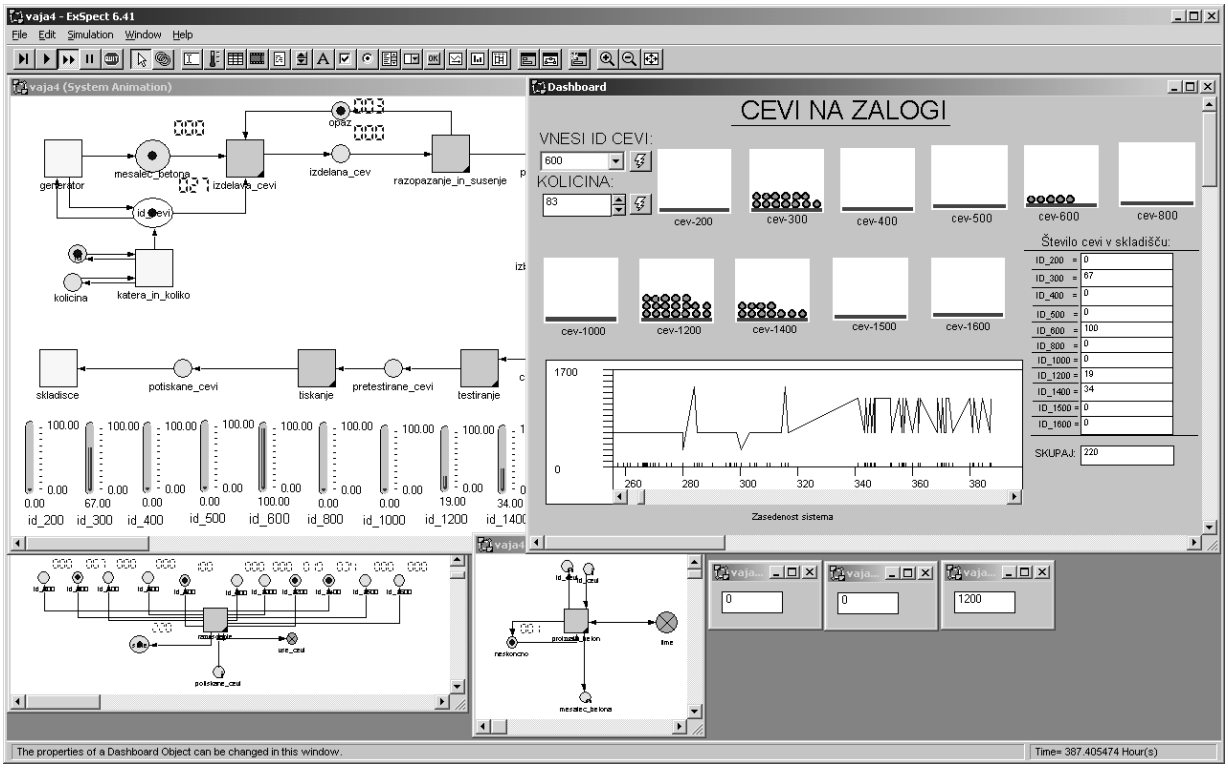

Fig. 4: Visual simulation of studied proces after scheduling optimization

model was developed in ExSpect because of its ability to analyze process with Petri nets. The system consists of scheduling optimization with GA and a discrete event simulation model in ExSpect, which hides model complexity behind visual and animated representation. Planner is therefore not focused on the process methodology but only on the searching of the most appropriate plan to fulfill system requirement, and that leads to better system operation. Visually represented production process on the simulation model and graphical representation of simulation results further simplify decision making in the search of "optimal" plan. By that way the better cognition of studied system should leads to optimal selection of the plan and to the best operation of production process.

After scheduling with GA, scheduling program shows most appropriate plans which have smallest (minimum) simulated times. In the last generation of evolution the scheduling program turned out three different possible schedules with the same fitness value (Table 1). All of them are candidates for production plan.

Results shows schedule of product order in individual plan according to the quantity in the database. Simulated times are the times from the simulated model, built into optimization program. From Table 1 it is clear that on the start and on the end of order in all plans are placed same products. That happens because of the restrictions and criteria for scheduling. For the collected results system behavior is observed on the simulated visual model according to the plan.

Simulation of the plan 1 from the Table 1 is shown on the Figure 4. After conducting visual simulation on all suitable plans, planers can also compare statistical results of simulation of each plan. Figures 5, 6 and 7 show statistical results (location utilization) for each plan from Table 1.

According to the observation of the visualized process and graphical representation of simulation results it is obvious, that according to different plans there are not big differences in the process. Regardless of the chosen schedule, the system functions well. In the case of bottlenecks or workstation overutilisation we chose a schedule that enables the system to operate more smoothly.

Based on the schedules and animated visual simulation results the decision-makers select a suitable

Table 1: Results of genetic algorithm scheduling

Plan:	Sim. time:	Products order in individual plan									
1	**6713.6**	400	300	1200	600	200	1400	800	1000	1600	1400A
2	**6713.6**	400	300	600	1200	800	1400	200	1000	1600	1400A
3	**6713.6**	400	300	600	1400	1000	1200	200	800	1600	1400A

system for implementation. The schedule selected, begins execution immediately and is followed through. In case of major changes in the system due to workstation failures, blocks or urgent orders, a part of the schedule is followed through, while a new schedule is developed with the new data.

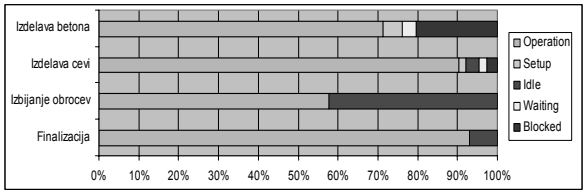

Fig. 5: Locations utilisation for plan 1

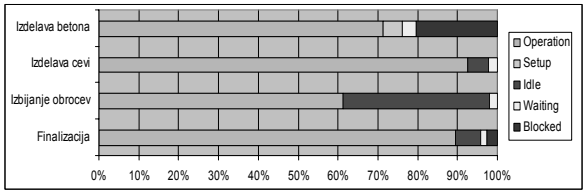

Fig. 6: Locations utilisation for plan 2

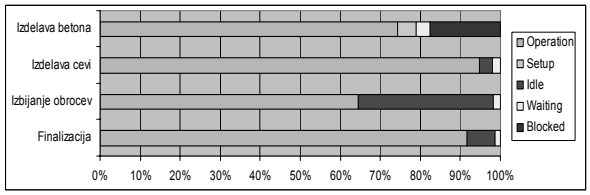

Fig. 7: Locations utilisation for plan 3

4 Conclusion

The methodology of multi criteria scheduling with genetic algorithms (GA) and its evaluation with visual simulation is described. Visual simulation model of the real process is designed by the method of Petri nets. Different schedules – possible plans, generated by GA are tested on the visual simulation model. System is connected to the corporate database, so the transfer of presented system to the real process is simple. After scheduling optimization, visual simulation model makes it possible to visually represent production process behavior according to different schedules.

Presented system can be easily used within modern e-commerce system on the global networks. The user doesn't have to delve in the methodology and can instead concentrate on the process operation. This leads to a better computer – decision-maker interaction. The model of scheduling algorithm and simulation coupling, providing visual system representation, shows actual system operation for the given schedule. In this way the decision-maker knows what to expect and can avoid possible problems or at least make precautions. Using visual simulation the planner verifies the influence of stochastic variables e.g. delivery deadlines, expenses and customer satisfaction on the system or system part operation. Using GA coupled with simulation is an important step in the development of a decision support system, that will enable the user – a planner – to quickly respond to changes in the system with a new schedule. The system described is used in the actual process as a scheduling decision support system and a stock reduction tools.

Acknowledgement

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