Proceedings of the 2012 Winter Simulation Conference
C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, eds

A FRAMEWORK TO SCHEDULE SURGERIES IN AN EYE HOSPITAL

Hanna Ewen, Lars Mönch

University of Hagen
Universitätsstraße 1
Hagen, Germany

ABSTRACT

This research is motivated by a scheduling problem found in a German eye hospital. We propose heuristics to schedule the daily surgeries. Our objective is to reduce the waiting time of the patients and to increase the utilization of the operating rooms (ORs). A Non-Dominated Sorting Genetic Algorithm II (NSGA-II) scheme with a random key representation is proposed to tackle this problem. The NSGA-II approach is hybridized with a local search procedure. Because of the stochastic surgery durations, discrete-event simulation is used to assess the fitness of the chromosomes. The schedules are executed using a simulation model of the eye hospital. Different rescheduling strategies are researched.

EXTENDED ABSTRACT

Given a set of patients and ORs, we are interested in assigning the patients to the ORs and in determining appointment times of the patients in such a way that the waiting time of the patients is small and the utilization of the ORs is high. In this research, we assume that decreasing the sum of the overtime of the staff and the amount of time where the ORs are not utilized for surgeries is a surrogate for increasing OR utilization. Clearly, the waiting time and the utilization measures are in conflict. A similar scheduling problem is considered by Gul et al. (2011). However, our scheduling approach is different with respect to the scheduling horizon and the modeled constraints. The researched scheduling problem is challenging because of the various real-world constraints, i.e., availability of the surgeons, anesthesia doctors, and nurses, different skills of doctors and nurses, and the stochastic duration of the surgeries. Furthermore, Erdogan and Denton (2011) and McKay (2011) identify the development of rules for reacting on deviations from the schedule on the day of surgery, i.e., rescheduling strategies, as a promising research area.

Because of the underlying randomness, a deterministic modeling approach is not appropriate. Therefore, we propose a framework based on stochastic discrete-event simulation. Simulation is used within the framework at two different places. On the one hand, simulation is required to solve the scheduling problem. On the other hand, simulation is used to execute selected Pareto-optimal schedules and study the performance of several rescheduling strategies.

The simulation model represents the base system and process of the eye hospital. It contains the process flow of the patients in the eye hospital that depends on type of surgery, anesthesia, and stay, i.e., inpatient vs. outpatient. Furthermore, it models the availability of surgeons, anesthesia doctors, nurses, and other resources and stochastic durations. The underlying probability distributions are derived from data of a German eye hospital. The simulation model is built using the C++ library SIM for discrete event simulation (see Bolier and Eliëns 1995) and is an extension of the model described by Reindl et al. (2009).

978-1-4673-4781-5/12/$31.00 ©2012 IEEE

The scheduling problem is solved by combining the NSGA-II approach, the simulation model, and a local search approach. A set of Pareto-optimal schedules is determined using NSGA-II. A random key representation (cf. Bean 1994) is used to encode the assignment and sequencing decisions. The appointment times of the patients are determined by hedging against the uncertainty of surgery durations. The simulation model is used to assess the fitness of the chromosomes within each generation of the NSGA-II approach. The number of independent simulation runs is increased until a predefined level of confidence is reached (cf. Gutjahr 2004 and Balaprakash et al. 2009). The objective values are computed as average over all simulation runs. All the chromosomes of the current Pareto frontier are improved by a local search scheme at the end of each generation. Here, a weighted objective function is considered in order to move the current Pareto frontier closer to the true Pareto frontier (cf. Deb and Goel 1993). The algorithm is coded using the C++ framework MOMHLIB (cf. Jaszkiewicz 2010).

A single Pareto-optimal schedule is chosen to be executed. At this point, simulation is used to present the behavior of the base system and base process. It allows for evaluating the schedule in a real-day scenario where no-shows and early or late patient arrivals further increase the variability in the system. Hence, the robustness und stability of the scheduling approach can be assessed. To react on deviations from the schedule, different rescheduling strategies are implemented and compared.

Results of extensive simulation experiments will be presented. The results show that the NSGA-II approach is able to outperform heuristics based on dispatching rules and that rescheduling strategies can be used to further increase the performance of the approach.

REFERENCES

Balaprakash, P., M. Birattari, T. Stützle, and M. Dorigo 2009. "Estimation-based Methaheuristics for the Probabilistic Traveling Salesman Problem." *Technical Report TR/IRIDA/2009-017*, IRIDA, Université Libre de Bruxelles, Brussels, Belgium.

Bean, J. C. 1994. "Genetic Algorithm and Random Keys for Sequencing and Optimization." *ORSA Journal of Computing*, 6(2), 154-160.

Bolier, D., and A. Eliëns 1995. "SIM: A C++ Library for Discrete Event Simulation." http://www.cs.vu.nl/~eliens/sim/sim_html/sim.html.

Deb, K., and T. Goel 2001. "A Hybrid Multi-Objective Evolutionary Approach to Engineering Shape Design." In *Proceedings of the First International Conference on Evolutionary Multi-Criterion Optimization*, LNCS 1993, 385-399.

Deb, K., A. Pratap, S. Agarwal, and T. Meyarivan 2002. "A Fast and Elitist Genetic Algorithm: NSGA-II." *IEEE Transactions on Evolutionary Computation*, 6(2), 182-197.

Erdogan, S. A., and B. T. Denton 2011. "Surgery Planning and Scheduling." *Wiley Encyclopedia of Operations Research and Management Science.*

Gul, S., B. T. Denton, J. W. Fowler, and T. Huschka 2011. "Bi-Criteria Scheduling of Surgical Services for an Outpatient Procedure Center." *Production and Operations Management*, 20(3), 406-417.

Gutjahr, W. J. 2004. "S-ACO: An Ant-Based Approach to Combinatorial Optimization Under Uncertainty." In *Proceedings of the 4th International Workshop on Ant Colony Optimization and Swarm Intelligence (ANTS 2004)*, LNCS 3172, 238-249.

Jaszkiewicz, A. 2010. "MOMHLIB++: Multiple Objective Metaheuristics Library in C++." http://home.gna.org/momh/index.html.

McKay, K. N. 2011. "Inter-Domain Translational Research on Planning and Scheduling: Operating Rooms vs. Job Shops." *International Journal of Planning and Scheduling*, 1(1), 42-57.

Reindl, S., L. Mönch, M. Mönch, and A. Scheider 2009. "Modeling and Simulation of Cataract Surgery Processes." In *Proceedings of the 2009 Winter Simulation Conference*, 1937-1945.