



A Discrete-Event and Agent-Based Hybrid Simulation
Approach for Solving the Patients Appointment Scheduling
Problem

by

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SUMMARY

Many countries around the world are facing an aging population problem, this is translated into more demand for healthcare services. This has resulted in a growing research interest directed to the healthcare sector. There are numerous issues and problems that healthcare providers face continuously due to the continuous increase in demand for healthcare services and the limited number of resources. Therefore, the proper use of resources is must. The patient appointment scheduling problem is an important problem in healthcare systems. An improper appointment system may result in long patient waiting times and inefficient utilization of resources.

Many operations research techniques were used to tackle healthcare systems' problems. Simulation modeling is one of the most familiar operations research techniques that were used in healthcare context. Simulation gained acceptance in the healthcare sector due to its capability of providing a visual interpretation, making few assumptions, and providing experimental results. There are three different simulation methods; discrete-event simulation, agent-based simulation and system dynamics. In addition, many attempts were done to hybridize/integrate several simulation methods.

In this thesis, first, a review of the literature discussing the use of the different simulation methods in healthcare applications is provided in order to identify the advantages and limitations of using individual simulation methods. Then, more focus is directed to the different hybrid simulation models that were reported in the literature adopting an integrated hierarchy, different integration formats, different software used and the integration challenges.

After that, three major approaches for integrating different simulation methods in a multi-methods simulation environment "AnyLogic[®]" are proposed. Then a general simulation framework for integrating discrete-event and agent-based simulation methods is proposed. The aim of the integration framework is to enable a realistic representation for the complexity of healthcare systems. There are two major elements in any healthcare system that have to be considered in order to obtain realistic models; the flows and queues concepts, and the human behaviors and interactions. The flows and queues are generally addressed using discrete-event simulation, while, the human behaviors and interactions are best represented using agent-based simulation.

In order to examine the feasibility of the proposed hybrid simulation approach and to illustrate its effectiveness, a real case study of a radiology center in Alexandria, Egypt was modeled using a hybrid discrete-event and agent-based simulation model. Data were collected from the center from different sources including the management information system, the video recording system as well as direct data recording and observation. A comprehensive data analysis was performed to identify the patient arrival patterns, patients' flows, different resources and activities, and the best fitting distribution functions that describe the different activities/processing time.

After the model validation, a simulation experiment was performed and different results and observations were deduced. Congestion and patients long waiting times in certain week days were the major problem reported in the case, in addition to the unbalanced utilization of the human resources. In order to overcome this problem, adopting a patient appointment system was proposed. The developed hybrid simulation model was used to examine numerous alternative scheduling scenarios. Three major performance measure were used for evaluating the proposed scenarios; the average patients waiting time, the average physicians utilization and the daily capacity of the facilities. Based on the evaluation of the different scenarios, a patient appointment system based on *individual-block/fixed-interval rule* has been recommended. According to the analysis results, adopting the recommended patient appointment system, significant improvement in patients waiting times and resources utilization may be achieved. The proposed system can reduce the average patient waiting time from 40 and 65 minutes in the examinations, follow-up, ultrasound imaging and mammography services facility, and, the minor operations service facility, respectively to 7 and 3 minutes only. Also, the average physicians' utilization which used to vary between 19% and 60%, can be balanced to be around a 75% average utilization.

The hybrid discrete-event and agent-based simulation approach enables better and applicable representation of the modeled systems. The human behaviors and interactions can be captured. Accurate resources utilization values can be obtained. Therefore, better improvement decisions can be taken.