A Simulation Knowledge Extraction-based Decision Support System for the Healthcare Emergency Department

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ABSTRACT

Nowadays, healthcare systems services have become a serious concern for many countries across the world. Due to its complexity and Variability the Emergency Department (ED) is considered the most critical unit of the hospital and the healthcare systems in general. Increasing the patient satisfaction, reducing as much as possible the patient’s waiting time and the patient’s length of stay, and optimizing the resources utilization are the overriding preoccupation for any ED manager. To support the performance enhancement in the ED, simulation studies have profusely been involved. In this paper the authors describe a decision support system based on the combination of a simulation and a temporal knowledge extraction model for the operation improvement of the emergency department in the public hospital Lakhdar Bouzidi in Bordj Bou Arreridj (Algeria). Their methodology points out how agent-based modeling simulation can benefit from data mining analysis methods to provide a powerful decision support system that can help managers to improve the functioning of the ED.

KEYWORDS

Agent-Based Modeling and Simulation, Data Mining Techniques, Decision Support System, Emergency Department, Temporal Knowledge Extraction

1. INTRODUCTION

Healthcare system is a sensitive and critical sector that has become a serious concern for most governments across the world. Accordingly, many researchers have become increasingly interested in modeling and improving the efficiency of such complex and dynamic systems. The efficiency of the healthcare systems has often been measured and related to the effectiveness of hospitals and their departments, more particularly the Emergency Department (ED), due to its complexity and variability compared to other hospital departments. Crowdedness, high demand (patient flow) for services, long waiting time and limited healthcare resources (doctors, nurses, equipment, space…) are the key problems that the emergency department managers must cope with. Furthermore, the emergency staff is required to adapt to those conditions and to provide a quick and appropriate care for all patients.

In order to improve the performance of the emergency department by reducing patients’ waiting time, decreasing the patients’ length of stay, optimizing the resources utilization, and increasing patients throughput (number of patient served), ED managers ought to have a good patient flow management and to find the optimal ED staff configurations. However, the unplanned and unpredictable nature of patients’ arrival hinders the managers to achieve this task. Hence, developing decision support systems
using computer simulation methods can be the best solution to anticipate and help ED managers choosing the adequate and efficient decision strategies and policies.

In recent years, simulation has profusely been used to model healthcare systems since it allows researchers to understand them better and analyze efficiently their functioning. Different simulation techniques have been presented in order to provide powerful systems that can help the managers to enhance the quality of services in the ED. A large portion of these studies have focused on the discrete event simulation (Evans, Gor, & Unger, 1996; Duguay & Chetouane, 2007; Konrad, et al., 2013) or the agent based modeling simulation (Cabrera, Taboada, Iglesias, Epelde, & Luque, 2012; Cabrera, Taboada, Iglesias, Epelde, & Luque, 2011; Jones & Evans, 2008).

Adopting simulation approaches facilitates the examination of different ‘‘what-if’’ scenarios and the evaluation of possible policies and changes in the system without making costly decisions and uncertain changes in the real one. Agent-based modeling is one of the most powerful simulation techniques that helps researchers to analyze a complex system such as the emergency department due to its ability to model systems close to the reality, to represent heterogeneous individuals and their interactions, to observe their behaviors and to understand their interrelations. In this paper, in addition to the choice of the multi-agent-based simulation model (programmable modeling environment Netlogo (Wilensky, 1999)), we used two data mining techniques (Pujari, 2001; Fayyad, Piatetsky-Shapiro, & Smyth, 1996; Hegland, 2001; Han, Kamber, & Pei, 2011) called respectively “preprocessing methods” and “linear regression”, to design a decision support system for the improving operation of the emergency department in the public hospital Lakhdar Bouzidi in Bordj Bou Arreridj (Algeria) and help the ED managers to enhance the quality of care provided. The first technique was used to process the simulation inputs and the second one to investigate the relationship between the patients’ arrival time and the acuity levels. Due to these latter techniques, we could find the optimal staff configurations and the simulation results showed that the average waiting time, the average length of stay and doctors’ utilization have been consequently, improved considerably.

The remainder of this paper is organized as follows; Section two focus on the simulation within the healthcare. Section three describes how the emergency department is functioning. In Section four, the phases of design and development of the proposed simulation model using data mining techniques are displayed. The proposed system verification and validation is presented in the fifth section, while the model results and discussion are given in section six. Finally, the paper is closed with the conclusion and prospects.

2. BACKGROUND

Many simulation studies have been touched on the different ways to enhance the quality of care in the emergency department. The authors in (Evans, Gor, & Unger, 1996) proposed a simulation model using Arena software package, the model developed investigated various schedules for nurses, doctors and ED technicians in order to reduce the average patient time in the system. A discrete event simulation study of an emergency department was described in (Duguay & Chetouane, 2007). To reduce waiting times, the methodology was based on considering physicians, nurses, and examination rooms as control variables and modeling and simulation were performed using Arena software. In (Konrad, et al., 2013) a discrete event simulation model was built to support process improvement in ED. The authors presented a split-flow process and evaluated the impact of different splitting patient flow configuration through the simulation on the patient length-of-stay and patient congestion in the ED. In order to help emergency department heads in setting up management guidelines to improve the operation of EDs a decision support system (DSS) for healthcare EDs using an agent-based modeling simulation was presented (Cabrera, Taboada, Iglesias, Epelde, & Luque, 2012; Cabrera, Taboada, Iglesias, Epelde, & Luque, 2011). To find out the optimal ED staff configuration the authors used Exhaustive Search (ES) optimization. The study presented in (Jones & Evans, 2008) developed an agent-based simulation tool using NetLogo software to evaluate the impact of various physician
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