Proceedings of the 2018 Winter Simulation Conference
M. Rabe, A.A. Juan, N. Mustafee, A. Skoogh, S. Jain, and B. Johansson, eds.

A HYBRID SYSTEMS APPROACH USING REAL-TIME DATA AND COMPUTER SIMULATION: A RESEARCH FRAMEWORK AND ITS IMPLEMENTATION IN THE CONTEXT OF URGENT AND EMERGENCY CARE

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ABSTRACT

Conventional simulations rely on historic data, but with the advent of technologies associated with business intelligence and data sciences, it is now possible to process and store an increasing volume and variety of data, including high-velocity and real-time data. With open architectures and standards for data sharing, this data is increasingly available for data-driven applications which may run, for example, prediction algorithms or visualizations. This study aims to investigate how real-time simulation can support short-term decision-making in urgent and emergency care. A hybrid systems modelling approach is proposed, which is the combined application of real time-data feeds, forecasting and simulation. This is encapsulated in a research framework, which proposes a step-by-step approach to inform the development of a real-time simulation. The framework is implemented through a case study that focuses on the urgent care network in Torbay and South Devon; it relies on the NHSquicker platform for real-time data feeds.

1 INTRODUCTION

Variability in demand for healthcare services leads to unbalanced utilization of resources and unpredictable demand surges. This is especially the case in emergency care, where clinical activities are necessarily adaptive hour-hour-hour, and overcrowding is the biggest problem facing emergency departments (ED). Conventional simulations are generally used for medium to long-term decision making, and rely on historic data. These are not accurate in the short-term in highly stochastic environments, and real-time simulation has been proposed as a solution to this problem (Bahrani et al. 2013). It has been extensively used in manufacturing and other industries to monitor and adjust the performance of a system in real time, and to react to correct deviations toward a critical situation as they occur, but has had limited application in the healthcare domain. With increasing quality and availability of data, standards for data sharing and increasing interest from health services in evidence-based operational support, the opportunity exists to use real-time data for visualization, prediction and real-time simulation to support SA and resultant decision-making. This gives operators the ability to react and adapt before a critical situation has unfolded. However it is also possible to forecast a future critical situation. In this case, the purpose of the real-time simulation is to prevent the critical condition, or at least to minimize its effects. It is proposed that a hybrid systems modelling approach combining forecasting with real-time simulation will improve situation awareness and earlier adaptive behavior, and reduce the risk of an escalation situation arising. The aim of this research is to evaluate a research framework and its implementation in the context of urgent and emergency care with an approach using real-time data feeds, forecasting and computer simulation.

2 METHODOLOGY

A framework is proposed which can be used to support the use of real time simulation studies in healthcare for short-term decision support. It maximizes the value that can be gained from real time data by using a range of analytic techniques to fully capture the problem situation as defined. The framework includes descriptive, diagnostic, predictive and prescriptive analytic components, and an evaluation component. The prescriptive component consists of the simulation model, which can be used to test pre-defined scenarios when a specified threshold is reached. The resultant changes to the real system will subsequently be reflected in the real-time data as it continues to be generated.

The framework is tested in a case study conducted at Torbay and South Devon NHS Foundation Trust ED. Real-time data is generated from NHSquicker (Mustafee et al. 2018), a platform delivering real-time wait time information from urgent care centers across the South-West of England. This data is available to the public, hence demand management may be co-occurring with capacity management. From the demand side, patients have access to the real-time data, and subsequently will have access to the predicted-time data. This is investigated using patient questionnaires to determine the degree to which real-time and predicted-time data constitute an element of decision-making about where to attend, establishing the need for the proposed methodology through potential users. This forms the 'diagnostic' component of the framework. From the NHS side, staff will have access to the forecasted data and the predicted-time simulation model. This will be evaluated with staff interviews using the critical decision method, which is a method for evaluating distributed situation awareness.

Predictions about overcrowding using data from NHSquicker will be made using seasonal ARIMA modelling. The purpose of the forecasting is that future information about queue length, or overcrowding, can be used to indicate the onset of a critical, or escalation, condition. Given advance notice from the forecasts, staff can use adaptive behaviors to attempt to control the potential future critical situation, and along with demand management this may be enough to stop the situation escalating. Alternatively, given a certain threshold, staff can make a decision based on a pre-defined set of discrete-event simulation scenarios from the Trust's emergency escalation policy to recover from this situation as quickly as possible. In other words, the recovery time is dependent upon the timing of detection and intervention.

The potential impact of the real-time model will be evaluated in terms of its contribution to distributed situation awareness (SA). Distributed SA is system knowledge held in both the human and technical components of a system which supports short-term decision-making and system resilience. Staff interviews will be conducted using the critical decision method. This approach examines how decision makers deal with uncertain situations under time pressure and with high stakes. This is done using semi-structured interviews, and the aim is to evaluate to what degree the information that can be provided by a real-time and predicted-time simulation can contribute to distributed SA. This aims to support more accurate short-term decision making and adaptive behavior to reduce the likelihood of a critical incident given more system knowledge. The expected contribution of this research is the research framework and the application of real-time simulation in healthcare. It also aims to contribute to debates on the value of hybrid simulation approaches, combining simulation with other analytics methods.

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