Simulation Modelling Practice and Theory 86 (2018) 139–154

Contents lists available at ScienceDirect

Simulation Modelling Practice and Theory

journal homepage: www.elsevier.com/locate/simpat

Implementing complex task allocation in a cytology lab via HCCM using Flexsim HC

Kanokporn Pongjetanapong[*,a], Michael O'Sullivan[b], Cameron Walker[c], Nikolaus Furian[d]

[a] Department of Engineering science, University of Auckland, New Zealand Uniservices house, 70 Symonds Street - Bldg 439, Level 3, Room 325, Auckland 1010, New Zealand
[b] Department of Engineering science, University of Auckland, New Zealand Uniservices house, 70 Symonds Street - Bldg 439, Level 3, Room 331, Auckland 1010, New Zealand
[c] Department of Engineering science, University of Auckland, New Zealand Uniservices house, 70 Symonds Street - Bldg 439, Level 3, Room 333, Auckland 1010, New Zealand
[d] Institute of Engineering and Business Informatics, Graz University of Technology, Austria

ARTICLE INFO

Keywords:
Discrete-event simulation
Conceptual modelling
Cytology
Workflow

ABSTRACT

Healthcare processes contain various complexities which make them difficult to model. These include: multiple-participant activities with flexible resourcing; dynamic task priorities; hierarchical skill levels of resources; and regular task pre-emption. Deciding which task in a care pathway a clinician next performs directly impacts on the performance of the healthcare process. The Hierarchical Control Conceptual Modeling (HCCM) approach has recently been proposed by Furian et al. [1] to provide a conceptual modelling framework purpose-built to explicitly model the decision-making structure in complex systems. Existing software packages for Discrete Event Simulation (DES) have been designed for conceptual models that consist of systems of queues. In particular, the lack of a module specifically designed to account for HCCM's control structure makes the implementation of a HCCM conceptual model in an off-the-shelf simulation package problematic. This research applies the HCCM framework to a real-world Cytology lab (with complex decision making for task allocations) and demonstrates how the resultant conceptual model can be implemented within an off-the-shelf healthcare simulation package (Flexsim HC). The primary goal is a proof-of-concept that the control mechanism, particular to the HCCM framework, can be implemented using such a simulation package.

1. Introduction

Healthcare processes are complex and difficult to model. The complexity includes: the utilization of multiple resources to carry out a task; a priority structure among competing task requests that can vary through time; the blurring of roles as staff can act as either a resource or a consumer or both; the pre-emption of tasks; and resources with multiple skill levels. Existing conceptual modelling frameworks for discrete-event simulation (DES), see for example [2–8], have not been designed to incorporate the complexity of healthcare systems. They arise primarily from applications in business [8] or the military [6]. Hay et al. [9] have identified the need for modelling control processes with mechanisms admitting greater complexity than common queueing methods if healthcare simulation models are to represent the true system with more accuracy. To address this modelling short-coming, Furian

* Corresponding author.
E-mail addresses: kpon157@aucklanduni.ac.nz (K. Pongjetanapong), michael.osullivan@auckland.ac.nz (M. O'Sullivan), nikolaus.furian@tugraz.at (N. Furian).

https://doi.org/10.1016/j.simpat.2018.05.007
Received 2 January 2018; Received in revised form 7 May 2018; Accepted 8 May 2018
Available online 24 May 2018
1569-190X/ © 2018 Elsevier B.V. All rights reserved.

et al. [1] describes a Hierarchical Control Conceptual Modeling (HCCM) approach that incorporates explicitly the control structure in its description, and centralizes all system logic within control units, as opposed to embedding this within queue protocols. This centralized control structure removes the requirement of assigning roles to entities a priori, and so enables the roles of entities in activities to be assigned dynamically. Furian et al. [1] demonstrated the application of the HCCM framework using the tugboat example of Arbez and Birta [7], and Golzapoor et al. [10] apply the framework to a construction industry example. The HCCM framework is well suited to modelling the complex control structure of task allocation within healthcare processes, and so we demonstrate here its application to model the workflow of pathologists in a Cytology lab. This research was motivated by the goal of developing a simulation tool able to evaluate whether given staffing rosters working under particular control policies can meet government performance targets. Such targets are used in many countries besides New Zealand, such as Canada [11] and the United Kingdom [12], and tend to be linked to government funding. The targets are often in terms of quantiles–for example, the turn-around target for cytology reports in New Zealand is 90% within 7 working days and 100% within 14 working days – and so a simulation approach is required, rather than a basic workload analysis using averages. The tool we developed has been used to investigate the relationship between staffing levels (and the properties of the roster) on the turn-around times for the Gynae and Non-Gynae samples analysed by the lab. The findings of that investigation is the subject of a non-technical paper [13].

The process by which tasks are allocated to, and prioritised by, pathologists is not straight-forward. By explicitly modelling the control process, HCCM provides transparency in the decision-making, giving confidence to the stakeholders that the allocation process reflects the real world. One potential difficulty arising from this new approach, however, is model implementation. Although it is feasible to develop a bespoke simulation from the conceptual model directly (see for example [14]), the main aim of the research presented here is to demonstrate that explicit modelling of the control structure is possible in an implementation using an off-the-shelf healthcare simulation package. Such packages have not been built with the HCCM framework in mind, but we implement a conceptual model of this type using an off-the-shelf package with minor modifications. This direct translation of the control process to a single module within the implemented simulation model maintains the transparency of its logic, and hence the stakeholders' confidence in its accuracy. This also means that any changes to the decision making process in the conceptual model can easily be transferred to the simulation model.

The focus of this paper is on the modelling of the Cytology lab's processes within the HCCM framework, and the implementation of the resulting conceptual model using off-the-shelf healthcare simulation software. In the following sections, we present the conceptual model for the pathologist workloads within a Cytology lab, and explain how we then implemented this model in FlexSim HC,[1] a simulation tool designed specifically for healthcare simulation. We also use this implementation to calibrate the model against the historical data, implementing a priority accumulation scheme [15] to best match the limited calibration data available. The outline of the paper is as follows. The following section discusses conceptual modelling for discrete event simulation. In Section 3, we describe the Cytology department and objectives of the model. In Section 4, we discuss the concept of dynamic priority and priority accumulation. In Section 5, we apply the HCCM framework to the modelling of the Cytology department. Section 6 illustrates how the HCCM framework is implemented using Flexsim HC. Model validation and calibration are discussed in Section 7. Finally, in Section 8, we discuss our results and make concluding remarks.

2. Conceptual modelling for discrete event simulation

Although there are varying guidelines for the development of a conceptual model, it is generally agreed that the conceptual model is the first thing to be considered at the outset of a simulation's project. Robinson defines the conceptual model is an abstraction of a real-world system, including objectives, inputs, outputs, content, assumptions and simplifications. A conceptual model can be revisited at any point in time throughout the project and is not influenced by the software implementation [16].

The conceptual modelling frameworks provide step by step guidelines for the development of a conceptual model. There has been much work to develop frameworks, deriving from different perspectives and application domains. Examples include Pace's four step approach [3] and Nance's hierarchical method [4]. Examples from manufacturing include [17–19] introduced an UML-based approach primarily for defence applications.

Balci and Ormsby [20] discuss a conceptual model for large scale simulations that focuses on modularity and reusability. They defined the 3 phases of simulation model's life cycle: conceptual model; design model; and model implementation. The conceptual model is the highest level of abstraction. It represents the modeler's view of the model, while the design model describes the composition of submodels. Finally, the design model is translated into programing languages for model implementation. Robinson [21] discussed the importance of selecting the right level of detail for simulation modelling, given the limited time and knowledge of the system, and how to determine what is a good conceptual model. Van der Zee [17] proposed an object oriented framework for modelling the control and decision making in the manufacturing process.

Robinson [8] provides a framework that includes five steps: understanding the problem situation; determination of the objectives; identification of the model's input; identification of model's output; and determination of model's components. The final step addresses the scope and details of the model, which includes providing details of entities, activities, queues, and resources.

Arbez and Birta [7] present a framework that consists of structural and behavioural constructs. This framework focuses on the trigger mechanism for activity initiation and management of the state change at the activity termination. This provides a flexible framework for handling complex system processes.

[1] HC stands for health care.

Download English Version:

https://daneshyari.com/en/article/6902514

Download Persian Version:

https://daneshyari.com/article/6902514

Daneshyari.com