

Envisioning Complexity in Healthcare Systems using Discrete Event Simulation and Social Network Analysis

Kon Shing Kenneth Chung
Complex Systems Research Group
The University of Sydney
Sydney, NSW 2006, Australia
kenneth.chung@sydney.edu.au

Alexander Komashie
Engineering Design Centre
University of Cambridge
Cambridge, CB2 1PZ, U.K.
a.komashie@eng.cam.ac.uk

Neil Yorke-Smith
Olayan School of Business
American University of Beirut
Beirut, 1107-2020, Lebanon
nysmith@aub.edu.lb

Abstract—This demonstration exhibit combines discrete event simulation and social network analysis to provide a lens on the complexity of socio-technical systems such as in healthcare.

Keywords—healthcare, complexity, discrete event simulation, social networks

I. INTRODUCTION

There is an urgent need for improving integration and coordination of healthcare systems due to the increasing complexity and challenge in patients' health issues in developed countries [13]. The ever-growing use of technology, ubiquity of information, health providers, infrastructure and diversity of protocols have made today's healthcare environment increasingly complex. Complexity, defined as the inter-relatedness of components of a system, is one of the key reasons for the significant unpredictability and variation in care coordination and patient outcomes [4,5,6,12]. Current models that explain complexity focus on analysis of work units using Cognitive Work Analysis [2], user modelling [9], or design and simulation [8]. These models are limited in that they do not account for node-level, tie-level and structural aspects of relation networks that affect individual and organizational outcomes such as healthcare coordination [1,11]. We aim to develop a model based on complex social networks (CSN) to quantify and characterize complexity in healthcare settings and its impact on coordination of care, founding the data for model on a Discrete Event Simulation.

II. CAPTURING AND QUANTIFYING COMPLEXITY

According to Kannampallil et al. [6], complexity within a social system can be studied and characterized using number of components and degree of interrelatedness (of these components). Degree of interrelatedness is further defined using Social Network Analysis (SNA) metrics by Rebehy and Chung [11]. Therefore, considering the healthcare environment as a socio-technical network ('network' from here on) from the healthcare system's perspective – for instance the perspective of the emergency department in a hospital – the doctors, patients, specialists and nurses are treated as 'components' of the network. Artefacts, such as beds, healthcare technologies, used by the patient or by the medical professionals within the

patient's network, are also deemed as components of the network. The range of complexity can thus be categorized into 'simple', 'complicated', 'relatively complex' or 'complex' clusters (Figure 1), which can then be associated with the coordination of care variable, with a view to testing the CSN model for empirical generalization.

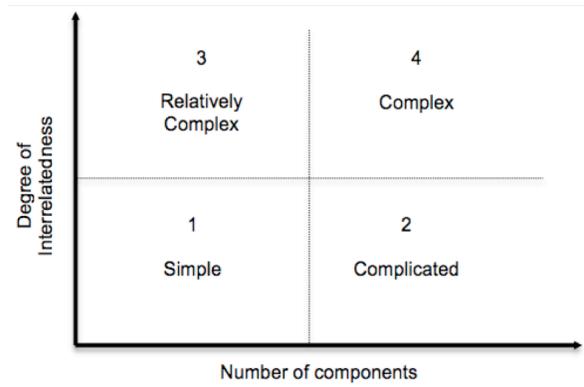


Fig. 1. Range of complexity of a social system [6]

III. DISCRETE EVENT SIMULATION

The focus of this work is on understanding the impact of complexity on patient queues and waiting times within a Discrete Event Simulation (DES) of a hospital emergency department. Simulation is known as a powerful tool for modelling socio-technical systems [3]. The DES model (see Figure 2) captures elements of healthcare coordination including accessing care, resourcing, delays, barriers, and ongoing coordination of individual patients' treatments during their entry, treatment and discharge phases within the emergency department setting [10]. The DES model is a sufficiently close replica of reality to allow us to perform a number of 'what-if' scenarios such as increasing the number of patients, reducing the number of beds, modifying policies, modifying departmental organization, and so forth [7].

We are interested in mining relational and structural data at various points in time in order to categorize complexity into one of the four quadrants as depicted in Figure 1. Assuming normality in data distribution, an independent samples t-test

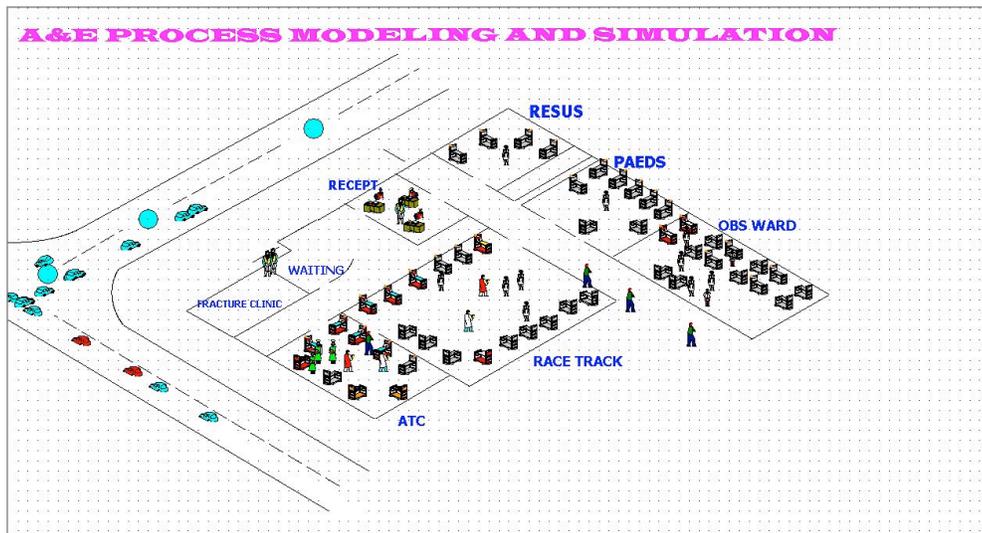


Fig. 2. Overview of system animation based on DES

can then be used to test for significant differences in patient queues and waiting times amongst all possible pairs of complexity levels.

Thus, by using a CSN model, two research objectives can be accomplished: (1) providing a scientific basis to quantify and characterize complexity for the entire healthcare (in the current context, the emergency department) system; and (2) modelling the impact of complexity on aspects of care coordination such as patient queues and waiting time.

For the first objective, the theoretical framework proposed by Kannampallil et al. [6] for studying complexity in healthcare settings and the extension to this framework using social network analysis metrics by Rebehy and Chung [11] are used. Assuming that data is captured at three-hour intervals (e.g., 12am, 3am, 6am, 9am, and so on), there are eight data points in a day. For a week, there are 56 data points and for two weeks, 112 data points, which is sufficient for statistical testing.

For the second objective, an independent samples t-test (or the Mann Whitney U-test as the non-parametric alternative) is used to test for significant differences in patient queues and waiting times amongst various pairs of complexity quadrants (levels).

IV. DEMONSTRATION

As the new paradigm of network thinking and complexity science converges, we believe that this line of research is one of the very few that marries social network analysis with complexity. We envisage that this simulation to be of interest to ASONAM scientists, scholars and practitioners (particularly in healthcare and for those academics interested in dynamic networks and complexity science). During the exhibit, we demonstrate the running of the DES model, showing how social network data for complexity is captured and operationalized throughout the entire simulation. It is our hope that theoretical, methodological and practical implications of this work will engage discussion in the fields of complexity and social network science.

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