Chapter 10
Modeling Operational Robustness and Resiliency with High–Level Petri Nets

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ABSTRACT

Military operations are highly complex workflow systems that require careful planning and execution. The interactive complexity and tight coupling between people and technological systems has been increasing in military operations, which leads to both improved efficiency and a greater vulnerability to mission accomplishment due to attack or system failure. Although the ability to resist and recover from failure is important to many systems and processes, the robustness and resiliency of workflow management systems has received little attention in literature. The authors propose a novel workflow modeling framework using high-level Petri nets (PNs). The proposed framework is capable of both modeling structure and providing a wide range of qualitative and quantitative analysis. The concepts of self-protecting and self-healing systems are captured by the robustness and resiliency measures proposed in this study. The proposed measures are plotted in a Cartesian coordinate system; a classification scheme with four quadrants (i.e., possession, preservation, restoration, and devastation) is proposed to show the state of the system in terms of robustness and resiliency. The authors introduce an overall sustainability index for the system based on the theory of displaced ideals. The application of the methodology in the evaluation of an air tasking order generation system at the United States Air Force is demonstrated.

INTRODUCTION

A workflow management system is a set of activities involving the coordinated execution of multiple tasks performed by different processing entities (Casati et al., 1995). Different techniques may be used for workflow modeling depending on the goals and objectives. There are two general categories of workflow management systems (Mentzas et al., 2001), communication-based and activity-based techniques. The communication-based techniques assume that the objective of business process reengineering is to improve customer satisfaction (Winograd & Flores, 1987). Activity-based techniques focus on modeling the tasks involved in a process and their dependencies (McCarthy & Sarin, 1993). Despite their popularity and wide-spread application, workflow management systems still suffer from lack of standards and an agreed-upon modeling method (Salimifard & Wright, 2001). Van der Aalst et al. (1994) have criticized that workflow management systems have (1) no needed functionality, (2) no clear set of definitions, and (3) no general conceptual model.

Although the ability to resist and recover from failure is important to many systems and processes, the robustness and resiliency of workflow management systems has received little focus in literature. The idea of self-protecting and self-healing systems is frequently discussed in relation to computer networks, but it has not been addressed thoroughly in other contexts despite its potential relevance (Dragoni et al., 2009). For example, military operations are highly interactive and complex systems that require efficient and effective command and control to be successful. The interactive complexity and tight coupling between people and technological systems has been increasing in military operations, which leads to unpredictability of operations and inevitably to failures.

Robustness is a property intimately associated with the organization's capacity to avoid failure while resiliency is the organization's ability to recover from failure. A deep understanding of robustness and resiliency has emerged from the study of many high-reliability organizations such as nuclear power production, aviation, space exploration, healthcare, air traffic control and chemical production (Gauthier et al., 2006; Perrow, 1999). The major interest in high-reliability organizations comes from their capacity to achieve high performance while operating in hazardous conditions (Weick & Sutcliffe, 2001). Robustness and resiliency are not technological or organizational properties but a combination of both. They are the combination of technological features, such as redundancy, protection systems, and good engineering design (Leveson et al., 2009), with organizational features such as sense-making and training (Weick, 2001). The recent studies on robustness and resiliency emphasize the integration between the organizational and technological views in complex socio-technical systems (Hollnagel et al., 2006). A good balance between robustness and resiliency should be envisaged (Nomura et al., 1998). We define robustness as the capacity of a system to avoid failure in the face of unexpected events, and resiliency as the ability of the system to recover from failure after it occurs. Robustness is important to keep the organization under control; resiliency is necessary to react to hazards.

Recently, Petri nets (PNs) have been used for workflow modeling (van der Aalst et al., 2000; van der Aalst et al., 1998). Although different modeling techniques can be used for workflow modeling, PNs are the only formal technique capable of both modeling structure and providing a wide range of qualitative and quantitative analysis. PNs allow a graphical representation to ease the understanding of the modeled system. They can also be used to formally analyze, verify, and validate the model (van der Aalst, 1997; Desel, 2000).

Zisman (1977) pioneered the concept of workflow management systems by applying PNs to represent office procedures. His work was followed

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