

Chapter 11

Fuzzy Multiple Criteria Workflow Robustness and Resiliency Modeling with Petri Nets

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ABSTRACT

The increasing complexity and tight coupling between people and computer systems in military operations has led to improved efficiency, as well as greater vulnerability due to system failure. Careful management of workflow systems can minimize operational vulnerability in command and control. Tavana et al. (2011) developed a workflow management framework capable of both modeling structure and providing a wide range of quantitative analysis with high-level Petri nets (PNs). The framework is based on a sustainability index that captures the concepts of self-protecting and self-healing systems. This index uses crisp numerical values to measure the robustness and resiliency of the system. However, the observed values of data in real-world military operations are often imprecise or vague. These inexact data can be represented by fuzzy numbers to reflect the decision makers' intuition and subjective judgments. In this paper, the authors extend this model to a fuzzy framework by proposing a new fuzzy workflow modeling system with PNs. The new model plots the fuzzy robustness and resiliency measures in a Cartesian coordinate system and derives an overall fuzzy sustainability index for the system based on the theory of displaced ideals. The proposed model also considers multiple criteria to produce this fuzzy index.

INTRODUCTION

Robustness, the ability of a system to avoid failure, and resiliency, the ability to recover from failure once it occurs, are essential elements of good workflow management systems. Nevertheless, there has been very little discussion of these properties in the workflow management literature. The necessity for readiness and the ability to cope with the possibility and reality of failure in complex systems makes this an important area for future workflow management studies, especially in highly critical areas such as military operations.

Tavana et al. (2011) proposed measures of *robustness* and *resiliency* for Petri nets (PNs) expanded with alternate paths and repair times. These measures require the use of crisp values for times and probabilities. However, in real-world situations, workflow management systems are characterized by a high level of imprecision, vague parameters, and ill-defined relationships. Imprecision reduction must occur to find the measures of robustness and resiliency for PNs. Few approaches are suggested in the literature to adequately represent imprecision, and formally reduce it to precise values. Fuzzy set theory has considerable potential for addressing the imprecision in workflow management systems.

In this paper, we propose the use of fuzzy sets in the calculation of resiliency and robustness for workflow management systems. These fuzzy values will account for the variability of data while still enabling the calculation of robustness and resiliency. Fuzzy logic and approximate reasoning enable computation in the face of uncertainty, generating approximate results (Nedjah & De Macedo Mourelle, 2005). Fuzzy triangular numbers are used for each property. Tavana et al. (2011) based their calculations of robustness and resiliency on three factors: arc breakage probability, transition completion time, and transition repair time. We incorporate additional cost-based

properties in the model proposed in this study. We also make use of available protection, as proposed by Zammori et al. (2009). Probabilities of failure are approximated by verbal expressions. The calculations of robustness and resiliency (κ and γ) are modified to accommodate these new and modified values. We extend the pragmatism and efficacy of the model proposed by Tavana et al. (2011). We will incorporate additional factors contributing to the resiliency and robustness of systems and allow for more flexible input of uncertain, vague, and ambiguous data through the use of fuzzy numbers.

This paper is organized as follows. We review the work on PN-based workflow management systems in the next section followed by a review of the literature on imperfect data representation methods. We next discuss the workflow management extensions considered in this study (i.e., probability of occurrence, time, cost, available protection). We next introduce our measures of robustness and resiliency for the PNs in fuzzy environments and provide a graphical representation of the model. We then present a numerical example and an application of the proposed model to an air tasking order generation process of the U.S. Air Force. Finally, we present our conclusions and future research directions.

PN-BASED WORKFLOW MANAGEMENT

A workflow management system is a set of activities involving the coordinated implementation of various tasks performed by different processing entities (Casati et al., 1995; van der Aalst & van Hee, 2002). Different techniques may be used for workflow modeling depending on the goals and objectives. While workflow management systems are popular, with wide-spread applications, they still suffer from lack of standards and an agreed-

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