ADAPTIVE THRESHOLDING IN CHAOS ENGINEERING: USING FUZZY LOGIC TO DYNAMICALLY SET ALERT LEVELS IN GAME THEORETICAL FRAMEWORKS

by

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DISSERTATION

Presented to the Swiss School of Business and Management Geneva

In Partial Fulfillment

Of the Requirements

For the Degree

DOCTOR OF BUSINESS ADMINISTRATION

SWISS SCHOOL OF BUSINESS AND MANAGEMENT GENEVA

JANUARY, 2024

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Dedication

This dissertation is dedicated to those who have been my pillars of strength, sources of inspiration, and guiding lights throughout this journey and my life.

To my family, whose unwavering support and unconditional love have been my constant comfort and motivation. Your belief in me, even in moments of doubt, has been the foundation upon which I built my dreams and aspirations. This accomplishment is as much yours as it is mine.

To my friends, for the laughter, encouragement, and respite you have offered me during this challenging journey. Your camaraderie and unwavering support have been invaluable. You have been my sounding board, my cheerleaders, and my confidants, making this journey more joyful and less arduous.

To my mentors, who have generously shared their wisdom, expertise, and time. Your guidance has shaped not only this dissertation but also my professional ethos and aspirations. I am deeply grateful for your mentorship, which has been pivotal in my growth and development as a scholar and a professional.

This dissertation is a testament to all of you who have touched my life in profound ways. It is a symbol of my gratitude and a reflection of the positive influence you have had on my journey. Thank you for being a part of my story.

Acknowledgements

I extend my deepest gratitude to all those who have contributed to my journey through the Doctor of Business Administration (DBA) program at SSBM, offered in collaboration with Upgrad in India. This journey has been one of immense learning, growth, and personal development, and it would not have been possible without the support and guidance of several key individuals.

Foremost, I would like to express my heartfelt thanks to my mentor, Dr. Bhawna. Her expertise, guidance, and unwavering support have been instrumental in the completion of this dissertation. Dr. Bhawna's insightful feedback, combined with her encouragement and academic rigor, have profoundly shaped my research and intellectual growth. Her dedication to my project, and her willingness to share her vast knowledge and experience, have been invaluable. I am deeply appreciative of her mentorship and the significant role she has played in my DBA journey.

I would also like to thank SSBM and Upgrad for facilitating this exceptional DBA program in India. The opportunity to engage with such a high-caliber curriculum and to be part of a vibrant academic community has been a truly enriching experience. The support and resources provided by both institutions have been pivotal in my academic pursuits and have greatly contributed to my professional development.

Additionally, my sincere appreciation goes to the faculty and staff at SSBM and Upgrad. Their dedication to creating a conducive learning environment and their commitment to academic excellence have not only facilitated a rewarding educational experience but also fostered a space for intellectual curiosity and discovery.

To my fellow DBA candidates and colleagues, I extend my gratitude for the collaborative spirit, insightful discussions, and mutual support that we shared throughout

this program. Learning alongside such a diverse and talented group of individuals has been one of the highlights of my academic journey.

Lastly, I would like to acknowledge my family, friends, and all who have supported me emotionally and intellectually throughout this process. Your belief in me and your unwavering support have been the bedrock of my perseverance and success.

This DBA journey has been a transformative experience, and I am profoundly grateful to everyone who has been a part of it. Thank you for your invaluable contributions to my academic and personal growth.

ABSTRACT

ADAPTIVE THRESHOLDING IN CHAOS ENGINEERING: USING FUZZY LOGIC TO DYNAMICALLY SET ALERT LEVELS IN GAME THEORETICAL FRAMEWORKS

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2024

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This research, titled "Adaptive Thresholding in Chaos Engineering: Using Fuzzy Logic to Dynamically Set Alert Levels in Game Theoretical Frameworks," explores a pioneering approach to enhancing system resilience and adaptability in chaotic environments. The study integrates the principles of chaos engineering, fuzzy logic, and game theory to develop a comprehensive framework for dynamic threshold setting in complex systems. Through the application of fuzzy logic, the model dynamically adjusts alert thresholds in response to real-time system states, effectively handling the inherent uncertainties and non-linearities of these environments. Game theory is employed to provide a strategic framework, anticipating and responding to potential adversarial actions, thereby reinforcing the system's adaptive capabilities. The methodology includes theoretical modeling, simulation, and case study analysis, offering a robust validation of the

proposed approach. The findings indicate that this integrated approach significantly improves system responsiveness and stability, highlighting its potential for broad application in various sectors where system reliability is crucial. This research contributes to the advancement of chaos engineering, presenting a novel solution to the challenges of maintaining system stability in unpredictable and rapidly evolving technological landscapes.

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INTRODUCTION

1.1 Introduction

The research area of "Adaptive Thresholding in Chaos Engineering: Using Fuzzy Logic to Dynamically Set Alert Levels in Game Theoretical Frameworks" lies at the intersection of chaos engineering, fuzzy logic, and game theory, focusing on improving system resilience and adaptability. Chaos engineering, a practice that tests systems' ability to withstand turbulent conditions, has become increasingly relevant as organizations depend more on complex, interlinked technological systems (Brown et al. 2011). Fuzzy logic contributes by providing a means to handle the uncertainty and imprecision inherent in real-world systems Zadeh (1965), enabling more nuanced and flexible responses to changing conditions.

The motivation for this research stems from the need for more dynamic and intelligent systems in the face of evolving cyber threats and complex operational environments. Traditional static thresholding methods are inadequate for contemporary, fast-paced technological landscapes. By leveraging game theory, which offers strategic insights into adversarial behaviours Osborne and Rubinstein (1994), in their research aims to predict and counteract potential system threats more effectively.

This research holds significant importance for industry practice and knowledge advancement. It addresses a critical need for adaptive security measures in sectors where system reliability and security are crucial, such as finance, healthcare, and critical infrastructure. By advancing the understanding of dynamic threshold setting in chaotic environments, this research contributes to the development of more resilient, intelligent,

and secure systems, essential for the smooth operation of modern societies and economies.

In the rapidly evolving landscape of system engineering and cyber security, the resilience and reliability of systems have become paramount. Traditional static methods for setting alert thresholds in systems have proven insufficient in handling the dynamic and often chaotic nature of modern technological environments. This research draws upon the principles of chaos engineering, an approach that systematically tests systems for weaknesses in the face of turbulent conditions (Brown et al. 2011).

Fuzzy logic, a form of multi-valued logic derived from fuzzy set theory, provides a method to handle uncertainty and imprecision (Zadeh, 1965). It offers a robust framework for dynamically adjusting system thresholds based on real-time data, thereby enabling more responsive and adaptive system behaviors (Ross, 2004).

Furthermore, game theory, a mathematical framework for analyzing strategic interactions among rational decision-makers, offers valuable insights into the behaviors of adversarial elements within system environments (Osborne & Rubinstein, 1994). David (2015), work on the application of game theory in cyber security and information assurance underscores its relevance in anticipating and strategically responding to threats in complex systems.

Combining these methodologies, this research aims to develop an innovative framework for adaptive thresholding in chaotic environments. By integrating the predictive strengths of game theory with the flexibility of fuzzy logic, this study seeks to contribute significantly to the field of chaos engineering, advancing the understanding and application of dynamic alert systems in cyber-physical environments.

1.2 Research Problem

The core problem addressed in "Adaptive Thresholding in Chaos Engineering: Using Fuzzy Logic to Dynamically Set Alert Levels in Game Theoretical Frameworks" centers around the inadequacy of current threshold-setting mechanisms in complex, dynamic systems. Traditional methods, which often rely on static thresholds, fail to adequately respond to the rapidly changing and unpredictable environments typical of modern technological systems (Brown et al. 2011). This static approach leads to either oversensitivity, causing frequent false alarms, or a lack of sensitivity, resulting in missed critical alerts.

The integration of fuzzy logic, which excels in handling uncertainty and imprecision in data Zadeh (1965), offers a solution to this problem by allowing thresholds to be set and adjusted in a more nuanced manner. However, the challenge lies in effectively integrating fuzzy logic into existing system architectures in a manner that is both efficient and effective.

Additionally, the strategic aspect of threshold management in adversarial environments, such as cybersecurity, is often overlooked. Game theory provides a structured way to understand and anticipate adversarial actions Osborne and Rubinstein (1994), but its application in real-time adaptive thresholding remains underexplored.

Therefore, this research aims to address these gaps by developing a framework that dynamically adjusts alert thresholds using fuzzy logic, within a game-theoretical context, to enhance the resilience and responsiveness of systems in chaotic environments. This approach is not only crucial for advancing theoretical knowledge in the field but also holds significant practical implications for industries reliant on complex, adaptive systems.