Using Multiple-Valued Logic Decision Diagrams to Model System Threat Probabilities

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Abstract—System security continues to be of increasing importance. To effectively address both natural and intentional threats to large systems, the threats must be cataloged and analyzed. Extremely large and complex system can have an accordingly large number of threat scenarios. Simply listing the threats and devising countermeasures for each is ineffective and not efficient. We describe a threat cataloging methodology whereby a large number of threats can be efficiently cataloged and analyzed for common features. This allows countermeasures to be formulated that address a large number of threats that share common features. The methodology utilizes Multiple-Valued Logic for describing the state of a large system and a multiple-valued decision diagram (MDD) for the threat catalog and analysis.

Large System Security, Threat cataloging, MDD

I. INTRODUCTION

In recent years, more emphasis has been placed on design for security, security assessment, disaster recovery, disaster tolerance, in addition to the ongoing efforts in the established areas in fault tolerance. All of these areas require the identification and analysis of faults or threats. Most fault models and analysis methods assume that a fault causes a system to either function or fail and are thus modeled with binary conditions.

Recent events have demonstrated our vulnerability to disasters, both natural and man-made. This motivates the need to incorporate disaster tolerance into large system designs. Disaster tolerance is a superset of the more established approaches commonly referred to as fault tolerance. Models for disaster tolerance differ from those for fault tolerance since they assume that failures can occur due to single or massive numbers of individual faults occurring simultaneously or in a rapidly cascading manner. Traditional fault tolerance models single points of failure. Therefore, a disaster-tolerant system can withstand a catastrophic failure and still function with some degree of normality [8, 15].

Threats on a system can include both accidental and intentional effects. Examples of accidental events include random component failures, natural disasters, and fires. Examples of intentional effects include sabotage and cyber threats. A variety of tree structures have been developed to represent possible system threats. These tree structures are commonly called fault trees or attack trees. Fault trees were originally developed to identify the effects of component failures on a system. [16] while attack trees traditionally focused on the effects of cyber security breaches [14]. There have been recent variants of these trees, and sometimes these trees have been used interchangeably [2, 5, 6, 7, 11]. However, these trees all have one thing in common: they are binary-valued trees, connected with AND and OR operators. This limits the effectiveness of how they can represent possible system-wide attacks. Modeling different operational modes other than just the binary case of failure or normal operation are critical in analyzing large systems in the presence of threats. As an example, in the 2003 blackout of the US power grid, many complex interactions caused a blackout to occur in a large portion of the northeastern US; however, it would be incorrect to state that the entire US power grid failed. In order to effectively catalog system threats, it is necessary to determine the probabilities of these threats based on various system stimuli, including input conditions and their probabilities.

As part of our preliminary research on large-scale system threat assessment, we developed threat tree models [12]. Threat trees are a superset of fault and attack trees since they are based on multiple-valued (MV) or radix-p valued algebras over a finite and discrete set of values [10]. When the radix $p=2$, the threat tree reduces to a fault or attack tree depending on the nature of the disruptive events. Generally, threat trees have $p>2$: these additional logic states allow for more complicated interactions to be modeled. In particular, these additional states can represent partial failures or degraded performance in a system, which are critical in analyzing large systems in the presence of threats.

The structure of this paper is the following: First, background information on decision diagram models is provided. Next, an approach is presented using decision diagram models to determine systems threat probabilities. Finally, a system example is used to illustrate these concepts.

II. DECISION DIAGRAMS

Fig. 1 shows an example of a simple binary fault tree where the circular nodes represent the event of a single component failure and the logic operators (AND/OR gates) show how the events combine to result in a subsystem failure. Referring to

The Twenty Fourth International Symposium On Multiple Valued Logic Proceedings May 25 27 1994 Boston Massachusetts

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The Twenty-fourth International Symposium on Multiple-Valued Logic ,1994 The Twenty-fourth International Symposium on Multiple-Valued Logic ,1994 *Proceedings* International Symposium on Multiple Valued Logic,1994 1997 27th International Symposium on Multiple-Valued Logic ,1997 **Spectral Logic and Its Applications for the Design of Digital Devices** Mark G. Karpovsky,Radomir S. Stankovic,Jaakko T. Astola,2008-04-15 Spectral techniques facilitate the design and testing of today s increasingly complex digital devices There is heightened interest in spectral techniques for the design of digital devices dictated by ever increasing demands on technology that often cannot be met by classical approaches Spectral methods provide a uniform and consistent theoretic environment for recent achievements in this area which appear divergent in many other approaches Spectral Logic and Its Applications for the Design of Digital Devices gives readers a foundation for further exploration of abstract harmonic analysis over finite groups in the analysis design and testing of digital devices After an introduction this book provides the essential mathematical background for discussing spectral methods It then delves into spectral logic and its applications covering Walsh Haar arithmetic transform Reed Muller transform for binary valued functions and Vilenkin Chrestenson transform generalized Haar and other related transforms for multiple valued functions Polynomial expressions and decision diagram representations for switching and multiple value functions Spectral analysis of Boolean functions Spectral synthesis and optimization of combinational and sequential devices Spectral methods in analysis and synthesis of reliable devices Spectral techniques for testing computer hardware This is the authoritative reference for computer science and engineering professionals and researchers with an interest in spectral methods of representing discrete functions and related applications in the design and testing of digital devices It is also an excellent text for graduate students in courses covering spectral logic and its applications

Unconventional Computation and Natural Computation Cristian S. Calude,Michael J. Dinneen,2015-08-07 This book constitutes the refereed proceedings of the 14th International Conference on Unconventional Computation and Natural Computation UCNC 2015 held in Auckland New Zealand in August September 2015 The 16 revised full papers were carefully reviewed and selected from 38 submissions The papers cover a wide range of topics including among others molecular DNA computing quantum computing optical computing chaos computing physarum computing computation in hyperbolic spaces collision based computing cellular automata neural computation evolutionary computation swarm intelligence nature inspired algorithms artificial immune systems artificial life membrane computing amorphous computing computational systems biology genetic networks protein protein networks transport networks synthetic biology cellular in vivo computing and computations beyond the Turing model and philosophical aspects of computing Fuzzy Logic and its Applications to Engineering, Information Sciences, and Intelligent Systems Zeungnam Bien,K.C. Min,2012-12-06 Fuzzy technology has

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functions are particularly attractive since in practical realization within today prevalent binary circuits environment they may be easy coded by binary values and realized with two stable state circuits At the same time there is much more considerable advent in design of four valued logic circuits than for other p valued functions Therefore this book is written using a hands on approach such that after introducing the general and necessarily abstract background theory the presentation is based on a large number of examples for ternary and quaternary functions that should provide an intuitive understanding of various representation methods and the interconnections among them Table of Contents Multiple Valued Logic Functions Functional Expressions for Multiple Valued Functions Spectral Representations of Multiple Valued Functions Decision Diagrams for Multiple Valued Functions Fast Calculation Algorithms **Computing with Words in Information/Intelligent Systems 1** Lotfi A. Zadeh,2013-03-09 These two volumes consIstmg of Foundations and Applications provide the current status of theoretical and empirical developments in computing with words In philosophy the twentieth century is said to be the century of language This is mainly due to Wittgenstein who said The meaning of a word is its use in the language game The concept game is a concept with blurred edges In the first phrase the language game implies the everyday human activity with language and in the latter game simply implies an ordinary word Thus Wittgenstein precisely stated that a word is fuzzy in real life Unfortunately this idea about a word was not accepted in the conventional science We had to wait for Zadeh s fuzzy sets theory Remembering Wittgenstein s statement we should consider on the one hand the concept of computing with words from a philosophical point of view It deeply relates to the everyday use of a word in which the meaning of a word is fuzzy in its nature Multiple-Valued Logic ,1997 Proceedings of the May 1997 symposium MVL researchers from around the world present 37 papers in sessions on algebra device technology circuits fuzzy logic logic design philosophical aspects spectral techniques testing and fault simulation and applications In addition three invited addresses recent developments in DNA computing many valuedness and uncertainty and ternary decision diagrams survey further illustrate the diverse nature of multiple valued research Topics of the papers include finding composition trees for multiple valued functions hyperclones on a finite set and multiple valued logic as a programming language No index Annotation copyrighted by Book News Inc Portland OR *Proceedings of the Twenty-fourth International Conference on Very Large Databases, New York, NY, USA, 24-27 August, 1998* Ashish Gupta,Oded Shmueli,Jennifer Widom,1998 **Publications in Engineering** ,1995 Novel Algorithms and Techniques in Telecommunications, Automation and Industrial Electronics Tarek Sobh,Khaled Elleithy,Ausif Mahmood,Mohammad A. Karim,2008-08-15 Novel Algorithms and Techniques in Telecommunications Automation and Industrial Electronics includes a set of rigorously reviewed world class manuscripts addressing and detailing state of the art research projects in the areas of Industrial Electronics Technology and Automation Telecommunications and Networking Novel Algorithms and Techniques in Telecommunications Automation and Industrial Electronics includes selected papers form the conference proceedings of the International Conference on Industrial Electronics Technology and Automation IETA

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