

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 systems 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 system 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

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Proceedings IEEE Computer Society,1989 Proceedings ,1989 **ISMVL 2004** International Symposium on Multiple Valued Logic (34, 2004, Toronto),IEEE Computer Society,2004 **Modern Uses of Multiple-Valued Logic** M. Dunn,G. Epstein,2012-12-06 This is a collection of invited papers from the 1975 International Symposium on Multiple valued Logic Also included is an extensive bibliography of works in the field of multiple valued logic prior to 1975 this supplements and extends an earlier bibliography of works prior to 1965 by Nicholas Rescher in his book Many Valued Logic McGraw Hill 1969 There are a number of possible reasons for interest in the present volume First the range of various uses covered in this collection of papers may be taken as indicative of a breadth which occurs in the field of multiple valued logic as a whole the papers here can do no more than cover a small sample question answering systems analysis of computer hazards algebraic structures relating to multiple valued logic algebra of computer programs fuzzy sets Second a large part of the interest in such uses and applications has occurred in the last twenty even ten years It would be too much to expect this to be reflected in Rescher s 1969 book Third in the 1970 s a series of annual symposia have been held on multiple valued logic which have brought much of this into a sharp focus The 1971 and 1972 symposia were held at the SUNY at Buffalo the 1973 symposium at the University of Toronto and the 1974 symposium at West Virginia University Papers from these symposia are included in the bibliography which may be found in an appendix of this book The Nineteenth International Symposium on Multiple-Valued Logic ,2002 *Claudio Moraga: A Passion for Multi-Valued Logic and Soft Computing* Rudolf Seising,Héctor Allende-Cid,2016-10-20 The book is an authoritative collection of contributions by leading experts on the topics of fuzzy logic multi valued logic and neural network Originally written as an homage to Claudio Moraga seen by his colleagues as an example of concentration discipline and passion for science the book also represents a timely reference guide for advance students and researchers in the field of soft computing and multiple valued logic **Beyond Two: Theory and Applications of Multiple-Valued Logic** Melvin Fitting,Ewa Orłowska,2013-06-05 This volume represents the state of the art for much current research in many valued logics Primary researchers in the field are among the authors Major methodological issues of many valued logics are treated as well as applications of many valued logics to reasoning with fuzzy information Areas covered include Algebras of multiple valued logics and their applications proof theory and automated deduction in multiple valued logics fuzzy logics and their applications and multiple valued logics for control theory and rational belief Finite State Machine Logic Synthesis for Complex Programmable Logic Devices Robert Czerwinski,Dariusz Kania,2013-01-12 This book is a monograph devoted to logic synthesis and optimization for CPLDs CPLDs macrocell can also be interpreted as programmable AND fixed OR structure well known as PAL based structure The question is what should be done when the number of implicants representing function exceeds the number of product terms available in a logic block

The answer is in the book *Logic synthesis and optimization methods dedicated for PAL based structures* are proposed. The methods strive to find the optimum fit for the combinational logic and finite state machines to the structure of the logic device and aim at area and speed optimization. The theoretical background and complete strategies are richly illustrated with examples and figures.

Logic Design of NanoICS Svetlana N. Yanushkevich, Vlad P. Shmerko, Sergey Edward Lyshevski, 2017-12-19 Today's engineers will confront the challenge of a new computing paradigm relying on micro and nanoscale devices. *Logic Design of NanoICs* builds a foundation for logic in nanodimensions and guides you in the design and analysis of nanoICs using CAD. The authors present data structures developed toward applications rather than a purely theoretical treatment. Requiring only basic logic and circuits background, *Logic Design of NanoICs* draws connections between traditional approaches to design and modern design in nanodimensions. The book begins with an introduction to the directions and basic methodology of logic design at the nanoscale, then proceeds to nanotechnologies and CAD graphical representation of switching functions and networks, word level and linear word level data structures, 3-D topologies based on hypercubes, multilevel circuit design and fault tolerant computation in hypercube like structures. The authors propose design solutions and techniques going beyond the underlying technology to provide more applied knowledge. This design oriented reference is written for engineers interested in developing the next generation of integrated circuitry, illustrating the discussion with approximately 250 figures and tables, 100 equations, 250 practical examples and 100 problems. Each chapter concludes with a summary, references and a suggested reading section.

The Many Valued and Nonmonotonic Turn in Logic Dov M. Gabbay, John Woods, 2007-08-13 The present volume of the *Handbook of the History of Logic* brings together two of the most important developments in 20th century non-classical logic: These are many valuedness and non-monotonicity. On the one approach, in deference to vagueness, temporal or quantum indeterminacy or reference failure, sentences that are classically non-bivalent are allowed as inputs and outputs to consequence relations. Many valued, dialetheic, fuzzy and quantum logics are among other things principled attempts to regulate the flow through of sentences that are neither true nor false. On the second or non-monotonic approach, constraints are placed on inputs and sometimes on outputs of a classical consequence relation with a view to producing a notion of consequence that serves in a more realistic way the requirements of real life inference. Many valued logics produce an interesting problem. Non-bivalent inputs produce classically valid consequence statements for any choice of outputs. A major task of many valued logics of all stripes is to fashion an appropriately non-classical relation of consequence. The chief preoccupation of non-monotonic and default logicians is how to constrain inputs and outputs of the consequence relation. In what is called left non-monotonicity, it is forbidden to add new sentences to the inputs of true consequence statements. The restriction takes notice of the fact that new information will sometimes override an antecedently and reasonably derived consequence. In what is called right non-monotonicity, limitations are imposed on outputs of the consequence relation. Most notably, perhaps, is the requirement that the rule of introduction

not be given free sway on outputs Also prominent is the effort of paraconsistent logicians both preservationist and dialetheic to limit the outputs of inconsistent inputs which in classical contexts are wholly unconstrained In some instances our two themes coincide Dialetheic logics are a case in point Dialetheic logics allow certain selected sentences to have as a third truth value the classical values of truth and falsity together So such logics also admit classically inconsistent inputs A central task is to construct a right non monotonic consequence relation that allows for these many valued and inconsistent inputs The Many Valued and Non Monotonic Turn in Logic is an indispensable research tool for anyone interested in the development of logic including researchers graduate and senior undergraduate students in logic history of logic mathematics history of mathematics computer science AI linguistics cognitive science argumentation theory and the history of ideas Detailed and comprehensive chapters covering the entire range of modal logic Contains the latest scholarly discoveries and interpretative insights that answers many questions in the field of logic

Decision Diagram Techniques for Micro- and Nanoelectronic Design Handbook Svetlana N. Yanushkevich,D. Michael Miller,Vlad P. Shmerko,Radomir S.

Stankovic,2018-10-03 Decision diagram DD techniques are very popular in the electronic design automation EDA of integrated circuits and for good reason They can accurately simulate logic design can show where to make reductions in complexity and can be easily modified to model different scenarios Presenting DD techniques from an applied perspective Decision Diagram Techniques for Micro and Nanoelectronic Design Handbook provides a comprehensive up to date collection of DD techniques Experts with more than forty years of combined experience in both industrial and academic settings demonstrate how to apply the techniques to full advantage with more than 400 examples and illustrations Beginning with the fundamental theory data structures and logic underlying DD techniques they explore a breadth of topics from arithmetic and word level representations to spectral techniques and event driven analysis The book also includes abundant references to more detailed information and additional applications Decision Diagram Techniques for Micro and Nanoelectronic Design Handbook collects the theory methods and practical knowledge necessary to design more advanced circuits and places it at your fingertips in a single concise reference

Electronic Design Automation for IC Implementation, Circuit Design, and Process Technology Luciano Lavagno,Igor L. Markov,Grant Martin,Louis K. Scheffer,2017-02-03 The second of two volumes in the Electronic Design Automation for Integrated Circuits Handbook Second Edition Electronic Design Automation for IC Implementation Circuit Design and Process Technology thoroughly examines real time logic RTL to GDSII a file format used to transfer data of semiconductor physical layout design flow analog mixed signal design physical verification and technology computer aided design TCAD Chapters contributed by leading experts authoritatively discuss design for manufacturability DFM at the nanoscale power supply network design and analysis design modeling and much more New to This Edition Major updates appearing in the initial phases of the design flow where the level of abstraction keeps rising to support more functionality with lower non recurring engineering NRE costs Significant revisions reflected in

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Multimedia Data Engineering Applications and Processing Chen, Shu-Ching, Shyu, Mei-Ling, 2013-02-28 With a variety of media types multimedia data engineering has emerged as a new opportunity to create techniques and tools that empower the development of the next generation of multimedia databases and information systems Multimedia Data Engineering Applications and Processing presents different aspects of multimedia data engineering and management research This collection of recent theories technologies and algorithms brings together a detailed understanding of multimedia engineering and its applications This reference source will be of essential use for researchers scientists professionals and software engineers in the field of multimedia

Computational Approaches to Analogical Reasoning: Current Trends Henri Prade, Gilles Richard, 2014-03-22 Analogical reasoning is known as a powerful mode for drawing plausible conclusions and solving problems It has been the topic of a huge number of works by philosophers anthropologists linguists psychologists and computer scientists As such it has been early studied in artificial intelligence with a particular renewal of interest in the last decade The present volume provides a structured view of current research trends on computational approaches to analogical reasoning It starts with an overview of the field with an extensive bibliography The 14 collected contributions cover a large scope of issues First the use of analogical proportions and analogies is explained and discussed in various natural language processing problems as well as in automated deduction Then different formal frameworks for handling analogies are presented dealing with case based reasoning heuristic driven theory projection commonsense reasoning about incomplete rule bases logical proportions induced by similarity and dissimilarity indicators and analogical proportions in lattice structures Lastly the volume reports case studies and discussions about the use of similarity judgments and the process of analogy making at work in IQ tests creativity or other cognitive tasks This volume gathers fully revised and expanded versions of papers presented at an international workshop as well as invited contributions All chapters have benefited of a thorough peer review process

Technologies for Constructing Intelligent Systems 1 Bernadette Bouchon-Meunier, Julio Gutierrez-Rios, Luis Magdalena, Ronald R. Yager, 2013-03-20 Intelligent systems enhance the capacities made available by the internet and other computer based technologies This book deals with the theory behind the solutions to difficult problems in the construction of intelligent systems Particular attention is paid to situations in which the available information and data may be imprecise uncertain incomplete or of linguistic nature Various methodologies for these cases are discussed among which are probabilistic possibilistic fuzzy logical evidential and network based frameworks

One purpose of the book is to consider how these methods can be used cooperatively Topics included in the book include fundamental issues in uncertainty the rapidly emerging discipline of information aggregation neural networks bayesian networks and other network methods as well as logic based systems **Logic and Metalogic** , New Essays on Belnap-Dunn Logic Hitoshi Omori,Heinrich Wansing,2020-01-01 This edited volume collects essays on the four valued logic known as Belnap Dunn logic or first degree entailment logic FDE It also looks at various formal systems closely related to it These include the strong Kleene logic and the Logic of Paradox Inside readers will find reprints of seminal papers written by the fathers of the field Nuel Belnap and Michael Dunn In addition the collection also features a well known but previously unpublished manuscript of Dunn an interview with Belnap and a new essay by Dunn Besides the original monumental papers the book also includes research by leading scholars They consider the extraordinary importance of Belnap Dunn logic from several perspectives They look at how philosophically it has served as a basic system of inconsistency tolerant reasoning as the core of underlying logics for theories based on dialetheism and more recently for theories based on Buddhist philosophy Coverage also explores its contributions to computer science such as knowledge representation and information processing This mix of seminal papers and insightful analysis by top scholars offers readers a comprehensive outlook on Belnap Dunn logic and its related expansions which have been agenda setting for the debate on philosophical logic as well as philosophy of logic The book will also enhance further discussion on the philosophical issues related to nonclassical logics in general

Embedded Systems Design with Special Arithmetic and Number Systems Amir Sabbagh Molahosseini,Leonel Seabra de Sousa,Chip-Hong Chang,2017-03-20 This book introduces readers to alternative approaches to designing efficient embedded systems using unconventional number systems The authors describe various systems that can be used for designing efficient embedded and application specific processors such as Residue Number System Logarithmic Number System Redundant Binary Number System Double Base Number System Decimal Floating Point Number System and Continuous Valued Number System Readers will learn the strategies and trade offs of using unconventional number systems in application specific processors and be able to apply and design appropriate arithmetic operations from these number systems to boost the performance of digital systems **Multiple-Valued Logic, 2006. ISMVL 2006. 36th International Symposium on IEEE Computer Society,2006** **Handbook of Satisfiability** Armin Biere,Hans van Maaren,Toby Walsh,2021-05-15 Propositional logic has been recognized throughout the centuries as one of the cornerstones of reasoning in philosophy and mathematics Over time its formalization into Boolean algebra was accompanied by the recognition that a wide range of combinatorial problems can be expressed as propositional satisfiability SAT problems Because of this dual role SAT developed into a mature multi faceted scientific discipline and from the earliest days of computing a search was underway to discover how to solve SAT problems in an automated fashion This book the Handbook of Satisfiability is the second updated and revised edition of the book first published in 2009 under the same name The handbook aims to capture the full breadth and depth of SAT and

to bring together significant progress and advances in automated solving Topics covered span practical and theoretical research on SAT and its applications and include search algorithms heuristics analysis of algorithms hard instances randomized formulae problem encodings industrial applications solvers simplifiers tools case studies and empirical results SAT is interpreted in a broad sense so as well as propositional satisfiability there are chapters covering the domain of quantified Boolean formulae QBF constraints programming techniques CSP for word level problems and their propositional encoding and satisfiability modulo theories SMT An extensive bibliography completes each chapter This second edition of the handbook will be of interest to researchers graduate students final year undergraduates and practitioners using or contributing to SAT and will provide both an inspiration and a rich resource for their work Edmund Clarke 2007 ACM Turing Award Recipient SAT solving is a key technology for 21st century computer science Donald Knuth 1974 ACM Turing Award Recipient SAT is evidently a killer app because it is key to the solution of so many other problems Stephen Cook 1982 ACM Turing Award Recipient The SAT problem is at the core of arguably the most fundamental question in computer science What makes a problem hard

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