Computer–Aided Reasoning for the Masses

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Abstract. A good test of the usability of formal verification techniques and tools is whether they can be successfully integrated into the undergraduate curriculum. Widespread use of formal verification techniques at the undergraduate level will require that we convince our colleagues that such techniques benefit our students more than the material they replace. Widespread use of formal verification tools will not only require robust, mature, and usable tools, but will highlight the true remaining usability issues. At Northeastern University, we embarked down this path several years ago. We introduced a required freshman class that teaches students how to reason about the programs they write using ACL2s, the ACL2 Sedan. So far, over 200 undergraduate students have taken the class.

1 Formal Methods at the Undergraduate Level

The case for teaching formal methods at the undergraduate level is easy to make: formal methods provide the foundations that allow us to understand, reason about, and gain predictive power over computational processes and artifacts. If we want to train engineers who can build the computational systems our society is increasingly dependent so that they are robust, dependable, and secure, then we have to teach these engineers how to model and reason about computational systems using mathematical rigor and precision. This is inherently different from what students learn in courses on algorithms. There the emphasis is on introducing paradigms that are useful for designing computationally efficient algorithms, such as dynamic programming and the greedy method.

The next step is to figure out where such a class fits in at the undergraduate level. What are the prerequisites? Well, students have to have a solid foundation in programming. At Northeastern, they get that in their first semester, when they learn how to design programs using a Scheme-based functional programming language [2]. The earliest we can teach a course on formal methods is in the second semester of the undergraduate program, and that is what we do. While there are obvious disadvantages to teaching such a course that early, the advantages are greater: if we want to change how students think about programming and computer science, we need to install these values in them early. Teaching formal methods during the first year, helps shape how they think about computer science as they navigate through the undergraduate program.

Computer Aided Reasoning

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Computer Aided Reasoning:

Computer-Aided Reasoning Matt Kaufmann,Panagiotis Manolios,J Strother Moore,2012-12-06 Computer Aided Reasoning An Approach is a textbook introduction to computer aided reasoning It can be used in graduate and upper division undergraduate courses on software engineering or formal methods It is also suitable in conjunction with other books in courses on hardware design discrete mathematics or theory especially courses stressing formalism rigor or mechanized support It is also appropriate for courses on artificial intelligence or automated reasoning and as a reference for business and industry Current hardware and software systems are often very complex and the trend is towards increased complexity Many of these systems are of critical importance therefore making sure that they behave as expected is also of critical importance By modeling computing systems mathematically we obtain models that we can prove behave correctly The complexity of computing systems makes such proofs very long complicated and error prone To further increase confidence in our reasoning we can use a computer program to check our proofs and even to automate some of their construction In this book we present A practical functional programming language closely related to Common Lisp which is used to define functions which can model computing systems and to make assertions about defined functions A formal logic in which defined functions correspond to axioms the logic is first order includes induction and allows us to prove theorems about the functions The computer aided reasoning system ACL2 which includes the programming language the logic and mechanical support for the proof process The ACL2 system has been successfully applied to projects of commercial interest including microprocessor modeling hardware verification microcode verification and software verification This book gives a methodology for modeling computing systems formally and for reasoning about those models with mechanized assistance The practicality of computer aided reasoning is further demonstrated in the companion book Computer Aided Reasoning ACL2 Case Studies Approximately 140 exercises are distributed throughout the book Additional material is freely available from the ACL2 home page on the Web including solutions to the exercises additional exercises case studies from the companion book research papers and the ACL2 system with detailed documentation   Computer-Aided Reasoning Matt Kaufmann,Panagiotis Manolios,J Strother Moore,2013-04-17 Computer Aided Reasoning ACL2 Case Studies illustrates how the computer aided reasoning system ACL2 can be used in productive and innovative ways to design build and maintain hardware and software systems Included here are technical papers written by twenty one contributors that report on self contained case studies some of which are sanitized industrial projects The papers deal with a wide variety of ideas including floating point arithmetic microprocessor simulation model checking symbolic trajectory evaluation compilation proof checking real analysis and several others Computer Aided Reasoning ACL2 Case Studies is meant for two audiences those looking for innovative ways to design build and maintain hardware and software systems faster and more reliably and those wishing to learn how to do this The former audience includes project managers and students in survey oriented courses The latter audience includes

students and professionals pursuing rigorous approaches to hardware and software engineering or formal methods Computer Aided Reasoning ACL2 Case Studies can be used in graduate and upper division undergraduate courses on Software Engineering Formal Methods Hardware Design Theory of Computation Artificial Intelligence and Automated Reasoning The book is divided into two parts Part I begins with a discussion of the effort involved in using ACL2 It also contains a brief introduction to the ACL2 logic and its mechanization which is intended to give the reader sufficient background to read the case studies A more thorough textbook introduction to ACL2 may be found in the companion book Computer Aided Reasoning An Approach The heart of the book is Part II where the case studies are presented The case studies contain exercises whose solutions are on the Web In addition the complete ACL2 scripts necessary to formalize the models and prove all the properties discussed are on the Web For example when we say that one of the case studies formalizes a floating point multiplier and proves it correct we mean that not only can you read an English description of the model and how it was proved correct but you can obtain the entire formal content of the project and replay the proofs if you wish with your copy of ACL2 ACL2 may be obtained from its home page The results reported in each case study as ACL2 input scripts as well as exercise solutions for both books are available from this page   *Computer-Aided Reasoning* Matt Kaufmann,Panagiotis Manolios,J Strother Moore,2012-10-12 Computer Aided Reasoning An Approach is a textbook introduction to computer aided reasoning It can be used in graduate and upper division undergraduate courses on software engineering or formal methods It is also suitable in conjunction with other books in courses on hardware design discrete mathematics or theory especially courses stressing formalism rigor or mechanized support It is also appropriate for courses on artificial intelligence or automated reasoning and as a reference for business and industry Current hardware and software systems are often very complex and the trend is towards increased complexity Many of these systems are of critical importance therefore making sure that they behave as expected is also of critical importance By modeling computing systems mathematically we obtain models that we can prove behave correctly The complexity of computing systems makes such proofs very long complicated and error prone To further increase confidence in our reasoning we can use a computer program to check our proofs and even to automate some of their construction In this book we present A practical functional programming language closely related to Common Lisp which is used to define functions which can model computing systems and to make assertions about defined functions A formal logic in which defined functions correspond to axioms the logic is first order includes induction and allows us to prove theorems about the functions The computer aided reasoning system ACL2 which includes the programming language the logic and mechanical support for the proof process The ACL2 system has been successfully applied to projects of commercial interest including microprocessor modeling hardware verification microcode verification and software verification This book gives a methodology for modeling computing systems formally and for reasoning about those models with mechanized assistance The practicality of computer aided reasoning is further demonstrated in the

companion book Computer Aided Reasoning ACL2 Case Studies Approximately 140 exercises are distributed throughout the book Additional material is freely available from the ACL2 home page on the Web including solutions to the exercises additional exercises case studies from the companion book research papers and the ACL2 system with detailed documentation   Computer-aided Reasoning Matt Kaufmann,Panagiotis Manolios,J Strother Moore,2008   **COMPUTER-AIDED REASONING** MATT. KAUFMANN,2011   **Computer-Aided Reasoning** Matt Kaufmann,Panagiotis Manolios,J. Strother Moore,2014-01-15   **Computer-aided Reasoning about Knowledge and Justifications** Natalia Novak,2009   **Computer-Aided Reasoning** Matt Kaufmann,Panagiotis Manolios,J Strother Moore,2000-06-30 Computer Aided Reasoning ACL2 Case Studies illustrates how the computer aided reasoning system ACL2 can be used in productive and innovative ways to design build and maintain hardware and software systems Included here are technical papers written by twenty one contributors that report on self contained case studies some of which are sanitized industrial projects The papers deal with a wide variety of ideas including floating point arithmetic microprocessor simulation model checking symbolic trajectory evaluation compilation proof checking real analysis and several others Computer Aided Reasoning ACL2 Case Studies is meant for two audiences those looking for innovative ways to design build and maintain hardware and software systems faster and more reliably and those wishing to learn how to do this The former audience includes project managers and students in survey oriented courses The latter audience includes students and professionals pursuing rigorous approaches to hardware and software engineering or formal methods Computer Aided Reasoning ACL2 Case Studies can be used in graduate and upper division undergraduate courses on Software Engineering Formal Methods Hardware Design Theory of Computation Artificial Intelligence and Automated Reasoning The book is divided into two parts Part I begins with a discussion of the effort involved in using ACL2 It also contains a brief introduction to the ACL2 logic and its mechanization which is intended to give the reader sufficient background to read the case studies A more thorough textbook introduction to ACL2 may be found in the companion book Computer Aided Reasoning An Approach The heart of the book is Part II where the case studies are presented The case studies contain exercises whose solutions are on the Web In addition the complete ACL2 scripts necessary to formalize the models and prove all the properties discussed are on the Web For example when we say that one of the case studies formalizes a floating point multiplier and proves it correct we mean that not only can you read an English description of the model and how it was proved correct but you can obtain the entire formal content of the project and replay the proofs if you wish with your copy of ACL2 ACL2 may be obtained from its home page The results reported in each case study as ACL2 input scripts as well as exercise solutions for both books are available from this page   *A Reasoning System for Computer Aided Engineering* Bengt Lundberg,1984   **Design and Verification of Microprocessor Systems for High-Assurance Applications** David S. Hardin,2010-03-02 Microprocessors increasingly control and monitor our most critical systems including automobiles airliners medical systems

transportation grids and defense systems The relentless march of semiconductor process technology has given engineers exponentially increasing transistor budgets at constant recurring cost This has encouraged increased functional integration onto a single die as well as increased architectural sophistication of the functional units themselves Additionally design cycle times are decreasing thus putting increased schedule pressure on engineers Not surprisingly this environment has led to a number of uncaught design flaws Traditional simulation based design verification has not kept up with the scale or pace of modern microprocessor system design Formal verification methods offer the promise of improved bug finding capability as well as the ability to establish functional correctness of a detailed design relative to a high level specification However widespread use of formal methods has had to await breakthroughs in automated reasoning integration with engineering design languages and processes scalability and usability This book presents several breakthrough design and verification techniques that allow these powerful formal methods to be employed in the real world of high assurance microprocessor system design   *Engineering Theories of Software Intensive Systems* Manfred Broy,Johannes Gruenbauer,David Harel,Tony Hoare,2005-11-13 Software engineering has over the years been applied in many different fields ranging from telecommunications to embedded systems in car and aircraft industry as well as in production engineering and computer networks Foundations in software technology lie in models allowing to capture application domains detailed requirements but also to understand the structure and working of software systems like software architectures and programs These models have to be expressed in techniques based on discrete mathematics algebra and logics However according to the very specific needs in applications of software technology formal methods have to serve the needs and the quality of advanced software engineering methods especially taking into account security aspects in Information Technology This book presents mathematical foundations of software engineering and state of the art engineering methods in their theoretical substance in the step towards practical applications to examine software engineering techniques and foundations used for industrial tasks The contributions in this volume emerged from lectures of the 25th International Summer School on Engineering Theories of Software Intensive Systems held at Marktoberdorf Germany from August 3 to August 15 2004   **Scalable Techniques for Formal Verification** Sandip Ray,2010-08-12 This book is about formal veri cation that is the use of mathematical reasoning to ensure correct execution of computing systems With the increasing use of c puting systems in safety critical and security critical applications it is becoming increasingly important for our well being to ensure that those systems execute c rectly Over the last decade formal veri cation has made signi cant headway in the analysis of industrial systems particularly in the realm of veri cation of hardware A key advantage of formal veri cation is that it provides a mathematical guarantee of their correctness up to the accuracy of formal models and correctness of r soning tools In the process the analysis can expose subtle design errors Formal veri cation is particularly effective in nding corner case bugs that are dif cult to detect through traditional simulation and testing Nevertheless and in spite of its promise the application of formal veri cation has so far been

limited in an ind trial design validation tool ow The dif culties in its large scale adoption include the following 1 deductive veri cation using theorem provers often involves cessive and prohibitive manual effort and 2 automated decision procedures e g model checking can quickly hit the bounds of available time and memory This book presents recent advances in formal veri cation techniques and d cusses the applicability of the techniques in ensuring the reliability of large scale systems We deal with the veri cation of a range of computing systems from quential programsto concurrentprotocolsand pipelined machines **Brigham Young University Law Review** ,1980 **Proceedings of the Java Virtual Machine Research and Technology Symposium** ,2001 **Verifiable Programming** Ole-Johan Dahl,1992 Software Software Engineering JSME International Journal ,2001 Advances in Design Automation, 1994: Dynamic mechanical systems. Geometric modeling and features. Concurrent engineering ,1994 ACM Transactions on Computational Logic ,2010 **Spatial Reasoning for Computer Aided Design, Manufacturing and Process Planning** Oscar Eduardo Ruiz,1995 Reasoning about geometric relations and construction of scenes satisfying them are critically important tasks in computer aided design manufacturing and process planning This work addresses these tasks by producing a centralized server for static and dynamic geometric reasoning Static reasoning involves geometric algorithms with fully and consistently defined entities The algorithms include i constructive queries intersection projections convex hulls etc and ii logical queries testing of inclusion intersection etc Dynamic reasoning addresses the geometric constraint satisfaction or scene feasibility GCS SF problem In GCS SF a context world is used to propose a series of geometric constraints among undefined entities points planes lines polyhedra The objective is to obtain either a diagnostic of inconsistency or a set of entities satisfying the constraints The solution to GCS SF finds applications in fixturing assembly planning parametric design tolerancing analysis kinematic analysis of mechanisms etc GCS SF can be expressed as a set of polynomial equations with the feasible configurations corresponding to common roots of the polynomials Using known results in algebraic geometry this work maps properties of Grobner bases to the GCS SF domain The mapping allows to determine multiplicity of feasible scenarios redundancy and consistency of constraints and degrees of freedom of the entities involved A compact and efficient formulation in terms of the subgroups of the special Euclidean group of displacements SE 3 has been used in conjunction with the Grobner bases algorithm The integration of these techniques i lowers the computational cost of the problem ii relates Grobner Bases to the degrees of freedom of the entities iii integrates the topological nature of the constraints and geometrical dimensions of the scene aspects and iv places no restriction on the constraints modeled This research has also explored a Divide and Conquer strategy that identifies GCS SF subproblems which are solved separately and then consolidated in the overall solution Experimental results obtained reflect the advantages of this approach Applications of this work to mobility analysis of mechanisms feasibility analysis of assemblies and form feature extraction are discussed *Journal of Applied Non-classical Logics* ,1993

Computer Aided Reasoning Book Review: Unveiling the Magic of Language

In an electronic era where connections and knowledge reign supreme, the enchanting power of language has be apparent than ever. Its capability to stir emotions, provoke thought, and instigate transformation is actually remarkable. This extraordinary book, aptly titled "**Computer Aided Reasoning**," published by a highly acclaimed author, immerses readers in a captivating exploration of the significance of language and its profound effect on our existence. Throughout this critique, we will delve in to the book is central themes, evaluate its unique writing style, and assess its overall influence on its readership.

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