

Automatic Verilog Code Generation through Grammatical Evolution

Ulya R. Karpuzcu

Department of Computer Engineering
Istanbul Technical University
Maslak 34469 Istanbul, Turkey
karpuzcu@itu.edu.tr

ABSTRACT

This work aims to investigate the automatic generation of Verilog code, representing digital circuits through Grammatical Evolution (GE). Preliminary tests using a simple full adder generation problem have been performed.

Categories and Subject Descriptors

I.2.2 [Artificial Intelligence]: Automatic Programming – program synthesis, program verification.

General Terms

Design, Verification.

Keywords

Grammatical Evolution, Automatic Code Generation, Verilog.

1. INTRODUCTION

Application of a HDL (Hardware Description Language) represents a basic step in the ASIC (Application Specific Integrated Circuit) design flow. In this context, (mostly) a digital circuit is represented in Verilog or VHDL. Then simulations are performed to check the functionality of the generated circuit representation. If the circuit model generated by a HDL shows the expected behavior, synthesis of the circuit, the conversion of the HDL code to an ensemble of logic gates, follows [2]. Because the syntax of Verilog is simpler, Verilog-code generation is aimed for in this study.

In Verilog, circuits can be described at various abstraction levels: behavioral, structural and RTL (Register Transfer Level) coding [4]. Behavioral coding provides a “black box” representation of the circuit to be designed and cannot be synthesized. Structural coding reflects components of a design (e. g. logic gates) and interconnections between them. RTL coding, representing the functionality of a design at register transfer level, employs only the synthesizable portion of Verilog syntax. The most descriptive type is behavioral, then RTL, and finally structural coding [2].

Generation of synthesizable Verilog code, using RTL coding, is intended within the scope of this work. Circuit models generated by synthesis tools stand in strong correlation with the HDL code written to represent the functionality of the circuit to be designed [2]. Automatic Verilog code generation through Grammatical Evolution covers this step.

2. DETERMINATION OF THE EVOLUTIONARY TECHNIQUE SUITED TO VERILOG CODE GENERATION

2.1 Genetic Programming (GP)

The first technique considered was Genetic Programming (GP). Since each element in the solution space of the problem is depicted as a tree, GP provides a proper representation mechanism for the automatic code¹ generation paradigm [1]. Main limitation of GP over crossover and mutation is closure. Closure allows any two points in a tree representing a computer program to be crossed over without loss of validity [11]. The set of syntactically valid individuals should be closed over the genetic operations. To achieve this, each non-terminal node of the tree representation of a program is expected to have the same arity and a return value of the same type [10].

Verilog syntax permits the use of code blocks such as “if” and “always”, which should be protected against the destructive operation of crossover. GP’s modularization scheme, Automatically Defined Functions (ADFs) can be used to achieve this. Besides, Verilog syntax constraints include:

1. An input variable on the left hand side of an assignment is not allowed.
2. An assignment cannot be generated as the condition statement of an “if” or “always” block.
3. Depending on the nature of the circuit to be represented, zero or more “always” blocks or alternatively zero or more assignment statements should be brought together. For instance, an expression defining the right hand side of an assignment, or a conditional statement (expected to be used in the context of an “if” or “always” block) should not be generated without context to represent a line of code.

If standard GP is used, the set of non-terminals consist of Verilog operators. To define constraint 1, e. g., the left child of a subtree having an assignment operator in its root should be restricted to include an element from the set of output variables, while various logical, bitwise, reduction or concatenation operators can be placed at the right hand side child. As no rules can be defined to

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Genetic and Evolutionary Computation Conference (GECCO’05, June 25–29, 2005, Washington DC, USA).

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¹ In this work, “code” is used to specify Verilog code.

Verilog Code For Automatic Switching

Chris Spear, Greg Tumbush



Verilog Code For Automatic Switching:

Digital Integrated Circuit Design Using Verilog and Systemverilog Ronald W. Mehler, 2014-09-30 For those with a basic understanding of digital design this book teaches the essential skills to design digital integrated circuits using Verilog and the relevant extensions of SystemVerilog In addition to covering the syntax of Verilog and SystemVerilog the author provides an appreciation of design challenges and solutions for producing working circuits The book covers not only the syntax and limitations of HDL coding but deals extensively with design problems such as partitioning and synchronization helping you to produce designs that are not only logically correct but will actually work when turned into physical circuits Throughout the book many small examples are used to validate concepts and demonstrate how to apply design skills This book takes readers who have already learned the fundamentals of digital design to the point where they can produce working circuits using modern design methodologies It clearly explains what is useful for circuit design and what parts of the languages are only software providing a non theoretical practical guide to robust reliable and optimized hardware design and development Produce working hardware Covers not only syntax but also provides design know how addressing problems such as synchronization and partitioning to produce working solutions Usable examples Numerous small examples throughout the book demonstrate concepts in an easy to grasp manner Essential knowledge Covers the vital design topics of synchronization essential for producing working silicon asynchronous interfacing techniques and design techniques for circuit optimization including partitioning

FPGA Prototyping by Verilog Examples Pong P. Chu, 2011-09-20 FPGA Prototyping Using Verilog Examples will provide you with a hands on introduction to Verilog synthesis and FPGA programming through a learn by doing approach By following the clear easy to understand templates for code development and the numerous practical examples you can quickly develop and simulate a sophisticated digital circuit realize it on a prototyping device and verify the operation of its physical implementation This introductory text that will provide you with a solid foundation instill confidence with rigorous examples for complex systems and prepare you for future development tasks

Field-Programmable Logic and Applications. The Roadmap to Reconfigurable Computing Reiner W. Hartenstein, Herbert Grünbacher, 2000-08-21 This book constitutes the refereed proceedings of the 10th International Conference on Field Programmable Logic and Applications FPL 2000 held in Villach Austria in August 2000 The 64 revised full papers presented together with eight invited contributions and 21 short papers were carefully reviewed and selected from a total of 131 submissions The book offers topical sections on network processors prototyping dynamic reconfigurability technology mapping routing and placement biologically inspired methods mobile communication design space exploration optimization architectures methodology and technology compilation applications and miscellaneous

Power Electronics Circuit Analysis with PSIM® Farzin Asadi, Kei Eguchi, 2021-09-20 Power electronics systems are nonlinear variable structure systems They involve passive components such as resistors capacitors and inductors semiconductor switches such as thyristors and MOSFETs and circuits

for control The analysis and design of such systems presents significant challenges Fortunately increased availability of powerful computer and simulation programs makes the analysis design process much easier PSIM is an electronic circuit simulation software package designed specifically for use in power electronics and motor drive simulations but can be used to simulate any electronic circuit With fast simulation speed and user friendly interface PSIM provides a powerful simulation environment to meet the user simulation and development needs This book shows how to simulate the power electronics circuits in PSIM environment The prerequisite for this book is a first course on power electronics This book is composed of eight chapters Chapter 1 is an introduction to PSIM Chapter 2 shows the fundamentals of circuit simulation with PSIM Chapter 3 introduces the Simview™ Simview is PSIM's waveform display and post processing program Chapter 4 introduces the most commonly used components of PSIM Chapter 5 shows how PSIM can be used for analysis of power electronics circuits 45 examples are studied in this chapter Chapter 6 shows how you can simulate motors and mechanical loads in PSIM Chapter 7 introduces the SimCoupler™ Simcoupler fuses PSIM with Simulink by providing an interface for co simulation Chapter 8 introduces the SmartCtrl SmartCtrl is a controller design software specifically geared towards power electronics applications <https://powersimtech.com> 2021 10 01 book release power electronics circuit analysis with psim

Digital Design of Signal Processing Systems Shoab Ahmed Khan, 2011-02-02 Digital Design of Signal Processing Systems discusses a spectrum of architectures and methods for effective implementation of algorithms in hardware HW Encompassing all facets of the subject this book includes conversion of algorithms from floating point to fixed point format parallel architectures for basic computational blocks Verilog Hardware Description Language HDL SystemVerilog and coding guidelines for synthesis The book also covers system level design of Multi Processor System on Chip MPSoC a consideration of different design methodologies including Network on Chip NoC and Kahn Process Network KPN based connectivity among processing elements A special emphasis is placed on implementing streaming applications like a digital communication system in HW Several novel architectures for implementing commonly used algorithms in signal processing are also revealed With a comprehensive coverage of topics the book provides an appropriate mix of examples to illustrate the design methodology Key Features A practical guide to designing efficient digital systems covering the complete spectrum of digital design from a digital signal processing perspective Provides a full account of HW building blocks and their architectures while also elaborating effective use of embedded computational resources such as multipliers adders and memories in FPGAs Covers a system level architecture using NoC and KPN for streaming applications giving examples of structuring MATLAB code and its easy mapping in HW for these applications Explains state machine based and Micro Program architectures with comprehensive case studies for mapping complex applications The techniques and examples discussed in this book are used in the award winning products from the Center for Advanced Research in Engineering CARE Software Defined Radio 10 Gigabit VoIP monitoring system and Digital Surveillance equipment has respectively won APICTA Asia Pacific Information

and Communication Alliance awards in 2010 for their unique and effective designs

Digital Design (Verilog) Peter J. Ashenden, 2007-10-24 Digital Design An Embedded Systems Approach Using Verilog provides a foundation in digital design for students in computer engineering electrical engineering and computer science courses It takes an up to date and modern approach of presenting digital logic design as an activity in a larger systems design context Rather than focus on aspects of digital design that have little relevance in a realistic design context this book concentrates on modern and evolving knowledge and design skills Hardware description language HDL based design and verification is emphasized Verilog examples are used extensively throughout By treating digital logic as part of embedded systems design this book provides an understanding of the hardware needed in the analysis and design of systems comprising both hardware and software components Includes a Web site with links to vendor tools labs and tutorials Presents digital logic design as an activity in a larger systems design context Features extensive use of Verilog examples to demonstrate HDL hardware description language usage at the abstract behavioural level and register transfer level as well as for low level verification and verification environments Includes worked examples throughout to enhance the reader s understanding and retention of the material Companion Web site includes links to tools for FPGA design from Synplicity Mentor Graphics and Xilinx Verilog source code for all the examples in the book lecture slides laboratory projects and solutions to exercises

SystemVerilog for Verification Chris Spear, Greg Tumbush, 2012-02-14 Based on the highly successful second edition this extended edition of SystemVerilog for Verification A Guide to Learning the Testbench Language Features teaches all verification features of the SystemVerilog language providing hundreds of examples to clearly explain the concepts and basic fundamentals It contains materials for both the full time verification engineer and the student learning this valuable skill In the third edition authors Chris Spear and Greg Tumbush start with how to verify a design and then use that context to demonstrate the language features including the advantages and disadvantages of different styles allowing readers to choose between alternatives This textbook contains end of chapter exercises designed to enhance students understanding of the material Other features of this revision include New sections on static variables print specifiers and DPI from the 2009 IEEE language standard Descriptions of UVM features such as factories the test registry and the configuration database Expanded code samples and explanations Numerous samples that have been tested on the major SystemVerilog simulators SystemVerilog for Verification A Guide to Learning the Testbench Language Features Third Edition is suitable for use in a one semester SystemVerilog course on SystemVerilog at the undergraduate or graduate level Many of the improvements to this new edition were compiled through feedback provided from hundreds of readers

Getting Started with FPGAs Russell Merrick, 2023-11-21 Skip the complexity and learn to program FPGAs the easy way through this hands on beginner friendly introduction to digital circuit design with Verilog and VHDL Whether you have been toying with field programmable gate arrays FPGAs for years or are completely new to these reprogrammable devices this book will teach you to think like an FPGA engineer and develop

reliable designs with confidence Through detailed code examples patient explanations and hands on projects Getting Started with FPGAs will actually get you started Russell Merrick creator of the popular blog Nandland com will guide you through the basics of digital logic look up tables and flip flops as well as high level concepts like state machines You ll explore the fundamentals of the FPGA build process including simulation synthesis and place and route You ll learn about key FPGA primitives such as DSP blocks and PLLs and examine how FPGAs handle math operations and I O Code examples are provided in both Verilog and VHDL making the book a valuable resource no matter your language of choice You ll discover how to Implement common design building blocks like multiplexers LFSRs and FIFOs Cross between clock domains without triggering metastable conditions or timing errors Avoid common pitfalls when performing math Transmit and receive data at lightning speeds using SerDes Write testbench code to verify your designs are working With this accessible hands on guide you ll be creating your own functional FPGA projects in no time Getting started with FPGAs has never been easier

Correct Hardware Design and Verification Methods Laurence Pierre,Thomas Kropf,2003-07-31 CHARME 99 is the tenth in a series of working conferences devoted to the development and use of leading edge formal techniques and tools for the design and verification of hardware and systems Previous conferences have been held in Darmstadt 1984 Edinburgh 1985 Grenoble 1986 Glasgow 1988 Leuven 1989 Torino 1991 Arles 1993 Frankfurt 1995 and Montreal 1997 This workshop and conference series has been organized in cooperation with IFIP WG 10.5 It is now the biannual counterpart of FMCAD which takes place every even numbered year in the USA The 1999 event took place in Bad Herrenalb a resort village located in the Black Forest close to the city of Karlsruhe The validation of functional and timing behavior is a major bottleneck in current VLSI design systems A predominantly academic area of study until a few years ago formal design and verification techniques are now migrating into industrial use The aim of CHARME 99 is to bring together researchers and users from academia and industry working in this active area of research Two invited talks illustrate major current trends the presentation by Gerard Berry Ecole des Mines de Paris Sophia Antipolis France is concerned with the use of synchronous languages in circuit design and the talk given by Peter Jansen BMW Munich Germany demonstrates an application of formal methods in an industrial environment The program also includes 20 regular presentations and 12 short presentations poster exhibitions that have been selected from the 48 submitted papers

Digital Control of High-Frequency Switched-Mode Power Converters Luca Corradini,Dragan Maksimovic,Paolo Mattavelli,Regan Zane,2015-07-10 This book is focused on the fundamental aspects of analysis modeling and design of digital control loops around high frequency switched mode power converters in a systematic and rigorous manner Comprehensive treatment of digital control theory for power converters Verilog and VHDL sample codes are provided Enables readers to successfully analyze model design and implement voltage current or multi loop digital feedback loops around switched mode power converters Practical examples are used throughout the book to illustrate applications of the techniques developed Matlab examples are also provided

Springer Handbook of Semiconductor

Devices Massimo Rudan, Rossella Brunetti, Susanna Reggiani, 2022-11-10 This Springer Handbook comprehensively covers the topic of semiconductor devices embracing all aspects from theoretical background to fabrication modeling and applications. Nearly 100 leading scientists from industry and academia were selected to write the handbook's chapters which were conceived for professionals and practitioners: material scientists, physicists, and electrical engineers working at universities, industrial R D, and manufacturers. Starting from the description of the relevant technological aspects and fabrication steps, the handbook proceeds with a section fully devoted to the main conventional semiconductor devices like e.g. bipolar transistors and MOS capacitors and transistors used in the production of the standard integrated circuits and the corresponding physical models. In the subsequent chapters, the scaling issues of the semiconductor device technology are addressed, followed by the description of novel concept-based semiconductor devices. The last section illustrates the numerical simulation methods ranging from the fabrication processes to the device performances. Each chapter is self-contained and refers to related topics treated in other chapters when necessary, so that the reader interested in a specific subject can easily identify a personal reading path through the vast contents of the handbook.

Reuse Techniques for VLSI Design Ralf Seepold, Arno Kunzmann, 2012-12-06 Reuse Techniques for VLSI Design is a reflection on the current state of the art in design reuse for microelectronic systems. To that end, it is the first book to garner the input of leading experts from both research and application areas. These experts document herein not only their more mature approaches but also their latest research results. Firstly, it sets out the background and support from international organisations that enforce System on a Chip SoC design by reuse-oriented methodologies. This overview is followed by a number of technical presentations covering different requirements of the reuse domain. These are presented from different points of view: i.e. IP provider, IP user, designer, isolated reuse, intra-company or inter-company reuse. More general systems or case studies e.g. metrics are followed by comprehensive reuse systems e.g. reuse management systems partly including business models. Since design reuse must not be restricted to digital components, mixed-signal and analog reuse approaches are also presented. In parallel to the digital domain, this area covers research in reuse database design. Design verification and legal aspects are two important topics that are closely related to the realization of design reuse. These hot topics are covered by presentations that finalize the survey of outstanding research, development, and application of design reuse for SoC design. Reuse Techniques for VLSI Design is an invaluable reference for researchers and engineers involved in VLSI/ASIC design.

Field-programmable Logic and Applications, 2000 **Power Converters for Medium Voltage Networks** Md. Rabiul Islam, Youguang Guo, Jianguo Zhu, 2014-09-15 This book examines a number of topics mainly in connection with advances in semiconductor devices and magnetic materials and developments in medium and large-scale renewable power plant technologies, grid integration techniques, and new converter topologies including advanced digital control systems for medium-voltage networks. The book's individual chapters provide an extensive compilation of fundamental theories and in

depth information on current research and development trends while also exploring new approaches to overcoming some critical limitations of conventional grid integration technologies Its main objective is to present the design and implementation processes for medium voltage converters allowing the direct grid integration of renewable power plants without the need for step up transformers

Research Infrastructures for Hardware Accelerators Yakun Sophia Shao,David Brooks,2022-05-31 Hardware acceleration in the form of customized datapath and control circuitry tuned to specific applications has gained popularity for its promise to utilize transistors more efficiently Historically the computer architecture community has focused on general purpose processors and extensive research infrastructure has been developed to support research efforts in this domain Envisioning future computing systems with a diverse set of general purpose cores and accelerators computer architects must add accelerator related research infrastructures to their toolboxes to explore future heterogeneous systems This book serves as a primer for the field as an overview of the vast literature on accelerator architectures and their design flows and as a resource guidebook for researchers working in related areas

Guide to FPGA Implementation of Arithmetic Functions Jean-Pierre Deschamps,Gustavo D. Sutter,Enrique Cantó,2012-04-05 This book is designed both for FPGA users interested in developing new specific components generally for reducing execution times and IP core designers interested in extending their catalog of specific components The main focus is circuit synthesis and the discussion shows for example how a given algorithm executing some complex function can be translated to a synthesizable circuit description as well as which are the best choices the designer can make to reduce the circuit cost latency or power consumption This is not a book on algorithms It is a book that shows how to translate efficiently an algorithm to a circuit using techniques such as parallelism pipeline loop unrolling and others Numerous examples of FPGA implementation are described throughout this book and the circuits are modeled in VHDL Complete and synthesizable source files are available for download

VLSI, Communication and Signal Processing R. K. Nagaria,V. S. Tripathi,Carlos Ruiz Zamarreno,Yogendra Kumar Prajapati,2023-07-01 This book covers a variety of topics in Electronics and Communication Engineering especially in the area of microelectronics and VLSI design communication systems and networks and signal and image processing The content is based on papers presented at the 5th International Conference on VLSI Communication and Signal Processing VCAS 2022 The book also discusses the emerging applications of novel tools and techniques in image video and multimedia signal processing This book is useful to students researchers and professionals working in the electronics and communication domain

Chip Multiprocessor Generator Ofer Shacham,2011 Recent changes in technology scaling have made power dissipation today s major performance limiter As a result designers struggle to meet performance requirements under stringent power budgets At the same time the traditional solution to power efficiency application specific designs has become prohibitively expensive due to increasing nonrecurring engineering NRE costs Most concerning are the development costs for design validation and software for new systems In this thesis we argue that one can harness ideas of

reconfigurable designs to build a design framework that can generate semi custom chips a Chip Generator A domain specific chip generator codifies the designer knowledge and design trade offs into a template that can be used to create many different chips Like reconfigurable designs these systems fix the top level system architecture amortizing software and validation and design costs and enabling a rich system simulation environment for application developers Meanwhile below the top level the developer can program the individual inner components of the architecture Unlike reconfigurable chips a generator compiles the program to create a customized chip This compilation process occurs at elaboration time long before silicon is fabricated The result is a framework that enables more customization of the generated chip at the architectural level because additional components and logic can be added if the customization process requires it At the same time this framework does not introduce inefficiency at the circuit level because unneeded circuit overheads are not taped out Using Chip Generators we argue will enable design houses to design a wide family of chips using a cost structure similar to that of designing a single chip potentially saving tens of millions of dollars while enabling per application customization and optimization

Complex Digital Hardware Design Istvan Nagy, 2024-05-09 This book is about how to design the most complex types of digital circuit boards used inside servers routers and other equipment from high level system architecture down to the low level signal integrity concepts It explains common structures and subsystems that can be expanded into new designs in different markets The book is targeted at all levels of hardware engineers There are shorter lower level introductions to every topic while the book also takes the reader all the way to the most complex and most advanced topics of digital circuit design layout design analysis and hardware architecture

Software-Hardware Integration in Automotive Product Development John Blyler, 2013-11-07 Software Hardware Integration in Automotive Product Development brings together a must read set of technical papers on one the most talked about subjects among industry experts The carefully selected content of this book demonstrates how leading companies universities and organizations have developed methodologies tools and technologies to integrate verify and validate hardware and software systems The automotive industry is no different with the future of its product development lying in the timely integration of these chiefly electronic and mechanical systems The integration activities cross both product type and engineering discipline boundaries to include chip embedded board and network vehicle level systems Integration verification and validation of each of these three domains are examined in depth attesting to the difficulties of this phase of the automotive hardware and software system life cycle The current state of the art is to integrate verify validate and test automotive hardware and software with a complement of physical hardware and virtual software prototyping tools The growth of sophisticated software tools sometimes combined with hardware in the loop devices has allowed the automotive industry to meet shrinking time to market decreasing costs and increasing safety demands It is also why most of the papers in this book focus on virtual systems prototypes and models to emulate and simulate both hardware and software Further such tools and techniques are the way

that hardware and software systems can be co verified and tested in a concurrent fashion The goal of this compilation of expert articles is to reveal the similarities and differences between the integration verification and validation IVV of hardware and software at the chip board and network levels This comparative study will reveal the common IVV thread among the different but ultimately related implementations of hardware and software systems In so doing it supports the larger systems engineering approach for the vertically integrated automobile namely that of model driven development

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