

DRILLS: Debugging RTL Intelligently with Localization from Long-Simulation

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ABSTRACT

As RTL design complexity increases it is more difficult to debug failing tests that from the use of powerful DSLs (Chisel) and higher levels of abstraction (HLS), the number of subtle bugs present in a design also increases. Many design bugs are difficult to catch with unit testing...

1 INTRODUCTION

Specification mining is a technique to extract LTL properties from a set of traces of signals. This technique can be applied for several purposes in the domain of digital hardware verification including:

- (1) Developing a suite of assertions to be used for design regressions: once a design is mature, most of the interface boundary specifications are well defined and fine-grained assertions derived from specification mining can help catch regressions when design refinements or optimizations are being made.
- (2) A starting point for formally specifying a design: once a design can pass random-stimulus based and directed unit tests, specification mining can be used to extract properties that have been consistently observed in the test waveforms. These properties can then be used as assertions to prove formally.
- (3) Early anomaly detection and localization on long-running tests on mature RTL: if a specific test fails on an RTL design while many other tests pass, specification mining can reveal *where and when* a failing test begins to produce unusual behavior in the RTL, guiding the designer to the bug location.

In this report, we will focus on applying specification mining to address the last point above.

1.1 Motivation

RTL designs are increasing in complexity and are thus more prone to having subtle bugs that are not caught in regular verification flows. Typical techniques such as randomized-stimulus testing, directed testing, and fuzz testing have a difficult time catching bugs that require the RTL be put into a very specific state.

These subtle bugs are usually caught when performing chip emulation or FPGA prototyping when running realistic workloads on the RTL. Real workloads usually involve traces that are billion of cycles long, and are thus too slow to perform using RTL simulation which provides full design visibility. DESSERT[18] demonstrates a technique to capture full-visibility waveform traces from fast running FPGA simulation. Using DESSERT, an out-of-order RISC-V processor (BOOM[5]) is deterministically emulated on an

FPGA with runtime assertion monitors while running the SPEC2017 benchmark suite. During the execution of several tests, synthesized assertions were violated which revealed there exists some subtle bugs in the core causing the tests to fail.

While these assertions are useful for catching errors, they are very high-level and don't direct the designer to where a bug originated. As an example, the "Pipeline has hung" assertion is generated with the following Chisel code:

```
// detect pipeline freezes and throw error
val idle_cycles = freechips.rocketchip.util.WideCounter(32)
when (rob.io.commit.valids.asUInt.orR ||
      csr.io.csr_stall ||
      io.rocc.busy ||
      reset.asBool) {
  idle_cycles := 0.U
}
assert (!(idle_cycles.value(13)), "Pipeline has hung.")
```

In words, this says, "If there is a good reason to stall the pipeline, reset `idle_cycles`, otherwise let it tick up to 13 before declaring something has gone wrong." This assertion does not give any insight as to what bad event happened, or when and where it happened. Since these assertions are thrown after billions of cycles it is possible that some latent state was corrupted early in the simulation and only triggered this assertion much later during execution. DESSERT enables extracting waveforms for a variable number of cycles before the assertion triggers, but even with the waveform dumps in hand, the designer was unable to localize the bug. Our aim in developing the specification mining tool is to hunt out the locations of these tricky bugs in BOOM and fix them.

1.2 Hypothesis

1.3 Problem Definition

2 APPROACH

2.1 Prior Work

2.2 High-Level Flow

3 SPEC MINING ENGINE AND ALGORITHMS

3.1 Delta Traces

3.2 LTL Templates

3.3 Mining with Automata

4 CHALLENGES

5 RESULTS

6 COURSE-RELATED

6.1 Roles

6.2 Usage of Class Topics

6.3 Feedback

If you are new to publishing with ACM, this document is a valuable guide to the process of preparing your work for publication. If you have published with ACM before, this document provides insight and instruction into more recent changes to the article template.

The “acmart” document class can be used to prepare articles for any ACM publication — conference or journal, and for any stage of publication, from review to final “camera-ready” copy, to the author’s own version, with very few changes to the source.

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As noted in the introduction, the “acmart” document class can be used to prepare many different kinds of documentation — a double-blind initial submission of a full-length technical paper, a two-page SIGGRAPH Emerging Technologies abstract, a “camera-ready” journal article, a SIGCHI Extended Abstract, and more — all by selecting the appropriate *template style* and *template parameters*.

This document will explain the major features of the document class. For further information, the *L^AT_EX User’s Guide* is available from <https://www.acm.org/publications/proceedings-template>.

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```
\documentclass[STYLE]{acmart}
```

Journals use one of three template styles. All but three ACM journals use the `acmsmall` template style:

- `acmsmall`: The default journal template style.
- `acmlarge`: Used by JOCCH and TAP.
- `acmtog`: Used by TOG.

The majority of conference proceedings documentation will use the `acmconf` template style.

- `acmconf`: The default proceedings template style.

- `sigchi`: Used for SIGCHI conference articles.
- `sigchi-a`: Used for SIGCHI “Extended Abstract” articles.
- `sigplan`: Used for SIGPLAN conference articles.

7.2 Template Parameters

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```
\title[short title]{full title}
```

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Each author must be defined separately for accurate metadata identification. Multiple authors may share one affiliation. Authors’ names should not be abbreviated; use full first names wherever possible. Include authors’ e-mail addresses whenever possible.

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```
\author{Brooke Aster, David Mehldau}
```

```
\email{dave,judy,steve@university.edu}
\email{firstname.lastname@phillips.org}
```

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```
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```

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CCS concepts and user-defined keywords are required for all short- and full-length articles, and optional for two-page abstracts.

14 SECTIONING COMMANDS

Your work should use standard \LaTeX sectioning commands: `section`, `subsection`, `subsubsection`, and `paragraph`. They should be numbered; do not remove the numbering from the commands.

Table 1: Frequency of Special Characters

Non-English or Math	Frequency	Comments
Ø	1 in 1,000	For Swedish names
π	1 in 5	Common in math
\$	4 in 5	Used in business
Ψ_1^2	1 in 40,000	Unexplained usage

Simulating a sectioning command by setting the first word or words of a paragraph in boldface or italicized text is **not allowed**.

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The "acmart" document class includes the "booktabs" package — <https://ctan.org/pkg/booktabs> — for preparing high-quality tables.

Table captions are placed *above* the table.

Because tables cannot be split across pages, the best placement for them is typically the top of the page nearest their initial cite. To ensure this proper "floating" placement of tables, use the environment `table` to enclose the table's contents and the table caption. The contents of the table itself must go in the `tabular` environment, to be aligned properly in rows and columns, with the desired horizontal and vertical rules. Again, detailed instructions on `tabular` material are found in the *\LaTeX User's Guide*.

Immediately following this sentence is the point at which Table 1 is included in the input file; compare the placement of the table here with the table in the printed output of this document.

To set a wider table, which takes up the whole width of the page's live area, use the environment `table*` to enclose the table's contents and the table caption. As with a single-column table, this wide table will "float" to a location deemed more desirable. Immediately following this sentence is the point at which Table 2 is included in the input file; again, it is instructive to compare the placement of the table here with the table in the printed output of this document.

16 MATH EQUATIONS

You may want to display math equations in three distinct styles: inline, numbered or non-numbered display. Each of the three are discussed in the next sections.

16.1 Inline (In-text) Equations

A formula that appears in the running text is called an inline or in-text formula. It is produced by the `math` environment, which can be invoked with the usual `\begin . . . \end` construction or with the short form `$. . . $`. You can use any of the symbols and structures, from α to ω , available in \LaTeX [22]; this section will simply show a few examples of in-text equations in context. Notice how this equation: $\lim_{n \rightarrow \infty} x = 0$, set here in in-line math style, looks slightly different when set in display style. (See next section).

16.2 Display Equations

A numbered display equation—one set off by vertical space from the text and centered horizontally—is produced by the `equation` environment. An unnumbered display equation is produced by the `displaymath` environment.

Table 2: Some Typical Commands

Command	A Number	Comments
<code>\author</code>	100	Author
<code>\table</code>	300	For tables
<code>\table*</code>	400	For wider tables

Again, in either environment, you can use any of the symbols and structures available in \LaTeX ; this section will just give a couple of examples of display equations in context. First, consider the equation, shown as an inline equation above:

$$\lim_{n \rightarrow \infty} x = 0$$

(1)

Notice how it is formatted somewhat differently in the `display-math` environment. Now, we'll enter an unnumbered equation:

$$\sum_{i=0}^{\infty} x + 1$$

and follow it with another numbered equation:

$$\sum_{i=0}^{\infty} x_i = \int_0^{\pi+2} f$$

(2)

just to demonstrate \LaTeX 's able handling of numbering.

17 FIGURES

The “figure” environment should be used for figures. One or more images can be placed within a figure. If your figure contains third-party material, you must clearly identify it as such, as shown in the example below.



Figure 1: 1907 Franklin Model D roadster. Photograph by Harris & Ewing, Inc. [Public domain], via Wikimedia Commons. (<https://goo.gl/VLCRBB>).

Your figures should contain a caption which describes the figure to the reader. Figure captions go below the figure. Your figures

should **also** include a description suitable for screen readers, to assist the visually-challenged to better understand your work.

Figure captions are placed *below* the figure.

17.1 The “Teaser Figure”

A “teaser figure” is an image, or set of images in one figure, that are placed after all author and affiliation information, and before the body of the article, spanning the page. If you wish to have such a figure in your article, place the command immediately before the `\maketitle` command:

```
\begin{teaserfigure}
  \includegraphics[width=\textwidth]{sampleteaser}
  \caption{figure caption}
  \Description{figure description}
\end{teaserfigure}
```

18 CITATIONS AND BIBLIOGRAPHIES

The use of \LaTeX for the preparation and formatting of one’s references is strongly recommended. Authors’ names should be complete — use full first names (“Donald E. Knuth”) not initials (“D. E. Knuth”) — and the salient identifying features of a reference should be included: title, year, volume, number, pages, article DOI, etc.

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```
\bibliographystyle{ACM-Reference-Format}
\bibliography{bibfile}
```

where “bibfile” is the name, without the “.bib” suffix, of the \LaTeX file.

Citations and references are numbered by default. A small number of ACM publications have citations and references formatted in the “author year” style; for these exceptions, please include this command in the **preamble** (before “`\begin{document}`”) of your \LaTeX source:

```
\citestyle{acmauthoryear}
```

Some examples. A paginated journal article [2], an enumerated journal article [8], a reference to an entire issue [7], a monograph (whole book) [21], a monograph/whole book in a series (see 2a in spec. document) [14], a divisible-book such as an anthology or compilation [10] followed by the same example, however we only output the series if the volume number is given [11] (so Editor00a’s series should NOT be present since it has no vol. no.), a chapter in a divisible book [32], a chapter in a divisible book in a series [9], a multi-volume work as book [20], an article in a proceedings (of a conference, symposium, workshop for example) (paginated proceedings article) [3], a proceedings article with all possible elements [31], an example of an enumerated proceedings article [12], an informally published work [13], a doctoral dissertation [6], a

master's thesis: [4], an online document / world wide web resource [1, 26, 33], a video game (Case 1) [25] and (Case 2) [24] and [23] and (Case 3) a patent [30], work accepted for publication [27], 'YYYYb'-test for prolific author [28] and [29]. Other cites might contain 'duplicate' DOI and URLs (some SIAM articles) [19]. Boris / Barbara Beeton: multi-volume works as books [16] and [15]. A couple of citations with DOIs: [17, 19]. Online citations: [33–35].

19 ACKNOWLEDGMENTS

Identification of funding sources and other support, and thanks to individuals and groups that assisted in the research and the preparation of the work should be included in an acknowledgment section, which is placed just before the reference section in your document.

This section has a special environment:

```
\begin{acks}
...
\end{acks}
```

so that the information contained therein can be more easily collected during the article metadata extraction phase, and to ensure consistency in the spelling of the section heading.

Authors should not prepare this section as a numbered or un-numbered \section; please use the “acks” environment.

20 APPENDICES

If your work needs an appendix, add it before the “\end{document}” command at the conclusion of your source document.

Start the appendix with the “appendix” command:

```
\appendix
```

and note that in the appendix, sections are lettered, not numbered. This document has two appendices, demonstrating the section and subsection identification method.

21 SIGCHI EXTENDED ABSTRACTS

The “sigchi-a” template style (available only in L^AT_EX and not in Word) produces a landscape-orientation formatted article, with a wide left margin. Three environments are available for use with the “sigchi-a” template style, and produce formatted output in the margin:

- sidebar: Place formatted text in the margin.
- marginfigure: Place a figure in the margin.
- margintable: Place a table in the margin.

ACKNOWLEDGMENTS

To Robert, for the bagels and explaining CMYK and color spaces.

REFERENCES

- [1] Rafal Ablamowicz and Bertfried Fauser. 2007. CLIFFORD: a Maple 11 Package for Clifford Algebra Computations, version 11. Retrieved February 28, 2008 from <http://math.tntech.edu/rafa/cliff11/index.html>
- [2] Patricia S. Abril and Robert Plant. 2007. The patent holder's dilemma: Buy, sell, or troll? *Commun. ACM* 50, 1 (Jan. 2007), 36–44. <https://doi.org/10.1145/1188913.1188915>
- [3] Sten Andler. 1979. Predicate Path expressions. In *Proceedings of the 6th. ACM SIGACT-SIGPLAN symposium on Principles of Programming Languages (POPL '79)*. ACM Press, New York, NY, 226–236. <https://doi.org/10.1145/567752.567774>
- [4] David A. Anisi. 2003. *Optimal Motion Control of a Ground Vehicle*. Master's thesis. Royal Institute of Technology (KTH), Stockholm, Sweden.
- [5] Christopher Celio, David A. Patterson, and Krste Asanovic. 2015. *The Berkeley Out-of-Order Machine (BOOM): An Industry-Competitive, Synthesizable, Parametrized RISC-V Processor*. Technical Report. <https://www.eecs.berkeley.edu/Pubs/TechRpts/2015/EECS-2015-167.html>
- [6] Kenneth L. Clarkson. 1985. *Algorithms for Closest-Point Problems (Computational Geometry)*. Ph.D. Dissertation. Stanford University, Palo Alto, CA. UMI Order Number: AAT 8506171.
- [7] Jacques Cohen (Ed.). 1996. Special issue: Digital Libraries. *Commun. ACM* 39, 11 (Nov. 1996).
- [8] Sarah Cohen, Werner Nutt, and Yehoshua Sagie. 2007. Deciding equivalences among conjunctive aggregate queries. *J. ACM* 54, 2, Article 5 (April 2007), 50 pages. <https://doi.org/10.1145/1219092.1219093>
- [9] Bruce P. Douglass, David Harel, and Mark B. Trakhtenbrot. 1998. Statecharts in use: structured analysis and object-orientation. In *Lectures on Embedded Systems*, Grzegorz Rozenberg and Frits W. Vaandrager (Eds.). Lecture Notes in Computer Science, Vol. 1494. Springer-Verlag, London, 368–394. https://doi.org/10.1007/3-540-65193-4_29
- [10] Ian Editor (Ed.). 2007. *The title of book one* (1st. ed.). The name of the series one, Vol. 9. University of Chicago Press, Chicago. <https://doi.org/10.1007/3-540-09237-4>
- [11] Ian Editor (Ed.). 2008. *The title of book two* (2nd. ed.). University of Chicago Press, Chicago, Chapter 100. <https://doi.org/10.1007/3-540-09237-4>
- [12] Matthew Van Gundy, Davide Balzarotti, and Giovanni Vigna. 2007. Catch me, if you can: Evading network signatures with web-based polymorphic worms. In *Proceedings of the first USENIX workshop on Offensive Technologies (WOOT '07)*. USENIX Association, Berkeley, CA, Article 7, 9 pages.
- [13] David Harel. 1978. *LOGICS of Programs: AXIOMATICS and DESCRIPTIVE POWER*. MIT Research Lab Technical Report TR-200. Massachusetts Institute of Technology, Cambridge, MA.
- [14] David Harel. 1979. *First-Order Dynamic Logic*. Lecture Notes in Computer Science, Vol. 68. Springer-Verlag, New York, NY. <https://doi.org/10.1007/3-540-09237-4>
- [15] Lars Hörmander. 1985. *The analysis of linear partial differential operators. III. Grundlehren der Mathematischen Wissenschaften [Fundamental Principles of Mathematical Sciences]*, Vol. 275. Springer-Verlag, Berlin, Germany. viii+525 pages. Pseudodifferential operators.
- [16] Lars Hörmander. 1985. *The analysis of linear partial differential operators. IV. Grundlehren der Mathematischen Wissenschaften [Fundamental Principles of Mathematical Sciences]*, Vol. 275. Springer-Verlag, Berlin, Germany. vii+352 pages. Fourier integral operators.
- [17] IEEE 2004. IEEE TCSC Executive Committee. In *Proceedings of the IEEE International Conference on Web Services (ICWS '04)*. IEEE Computer Society, Washington, DC, USA, 21–22. <https://doi.org/10.1109/ICWS.2004.64>
- [18] Donggyu Kim, Christopher Celio, Sagar Karandikar, David Biancolin, Jonathan Bachrach, and Krste Asanovic. 2018. DESSERT: Debugging RTL Effectively with State Snapshotting for Error Replays across Trillions of Cycles. In *2018 28th International Conference on Field Programmable Logic and Applications (FPL)*. IEEE. <https://doi.org/10.1109/fpl.2018.00021>
- [19] Markus Kirschmer and John Voight. 2010. Algorithmic Enumeration of Ideal Classes for Quaternion Orders. *SIAM J. Comput.* 39, 5 (Jan. 2010), 1714–1747. <https://doi.org/10.1137/080734467>
- [20] Donald E. Knuth. 1997. *The Art of Computer Programming, Vol. 1: Fundamental Algorithms (3rd. ed.)*. Addison Wesley Longman Publishing Co., Inc.
- [21] David Kosior. 2001. *Understanding Policy-Based Networking* (2nd. ed.). Wiley, New York, NY.
- [22] Leslie Lamport. 1986. *L^AT_EX: A Document Preparation System*. Addison-Wesley, Reading, MA.
- [23] Newton Lee. 2005. Interview with Bill Kinder: January 13, 2005. Video. *Comput. Entertain.* 3, 1, Article 4 (Jan.-March 2005). <https://doi.org/10.1145/1057270.1057278>
- [24] Dave Novak. 2003. Solder man. Video. In *ACM SIGGRAPH 2003 Video Review on Animation theater Program: Part I - Vol. 145 (July 27–27, 2003)*. ACM Press, New York, NY, 4. <https://doi.org/99.9999/woot07-S422>
- [25] Barack Obama. 2008. A more perfect union. Video. Retrieved March 21, 2008 from <http://video.google.com/videoplay?docid=6528042696351994555>
- [26] Poker-Edge.Com. 2006. Stats and Analysis. Retrieved June 7, 2006 from <http://www.poker-edge.com/stats.php>
- [27] Bernard Rous. 2008. The Enabling of Digital Libraries. *Digital Libraries* 12, 3, Article 5 (July 2008). To appear.
- [28] Mehdi Saeedi, Morteza Saheb Zamani, and Mehdi Sedighi. 2010. A library-based synthesis methodology for reversible logic. *Microelectron. J.* 41, 4 (April 2010), 185–194.
- [29] Mehdi Saeedi, Morteza Saheb Zamani, Mehdi Sedighi, and Zahra Sasanian. 2010. Synthesis of Reversible Circuit Using Cycle-Based Approach. *J. Emerg. Technol. Comput. Syst.* 6, 4 (Dec. 2010).
- [30] Joseph Scientist. 2009. The fountain of youth. Patent No. 12345, Filed July 1st., 2008, Issued Aug. 9th., 2009.
- [31] Stan W. Smith. 2010. An experiment in bibliographic mark-up: Parsing metadata for XML export. In *Proceedings of the 3rd. annual workshop on Librarians and*

- Computers (LAC '10)*, Reginald N. Smythe and Alexander Noble (Eds.), Vol. 3. Paparazzi Press, Milan Italy, 422–431. <https://doi.org/99.9999/woot07-S422>
- [32] Asad Z. Spector. 1990. Achieving application requirements. In *Distributed Systems* (2nd. ed.), Sape Mullender (Ed.). ACM Press, New York, NY, 19–33. <https://doi.org/10.1145/90417.90738>
- [33] Harry Thornburg. 2001. Introduction to Bayesian Statistics. Retrieved March 2, 2005 from <http://ccrma.stanford.edu/~jos/bayes/bayes.html>
- [34] TUG 2017. Institutional members of the T_EX Users Group. Retrieved May 27, 2017 from <http://www.tug.org/instmem.html>
- [35] Boris Veytsman. [n.d.]. acmart—Class for typesetting publications of ACM. Retrieved May 27, 2017 from <http://www.ctan.org/pkg/acmart>

A RESEARCH METHODS

A.1 Part One

Lorem ipsum dolor sit amet, consectetur adipiscing elit. Morbi malesuada, quam in pulvinar varius, metus nunc fermentum urna, id sollicitudin purus odio sit amet enim. Aliquam ullamcorper eu ipsum vel mollis. Curabitur quis dictum nisl. Phasellus vel semper risus, et lacinia dolor. Integer ultricies commodo sem nec semper.

A.2 Part Two

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