Jörg Brauer

Curriculum Vitae

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Personal Information

date/place of birth	13/04/1982 in Rendsburg, Germany
nationality	German
marital status	Married to Sarah Denise Brauer

Research Summary

Jörg's research interests circle around automated verification techniques for low-level embedded programs using abstract interpretation. His work concentrates on the automatic generation of abstractions using decision procedures such as SAT/SMT solvers, with the expressed aim of generating tools that verify real-world software. He is the co-author of more than 25 peer-reviewed papers on program analysis.

Education

since October 2008 — **PhD Student**, *Embedded Software Laboratory, RWTH Aachen University*, Aachen, Germany.
Work on [mc]square, a verification platform for microcontroller binary code, with a focus on the development of new static analysis techniques specifically suited for supporting the verification of binary code. Project lead since January 2010 (Advisor: Prof. Dr.-Ing. Stefan Kowalewski.

October 2002 – September 2008 — **Diploma in Computer Science**, *Christian-Albrechts University*, Kiel, Germany, Grade *1,6*.
Focused on studying embedded and concurrent systems as well as program analysis during the main study period. Minor Subject: Business Studies. Intermediate Diploma received in October 2005, Grade *1,7*

August 1992 – June 2001 — **Abitur**, *Gymnasium Kronwerk*, Rendsburg, Germany.

August 1988 – July 1992 — **Elementary School**, *Grundschule*, Fockbek, Germany.

Diploma Thesis

title	*Interprocedural Static Analysis by Model Checking*
supervisors	Priv.-Doz. Dr. Frank Huch and Dr. Ralf Huuck (work carried out at National ICT Australia, Kensington Lab, Sydney, Australia)

Academic Activities

Symposium Co-Chair, *8th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA 2012), Symposium* Design & Verification Tools for Mechatronic & Embedded System, Suzhou, China.

Program Committee Co-Chair, *6th International Workshop on Systems Software Verification (SSV 2011)*, Nijmegen, The Netherlands.

Symposium Co-Chair, *7th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA 2011), Symposium* Design & Verification Tools for Mechatronic & Embedded System, Washington DC, USA.

Program Committee, *15th International Workshop on Formal Methods in Industrial Critical Systems (FMICS 2010)*, Antwerp, Belgium.

Workshop Organizer, *4th International Workshop on Systems Software Verification (SSV 2009)*, Aachen, Germany.

External Reviewer, *23rd International Conference on Computer Aided Verification (CAV 2011), 16th International Workshop on Formal Methods for Industrial Critical Systems (FMICS 2011), 14th IEEE International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing (ISORC 2011), 6th IEEE/ASME International Conference on Mechatronic and Embedded Systems and Applications (MESA 2010), 7th International Workshop on Model-based Methodologies for Pervasive and Embedded Software (MOMPES 2010), 4th International Workshop on Systems Software Verification (SSV 2009), 5th International Workshop on Systems Software Verification (SSV 2010), 15th International Conference on Tools and Algoritms for the Construction and Analysis of Systems (TACAS 2009), 16th International Conference on Tools and Algoritms for the Construction and Analysis of Systems (TACAS 2010), ACM Transactions on Embedded Computing Systems, Journal of Automated Reasoning, Science of Computer Programming, Software Tools for Technology Transfer, European Journal of Control*.

Prizes

Best Paper Award, *16th International Workshop on Formal Methods for Industrial Critical Systems (FMICS 2011)*.
for the paper *Past Time LTL Runtime Verification for Microcontroller Binary Code* with Thomas Reinbacher, Martin Horauer, Andreas Steininger and Stefan Kowalewski

Best Paper Award, *Doctoral Workshop on Mathematical and Engineering Methods in Computer Science (MEMICS 2010)*.
for the paper *Test-Case Generation for Embedded Binary Code Using Abstract Interpretation* with Thomas Reinbacher, Martin Horauer, Andreas Steininger and Stefan Kowalewski (prize money: CZK 10.000,-)

One Minute Madness 2009, *Faculty of Computer Science*, RWTH Aachen University.
Winner in a competition among PhD students of all research groups, consisting of a short presentation and a research abstract (prize money: EUR 444,44)

since April 2010

CevTes Project, *CounterExample Validation and Test Case Generation Framework for Verifying Embedded Software*.
Project partners: Vienna Technical University, University of Applied Sciences Technikum Wien, and RWTH Aachen University. Project lead: Prof. Dr. Andreas Steininger

since January 2010 — **[mc]square Project Leader**, *Embedded Software Laboratory*, RWTH Aachen University, Aachen, Germany.
Leading the development team consisting of 5 PhD students and 10–15 undergraduate students

since October 2008 — **Collegiate in DFG Research Training Group 1298 (Algorithmic Synthesis of Reactive and Discrete-Continuous Systems)**, *RWTH Aachen University*, Aachen, Germany, Advisors: Prof. Dr.-Ing. Stefan Kowalewski and Prof. Dr. Ir. Joost-Pieter Katoen.

October 2007 – April 2008 — **Thesis Student (Formal Methods Program)**, *National ICT Australia Ltd*, Sydney, Australia.
Developed and implemented new approaches to interprocedural pointer analysis for the C programming languages. Advisor: Dr. Ralf Huuck

August 2006 – February 2007 — **Research Intern (Formal Methods Program)**, *National ICT Australia Ltd*, Sydney, Australia.
Worked on the Goanna project, wrote an interface to a compiler backend for the C and C++ programming languages, developed and implemented numerous checks for programs, and worked on interval analysis techniques. Advisor: Dr. Ralf Huuck

April 2006 – July 2006 — **Student Research Assistant**, *Multimedia Information Processing Group, Christian-Albrechts University*, Kiel, Germany.
Evaluated numerous 3d modelling software packages and created models and animations for research projects and trade fairs. Advisor: Dr.-Ing. Daniel Grest

Grants

International Joint Project — **Royal Society**, *with Dr. Andy King and Prof. Dr.-Ing. Stefan Kowalewski*, Random Interpretation for Verifying Embedded Systems Software.

Travel Grant — **Royal Society**, *with Dr. Andy King*, Knitting together Model Checking and Abstract Interpretation, reference TG092357 (£571,-).

Research Visits

November 2011 — **Vienna Technical University**, *Thomas Reinbacher, M.Sc.*.

July 2011 — **University of Kent**, *Dr. Andy King*.

April 2011 – June 2011 — **Aalborg University**, *Prof. Kim G. Larsen and Rene Rydhof Hansen, Ph.D.*

September 2010 — **University of Kent**, *Dr. Andy King*.

January 2010 — **University of Applied Sciences Technikum Wien**, *FH-Prof. Dr. Martin Horauer*.

August 2009 — **University of Kent**, *Dr. Andy King*.

December 2009 — **University of Bremen**, *Prof. Dr. Jan Peleska*.

March 2009 — **University of Applied Sciences Technikum Wien**, *FH-Prof. Dr. Martin Horauer*.

Invited Talks

November 2011 **CEA LIST, Paris**, *France*, Automatic Abstraction of Binary Code.

November 2011 **University of Bremen**, *Germany*, Formel Methods for PLCs.

November 2011 **Vienna Technical University & Institute of Science and Technology Austria**, *Austria*, Automatic Abstraction for Bit-Vector Relations.

June 2011 **Technical University of Denmark**, *Denmark*, Existential Quantification as Incremental SAT.

April 2011 **Aalborg University**, *Denmark*, Automatic Abstraction for Bit-Vector Relations.

May 2010 **Technical University of Munich**, *Germany*, Automatic Abstraction for Intervals using Boolean Formulae.

August 2009 **University of Kent in Canterbury**, *UK*, Static Analysis of Microcontroller Binary Code.

March 2009 **University of Applied Sciences Technikum Wien**, *Austria*, Static Analysis of Microcontroller Binary Code.

Teaching

Winter term 2010 **Lecture**, *Formal Methods for Embedded Systems*.

Summer term 2010 **Seminar**, *Program Analysis*.

Winter term 2009 **Seminar**, *Verification and Program Analysis*.

Exercises, *Formal Methods for Embedded Systems*.

Summer term 2009 **Seminar**, *Applying Formal Verification Methods to Embedded Systems*.

Winter term 2008 **Seminar**, *Static Analysis of Software for Embedded Systems*.

Lab Course, *Hardware Programming*.

Student Supervision

B.Sc., *Lucas Brutschy*, Static Analysis of Microcontroller Software using SAT- and SMT-Solving.

Diploma, *Na Bai*, Dataflow Analysis for PLCs.

Diploma, *Sebastian Biallas*, Counterexample-Guided Abstraction Refinement for Programmable Logic Controllers.

Diploma, *Frank Birbacher*, Relational Static Analysis of IL-Programs Using Congruences.

Diploma, *Mustafa Karafil*, Recovering Indirect Control from Binary Code.

Diploma, *Jörg Toborg*, Static Analysis for the Renesas R8C/23 Tiny Microcontroller.

Further Work Experience

April 2002 – September 2002
Software Engineering Intern, *Vulpine GmbH 3D Technologies*, Reutlingen, Germany.
Implemented a gameplay prototype for a 3d role play game in C++ using the Vulpine Vision engine. Advisor: Dr.-Ing. Stefan Blanck

July 2001 – March 2002
Compulsory Social Service, *Johanniter-Unfall-Hilfe eV*, Rendsburg, Germany.

Hobbies

Photography
Sports (table tennis)

Languages

German Native
English Fluent

Publications

Journals

(1) Bastian Schlich, Jörg Brauer, and Stefan Kowalewski. Application of Static Analyses for State-Space Reduction to the Microcontroller Binary Code. In *Sci. Comp. Program. 76(2)*. Pages 100–118, 2011.

(2) Thomas Reinbacher, Martin Horauer, Bastian Schlich, Jörg Brauer, and Florian Scheuer. Model Checking Embedded Software of an Industrial Knitting Machine. *Int. J. Information Technology, Communication and Convergence*, 2011. To appear.

Conferences & Workshops

(3) Jörg Brauer and Axel Simon. Inferring Definite Counterexamples through Under-Approximation. In *4th NASA Formal Methods Symposium (NFM 2012), Norfolk, Virginia, USA*. Pages 54–59, volume 7226 in Lecture Notes in Computer Science, Springer. 2012.

(4) Thomas Reinbacher and Jörg Brauer. Precise Control Flow Reconstruction Using Boolean Logic. In *11th International Conference on Embedded Software (EMSOFT 2011), Taipei, Taiwan*. Pages 117–126, ACM Press, 2011.

(5) Jörg Brauer, Rene Rydhof Hansen, Stefan Kowalewski, Kim G. Larsen, Mads Chr. Olesen. Adaptable Value-Set Analysis for Low-Level Code. In *6th International Workshop on Systems Software Verification (SSV 2011), Nijmegen, The Netherlands*. To appear.

(6) Thomas Reinbacher, Jörg Brauer, Martin Horauer, Andreas Steininger, and Stefan Kowalewski. Past Time LTL Runtime Verification for Microcontroller Binary Code. In *16th International Workshop on Formal Methods for Industrial Critical Systems (FMICS 2011), Trento, Italy*. Pages 37–51, volume 6959 in Lecture Notes in Computer Science, Springer, 2011.

(7) Thomas Reinbacher, Andreas Steininger, Tobias Müller, Martin Horauer, Jörg Brauer, and Stefan Kowalewski. Hardware Support for Efficient Testing of Embedded Software. In *7th ASME/IEEE Conference on Mechatronics and Embedded Systems and Applications (MESA 2011), Washington, DC, USA*. 2011. To appear.

(8) Jörg Brauer, Andy King, and Jael Kriener. Existential Quantification as Incremental SAT. In *23rd International Conference on Computer Aided Verification (CAV 2011), Snowbird, Utah, USA*. Pages 191–207, volume 6806 in Lecture Notes in Computer Science, Springer, 2011.

(9) Sebastian Biallas, Jörg Brauer, and Stefan Kowalewski. SAT-Based Abstraction Refinement for Programmable Logic Controllers. In *3rd International Workshop on Dependable Control of Discrete Systems (DCDS 2011), Saarbrücken, Germany*. Pages 96–101, IEEE Computer Society Press, 2011.

(10) Jörg Brauer and Andy King. Approximate Quantifier Elimination for Propositional Boolean Formulae. In *3rd NASA Formal Methods Symposium (NFM 2011), Pasadena, California, USA*. Pages 73–88, volume 6617 in Lecture Notes in Computer Science, Springer, 2011.

(11) Eva Beckschulze, Jörg Brauer, Andre Stollenwerk, and Stefan Kowalewski. Analyzing Embedded Systems Code for Mixed-Critical Systems using Hybrid Memory Representations", in *1st International Workshop on Architectures and Applications for Mixed-Criticality Systems (AMICS 2011)*. 2011. To appear.

(12) Jörg Brauer and Andy King. Transfer Function Synthesis without Quantifier Elimination. In *20th European Symposium on Programming (ESOP 2011), Saarbrücken, Germany*. Pages 97–115, volume 6602 in Lecture Notes in Computer Science, Springer, 2011.

(13) Sebastian Biallas, Jörg Brauer, Dominique Gückel, and Stefan Kowalewski. On-the-fly path reduction. In *Workshop on Harnessing Theories for Tool Support in Software (TTSS 2010), Shanghai, China*. Pages 3–16, volume 274 in Electronic Notes in Theoretical Computer Science, Elsevier, 2011.

(14) Thomas Reinbacher, Jörg Brauer, Martin Horauer, Andreas Steininger, and Stefan Kowalewski. Test-Case Generation for Embedded Binary Code Using Abstract Interpretation. In *6th Doctoral Workshop on Mathematical and Engineering Methods in Computer Science (MEMICS 2010), Mikulov, Czech Republic*. Pages 101–108, volume 16 in OASICS, Schloss Dagstuhl - Leibniz-Zentrum für Informatik, Germany, 2011. Best Paper Award.

(15) Sebastian Biallas, Jörg Brauer, Stefan Kowalewski, and Bastian Schlich. Automatically Deriving Symbolic Invariants for PLC Programs written in IL. In *8th Symposium on Formal Methods for Automation and Safety in Railway and Automotive Systems (FORMS/FORMAT 2010), Braunschweig, Germany*. Pages 237–245, Springer, 2011.

(16) Jörg Brauer, Volker Kamin, Stefan Kowalewski, and Thomas Noll. Loop Refinement using Octagons and Satisfiability. In *5th International Workshop on Systems Software Verification (SSV 2010), Vancouver, Canada*. Pages 10–18, USENIX Association, 2010.

(17) Sebastian Biallas, Jörg Brauer and Stefan Kowalewski. Counterexample-Guided Abstraction Refinement for PLCs. In *5th International Workshop on Systems Software Verification (SSV 2010), Vancouver, Canada*. Pages 2–9, USENIX Association, 2010.

(18) Jörg Brauer, Andy King, and Stefan Kowalewski. Range Analysis of Microcontroller Code using Bit-Level Congruences. In *15th International Workshop on Formal Methods for Industrial Critical Systems (FMICS 2010), Antwerp, Belgium*. Pages 82–98, volume 6371 in Lecture Notes in Computer Science, Springer, 2010.

(19) Dominique Gückel, Jörg Brauer, and Stefan Kowalewski. A System for Synthesizing Abstraction-Enabled Simulators for Binary Code Verification. In *IEEE Symposium on Industrial Embedded Systems (SIES 2010), Trento, Italy*. Pages 118–127, IEEE Computer Society Press, 2010.

(20) Jörg Brauer and Andy King. Automatic Abstraction for Intervals using Boolean Formulae. In *17th International Static Analysis Symposium (SAS 2010), Perpignan, France*. Pages 167–183, volume 6337 in Lecture Notes in Computer Science, Springer, 2010.

(21) Jörg Brauer, Thomas Noll, and Bastian Schlich. Interval Analysis of Microcontroller Code using Abstract Interpretation of Hardware and Software. In *13th International Workshop on Software and Compilers for Embedded Systems (SCOPES 2010), St. Goar, Germany*. ACM Press, 2010.

(22) Dominique Gückel, Bastian Schlich, Jörg Brauer, and Stefan Kowalewski. Synthesizing Simulators for Model Checking Binary Code. In *13th IEEE International Symposium on Design and Diagnostics of Electronic Circuits and Systems (DDECS 2010), Vienna, Austria*. Pages 313–316, IEEE Computer Society Press, 2010.

(23) Thomas Reinbacher, Martin Horauer, Bastian Schlich, Jörg Brauer, and Florian Scheuer. Model Checking Assembly Code of an Industrial Knitting Machine. In *4th International Conference on Embedded and Multimedia Computing (EM-Com 2009), Jeju, Korea*. Pages 1–8, IEEE Computer Society Press, 2010.

(24) Jörg Brauer, Bastian Schlich, Thomas Reinbacher, and Stefan Kowalewski. Stack Bounds Analysis of Microcontroller Assembly Code. In *5th Workshop on Embedded Systems Security (WESS 2009), Grenoble, France*. ACM Press, 2009

(25) Bastian Schlich, Thomas Noll, Jörg Brauer, and Lucas Brutschy. Reduction of Interrupt Handler Executions for Model Checking Embedded Software. In *5th Haifa Verification Conference (HVC 2009), Haifa, Israel*. Pages 5–20, volume 6405 in Lecture Notes in Computer Science, Springer, 2011.

(26) Thomas Reinbacher, Jörg Brauer, Martin Horauer, and Bastian Schlich. Refining Assembly Code Static Analysis for the Intel MCS-51 Microcontroller. In *IEEE Symposium on Industrial Embedded Systems (SIES 2009), Lausanne, Switzerland*. Pages 161–170, IEEE Computer Society Press, 2009.

(27) Jörg Brauer, Bastian Schlich, and Stefan Kowalewski. Parallel and Distributed Invariant Checking of Microcontroller Software. In *4th International Workshop on Systems Software Verification (SSV 2009), Aachen, Germany*. Pages 45–63, volume 254 of Electronic Notes in Theoretical Computer Science, Elsevier, 2009.

(28) Jörg Brauer, Ralf Huuck, and Bastian Schlich. Interprocedural Pointer Analysis in Goanna. In *4th International Workshop on Systems Software Verification (SSV 2009), Aachen, Germany*. Pages 65–83, volume 254 of Electronic Notes in Theoretical Computer Science, Elsevier, 2009.

(29) Bastian Schlich, Jörg Brauer, Jörg Wernerus, and Stefan Kowalewski. Direct Model Checking of PLC Programs in IL. In *2nd International Workshop on Dependable Control of Discrete Systems (DCDS 2009), Bari, Italy*. 2009.

(30) Ralf Huuck, Ansgar Fehnker, Sean Seefried, and Jörg Brauer. Goanna: Syntactic Software Model Checking. In *6th International Symposium on Automated Technology for Verification and Analysis (ATVA 2008), Seoul, Korea*. Pages 216–221, volume 5311 in Lecture Notes in Computer Science, Springer, 2008.

Editorship

(30) Jörg Brauer, Marco Roveri, and Hendrik Tews. Proceedings of the 6th International Workshop on Systems Software Verification (SSV 2011). Published as Technical Report TUD-FI11-02-August 2011, TU Dresden, 2011.

Under Review

Sebastian Biallas, Jörg Brauer, and Stefan Kowalewski. A Verification Platform for Programmable Logic Controllers. Submitted to *24th International Conference on Computer Aided Verification (CAV 2012)*

Jörg Brauer and Andy King. Transfer Function Synthesis without Quantifier Elimination. Submitted to *Logical Methods in Computer Science*

Jörg Brauer, Andy King, and Stefan Kowalewski. Abstract Interpretation of Microcontroller Code: Intervals Meet Congruences. Submitted to *Sci. Comp. Program.*

Thomas Reinbacher, Jörg Brauer, Matthias Függer, and Stefan Kowalewski. Real-Time Runtime Verification On-Chip. Submitted to *24th International Conference on Computer Aided Verification (CAV 2012)*

Thomas Reinbacher, Jörg Brauer, Martin Horauer, Andreas Steininger, and Stefan Kowalewski. Runtime Verification of Microcontroller Binary Code. Submitted to *Sci. Comp. Program.*