

CONTACT DEIS Group  
 Aalborg University  
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RESEARCH INTERESTS Formal methods, Safe artificial intelligence, Dynamical and cyber-physical systems, Model and parameter synthesis

RESEARCH PATH **Aalborg University**, Aalborg, Denmark

Assistant professor (tenure track) Since Oct. 2021  
 Member of DIREC bridge project “Verifiable and Safe AI for Autonomous Systems”

**University of Konstanz**, Konstanz, Germany

Interim professor for “Cyber-Physical Systems” Oct. 2020 – Sept. 2021  
 (Vertretungsprofessor)

**IST Austria**, Klosterneuburg, Austria

Postdoctoral fellow (ISTplus program) Oct. 2018 – Sept. 2020  
 Group of Thomas A. Henzinger

**University of Freiburg**, Freiburg, Germany

Ph.D. student (Doktorand) Nov. 2013 – Sept. 2018  
 Group of Andreas Podelski  
 Thesis: *Fundamental techniques for the scalable analysis of systems*  
 Awarded with distinction (summa cum laude)

GRANTS • ISTplus postdoc fellowship (2 years), 2018  
 Supported by European Union’s Horizon 2020 research and innovation programme under Marie Skłodowska-Curie grant agreement No. 754411

EDUCATION **University of Freiburg**, Freiburg, Germany

- Master of Science Oct. 2011 – Sept. 2013
- Bachelor of Science Oct. 2008 – Sept. 2011

SERVICE **Organization**

- 29th International Symposium on Model Checking of Software (SPIN) 2023 (co-chair)
- Wolverine (workshop on open problems in learning and verification of neural networks) 2022 (collocated with FLoC 2022) and 2021 (collocated with ATVA 2021) (co-organizer)
- JuliaReach & JuliaIntervals Days 3 (workshop in 2021) (co-organizer)
- Set propagation methods in Julia: techniques and applications (minisymposium at Julia-Con 2021) (video) (co-organizer)
- SAS 2018 (assistance)

### PC member

- AAAI 2023, FORMATS 2022, SPIN 2022, HSCC 2022, VSTTE 2020

### PC member (artifact evaluation)

- TAP 2021, TAP 2020, VMCAI 2020, TAP 2019, ECOOP 2019, HSCC 2019, HSCC 2018, CAV 2017, HSCC 2017

### Reviewer

- ATVA 2022, STTT (2022), TECS (2022), TACAS 2022, SoSyM (2021), RTSS 2021, Inf. Comput. (2020), TACAS 2020, ICCPS 2020, DARS 2019, FORMATS 2019, TACAS 2018, EMSOFT 2018, VMCAI 2017, SV-COMP 2017, PLDI 2017, SAS 2017, FORMATS 2017, VMCAI 2016, HSCC 2016, CAV 2016, ATVA 2016, POPL 2014, HSCC 2014, FSTTCS 2014

### Other

- GSoC/JSoc mentor 2022 and 2020

### INVITED TALKS

- Presentation at the Institute for Risk and Uncertainty in Liverpool (2022) (video)
- Visiting the Algorithmics group at TU Delft (2022)
- Presentation at the MIT Julia Lab (2021)
- Presentation at JuliaCon 2021 (workshop It's all Set: A hands-on introduction to JuliaReach) (video)
- Participation in the Ph.D. Summer School at MSR Cambridge (2016)
- Presentation in the RiSE Seminar at IST Austria (2015)

### TOOLS

- *JuliaReach* (framework for analysis of dynamical systems) [Julia]  
**Won “ARCH 2020 Best Result” and “ARCH 2018 Best Friendly Competition Result” awards.** (video of workshop presentation)  
Notable packages:
  - *LazySets.jl* (scalable symbolic-numeric set computations)
  - *ReachabilityAnalysis.jl* (reachability analysis for dynamical and hybrid systems)
  - *ClosedLoopReachability.jl* (closed-loop systems with neural-network controllers)
  - *RangeEnclosures.jl* (range enclosures of real-valued functions)
- Tools for synthesis of hybrid-automaton models from time-series data
  - *HySynth* (automata with constant or affine continuous dynamics) [Python/Julia]
  - *HySynthParametric* (parametric linear hybrid automata) [Julia]
- Tools for monitoring of neural networks [Python]
  - *Into the Unknown* (active monitoring of neural networks)
  - *Outside the Box* (novelty detection for neural networks)
- *ULTIMATE* (framework for program analysis), particularly the *ULTIMATE Automata library* (link to web interface) [Java]
- *HyST Stateflow Converter* (conversion from hybrid-automaton models to Simulink / Stateflow models), now part of *HyST* [Matlab/Java]
- *AdaptiveMomentClosure* (parameter synthesis for chemical reaction networks) [Matlab]
- *Hydentify* (robustness verification and parameter synthesis for multiaffine systems), based on RoVerGeNe [Matlab/C++]

### TEACHING

**Aalborg University, Aalborg, Denmark**

- Seminar: Specialization Course in Machine Intelligence

Fall term 2022

**University of Konstanz**, Konstanz, Germany

- Lecture: Software Project Summer term 2021
- Seminar: Automata Theory Summer term 2021
- Lecture: Analysis of Dynamical and Cyber-physical Systems Winter term 2020/21
- Lecture: Program Verification Winter term 2020/21
- Seminar: Machine Learning and Formal Verification Winter term 2020/21

**IST Austria**, Klosterneuburg, Austria

- Seminar: Formal Methods for Learned Systems (co-advisor) Spring term 2020
- Workshop: Scientific Writing in Computer Science Fall term 2019

**University of Freiburg**, Freiburg, Germany (Teaching assistant)

- Lecture: Software Engineering Summer term 2018
- Seminar: Automata Theory Summer term 2018
- Lecture: Theoretical Computer Science Winter term 2017/18  
(Theoretische Informatik)
- Seminar: Automata Theory Winter term 2017/18
- Seminar: Program Analysis & Software Testing Winter term 2017/18
- Lecture: Program Verification Summer term 2017
- Lecture: Cyber-Physical Systems - Hybrid Models Summer term 2017
- Seminar: Automata Theory Summer term 2017
- Seminar: Program Analysis & Software Testing Summer term 2017
- Lecture: Cyber-Physical Systems - Discrete Models Winter term 2016/17
- Seminar: Automata Theory Winter term 2016/17
- Seminar: Program Analysis & Software Testing Winter term 2016/17
- Lecture: Cyber-Physical Systems - Hybrid Models Summer term 2016
- Seminar: Automata Theory Summer term 2016
- Seminar: Program Analysis & Software Testing Summer term 2016
- Seminar: Automata Theory Winter term 2015/16
- Seminar: Program Analysis & Software Testing Winter term 2015/16
- Seminar: Automata Theory Summer term 2015
- Seminar: Program Analysis Summer term 2015
- Lecture: Theoretical Computer Science Winter term 2014/15  
(Theoretische Informatik)
- Seminar: Introduction to Automata Theory Winter term 2014/15  
(Einführung in die Automatentheorie)
- Tutorial: Computer Science Theory Summer term 2014
- Seminar: Automata Theory Summer term 2014
- Lecture: Theoretical Computer Science Winter term 2013/14  
(Theoretische Informatik)

STUDENT  
ADVISING

**Aalborg University**, Aalborg, Denmark

- Supervision of student projects (28 students) Fall term 2022
- Supervision of student projects (32 students) Spring term 2022

### **University of Konstanz, Konstanz, Germany**

- F. Oberfell. Implementation of cryptographic functions to a central control system for satellite command and control. Bachelor project and thesis (in collaboration with Airbus Defence and Space). 2021.
- F. Hartmann. Implementation of cryptographic functions to a central control system for satellite command and control. Bachelor project and thesis (in collaboration with Airbus Defence and Space). 2021.

### **IST Austria, Klosterneuburg, Austria**

- Z. Di. Set-based backpropagation to explain decisions of neural networks. Scientific intern project. 2020.
- S. Guadalupe. Reachability-based verification of neural networks. GSoC project. 2020.

### **University of Freiburg, Freiburg, Germany**

- N. Mansur. Static Error Trace Analysis Using Aberrant Trace Elements. Master thesis. 2018.
- N. Mansur. Static Fault Localization for Simple Bugs. Master project. 2017.
- D. Wadehn. Implementierung eines Delta-Debugging-Frameworks für Werkzeuge zur Analyse von C-Programmen. Bachelor thesis. 2016.
- D. Tischner. Minimization of Büchi Nested Word Automata. Master project. 2016.
- N. Mansur. Flow-Sensitive Fault Localization. Master laboratory. 2016.
- J. Stimpfle. A Max-Horn-SAT-Based Approach to Minimization of Visibly Pushdown Automata. Bachelor thesis. 2016.
- A. Heinz. Extending Nonlinear Decision Procedures to Automata Networks. Bachelor thesis. 2015.
- L. Franke. Parallel Execution of Minimization Algorithms. Bachelor thesis. 2015.
- D. Tischner. Generation and Minimization of Random Deterministic Finite Automata. Bachelor project. 2015.
- B. Hagemester. Vergleich aktueller Minimierungsalgorithmen für deterministische endliche Automaten. Bachelor thesis. 2014.

### PUBLICATIONS

In computer science, conference publications are considered more prestigious. In my main subfield, authors are usually listed in alphabetic order.

#### **Links to online archives**

**ORCID** (open researcher and contributor ID)

**DBLP** (bibliography)

**Scholar** (bibliography incl. citation count)

**arXiv** (open-access publication archive)

### Peer-reviewed conference publications

- [1] Miriam García Soto, Thomas A. Henzinger, and Christian Schilling. Synthesis of parametric hybrid automata from time series. Accepted at ATVA 2022 (rank B, acceptance: 32%). [PDF].
- [2] Fabian Bauer-Marquart, David Boetius, Stefan Leue, and Christian Schilling. SpecRepair: Counterexample guided safety repair for deep neural networks. SPIN 2022 (acceptance: 72%). [DOI] [PDF] [BIB].
- [3] Marcelo Forets and Christian Schilling. Conservative time discretization: A comparative study. iFM 2022 (rank B, acceptance: 35%). [DOI] [PDF] [BIB].
- [4] Christian Schilling, Marcelo Forets, and Sebastián Guadalupe. Verification of neural-network control systems by integrating Taylor models and zonotopes. AAAI 2022 (rank A\*, acceptance: 15%). [DOI] [PDF] [BIB].
- [5] Marcelo Forets and Christian Schilling. Reachability of weakly nonlinear systems using Carleman linearization. RP 2021 (acceptance: 46%). [DOI] [PDF] [BIB].
- [6] Anna Lukina, Christian Schilling, and Thomas A. Henzinger. Into the unknown: Active monitoring of neural networks. RV 2021 (rank B, acceptance: 45%). [DOI] [PDF] [BIB].
- [7] Miriam García Soto, Thomas A. Henzinger, and Christian Schilling. Synthesis of hybrid automata with affine dynamics from time-series data. HSCC 2021 (acceptance: 35%). [DOI] [BIB] [extended version].
- [8] Marcelo Forets, Daniel Freire, and Christian Schilling. Efficient reachability analysis of parametric linear hybrid systems with time-triggered transitions. MEMOCODE 2020 (acceptance: 53%). [DOI] [PDF] [BIB].
- [9] Thomas A. Henzinger, Anna Lukina, and Christian Schilling. Outside the box: Abstraction-based monitoring of neural networks. ECAI 2020 (rank A, acceptance: 27%). [DOI] [PDF] [BIB].
- [10] Miriam García Soto, Thomas A. Henzinger, Christian Schilling, and Luka Zeleznik. Membership-based synthesis of linear hybrid automata. CAV 2019 (rank A\*, acceptance: 26%). [DOI] [PDF] [BIB].
- [11] Sergiy Bogomolov, Marcelo Forets, Goran Frehse, Kostiantyn Potomkin, and Christian Schilling. JuliaReach: A toolbox for set-based reachability. HSCC 2019 (acceptance: 30%). [DOI] [BIB] [extended version].
- [12] Maria Christakis, Matthias Heizmann, Muhammad Numair Mansur, Christian Schilling, and Valentin Wüstholtz. Semantic fault localization and suspiciousness ranking. TACAS 2019 (rank A, acceptance: 24%). [DOI] [BIB].
- [13] Sergiy Bogomolov, Marcelo Forets, Goran Frehse, Andreas Podelski, Christian Schilling, and Frédéric Viry. Reach set approximation through decomposition with low-dimensional sets and high-dimensional matrices. HSCC 2018 (acceptance: 45%). [DOI] [BIB] [extended version].
- [14] Hui Kong, Sergiy Bogomolov, Yu Jiang, Thomas A. Henzinger, and Christian Schilling. Safety verification of nonlinear hybrid systems based on invariant clusters. HSCC 2017 (acceptance: 39%). [DOI] [PDF] [BIB].
- [15] Matthias Heizmann, Christian Schilling, and Daniel Tischner. Minimization of visibly pushdown automata using partial Max-SAT. TACAS 2017 (rank A, acceptance: 29%). [DOI] [BIB] [extended version].
- [16] Sergiy Bogomolov, Christian Schilling, Ezio Bartocci, Grégory Batt, Hui Kong, and Radu Grosu. Abstraction-based parameter synthesis for multiaffine systems. HVC 2015 (rank B, acceptance: 53%). [DOI] [PDF] [BIB].
- [17] Luan Viet Nguyen, Christian Schilling, Sergiy Bogomolov, and Taylor T. Johnson. Runtime verification for hybrid analysis tools. RV 2015 (rank C, acceptance: 47%). [DOI] [BIB].

- [18] Sergiy Bogomolov, Thomas A. Henzinger, Andreas Podelski, Jakob Ruess, and Christian Schilling. Adaptive moment closure for parameter inference of biochemical reaction networks. *CMSB 2015* (acceptance: 46%). [DOI] [BIB].
- [19] Jan-Georg Smaus, Christian Schilling, and Fabian Wenzelmann. Implementations of two algorithms for the threshold synthesis problem. *ISAIM 2012* (rank B). [PDF] [BIB].

#### Peer-reviewed journal publications

- [20] Sergiy Bogomolov, Marcelo Forets, Goran Frehse, Andreas Podelski, and Christian Schilling. Decomposing reach set computations with low-dimensional sets and high-dimensional matrices (extended version). *Information and Computation 2022* (impact factor: 0.704 (2020)), special issue. [DOI].
- [21] Marcelo Forets and Christian Schilling. *LazySets.jl: Scalable symbolic-numeric set computations. Proceedings of the JuliaCon Conferences 2021.* [DOI] [PDF].
- [22] Sergiy Bogomolov, Marcelo Forets, Goran Frehse, Kostiantyn Potomkin, and Christian Schilling. Reachability analysis of linear hybrid systems via block decomposition. *TCAD 2020* (impact factor: 2.807 (2020)), special issue for *EMSOFT 2020* (rank A, acceptance: 22%). **Nominated for best paper.** [DOI] [PDF] [BIB].
- [23] Stanley Bak, Omar Ali Beg, Sergiy Bogomolov, Taylor T. Johnson, Luan Nguyen, and Christian Schilling. Hybrid automata: From verification to implementation. *STTT 2017* (impact factor: 1.270 (2018)). [DOI] [BIB].
- [24] Christian Schilling, Sergiy Bogomolov, Thomas A. Henzinger, Andreas Podelski, and Jakob Ruess. Adaptive moment closure for parameter inference of biochemical reaction networks. *Biosystems 2016* (impact factor: 1.623 (2018)). [DOI] [BIB].

#### Peer-reviewed workshop & tutorial publications

- [25] Luis Benet, Marcelo Forets, David P. Sanders, and Christian Schilling. *TaylorModels.jl: Taylor models in Julia and their application to validated solutions of ODEs. SWIM 2019.* [PDF] [BIB].
- [26] Hui Kong, Ezio Bartocci, Sergiy Bogomolov, Radu Grosu, Thomas A. Henzinger, Yu Jiang, and Christian Schilling. Discrete abstraction of multiaffine systems. *HSB 2016.* [DOI] [PDF] [BIB].
- [27] Parasara Sridhar Duggirala, Chuchu Fan, Matthew Potok, Bolun Qi, Sayan Mitra, Mahesh Viswanathan, Stanley Bak, Sergiy Bogomolov, Taylor T. Johnson, Luan Viet Nguyen, Christian Schilling, Andrew Sogokon, Hoang-Dung Tran, Weiming Xiang. Tutorial: Software tools for hybrid systems verification, transformation, and synthesis: C2E2, HyST, and TuLiP. *CCA 2016.* [DOI] [PDF] [BIB].
- [28] Stanley Bak, Sergiy Bogomolov, and Christian Schilling. High-level hybrid systems analysis with Hypy. *ARCH 2016.* “**Best tool**“ award. [DOI] [PDF] [BIB].
- [29] Christian Schilling, Jan-Georg Smaus, and Fabian Wenzelmann. Implementation of two algorithms for the threshold synthesis problem. *FAC 2014.* [PDF].

#### Competitions

- [30] Matthias Althoff, Erika Ábrahám, Marcelo Forets, Goran Frehse, Daniel Freire, Christian Schilling, Stefan Schupp, and Mark Wetzlinger. ARCH-COMP21 category report: Continuous and hybrid systems with linear continuous dynamics. *ARCH 2021.* [DOI] [PDF] [BIB].
- [31] Luca Geretti, Julien Alexandre Dit Sandretto, Matthias Althoff, Luis Benet, Alexandre Chapoutot, Pieter Collins, Parasara Sridhar Duggirala, Marcelo Forets, Edward Kim, Uziel Linares, David P. Sanders, Christian Schilling, and Mark Wetzlinger. ARCH-COMP21 category report: Continuous and hybrid systems with nonlinear continuous dynamics. *ARCH 2021.* [DOI] [PDF] [BIB].
- [32] Taylor T. Johnson, Diego Manzananas Lopez, Luis Benet, Marcelo Forets, Sebastián Guadalupe, Christian Schilling, Radoslav Ivanov, Taylor J. Carpenter, James Weimer, and Insup Lee. ARCH-COMP21 category report: Artificial intelligence and neural network control systems (AINNCS) for continuous and hybrid systems plants. *ARCH 2021.* [DOI] [PDF] [BIB].



- [33] Matthias Althoff, Stanley Bak, Zongnan Bao, Marcelo Forets, Goran Frehse, Daniel Freire, Niklas Kochdumper, Yangge Li, Sayan Mitra, Rajarshi Ray, Christian Schilling, Stefan Schupp, and Mark Wetzlinger. ARCH-COMP20 category report: Continuous and hybrid systems with linear continuous dynamics. ARCH 2020. **“ARCH 2020 Best Result” award**. [DOI] [PDF] [BIB].
- [34] Luca Geretti, Julien Alexandre Dit Sandretto, Matthias Althoff, Luis Benet, Alexandre Chapoutot, Xin Chen, Pieter Collins, Marcelo Forets, Daniel Freire, Fabian Immler, Niklas Kochdumper, David P. Sanders and Christian Schilling. ARCH-COMP20 category report: Continuous and hybrid systems with nonlinear continuous dynamics. ARCH 2020. **“ARCH 2020 Best Result” award**. [DOI] [PDF] [BIB].
- [35] Matthias Althoff, Stanley Bak, Marcelo Forets, Goran Frehse, Niklas Kochdumper, Rajarshi Ray, Christian Schilling, and Stefan Schupp. ARCH-COMP19 category report: Continuous and hybrid systems with linear continuous dynamics. ARCH 2019. [DOI] [PDF] [BIB].
- [36] Fabian Immler, Matthias Althoff, Luis Benet, Alexandre Chapoutot, Xin Chen, Marcelo Forets, Luca Geretti, Niklas Kochdumper, David P. Sanders, and Christian Schilling. ARCH-COMP19 category report: Continuous and hybrid systems with nonlinear dynamics. ARCH 2019. [DOI] [PDF] [BIB].
- [37] Matthias Althoff, Stanley Bak, Xin Chen, Chuchu Fan, Marcelo Forets, Goran Frehse, Niklas Kochdumper, Yangge Li, Sayan Mitra, Rajarshi Ray, Christian Schilling, and Stefan Schupp. ARCH-COMP18 category report: Continuous and hybrid systems with linear continuous dynamics. ARCH 2018. **“ARCH 2018 Best Friendly Competition Result” award**. [DOI] [BIB].
- [38] Matthias Heizmann and Christian Schilling. MaxSAT evaluation 2018 (Benchmark contribution). MSE 2018. [DOI] [PDF].
- [39] Matthias Heizmann, Yu-Fang Chen, Daniel Dietsch, Marius Greitschus, Jochen Hoenicke, Yong Li, Alexander Nutz, Betim Musa, Christian Schilling, Tanja Schindler, and Andreas Podelski. Ultimate Automizer and the search for perfect interpolants - (competition contribution). TACAS 2018. [DOI] [BIB].
- [40] Daniel Dietsch, Marius Greitschus, Matthias Heizmann, Jochen Hoenicke, Alexander Nutz, Andreas Podelski, Christian Schilling, and Tanja Schindler. Ultimate Taipan with dynamic block encoding - (competition contribution). TACAS 2018. [DOI] [BIB].
- [41] Matthias Heizmann, Yu-Wen Chen, Daniel Dietsch, Marius Greitschus, Alexander Nutz, Betim Musa, Claus Schätzle, Christian Schilling, Frank Schüssele, and Andreas Podelski. Ultimate Automizer with an on-demand construction of Floyd-Hoare automata - (competition contribution). TACAS 2017. [DOI] [BIB].
- [42] Marius Greitschus, Daniel Dietsch, Matthias Heizmann, Alexander Nutz, Claus Schätzle, Christian Schilling, Frank Schüssele, and Andreas Podelski. Ultimate Taipan: Trace abstraction and abstract interpretation - (competition contribution). TACAS 2017. [DOI] [BIB].
- [43] Matthias Heizmann, Jürgen Christ, Daniel Dietsch, Jochen Hoenicke, Markus Lindenmann, Betim Musa, Christian Schilling, Stefan Wissert, and Andreas Podelski. Ultimate Automizer with unsatisfiable cores - (competition contribution). TACAS 2014. [DOI] [BIB].
- [44] Matthias Heizmann, Jürgen Christ, Daniel Dietsch, Evren Ermis, Jochen Hoenicke, Markus Lindenmann, Alexander Nutz, Christian Schilling, and Andreas Podelski. Ultimate Automizer with SMTInterpol - (competition contribution). TACAS 2013. [DOI] [BIB].

#### Peer-reviewed extended abstracts

- [45] Ander Gray, Marcelo Forets, Christian Schilling, Luis Benet, and Scott Ferson. Rigorous time evolution of p-boxes in non-linear ODEs. Accepted at ESREL 2022.

#### Extended abstracts

- [46] Anna Lukina, Christian Schilling, and Thomas A. Henzinger. Active monitoring of neural networks. BNAIC/BeneLearn 2021. [PDF] [proceedings].

## Posters

- [47] Maria Christakis, Matthias Heizmann, Muhammad Numair Mansur, Christian Schilling, and Valentin Wüstholtz. Semantic fault localization and suspiciousness ranking. *TACAS 2019*.
- [48] Matthias Heizmann, Yu-Fang Chen, Daniel Dietsch, Marius Greitschus, Jochen Hoenicke, Yong Li, Alexander Nutz, Pavel Andrianov, Christian Schilling, Tanja Schindler, Andreas Podelski. Ultimate Automizer. *TACAS 2019*.
- [49] Luan Viet Nguyen, Christian Schilling, Sergiy Bogomolov, and Taylor T. Johnson. HyRG: A random generation tool for affine hybrid automata. *HSCC 2015*. [DOI] [BIB].
- [50] Jan-Georg Smaus, Christian Schilling, and Fabian Wenzelmann. A pretty complete combinatorial algorithm for the threshold synthesis problem. *IWOCA 2013*. [DOI] [BIB].