

# Si Liu

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## Research Interests

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Si Liu's research lies at the intersection of formal methods (FM), software engineering (SE), distributed systems, and security, with a particular emphasis on **leveraging FM and SE techniques to build reliable, secure, and high-performance distributed systems**. His current work focuses on verifying and validating the **designs & deployments of databases and DNS**, addressing both **qualitative** (e.g., reliability and security) & **quantitative** (e.g., availability and scalability) aspects. His interests also include verifying AI-powered systems.

## Education

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### University of Illinois Urbana-Champaign (UIUC)

PHD IN COMPUTER SCIENCE

Aug. 2012 – May 2019

- Advisor: Prof. Dr. Jose Meseguer

### East China Normal University (ECNU)

MASTER IN COMPUTER SCIENCE

Sep. 2009 – May 2012

### East China Normal University (ECNU)

BACHELOR IN SOFTWARE ENGINEERING

Sep. 2005 – Jun. 2009

## Professional Experience

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- May 2023 – Present **Senior Researcher (Deutsch: Oberassistent)**, ETH Zurich
- Aug. 2019 – May 2023 **Postdoc Researcher**, ETH Zurich
- Oct. 2014 – Sep. 2018 **Research Assistant**, Assured Cloud Computing Center, UIUC
- Jun. 2011 – Aug. 2011 **Research Intern**, National Cyber-Physical Systems Camp, USTC
- Sep. 2009 – May 2012 **Research Assistant**, Danish-Chinese Research Center, ECNU
- May 2008 – Feb. 2009 **Software Engineering Intern**, Dept. of Talent House, Hewlett-Packard Co. Ltd.

## Awards & Honors

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- 2024 **Official Project Partner on the grant for Project “Formal Verification of Isolation Guarantees in Database Systems”**, SNSF (Swiss National Science Foundation) CHF 181,099
- 2024 **Career Seed Award**, ETH Zurich CHF 30,000
- 2012 **Outstanding Graduate Award (Ranked 1st)**, East China Normal University
- 2011 **Excellent Student Award (Ranked 1st)**, East China Normal University

## Publications

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\* I contributed equally as a co-first author † indicates the students I supervised

### • FM/SE x DATABASES (RECENT)

- [OOPSLA'24] **Si Liu**, Long Gu, Hengfeng Wei, David Basin. Plume: Efficient and Complete Black-box Checking of Weak Isolation Levels
- [SIGMOD'24] **Si Liu**, Luca Multazzu, Hengfeng Wei, David Basin. NOC-NOC: Towards Performance-optimal Distributed Transactions
- [VLDB'24] Long Gu<sup>†</sup>, **Si Liu**, Tiancheng Xing, Hengfeng Wei, Yuxing Chen, David Basin. IsoVista: Black-box Checking Database Isolation Guarantees. **Demo Track**
- [VLDB'23] **Si Liu**<sup>\*</sup>, Kaile Huang<sup>\*</sup>, Zhenge Chen, Hengfeng Wei, David Basin, Haixiang Li, Anqun Pan. Efficient Black-box Checking of Snapshot Isolation in Databases

- [OSDI'23] Zu-Ming Jiang, **Si Liu**, Manuel Rigger, Zhendong Su. Detecting Transactional Bugs in Database Engines via Graph-Based Oracle Construction
- [OOPSLA'22] **Si Liu**, Jose Meseguer, Peter Csaba Olveczky, Min Zhang, David Basin. Bridging the Semantic Gap between Qualitative and Quantitative Models of Distributed Systems
- [TOSEM'22] **Si Liu**. All in One: Design, Verification, and Implementation of SNOW-Optimal Read Atomic Transactions

*Under Revision:*

- [VLDB'25] Shabnam Ghasemirad<sup>†</sup>, **Si Liu**, Luca Multazzu, Christoph Sprenger, David Basin. VerIso: Verifiable Isolation Guarantees for Database Transactions

*Under Submission:*

- [VLDB'25] Zijing Yin<sup>†</sup>, **Si Liu**, David Basin. Testing Graph Databases with Synthesized Queries
- [–'25] **Si Liu**<sup>\*</sup>, Zhiheng Cai<sup>\*</sup>, Hengfeng Wei. Uniso: A Unified Framework for Black-box Checking Database Isolation Guarantees
- [–'25] Shabnam Ghasemirad<sup>†</sup>, Christoph Sprenger, **Si Liu**, Luca Multazzu, David Basin. Pushing the Limit: Verified Performance-Optimal Causally Consistent Database Transactions
- [–'25] Jiang Xiao<sup>†</sup>, **Si Liu**, Hengfeng Wei. Boosting Database Isolation Checking via Mini-Transactions

#### • FM x DNS (AND BEYOND)

- [POPL'25] Dhruv Nevatia<sup>†</sup>, **Si Liu**, David Basin. Reachability Analysis of the Domain Name System.
- [USENIX SEC'24] Huayi Duan, Marco Bearzi, Jodok Vieli, Adrian Perrig, David Basin, **Si Liu**, Bernhard Tellenbach. CAMP: Compositional Amplification Attacks against DNS
- [SIGCOMM'23] **Si Liu**, Huayi Duan, Lukas Heimes, Marco Bearzi, Jodok Vieli, Adrian Perrig, David Basin. A Formal Framework for End-to-End DNS Resolution
- [NSDI'23] Huayi Duan, Fischer Ruben, Lou Jie, **Si Liu**, David Basin, Adrian Perrig. RHINE: Robust and High-performance Internet Naming with E2E Authenticity
- [CSF'22] **Si Liu**<sup>\*</sup>, Thilo Weghorn<sup>\*</sup>, Christoph Sprenger, Adrian Perrig, David Basin. N-Tube: Formally Verified Secure Bandwidth Reservation in Path-Aware Internet Architectures
- [Book Chapter] David Basin, Tobias Klenze, **Si Liu**, Christoph Sprenger. *Design-Level Verification in The Complete Guide to SCION: From Design Principles to Formal Verification*. 2022
- [Book Chapter] Giacomo Giuliani, Markus Legner, **Si Liu**, Adrian Perrig, Thilo Weghorn, Marc Wyss. *Extensions for the Data Plane in The Complete Guide to SCION: From Design Principles to Formal Verification*. 2022

#### • OTHER PUBLICATIONS

- [CAV'24] Dapeng Zhi, Peixin Wang, **Si Liu**, Luke Ong, Min Zhang. Unifying Qualitative and Quantitative Safety Verification of DNN-Controlled Systems
- [VMCAI'24] Jiayu Tian, Dapeng Zhi, **Si Liu**, Peixin Wang, Guy Katz, Min Zhang. Taming Reachability Analysis of DNN-Controlled Systems via Abstraction-Based Training
- [NeurIPS'23] Jiayu Tian, Dapeng Zhi, **Si Liu**, Peixin Wang, Cheng Chen, Min Zhang. Boosting Verification of Deep Reinforcement Learning via Piece-Wise Linear Decision Neural Networks
- [CVPR'23] Zhaodi Zhang, Zhiyi Xue, Yang Chen, **Si Liu**, Yueling Zhang, Jing Liu, Min Zhang. Boosting Verified Training for Robust Image Classifications via Abstraction
- [ISSTA'23] Zhiyi Xue, **Si Liu**, Zhaodi Zhang, Yiting Wu, Min Zhang. A Tale of Two Approximations: Tightening Over-Approximation for DNN Robustness Verification via Under-Approximation
- [ASE'22] Zhaodi Zhang, Yiting Wu, **Si Liu**, Jing Liu, Min Zhang. Provably Tightest Linear Approximation for Robustness Verification of Sigmoid-like Neural Networks

- [TASE'21] Lei Liang, **Si Liu**. Exploring Design Alternatives for Replicated RAMP Transactions Using Maude
- [NFM'20] **Si Liu**, Atul Sandur, Jose Meseguer, Peter Olveczky, Qi Wang. Generating Correct-by-Construction Distributed Implementations from Formal Maude Designs
- [TACAS'19] **Si Liu**, Peter Csaba Olveczky, Min Zhang, Qi Wang, Jose Meseguer. Automatic Analysis of Consistency Properties of Distributed Transaction Systems in Maude.
- [FAoC'19] **Si Liu**, Peter Csaba Olveczky, Qi Wang, Indranil Gupta, José Meseguer. Read Atomic Transactions with Prevention of Lost Updates: ROLA and Its Formal Analysis. *Formal Aspects of Computing*
- [CCS'19] Qi Wang, Pubali Datta, Wei Yang, **Si Liu**, Carl Gunter, Adam Bates. Charting the Attack Surface of Trigger-Action IoT Platforms.
- [FASE'18] **Si Liu**, Peter Csaba Olveczky, Keshav Santhanam, Qi Wang, Indranil Gupta, José Meseguer. ROLA: A New Distributed Transaction Protocol and Its Formal Analysis.
- [LITES'17] **Si Liu**, Jatin Ganhotra, Muntasir Raihan Rahman, Son Nguyen, Indranil Gupta, José Meseguer. Quantitative Analysis of Consistency in NoSQL Key-value Stores. *Leibniz Transactions on Embedded Systems*
- [ICFEM'17] **Si Liu**, Peter Csaba Olveczky, Jatin Ganhotra, Indranil Gupta, José Meseguer. Exploring Design Alternatives for RAMP Transactions through Statistical Model Checking.
- [JLAMP'16] **Si Liu**, Peter Csaba Olveczky, José Meseguer. Modeling and Analyzing Mobile Ad hoc Networks in Real-Time Maude. *Journal of Logical and Algebraic Methods in Programming*
- [SAC'16] **Si Liu**, Peter Csaba Olveczky, Muntasir Raihan Rahman, Jatin Ganhotra, Indranil Gupta, José Meseguer. Formal Modeling and Analysis of Ramp Transaction Systems.
- [QEST'15] **Si Liu**, Son Nguyen, Jatin Ganhotra, Muntasir Raihan Rahman, Indranil Gupta, José Meseguer. Quantitative Analysis of Consistency in NoSQL Key-value Stores. *Nominated for Best Paper*.
- [ICFEM'14] **Si Liu**, Muntasir Raihan Rahman, Stephen Skeirik, Indranil Gupta, José Meseguer. Formal Modeling and Analysis of Cassandra in Maude.
- [PRDC'14] Xi Wu, **Si Liu**, Huibiao Zhu and Yongxin Zhao. Reasoning about Group-Based Mobility in MANETs.
- [ComSIS'13] Xi Wu, Huibiao Zhu, Yongxin Zhao, Zheng Wang, **Si Liu**. Modeling and verifying the Ariadne protocol using process algebra. *Computer Science and Information Systems Journal*
- [ECBS'12] Xi Wu, **Si Liu**, Huibiao Zhu, Yongxin Zhao, Lei Chen. Modeling and Verifying the Ariadne Protocol Using CSP.
- [HASE'11] **Si Liu**, Yongxin Zhao, Huibiao Zhu, Qin Li. A Calculus for Mobile Ad Hoc Networks from a Group Probabilistic Perspective.
- [SSIRI'11] **Si Liu**, Xiaofeng Wu, Qin Li, Huibiao Zhu, Qian Wang. Formal Approaches to Wireless Sensor Networks.
- [TASE'11] **Si Liu**, Yongxin Zhao, Huibiao Zhu, Qin Li. Towards a Probabilistic Calculus for Mobile Ad Hoc Networks.
- [TASE'11] Mengying Wang, Huibiao Zhu, Yongxin Zhao, **Si Liu**. Modeling and Analyzing the  $\mu$ TESLA Protocol Using CSP.
- [ICECCS'11] Yongxin Zhao, Yanhong Huang, Jifeng He, **Si Liu**. Formal Model of Interrupt Program from a Probabilistic Perspective.
- [UTP'10] Qin Li, Yongxin Zhao, Xiaofeng Wu, **Si Liu**. Promoting Models.

## WORKSHOP PAPERS

- [WRLA'18] **Si Liu**, Peter Csaba Olveczky, Qi Wang, José Meseguer. Formal Modeling and Analysis of the Walter Transactional Data Store.
- [SSS'15] **Si Liu**, Peter Csaba Olveczky and José Meseguer. Formal analysis of Leader Election in MANETs Using Real-Time Maude.
- [WRLA'14] **Si Liu**, Peter Csaba Olveczky and José Meseguer. A Framework for Mobile Ad hoc Networks in Real-Time Maude.
- [SSIRI'11] Han Zhu, Huibiao Zhu, **Si Liu**, Jian Guo. Towards Denotational Semantics for Verilog in PVS.

## OTHER BOOK CHAPTERS

- Rakesh Bobba, Jon Grov, Indranil Gupta, **Si Liu**, José Meseguer, Peter Csaba Ölveczky, Stephen Skeirik. Survivability: Design, Formal Modeling, and Validation of Cloud Storage Systems using Maude. 2018.

## PHD THESIS

- Design, Verification and Automatic Implementation of Correct-by-Construction Distributed Transaction Systems in Maude. University of Illinois Urbana-Champaign. 2019

## Teaching Experience

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Fall 2024	<b>Computer Systems</b> , Teaching Assistant	<i>ETH Zurich</i>
Spring 2024	<b>Data Modeling and Databases</b> , Teaching Assistant	<i>ETH Zurich</i>
Fall 2023	<b>Computer Systems</b> , Teaching Assistant	<i>ETH Zurich</i>
Spring 2023	<b>Data Modeling and Databases</b> , Teaching Assistant	<i>ETH Zurich</i>
Fall 2022	<b>Information Systems for Engineers</b> , Head Teaching Assistant	<i>ETH Zurich</i>
Spring 2022	<b>Data Modeling and Databases</b> , Teaching Assistant	<i>ETH Zurich</i>
Fall 2021	<b>Applied Security Lab</b> , Teaching Assistant	<i>ETH Zurich</i>
Spring 2021	<b>Data Modeling and Databases</b> , Teaching Assistant	<i>ETH Zurich</i>
Fall 2020	<b>Computer Systems</b> , Teaching Assistant	<i>ETH Zurich</i>
Spring 2020	<b>Data Modeling and Databases</b> , Teaching Assistant	<i>ETH Zurich</i>
Fall 2019	<b>Applied Security Lab</b> , Teaching Assistant	<i>ETH Zurich</i>
Fall 2016	<b>Distributed Systems</b> , Teaching Assistant	<i>UIUC</i>
Fall 2011	<b>Process Algebra</b> , Teaching Assistant	<i>ECNU</i>
Spring 2011	<b>Algorithms and Data Structures</b> , Teaching Assistant	<i>ECNU</i>
Fall 2010	<b>Discrete Mathematics</b> , Teaching Assistant	<i>ECNU</i>
Spring 2010	<b>Algorithms and Data Structures</b> , Teaching Assistant	<i>ECNU</i>

## Mentoring

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### • PhD students

- Dhruv Nevatia (co-supervised with Prof. David Basin), ETH Zurich
- Shabnam Ghasemirad (co-supervised with Dr. Christoph Sprenger and Prof. David Basin), ETH Zurich
- Zijing Yin (co-supervised with Prof. David Basin), ETH Zurich
- Ziwei Zhou (co-supervised with Prof. Min Zhang), ECNU
- Shi Peng (co-supervised with Prof. Min Zhang), ECNU
- Zhaodi Zhang (co-supervised with Prof. Min Zhang; first employment: Chengdu Education Research Institute), ECNU

### • Master students

- Theodor Moroianu, ETH Zurich
- Yunxin Sun, ETH Zurich
- Yufei Zhang, ETH Zurich
- Rolando Grave de Peralta, ETH Zurich
- Zhou Zhou, ECNU

- Long Gu, Nanjing University
  - Qiuhan Xiong, Nanjing University
  - Luca Multazz (first employment: SICPA), ETH Zurich
    - \* **honoured with the ETH Medal for his Master thesis “NOCS-Optimal Distributed Transactions and Beyon” (top 2.5%)**
  - Lukas Heimes (first employment: SBB CFF FFS), ETH Zurich
    - \* **honoured with the ETH Medal for his Master thesis “A Formal Framework for End-to-End DNS Resolution” (top 2.5%)**
  - Jodok Vieli (graduated), ETH Zurich
  - Marco Bearzi (graduated), ETH Zurich
  - Shabnam Ghasemirad (now PhD at ETH Zurich), ETH Zurich
  - Jiang Xiao (first employment: Agricultural Bank of China), Nanjing University
  - Jiayu Tian (first employment: CITIC Securities), ECNU
  - Zhiyi Xue (now PhD at ECNU), ECNU
- **Undergraduate students**
    - Tiancheng Xing (graduated, now Master at NUS), Nanjing University
    - Zhiheng Cai (graduated, now PhD at Tsinghua University), Nanjing University
    - Long Gu (graduated, now Master at Nanjing University), Nanjing University
    - Zhenge Chen (graduated, now Master at UCSD), Nanjing University
    - Zhou Zhou (graduated, now Master at ECNU), ECNU
    - Ziwei Zhou (graduated, now PhD at ECNU), ECNU
    - Ruiyang Liu (graduated, now Master at JHU), ECNU
    - Lei Liang (graduated, now at CITIC Securities), ECNU
    - Plamen Stefanov (graduated, now Master at ETH Zurich), ETH Zurich
    - Keshav Santhanam (graduated, now PhD at Stanford University), UIUC

## Professional Activities

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- **Program Committee:** NSDI’25, ICFEM’24, ICFEM’23
- **Journal Reviewer:** The VLDB Journal, JLAMP (Journal of Logical and Algebraic Methods in Programming), SCP (Science of Computer Programming)
- **Sub-Reviewer:** ICFEM (’22, ’16, ’14, ’13, ’12, ’11, ’10), FM (’21, ’18), FASE’14, TASE (’12, ’11)
- **Judge:** Student Research Competition (SPLASH 2024)
- **Dagstuhl Seminar:** “Ensuring the Reliability and Robustness of Database Management Systems (21442)” 2021 (participant)
- **Grant:**

- Official Project Partner on the SNSF grant for Project “Formal Verification of Isolation Guarantees in Database Systems” (CHF 181,099; 2024–2027)
- Preparing the proposal for NSF CNS 1409416 (\$584,508; 2014–2018), Availability-Consistency Trade-offs in Key-Value and NoSQL Storage Systems

## Talks & Presentations

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- Plume: Efficient and Complete Black-box Checking of Weak Isolation Levels. OOPSLA’24, Pasadena, USA, 2024.
- NOC-NOC: Towards Performance-optimal Distributed Transactions. SIGMOD’24, Santiago, Chile, 2024.
- Generating Correct-by-Construction Distributed Implementations from Formal Maude Designs. NFM’20, Virtual, 2020.
- Design, Verification and Automatic Implementation of Correct-by-Construction Distributed Transaction Systems in Maude. University Paris Diderot, France, 2019.
- Design, Verification and Automatic Implementation of Correct-by-Construction Distributed Transaction Systems in Maude. ETH Zurich, Switzerland, 2019.
- Automatic Analysis of Consistency Properties of Distributed Transaction Systems in Maude. TACAS’19, Prague, Czech Republic, 2019.
- Exploring Design Alternatives for RAMP Transactions through Statistical Model Checking. ICFEM’17, Xi’an, China, 2017.
- Design, Formal Modeling, and Validation of Cloud Storage Systems using Maude. Huawei, Urbana-Champaign, USA, 2017.
- Exploring Design Alternatives for the RAMP Transaction System Through Statistical Model Checking. Assured Cloud Computing Center, Urbana-Champaign, USA, 2017.
- Formal Modeling and Analysis of Ramp Transaction Systems. SAC’16, Pisa, Italy, 2016.
- Formal Modeling and Analysis of Ramp Transaction Systems. Assured Cloud Computing Center, Urbana-Champaign, USA, 2016.
- Quantitative Analysis of Consistency in NoSQL Key-value Stores. QEST’15, Madrid, Spain, 2015.
- Quantitative Analysis of Consistency in NoSQL Key-value Stores. Assured Cloud Computing Center, Urbana-Champaign, USA, 2015.
- A Framework for Mobile Ad hoc Networks in Real-Time Maude. WRLA’14, Grenoble, France, 2014.
- Formal Modeling and Analysis of Cassandra in Maude. Assured Cloud Computing Center, Urbana-Champaign, USA, 2014.
- A Calculus for Mobile Ad Hoc Networks from a Group Probabilistic Perspective. HASE’11, Boca Raton, USA, 2011.
- Towards a Probabilistic Calculus for Mobile Ad Hoc Networks. USTC, Suzhou, China, 2011.
- Towards a Probabilistic Calculus for Mobile Ad Hoc Networks. TASE’11, Xi’an, China, 2011.
- Formal Approaches to Wireless Sensor Networks. SSIRI’11, Jeju Island, Korea, 2011.