

# Mukund Raghathan

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## Research Interests

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Program synthesis, formal verification, probabilistic methods in static analysis

## Experience

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### University of Southern California

*Assistant Professor*

Thomas Lord Department of Computer Science

Los Angeles, CA

August, 2019–Present

### University of Pennsylvania

*Postdoctoral Researcher*

Advisor: Mayur Naik

I combined probabilistic and logical reasoning techniques to reduce false alarm rates, incorporating user feedback, and improving the usability of static analysis tools [PLDI18, MLP18, PLDI19, IJCAI19].

Philadelphia, PA

May, 2017–August, 2019

### École Polytechnique Fédérale de Lausanne

*Visiting Researcher*

Advisor: Viktor Kuncak

I worked on using patterns derived from code corpora and developed probabilistic enumeration techniques to improve the state of the art in program synthesis algorithms [TR17].

Lausanne, Switzerland

September–December, 2016

### Microsoft Research Ltd.

*Research Intern*

Advisor: Youssef Hamadi, Yi Wei

I developed an algorithm to extract API usage idioms from open-source C# projects and a program synthesizer to answer natural language API-related queries [ICSE16].

Cambridge, UK

June–August, 2013, June–August, 2014

## Education

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### University of Pennsylvania

*Ph.D. in Computer Science*

Thesis: *Regular Programming over Data Streams*

Advisor: Rajeev Alur

Philadelphia, PA

September, 2010–May, 2017

### Indian Institute of Technology Guwahati

*Bachelor of Technology in Computer Science*

Thesis: *State Reachability in Counter Automata*

Advisor: Purandar Bhaduri

Guwahati, India

August, 2006–May, 2010

## Teaching

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### CSCI 625, Program Synthesis and Computer-Aided Verification

*Graduate*

Offered in 2020 and 2021 as CSCI 699: Computer-Aided Verification

University of Southern California

Spring 2020, 2021, 2023, 2024

### CSCI 431, An Introduction to Functional Programming

*Undergraduate*

University of Southern California

Fall 2021, 2022, 2024

## Students

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1. Sima Arasteh. Ph.D. student. Fall 2019–Present.
2. Yifei Huang. Ph.D. student. Summer 2021–Present.
3. Amirmohammad Nazari. Ph.D. student. Summer 2021–Present.
4. Sara Baradaran. Ph.D. student. Fall 2023–Present.
5. Matin Amini. Ph.D. student. Spring 2024–Present.
6. Marta Dávila Mateu. Ph.D. student. Fall 2024–Present.

## Publications

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### Drafts

- [TR24a] Yifei Huang, Matin Amini, Alexis Le Glaunec, Konstantinos Mamouras, and Mukund Raghothaman. Membership Testing for Semantic Regular Expressions. In submission. 2024.

### Conference Papers

- [ACSAC24] Sima Arasteh, Jelena Mirkovic, Mukund Raghothaman, and Christophe Hauser. BinHunter: A Fine-Grained Graph Representation for Localizing Vulnerabilities in Binary Executables. In: *Annual Computer Security Applications Conference*. ACSAC. To appear. 2024.
- [VL/HCC24] Amirmohammad Nazari, Swabha Swayamdipta, Souti Chattopadhyay, and Mukund Raghothaman. Generating Function Names to Improve Comprehension of Synthesized Programs. In: *IEEE Symposium on Visual Languages and Human-Centric Computing*. IEEE, 2024.
- [OOPSLA23b] Amirmohammad Nazari, Yifei Huang, Roopsha Samanta, Arjun Radhakrishna, and Mukund Raghothaman. “Explainable Program Synthesis by Localizing Specifications”. In: *Proceedings of the ACM on Programming Languages* 7.OOPSLA2 (2023).
- [OOPSLA23a] Aalok Thakkar, Nathaniel Sands, Georgios Petrou, Rajeev Alur, Mayur Naik, and Mukund Raghothaman. “Mobius: Synthesizing Relational Queries with Recursive and Invented Predicates”. In: *Proceedings of the ACM on Programming Languages* 7.OOPSLA2 (2023).
- [PADL23] David Zhao, Pavle Subotić, Mukund Raghothaman, and Bernhard Scholz. Automatic Rollback Suggestions for Incremental Datalog Evaluation. In: *Practical Aspects of Declarative Languages*. Springer, 2023, pp. 295–312.
- [ICSE22] Hyunsu Kim, Mukund Raghothaman, and Kihong Heo. Learning Probabilistic Models for Static Analysis Alarms. In: *Proceedings of the 44th International Conference on Software Engineering*. ICSE. Best Artifact Award. ACM, 2022, pp. 1282–1293.
- [FSE21] Tianyi Chen, Kihong Heo, and Mukund Raghothaman. Boosting Static Analysis Accuracy with Instrumented Test Executions. In: *Proceedings of the 29th ACM Joint Meeting on European Software Engineering Conference and Symposium on Foundations of Software Engineering*. ESEC / FSE. ACM, 2021, pp. 1154–1165.
- [AAAI21] Jonathan Mendelson, Aaditya Naik, Mayur Naik, and Mukund Raghothaman. GenSynth: Synthesizing Datalog Programs Without Language Bias. In: *Proceedings of the 35th AAAI Conference on Artificial Intelligence*. Vol. 35. 7. 2021, pp. 6444–6453.

- [UIST21] Aaditya Naik, Jonathan Mendelson, Nathaniel Sands, Yuepeng Wang, Mayur Naik, and Mukund Raghothaman. Sporq: An Interactive Environment for Exploring Code using Query-by-Example. In: *Proceedings of the 34th ACM Symposium on User Interface Science and Technology*. UIST. ACM, 2021, pp. 84–99.
- [PLDI21] Aalok Thakkar, Aaditya Naik, Nathaniel Sands, Rajeev Alur, Mayur Naik, and Mukund Raghothaman. Example-Guided Synthesis of Relational Queries. In: *Proceedings of the 42nd ACM SIGPLAN Conference on Programming Language Design and Implementation*. PLDI. ACM, 2021, pp. 1110–1125.
- [ICSE21] Jingbo Wang, Chungha Sung, Mukund Raghothaman, and Chao Wang. Data-Driven Synthesis of Provably Sound Side Channel Analyses. In: *Proceedings of the 43rd International Conference on Software Engineering*. 2021, pp. 810–822.
- [PPDP21] David Zhao, Pavle Subotić, Mukund Raghothaman, and Bernhard Scholz. Towards Elastic Incrementalization for Datalog. In: *Proceedings of the 23rd International Symposium on Principles and Practice of Declarative Programming*. PPDP. ACM, 2021, pp. 1–16.
- [POPL20] Mukund Raghothaman, Jonathan Mendelson, David Zhao, Mayur Naik, and Bernhard Scholz. Provenance-Guided Synthesis Of Datalog Programs. In: *Proceedings of the 47th ACM SIGPLAN Symposium on Principles of Programming Languages*. POPL. ACM, 2020.
- [PLDI19] Kihong Heo, Mukund Raghothaman, Xujie Si, and Mayur Naik. Continuous Program Reasoning via Differential Bayesian Inference. In: *Proceedings of the 40th ACM SIGPLAN Conference on Programming Language Design and Implementation*. PLDI. SIGPLAN Distinguished Paper Award. ACM, 2019, pp. 561–575.
- [IJCAI19] Xujie Si, Mukund Raghothaman, Kihong Heo, and Mayur Naik. Synthesizing Datalog Programs By Numerical Relaxation. In: *Proceedings of the 28th International Joint Conference on Artificial Intelligence*. IJCAI. International Joint Conferences on Artificial Intelligence Organization, 2019, pp. 6117–6124.
- [PLDI18] Mukund Raghothaman, Sulekha Kulkarni, Kihong Heo, and Mayur Naik. User-Guided Program Reasoning Using Bayesian Inference. In: *Proceedings of the 39th ACM SIGPLAN Conference on Programming Language Design and Implementation*. PLDI. ACM, 2018, pp. 722–735.
- [MLP18] Mukund Raghothaman, Sulekha Kulkarni, Richard Zhang, Xujie Si, Kihong Heo, Woosuk Lee, and Mayur Naik. Beyond Deductive Methods in Program Analysis. In: *Machine Learning for Programming*. 2018.
- [NeurIPS18] Xujie Si, Hanjun Dai, Mukund Raghothaman, Mayur Naik, and Le Song. Learning Loop Invariants for Program Verification. In: *Advances in Neural Information Processing Systems 31*. NeurIPS (Spotlight). 2018, pp. 7762–7773.
- [PLDI17] Konstantinos Mamouras, Mukund Raghothaman, Rajeev Alur, Zachary Ives, and Sanjeev Khanna. StreamQRE: Modular Specification and Efficient Evaluation of Quantitative Queries Over Streaming Data. In: *Proceedings of the 38th ACM SIGPLAN Conference on Programming Language Design and Implementation*. PLDI. ACM, 2017, pp. 693–708.
- [ESOP16] Rajeev Alur, Dana Fisman, and Mukund Raghothaman. Regular Programming for Quantitative Properties of Data Streams. In: *Programming Languages and Systems: 25th European Symposium on Programming*. ESOP. Springer, 2016, pp. 15–40.
- [ICSE16] Mukund Raghothaman, Yi Wei, and Youssef Hamadi. SWIM: Synthesizing What I Mean. Code Search and Idiomatic Snippet Synthesis. In: *Proceedings of the 38th International Conference on Software Engineering*. ICSE. ACM, 2016, pp. 357–367.

- [POPL15] Rajeev Alur, Loris D’Antoni, and Mukund Raghothaman. DReX: A Declarative Language for Efficiently Evaluating Regular String Transformations. In: *Proceedings of the 42nd Annual Symposium on Principles of Programming Languages*. POPL. ACM, 2015, pp. 125–137.
- [CAV15] Rajeev Alur, Mukund Raghothaman, Christos Stergiou, Stavros Tripakis, and Abhishek Udupa. Automatic Completion of Distributed Protocols With Symmetry. In: *Proceedings of the 27th International Conference on Computer Aided Verification*. CAV. Springer, 2015, pp. 395–412.
- [LICS14] Rajeev Alur, Adam Freilich, and Mukund Raghothaman. Regular Combinators for String Transformations. In: *Proceedings of the Joint Meeting of the 23rd Annual Conference on Computer Science Logic and the 29th Annual Symposium on Logic in Computer Science*. CSL-LICS. ACM, 2014, 9:1–9:10.
- [HVC14] Rajeev Alur, Milo Martin, Mukund Raghothaman, Christos Stergiou, Stavros Tripakis, and Abhishek Udupa. Synthesizing Finite-State Protocols from Scenarios and Requirements. In: *Hardware and Software: Verification and Testing: Proceedings of the 10th International Haifa Verification Conference*. HVC. Springer, 2014, pp. 75–91.
- [FMCAD13] Rajeev Alur, Rastislav Bodik, Garvit Juniwal, Milo Martin, Mukund Raghothaman, Sanjit Seshia, Rishabh Singh, Armando Solar-Lezama, Emina Torlak, and Abhishek Udupa. Syntax-Guided Synthesis. In: *Formal Methods in Computer-Aided Design*. FMCAD. Extended version published as [DSSE15]. IEEE, 2013, pp. 1–8.
- [LICS13] Rajeev Alur, Loris D’Antoni, Jyotirmoy Deshmukh, Mukund Raghothaman, and Yifei Yuan. Regular Functions and Cost Register Automata. In: *Proceedings of the 28th Annual Symposium on Logic in Computer Science*. LICS. IEEE, 2013, pp. 13–22.
- [ICALP13] Rajeev Alur and Mukund Raghothaman. Decision Problems for Additive Regular Functions. In: *Proceedings of the 40th International Colloquium on Automata, Languages, and Programming, Part II*. ICALP. Springer, 2013, pp. 37–48.

### Journal Papers.....

- [TNET23] Haoxian Chen, Chenyuan Wu, Andrew Zhao, Mukund Raghothaman, Mayur Naik, and Boon Thau Loo. “Synthesizing Formal Network Specifications from Input-Output Examples”. In: *IEEE / ACM Transactions on Networking* (2023), pp. 994–1009.
- [TCS20] Rajeev Alur, Dana Fisman, Konstantinos Mamouras, Mukund Raghothaman, and Caleb Stanford. Streamable Regular Transductions. In: vol. 807. Elsevier, 2020, pp. 15–41.
- [DSSE15] Rajeev Alur, Rastislav Bodik, Eric Dallal, Dana Fisman, Pranav Garg, Garvit Juniwal, Hadas Kress-Gazit, Madhusudan Parthasarathy, Milo Martin, Mukund Raghothaman, Shambwaditya Saha, Sanjit Seshia, Rishabh Singh, Armando Solar-Lezama, Emina Torlak, and Abhishek Udupa. Syntax-Guided Synthesis. In: *Dependable Software Systems Engineering*. IOS Press, 2015, pp. 1–25.

### Theses.....

- [Ths17] Mukund Raghothaman. Regular Programming over Data Streams. PhD thesis. University of Pennsylvania, 2017.

### Technical Reports.....

- [ICSE24 Poster] Amirmohammad Nazari, Souti Chattopadhyay, Swabha Swayamdipta, and Mukund Raghothaman. NomNom: Explanatory Function Names for Program Synthesizers. In: *Proceedings of the 46th ACM / IEEE International Conference on Software Engineering: Companion Proceedings*. ICSE Companion. ACM, 2024, pp. 418–419.

- [TR17] Manos Koukoutos, Mukund Raghothaman, Etienne Kneuss, and Viktor Kuncak. On Repair with Probabilistic Attribute Grammars. Tech. rep. 2017. CoRR: abs/1707.04148.
- [TR14] Mukund Raghothaman and Abhishek Udupa. Language to Specify Syntax-Guided Synthesis Problems. Tech. rep. 2014. CoRR: abs/1405.5590.

## Invited Talks

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<b>Precise Program Reasoning Using Probabilistic Methods</b> <i>Workshop on AI for Static Analysis (ASA)</i>	<i>June 2022</i>
<b>Interactively Exploring Code Using Query-by-Example</b> <i>5th Annual Symposium on Machine Programming</i>	<i>June 2021</i>
<b>Precise Program Reasoning Using Probabilistic Methods</b> <i>Workshop on Declarative Program Analysis</i>	<i>June 2019</i>

## Software

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### **Bingo, Drake, Dynaboost**

*Interactive systems for prioritizing static analysis alarms by confidence and relevance*

[PLDI18, MLP18, PLDI19, FSE21]

<https://zenodo.org/record/4902782>, <https://github.com/petablox/pldi19-artifact>, <https://github.com/difflog-project/bingo>

### **CODE2INV**

*System to automatically synthesize loop invariants by reinforcement learning [NeurIPS18]*

<https://github.com/PL-ML/code2inv>

### **Difflog, Prosynth, EGS**

*Systems to learn Datalog queries from input-output examples [IJCAI19, POPL20, AAAI21, PLDI21]*

<https://github.com/petablox/difflog>, <https://github.com/petablox/pop12020-artifact>, <https://github.com/aalok-thakkar/egs-artifact>

### **SyGuS**

*Interchange format for syntax-guided synthesis problems [FMCAD13, TR14]*

<https://github.com/rishabhs/syguS-comp14>

### **StreamQRE**

*Domain-specific language for easy, efficient stream processing [TCS20, Ths17, PLDI17, ESOP16]*

<http://www.cis.upenn.edu/~rmukund/StreamQRE.html>

### **DReX**

*Highly expressive DSL for string transformations supporting fast, one-pass evaluation [Ths17, POPL15, LICS14]*

<https://bitbucket.org/strexp/drex>

## Awards

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1. Distinguished Artifact Award at ICSE 2022 for paper on Bayesmith.
2. NSF CAREER Award, 2022, for project on Statistical Foundations of Program Reasoning.
3. SIGPLAN Distinguished Paper Award at PLDI 2019 for paper describing Drake.
4. Second place in SyGuS competition 2014 for the stochastic SyGuS solver STOCH.
5. Honourable mention at the ACM ICPC Asia Regionals, 2009, held at IIT Kanpur.
6. National Talent Search Scholarship, 2004, by the National Council for Educational Research and Training.

## Research Funding

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1. Mukund Raghothaman. *CAREER: Foundations of Statistical Program Reasoning*. NSF CCF #2146518, \$640,000, February 2022 (5 years).
2. Mukund Raghothaman (PI), Srivatsan Ravi, Jyotirmoy Desmukh, and Michael Collins. *Synthesis of Quantitative Network Analytics: From Left-of-Launch to Right-of-Boom*. NSF CCF #2124431, \$750,000, September 2021 (3 years). PI Share: \$200,000.
3. Rajeev Alur, Mayur Naik, Mukund Raghothaman (USC PI). *Collaborative Research: SHF: Medium: Synthesis of Logic Programs for Democratizing Program Analysis*. NSF CCF #2107261, \$1,080,000, May 2021 (4 years). USC share: \$480,000.

## Service

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### External Service.....

<b>POPL 2025</b>	Program Committee Member
<b>SPLASH 2024</b>	Local Arrangements Chair
<b>NSF 2024</b>	Panel Reviewer
<b>PLDI 2024</b>	Program Committee Member
<b>PADL 2024</b>	Program Committee Member
<b>ACM India Doctoral Dissertation Award 2023</b>	Committee Member
<b>NSF 2023</b>	Panel Reviewer
<b>PLDI 2023</b>	Program Committee Member
<b>POPL 2023</b>	Artifact Evaluation Committee Co-Chair
<b>NSF 2022</b>	Panel Reviewer
<b>PLDI 2022</b>	Program Committee Member
<b>POPL 2022</b>	Artifact Evaluation Committee Co-Chair
<b>NSF 2021</b>	Panel Reviewer
<b>IJCAI 2021</b>	Reviewer (Survey Track)
<b>OOPSLA 2020</b>	External Review Committee Member
<b>SYNT 2020</b>	Program Committee Member
<b>CAV 2020</b>	Program Committee Member
<b>PLDI 2020</b>	Program Committee Member
<b>SYNT 2019</b>	Program Committee Member
<b>IBM PL Day 2018</b>	Selection Committee Member
<b>CAV 2017</b>	Artifact Evaluation Committee Member
<b>CAV 2016</b>	Artifact Evaluation Committee Member
<b>POPL 2016</b>	Artifact Evaluation Committee Member
<b>PLDI 2016</b>	External Review Committee Member

### University and Departmental Service.....

1. Computer Science Department Distinguished Lectures and Colloquium Series Co-chair (2021–2022)
2. Computer Science Department Hiring Sub-Committee for Programming Languages (2020, 2022)
3. Computer Science Graduate Admissions Committee for Systems Area (2020–2023)