University of Wisconsin-Madison
Dept. of Computer Science
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Charlie Murphy

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My research helps software developers write code that executes as intended. My interests are in programming languages, formal methods, automated reasoning, program synthesis and verification, and logic.

ACADEMICS

Princeton University Princeton, NJ
Ph.D. in Computer Science Jan. 2023
M.A. in Computer Science April 2018
Area: Automated Verification, Concurrency, Programming Languages, Formal Methods
Thesis title: *Relational Verification of Distributed Systems via Weak Simulations*
Advisor: Zachary Kincaid

Ohio University (Honors Tutorial College) Athens, OH
B.S. in Computer Science May 2016
Thesis title: *Examining the Effects of Key Point Detector and Descriptors on 3D Visual SLAM*
Advisor: David Chelberg

WORK EXPERIENCE

University of Wisconsin-Madison Madison, WI
Post-Doctoral Research Associate for Loris D'Antoni Feb. 2023-Present
  Worked with Loris D'Antoni and Tom Reps to develop logic and constraint-based techniques for verification and synthesis within the Semantics-Guided Synthesis framework.

Amazon Web Services New York, NY
Applied Science Intern 7/20-9-20
  Developed techniques to ensure correct runtime operation of distributed databases at scale with minimal memory, disk, and CPU overheads.

GrammaTech Ithaca, NY
Research Intern 6/18-8/18
  Developed a technique to dynamically re-rank bug reports using user feedback, machine learning, and formal methods.

NOAA VizLab Silver Springs, MD
Ernest F. Hollings Intern 5/15-7/15
  Developed NOAA WeatherView – A 3D Visualization system for education of global weather patterns.
  https://www.nnvl.noaa.gov/weatherview/index.html

Ohio University Athens, OH
Smart Health Lab 5/14-5/16
  National Science Foundation Research Experience for Undergraduates. Created and maintained database and visualization tools for analysis of physiological sensor data for prediction of hypoglycemia in patients with type 1 diabetes.

Ohio University Athens, OH
Voinovich Research Assistant 8/13-5/14
  Performed data analysis of social networks / surveys for various educational and incarceration reform programs to determine the effectiveness of programs given level of involvement.

WORKS IN PROGRESS/UNDER SUBMISSION

Charlie Murphy, Tom Reps, Loris D'Antoni. Strategy Synthesis for Validity of the μCLP Calculus. *Work in Progress*.
Abstract:
  The μCLP calculus is a fragment of first-order logic that is capable of expressing complex fixed-points. Several works have shown that many tasks in program verification and synthesis may be reduced to validity of formulas within the μCLP calculus. This paper introduces the first game semantics for the μCLP calculus. Each μCLP formula induces a validity game between VALID and INVALID—whose goals are respectively to prove or disprove validity of the given formula. We show that VALID (resp. INVALID) has a winning strategy to the induced game if and only if the input formula is valid (resp. invalid). Furthermore, as plays of the validity game may be of infinite duration (due to the inclusion of fixed-points), we introduce validity game unwindings that serve as finite representations of a player's strategy. Validity game unwindings form the basis of the semi-algorithm presented within this paper used to decide validity of a μCLP formula. Finally, we implement our algorithm in a tool called Muse and compare againts MuVal—a tool for deciding validity of μCLP formula based on counter-example guided inductive synthesis.

Charlie Murphy, Keith Johnson, Tom Reps, Loris D'Antoni. Verifying Solutions to Semantics-Guided Synthesis Problems.

Abstract:

Semantics-Guided Synthesis (SemGuS) provides a framework to specify synthesis problems in a solver-agnostic and domain-agnostic way by allowing a user to provide both the syntax and semantics of the language in which the desired program should be synthesized. Because synthesis and verification are closely intertwined, the SemGuS framework raises the problem of how to *verify* programs in a solver and domain-agnostic way.

We prove that the problem of verifying whether a program is a valid solution to a SemGuS problem can be reduced to proving validity of a query in the μCLP calculus, a fixed-point logic that generalizes (co-)constrained-Horn clauses. Our encoding into μCLP allows us to further classify the SemGuS verification problems into ones that are reducible to validity of (i) first-order-logic formulas, (ii) (co-)constrained-Horn clauses, and (iii) μCLP queries. Furthermore, our encoding shines light on some limitations of the SemGuS framework, such as its inability to model nondeterminism and reactive synthesis. We thus propose a modification to SemGuS that makes it more expressive, and for which verifying solutions is exactly equivalent to proving validity of a query in the μCLP calculus. Our implementation of SemGuS verifiers based on the above encoding can verify instances that were not even encodable in previous work.

Charlie Murphy, Zachary Kincaid. Relational Verification via Weak Simulation.

Abstract:

Distributed systems are notoriously hard to get right, even when based on existing protocols. We propose a novel method to automatically prove that message passing programs match an executable specification. The specification is a variant of relational Hoare logic based on weak simulation. Our technique, simulation synthesis, is the first to handle both infinite state programs and infinite state specifications. Simulation synthesis is based on the game semantics of weak simulation and synthesizes a winning strategy to the game induced by the relational verification query.

PUBLICATIONS

Jiangyi Liu, Anvay Grover, Keith Johnson, **Charlie Murphy**, Tom Reps, Loris D'Antoni. Synthesizing Semantics from Closed-Boxed Interpreters. *Proceedings of the ACM on Programming Languages. OOPSLA*. Pasedena, California. October 2024.

Charlie Murphy, Zachary Kincaid. Quantified Linear Arithmetic Satisfiability Via Fine-Grained Strategy Improvement. *CAV'24: 36th International Conference on Computer Aided Verification*. Montreal, Canada. July 2024.

Charlie Murphy, Zachary Kincaid. Practical Algorithm for Structure Embedding. *VMCAI'19: 20th International Conference on Verification, Model Checking, and Abstract Interpretation*. Lisbon, Portugal. January 2019.

Charlie Murphy, Patrick Gray, Gordon Stewart. Verified Perceptron Convergence Theorem. *MAPL'17: The first ACM SIGPLAN Workshop on Machine Learning and Programming Languages*. Barcelona, Spain. June 2017.

Timothy Murphy, David Chelberg. Development of a Robust Indoor 3D SLAM Algorithm. *Proceedings of Midstates Conference on Undergraduate Research in Computer Science and Mathematics*. Wooster University. November 2014.

TALKS

Timothy Murphy, Dan Pisut. New Web Interface for Real-Time-Visualization of NOAA Weather Data. American Meteorological Society. *32nd Conference on Environmental Information Processing Technologies*. January 2016.

Timothy Murphy. New Web Interface for Real-Time-Visualization of NOAA Atmosphere Model Data. *NOAA 2015 Science Symposium*. Silver Springs, MD. July 2015.

Timothy Murphy. Developing an Indoor 3D SLAM Algorithm. Ohio University. *Ohio University Student Expo*. April 2015

Timothy Murphy, Hannah Quillin. Towards the Quantified Self: Fitness Bands for Blood Glucose Prediction. Ohio University. *Ohio University Student Expo*. April 2015

Teaching

9/22-1/23	Assistant in Instruction. COS-516 - Automated Reasoning about Software, Princeton
9/22-1/23	Assistant in Instruction. COS-226 - Data Structures and Algorithms, Princeton
2/19-6/19	Lecturer. Mat-015C – Basic College Math, Prison Teaching Initiative
2/18-6/19	Assistant in Instruction. COS-226 – Data Structures and Algorithms, Princeton
9/17-1/18	Assistant in Instruction. COS-418 – Distributed Systems, Princeton
5/17-5/20	Course design. CS-103 – Intro to Computer Science, Prison Teaching Initiative

Service

10/24	PC member OOPSLA'25
2/24	ERC member USENIX ATC'24
10/23	Sub-reviewer ESOP'24
10/23	Sub-reviewer SOFSEM'24
11/20	POPL'21 Artifact Evaluation Committee
5/16-05/20	Princeton Computer Science Graduate Social Committee, Chair
9/17-9/19	Programming Languages Seminar, Organizer
8/17-9/19	Princeton Graduate Board Games, Treasurer
1/17-4/17	Graduate Student Faculty Recruiting Committee (Princeton Computer Science)
12/15	Hour of Code Event (Ohio University), Organizer
5/15-7/16	Ohio University Association of Computing Machinery (ACM), President
5/15-5/16	Bobcat Tabletop (Ohio University), Treasurer
12/14	Hour of Code Event (Ohio University), Organizer
5/14-5/15	Ohio University Association of Computing Machinery (ACM), Web Master

Honors

5/16	Honorable mention for best thesis. Ohio University Honors Tutorial College.
4/15	2nd Place presentation (Undergrad EECS). Ohio University Student Expo.
4/15	2nd Place presentation (Diabetes Institute). Ohio University Student Expo.
5/14	Ernest F. Hollings Scholarship. Class of 2014-2016.
5/13	Benjamin A. Gilman Scholarship Recipient (Ukraine).