October 12–18, 2025 Singapore, Singapore



Advancing Computing as a Science & Profession



PAINT '25

Proceedings of the 4th ACM SIGPLAN International Workshop on

Programming Abstractions and Interactive Notations, Tools, and Environments

Edited by:

Tom Beckmann, Lukas Böhme, Luke Church, Robert Hirschfeld, and Mauricio Verano Merino

Sponsored by:

ACM SIGPLAN, ACM SIGAda

Co-located with:

ICFP/SPLASH '25

Association for Computing Machinery, Inc. 1601 Broadway, 10th Floor New York, NY 10019-7434 USA

Copyright © 2025 by the Association for Computing Machinery, Inc (ACM). Permission to make digital or hard copies of portions of this work for personal or classroom use is granted without fee provided that the copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted.

To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permission to republish from: Publications Dept. ACM, Inc. Fax +1-212-869-0481 or E-mail permissions@acm.org.

For other copying of articles that carry a code at the bottom of the first or last page, copying is permitted provided that the per-copy fee indicated in the code is paid through the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, USA.

ACM ISBN: 979-8-4007-2160-1

Cover photo:

Title: "Marina Bay and Merlion",

Copyright 2025 Singapore Tourism Board, licensed to ICFP/SPLASH 2025

Production: Conference Publishing Consulting

D-94034 Passau, Germany, info@conference-publishing.com

Welcome from the Chairs

Welcome to the 2025 ACM SIGPLAN International Symposium on New Ideas, New Paradigms, and Reflections on Programming and Software (Onward! 2025), the premier multidisciplinary conference focused on everything to do with programming and software, including processes, methods, languages, communities and applications. Onward! is more radical, more visionary and more open than other conferences to ideas that are well-argued but not yet proven. We welcome different ways of thinking about, approaching, and reporting on programming language and software engineering research. Onward! 2025 is co-located with SPLASH 2025, running from Sunday the 12th of October till Saturday the 18th of October, in Singapore.

Onward! distinguishes two kinds of texts: papers and essays. Papers are aiming for grand visions and new paradigms that could make a big difference in how we will one day build software. Essays are looking for clear and compelling pieces of writing about topics important to the software community. Both kinds are not research-as-usual texts while they do deliver on compelling arguments, exploratory implementations, or substantial examples and perspectives.

Onward! follows a two-phase review process. This enables us to welcome contributions that contain promising material and have the potential to meet the conference's standards, but which may fall short of this in their initial form. At the end of the first round, all submissions will be either accepted normally, subject to mandatory revisions, or rejected outright. The authors of submissions in the second category received one month to complete the requested revisions, at which point the original reviewers decided on final acceptance or rejection. We received 23 papers, out of which 12 were accepted; we received 13 essays, out of which 5 were accepted. We hope that the papers and essays here will stimulate and provoke your thinking about programming and software engineering, and we are expecting fruitful discussions at the conference.

Shigeru Chiba	Clemens N. Klokmose	Colin S. Gordon
Papers Co-chair	Papers Co-chair	Essays Co-chair
The University of Tokyo	Aarhus University	Drexel University
Japan	Denmark	United States of America

Onward! 2025 Organization

Onward! 2025 Papers - Program Committee

Shigeru Chiba (University of Tokyo, Japan), Co-chair Clemens Nylandsted Klokmose (Aarhus University, Denmark), Co-chair

Antranig Basman (Raising the Floor - International, UK)

Jacques Carette (McMaster University, Canada)

Luke Church (University of Cambridge, Candela Inc., UK)

Siobhán Clarke (Trinity College Dublin, Ireland)

Stéphane Ducasse (Inria, University of Lille, CNRS, Centrale Lille, CRIStAL, France)

Elisa Gonzalez Boix (Vrije Universiteit Brussel, Belgium)

Philipp Haller (KTH Royal Institute of Technology, Sweden)

Reid Holmes (University of British Columbia, Canada)

Joel Jakubovic (Charles University in Prague, Czechia)

Jun Kato (National Institute of Advanced Industrial Science and Technology, Japan)

Raffi Khatchadourian (CUNY Hunter College, USA)

Patrick Lam (University of Waterloo, Canada)

Daan Leijen (Microsoft Research, USA)

Sorin Lerner (University of California at San Diego, USA)

Magnus Madsen (Aarhus University, Denmark)

Ole Lehrmann Madsen (Aarhus University, Denmark)

Hidehiko Masuhara (Institute of Science Tokyo, Japan)

Steve Oney (University of Michigan, USA)

Roly Perera (University of Cambridge, University of Bristol, UK)

Guillermo Polito (Univ. Lille, Inria, CNRS, Centrale Lille, UMR 9189 CRIStAL, France)

Alexander Repenning (University of Colorado at Boulder, USA)

Andrea Rosà (USI Lugano, Switzerland)

Giancarlo Succi

Emma Söderberg (Lund University, Sweden)

Tijs van der Storm (CWI, University of Groningen, Netherlands)

Onward! 2025 Essays - Program Committee

Colin Gordon (Drexel University, USA), Program Chair

Adrian Sampson (Cornell University, USA)

Andre van der Hoek (University of California at Irvine, USA)

Annette Bieniusa (University of Kaiserslautern-Landau, Germany)

Carolyn Jane Anderson (Wellesley College, USA)

Chris Martens (Northeastern University, USA)

Cristina Cifuentes (Oracle Software Assurance, Australia)

Dimi Racordon (EPFL, Switzerland)

Elena Glassman (Harvard University, USA)

Friedrich Steimann (Fernuniversität in Hagen, Germany)

John Regehr (University of Utah, USA)

Kelly Blincoe (University of Auckland, New Zealand)

Madeline Endres (University of Massachusetts at Amherst, USA)

Michael Coblenz (University of California at San Diego, USA)

Michael Sperber (Active Group GmbH, Germany)

Oscar Nierstrasz (feenk.com, Switzerland)

Shraddha Barke (Microsoft Research Redmond, USA)

William J. Bowman (University of British Columbia, Canada)

Onward! 2025 - Steering Committee

Stephen Kell (King's College London, UK), Steering Committee Chair

Shigeru Chiba (University of Tokyo, Japan)

Wolfgang De Meuter (Vrije Universiteit Brussel, Belgium)

Jonathan Edwards (Independent, USA)

Colin Gordon (Drexel University, USA)

Robert Hirschfeld (Hasso Plattner Institute, University of Potsdam, Germany)

Hidehiko Masuhara (Institute of Science Tokyo, Japan)

Clemens Nylandsted Klokmose (Aarhus University, Denmark)

Tomas Petricek (Charles University, Czechia)

Manu Sridharan (University of California at Riverside, USA)

Marcel Taeumel (University of Potsdam, Hasso Plattner Institute, Germany)

Vasco T. Vasconcelos (LASIGE, University of Lisbon, Portugal)

Tijs van der Storm (CWI, University of Groningen, Netherlands)

Contents

Frontmatter

Papers	
Synchronous Programming for Kids: A Manifesto	
Jean Pichon-Pharabod — Aarhus University, Denmark	
ScooPy: Enhancing Program Synthesis with Nested Example Specifications Tomer Katz and Hila Peleg — Technion, Israel	
Foundational Design Principles and Patterns for Building Robust and Adaptive GenAl-Native Systems Frederik Vandeputte — Nokia Bell Labs, Belgium	
Sharing Is Scaring: Linking Cloud File-Sharing to Programming Language Semantics Skyler Austen, Shriram Krishnamurthi, and Kathi Fisler — Brown University, USA	
An Argument for the Practicality of Entity Component Systems as the Primary Data Structure for an Interpreter or Oshua Dahl and Frederick C. Harris Jr. — <i>University of Nevada at Reno, USA</i>	
X-by-Construction: Towards Ensuring Non-functional Properties in by-Construction Engineering Maximilian Kodetzki, Tabea Bordis, Alex Potanin, and Ina Schaefer — KIT, Germany; Australian National University, Austra	lia 99
On Collective Control over User Interfaces in the Face of Network Effects Caleb Malchik and Joan Feigenbaum — Yale University, USA	116
Exploring the Design Space for Runtime Enforcement of Dynamic Capabilities Andrew Fawcet, James Noble, and Michael Homer — Victoria University of Wellington, New Zealand; Creative Research & Proposed Revealand	
Literate Tracing Matthew Sotoudeh — Stanford University, USA	143
TideScript: A Domain Specific Language for Peptide Chemistry Nicholas Morris, Blair Archibald, and S. Hessam M. Mehr — University of Glasgow, UK	161
What You See Is What It Does: A Structural Pattern for Legible Software Eagon Meng and Daniel Jackson — Massachusetts Institute of Technology, USA	178
Essays	
Carving Text at Its Joints: A New Perspective on Writing and Computers Kevin Graaf — Independent Researcher, USA	194
Gauguin, Descartes, Bayes: A Diurnal Golem's Brain Kartik Chandra, Amanda Liu, Jonathan Ragan-Kelley, and Joshua B. Tenenbaum — Massachusetts Institute of Technology, U.	SA 204
Let's Take Esoteric Programming Languages Seriously Jeremy Singer and Steve Draper — University of Glasgow, UK	213
The Unix Executable as a Smalltalk Method: And Its Implications for Unix-Smalltalk Unification Joel Jakubovic — Charles University, Czechia	
The Proof Must Go On: Formal Methods in the Theater of Secure Software Development of the Future Charles Averill — University of Texas at Dallas, USA	