Genetic and Evolutionary Computation

More information about this series at http://www.springer.com/series/7373

Wolfgang Banzhaf • Lee Spector • Leigh Sheneman
Editors

Genetic Programming Theory and Practice XVI

Springer

Editors
Wolfgang Banzhaf
Computer Science and Engineering
John R. Koza Chair, Michigan State University
East Lansing, MI, USA

Lee Spector
Cognitive Science
Hampshire College
Amherst, MA, USA

Leigh Sheneman
Department of Computer Science and Engineering
Michigan State University
East Lansing, MI, USA

ISSN 1932-0167 ISSN 1932-0175 (electronic)
Genetic and Evolutionary Computation
ISBN 978-3-030-04734-4 ISBN 978-3-030-04735-1 (eBook)
https://doi.org/10.1007/978-3-030-04735-1

Library of Congress Control Number: 2018965727

This Springer imprint is published by the registered company Springer Nature Switzerland AG.
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

We dedicate this book to the memory of the co-founder of the workshop series on Genetic Programming Theory and Practice, Rick Riolo, who passed away on August 25, 2018.

Foreword

I first met Rick Riolo in the late 1990s. I'd followed a well-beaten path by contacting John Holland to talk about GP. John politely referred me to Rick, and when I got to Rick's office in the Program for the Study of Complex Systems, I found a tall, slightly balding man in a tie-dye shirt with a face like a figure out of Leonardo's sketchbook. I asked if he was Rick Riolo. He agreed that he was, and we talked for about an hour about a scheme that I had for a Genetic Programming system. He was courteous but to the point saying what I was proposing was something he hadn't heard of before but was interested in seeing if it would work. This was the start of a friendship that lasted until his death this year. Over the years, we did some consulting work together, our families socialized, and we worked on several of the GPTP Workshops over the years.

He introduced himself as being in charge of the hardware at CSCS—I took this to mean he was a tech. I quickly learned that he was much more than that! Rick was one of the members of the BACH group at CSCS and was known in particular for his use of GAs to study the prisoner's dilemma. He had been working with GAs for decades with John Holland and the other members of the BACH group and was one of the early people working and teaching at the Santa Fe Institute.

Elsewhere I've told the story of how GPTP came to be, but while I made some suggestions of the organization of GPTP, Rick was the person who was the one constant throughout the years until he became too ill to manage the workshop. With the gracious staff of CSCS and Rick's quiet skill at making hard things look easy, GPTP was always on an even keel for the days of the workshop. More and more over the years, GPTP grew in importance under Rick's quiet stewardship.

However, though Rick was quiet, he was funny and his humor was often acerbic. One time, when we were putting together one of the early books, we had an author whose chapter was way over the page limit we set. We had sent it back and asked him to cut it in half, and when he returned it, he had cut maybe two pages. I expressed my frustration as time was getting short, but all Rick said was that for a smart man, he couldn't count very well.

When we started GPTP, we had no idea that it would last as long as it did. In fact, we thought it was a one-off event. As the years past, I would often sit next to Rick for at least one of the days, and after a particularly exciting talk, I leaned over to Rick and asked him if GPTP reminded him of the early years of GAs. He paused a moment and said that it reminded him more of the early days of the Santa Fe Institute.

When his disease kept him from joining us at GPTP, we took GPTP to him by live streaming and also visiting him at his home. In 2015 John Holland, who was one of the godfathers of GPTP, died. John was a close friend of Rick, and in the normal course of things, Rick would have written the dedication to John in the Foreword of that year's GPTP book, but his disease stopped him from doing so. He asked me to write them a thing that was both heartbreaking and daunting, but since Rick asked, I did my best. When I had done, I read it to him and told him that I tried to find the words that he would have used and wished with all my heart that he could have written them. We both cried a little, and I left that night knowing that Rick was slipping away from us.

When I heard from Carl Simon that Rick had died, I sat and thought about the years I'd known Rick, the things we'd done together, particularly at GPTP. Our children had grown up and were adults. CSCS had changed; Carl Simon, who had started the ball rolling for GPTP, had retired. But in thinking of Rick, I am grateful for all that he did for us, and I know how much we will all miss him.

Ann Arbor, MI, USA Bill Worzel
October 2018

Preface

The 16th instance of the *Workshop on Genetic Programming Theory and Practice* (GPTP) was held in Ann Arbor, Michigan, from May 17 to May 20, 2018. It was held at the University of Michigan and was organized and supported by the University's Center for the Study of Complex Systems.

This book contains the written contributions of the workshop's participants. Each contribution was drafted, read, and reviewed by other participants prior to the workshop. Each was then presented at the workshop and subsequently revised after the workshop on the basis of feedback received during the event.

GPTP has long held a special place in the genetic programming community, as an unusually intimate, interdisciplinary, and constructive meeting. It brings together researchers and practitioners who are eager to engage with one another deeply, in thoughtful, unhurried discussions of the major challenges and opportunities in the field.

Participation in the workshop is by invitation only, and an effort is made to invite a group of participants each year that is diverse in several ways, including participants both from academia and industry. Efforts are also made to include participants in "adjacent" fields such as evolutionary biology.

GPTP is a single-track workshop, with a schedule that provides ample time for presentations and for discussions, both in response to specific presentations and on more general topics. Participants are encouraged to contribute observations from their own, unique perspectives and to help one another to engage with the presented work. Often, new ideas are developed in these discussions, leading to collaborations after the workshop.

Aside from the presentations of regular contributions, the workshop also features keynote presentations that are chosen to broaden the group's perspective on the theory and practice of genetic programming. This year, the workshop began with a keynote presented by longtime GPTP participant Katya Vladislavleva, now the CEO of DataStories, on "Moonshot thinking and abundance mentality for better data science." On the second day, the keynote was presented by Walter Fontana, Professor of Systems Biology at Harvard Medical School, on "Actual causality in rule-based models." The third and final keynote was delivered by Marco Tomassini,

Professor Emeritus in the Department of Information Systems at the University of Lausanne, on "Strategic games: theory and human behavior." As can be gathered from their titles, none of these talks focused explicitly on genetic programming per se. But each presented fascinating developments that connect to open issues in genetic programming theory and practice in intriguing ways.

While most readers of this volume will not have had the pleasure of attending the workshop's presentations and discussions, our hope is that they will nonetheless be able to appreciate and engage with the ideas that were presented. We also hope that all readers will gain an understanding of the current state of the field and that those who seek to do so will be able to use the work presented herein to advance their own work and to make additional contributions to the future of the field.

Acknowledgments

We would like to thank all of the participants for again making GP Theory and Practice a successful workshop 2018. As is always the case, it produced a lot of interesting and high-energy discussions, as well as speculative thoughts and new ideas for further work. The keynote speakers did an excellent job at raising our awareness and provided thought-provoking ideas about the potential of Genetic Programming and its place in the world.

We would also like to thank our financial supporters for making the existence of GP Theory and Practice possible for the past 15 years and counting. For 2018, we did not have a major fund-raising drive but instead made good use of what had been left from earlier workshops. Those funds were contributed by:

- The Center for the Study of Complex Systems at the University of Michigan
- John Koza
- Jason H. Moore
- Babak Hodjat at Sentient
- Michael Korns, Lantern LLC
- Mark Kotanchek at Evolved Analytics
- Stuart Card
- Thomas Kern
- The Heuristic and Evolutionary Algorithms Laboratory at the Upper Austria University of Applied Sciences

A number of people made key contributions to the organization and assisted our participants during their stay in Ann Arbor. Foremost among them are Linda Wood and Mita Gibson who made the workshop run smoothly with their diligent efforts behind the scene before, during, and after the workshop. Special thanks go to the Springer Publishing Company for providing the editorial assistance for producing this book. We are particularly grateful for the contractual assistance by Melissa Fearon at Springer and all their staff has done to make this book possible.

We would like to express our gratitude especially to Carl Simon and Charles Doering, the champions of the workshop series at the Center for the Study of Complex Systems. Finally and foremost, we want to thank Rick Riolo for his dedication to the workshop series since its beginning. With the passing of Rick, one of the founders of the workshop series, we are entering a new era for GPTP. This 16th edition represents a transition with some organizational changes that will need to be considered to secure the future of this very successful workshop series.

East Lansing, MI, USA — Wolfgang Banzhaf
Amherst, MA, USA — Lee Spector
East Lansing, MI, USA — Leigh Sheneman
October 2018

Contents

Contributors

Michael Affenzeller Heuristic and Evolutionary Algorithms Laboratory (HEAL), University of Applied Sciences Upper Austria, Hagenberg, Austria

Institute for Formal Models and Verification, Johannes Kepler University, Linz, Austria

Clifford Bohm Department of Integrative Biology and BEACON Center for the Study of Evolution in Action, Michigan State University, East Lansing, MI, USA

Bogdan Burlacu Heuristic and Evolutionary Algorithms Laboratory (HEAL), University of Applied Sciences Upper Austria, Hagenberg, Austria

Institute for Formal Models and Verification, Johannes Kepler University, Linz, Austria

Josef Ressel Center for Symbolic Regression, University of Applied Sciences Upper Austria, Hagenberg, Austria

Sylvain Cussat-Blanc University of Toulouse, IRIT - CNRS - UMR5505, Toulouse, France

Emily Dolson BEACON Center for the Study of Evolution in Action and Department of Computer Science and Ecology, Evolutionary Biology, and Behavior Program, Michigan State University, East Lansing, MI, USA

Alexander Elkholy Maana, Inc., Bellevue, WA, USA

David Fagan Natural Computing Research & Applications Group, School of Business, University College Dublin, Dublin, Ireland

Steven Gustafson Maana, Inc., Bellevue, WA, USA

Daniel E. Hernández Instituto Tecnológico de Tijuana, Tijuana, B.C., México

Malcolm I. Heywood Faculty of Computer Science, Dalhousie University, Halifax, NS, Canada

Arend Hintze Department of Integrative Biology and Department of Computer Science and Engineering and BEACON Center for the Study of Evolution in Action, Michigan State University, East Lansing, MI, USA

Lukas Kammerer Heuristic and Evolutionary Algorithms Laboratory (HEAL), University of Applied Sciences Upper Austria, Hagenberg, Austria

Institute for Formal Models and Verification, Johannes Kepler University, Linz, Austria

Josef Ressel Center for Symbolic Regression, University of Applied Sciences Upper Austria, Hagenberg, Austria

Stephen Kelly Faculty of Computer Science, Dalhousie University, Halifax, NS, Canada

Michael Kommenda Heuristic and Evolutionary Algorithms Laboratory (HEAL), University of Applied Sciences Upper Austria, Hagenberg, Austria

Institute for Formal Models and Verification, Johannes Kepler University, Linz, Austria

Josef Ressel Center for Symbolic Regression, University of Applied Sciences Upper Austria, Hagenberg, Austria

Michael F. Korns Lantern Credit LLC, Henderson, NV, USA

Gabriel Kronberger Heuristic and Evolutionary Algorithms Laboratory (HEAL), University of Applied Sciences Upper Austria, Hagenberg, Austria

Josef Ressel Center for Symbolic Regression, University of Applied Sciences Upper Austria, Hagenberg, Austria

Alexander Lalejini BEACON Center for the Study of Evolution in Action and Department of Computer Science and Ecology, Evolutionary Biology, and Behavior Program, Michigan State University, East Lansing, MI, USA

Bo Liu Auburn University, Auburn, AL, USA

Uriel López Instituto Tecnológico de Tijuana, Tijuana, B.C., México

Daoming Lyu Auburn University, Auburn, AL, USA

Tim May Insight Sciences Corporation, Henderson, NV, USA

Blossom Metevier College of Information and Computer Sciences, University of Massachusetts, Amherst, MA, USA

Julian F. Miller University of York, Heslington, York, UK

Luis Muñoz Instituto Tecnológico de Tijuana, Tijuana, B.C., México

Charles Ofria BEACON Center for the Study of Evolution in Action and Department of Computer Science and Ecology, Evolutionary Biology, and Behavior Program, Michigan State University, East Lansing, MI, USA

Michael O'Neill Natural Computing Research & Applications Group, School of Business, University College Dublin, Dublin, Ireland

Anil Kumar Saini College of Information and Computer Sciences, University of Massachusetts, Amherst, MA, USA

Jory Schossau Department of Integrative Biology and BEACON Center for the Study of Evolution in Action, Michigan State University, East Lansing, MI, USA

Robert J. Smith Faculty of Computer Science, Dalhousie University, Halifax, NS, Canada

Lee Spector School of Cognitive Science, Hampshire College, Amherst, MA, USA

College of Information and Computer Sciences, University of Massachusetts, Amherst, MA, USA

Leonardo Trujillo Instituto Tecnológico de Tijuana, Tijuana, B.C., México

Dennis G. Wilson University of Toulouse, IRIT - CNRS - UMR5505, Toulouse, France

Stephan M. Winkler Heuristic and Evolutionary Algorithms Laboratory (HEAL), University of Applied Sciences Upper Austria, Hagenberg, Austria

Institute for Formal Models and Verification, Johannes Kepler University, Linz, Austria

Fangkai Yang Maana, Inc., Bellevue, WA, USA