PAOLO TONELLA

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EDUCATION

PhD: Faculty of Engineering, Department of Electronics, University of Padua, Italy　　1999
Thesis title: *Code Analysis in Support to Software Maintenance*

MSc: Faculty of Engineering, Department of Electronics, University of Padua, Italy　　1992
Awarded as the best student who graduated in 1992

EMPLOYMENT HISTORY

Full Professor　　2018 – Present
Università della Svizzera italiana (USI), Lugano, Switzerland

Head of Software Engineering　　2007 – 2018
Fondazione Bruno Kessler, Trento, Italy

Honorary Professor　　2013 – Present
University College London, UK

Researcher　　1994 – 2007
IRST (Istituto per la Ricerca Scientifica e Tecnologica), Trento, Italy

STEERING COMMITTEES (SELECTION)

ESEC/FSE　　2021 – Present
ACM Joint European Software Engineering Conference and Symposium on the Foundations of Software Engineering

ISSTA　　2010 – 2017; 2023 – Present
ACM International Symposium on Software Analysis and Testing

ICSME　　2006 – 2009; 2012 – 2015
IEEE International Conference on Software Maintenance and Evolution

PROJECTS

I participated in several research projects on software analysis and testing, including industrial and European projects, among which:

- **Sec4AI4Sec** (2023-2026): Horizon European project. The overall goal of Sec4AI4Sec is to provide enhanced security assurance methods for AI-augmented systems, but also to use AI to support developers and testers in secure coding and vulnerability eradication.

- **Toposcope** (2023-2027): SNSF grant. This project investigates a novel topographical approach to test software components that handle highly complex inputs. Toposcope consists of an input topography construction phase, in which the elements of the input space are organized into an N-dimensional map, which is used to guide automated test input generation.

- **Precrime** (2019-2023): ERC Advanced grant. The PRECRIME project is developing a new type of testing, called anticipatory testing, for deep learning based systems, which is activated at run-time by self-assessment oracles: oracles that observe and report unexpected execution contexts.

- **Gauss** (2017-2020): MIUR/PRIN project. Methodological enablers needed to identify, integrate, and manage emergent systems of systems.

- **SEAC** (2014-2015): Industrial project with SEAC, a company that has reengineered their software system from the old platform (Cobol/ISAM) to the .NET platform with Microsoft SQL Server. The objective of this project was to support such reengineering effort, by introducing an agile development process and by adopting automated tools for testing. Project leader.

- **Aspire** (2013-2016): FP7 European project n. 609734. Automated code protection and obfuscation.

- **FITTEST** (2010-2013): FP7 European project n. 257574. Development of the model based testing tool ReAjax. Workpackage leader.

- **IBT** (2007-2010): Industrial project with IBT (Informatica Bancaria Trentina), for the reengineering of a large (8 million lines of code) legacy application and its migration toward a modern, object-oriented architecture. Project leader.

- **CERN** (2000-2007): Development of the C++ static analysis tool RuleChecker for CERN, Geneva, within the Alice Large Hadron Collider (LHC) experiment. Project leader.

Supervision of Students and Postdocs

In the past, I have supervised or co-supervised several MSc students, 11 PhD students and 13 Postdocs. Among the PhD students: **Filippo Ricca** (2000-2003, now associate professor at University of Genova), **Mariano Ceccato** (2003-2006, now with University of Verona), **Cu Duy Nguyen** (2005-2009, now a data scientist and security expert at POST Luxembourg), **Gunel Jahangirova** (2014-2018, now Lecturer at King's College London). Among the Postdocs: **Andrea Stocco** (2018-2022, now associate professor at Technical University of Munich), **Vincenzo Riccio** (2018-2022, now with University of Udine). I am currently supervising or co-supervising 7 PhD students and 3 Postdocs.

Teaching

At Università della Svizzera italiana (USI), Master in Software and Data Engineering, I teach "Information Modeling & Analysis", "Knowledge Search & Extraction", "Software & Data Engineering Seminar". Over the years, I have taught several BSc and MSc classes at the University of Trento, among which the graduate courses "Software Analysis and Testing" and "Security Testing". The latter was part of the EIT (European Institute of Technology) ICT Labs curriculum on Security and Privacy.

Reviews and Editorial Boards

I regularly review papers submitted to journals such as TSE, TOSEM (awarded as a distinguished referee in 2007-2008, 2009-2010 and 2011-2012), EMSE, JSS, STVR, JSEP, IST and conferences such as ICSE, FSE, ISSTA, ICST, ASE, ICSME, ICPC. I am/was in the editorial board of:

TOSEM 2017 – Present
ACM Trans. on Software Engineering and Methodology (Guest Editor in Chief for the Special Section on AI&SE)

TSE 2013 – 2017
IEEE Transactions on Software Engineering, IEEE Computer Society

EMSE 2011 – Present
Empirical Software Engineering, Springer

JSEP 2013 – Present
Journal of Software: Evolution and Process, Wiley

Awards (selection)

ICST Best Tool Paper award 2021
Uncertainty-Wizard: Fast and User-Friendly Neural Network Uncertainty Quantification. Proceedings of the IEEE International Conference on Software Testing (ICST), pp. 436-441, April 12-16, 2021

ICST Best Paper award 2020
An Empirical Evaluation of Mutation Operators for Deep Learning Systems. Proceedings of the IEEE International Conference on Software Testing (ICST), pp. 74-84, October 24-28, 2020

ICST 2008 Most Influential Paper (MIP) award 2018
State-Based Testing of Ajax Web Applications. Proceedings of the IEEE International Conference on Software Testing (ICST), pp. 121-130, Lillehammer, Norway, April 9-11, 2008

Best paper award and ACM SIGSOFT Distinguished paper award 2017
How Professional Hackers Understand Protected Code while Performing Attack Tasks. Proceedings of the IEEE International Conference on Program Comprehension (ICPC), Buenos Aires, Argentina, 2017

Distinguished paper award 2016
Clustering-Aided Page Object Generation for Web Testing. Proceedings of the IEEE International Conference on Web Engineering (ICWE), Lugano, Switzerland, 2016

ICSE 2001 Most Influential Paper (MIP) award 2011
Analysis and Testing of Web Applications. Proceedings of the International Conference on Software Engineering (ICSE), pp. 25-34, Toronto, Canada, May 12-19, 2001

ISSTA 2025
ACM SIGSOFT International Symposium on Software Testing and Analysis, Trondheim, Norway; Program Chair

ESEC/FSE 2023
ACM Joint European Software Engineering Conference and Symposium on the Foundations of Software Engineering, San Francisco, USA; Program Chair

SSBSE 2015
International Symposium on Search Based Software Engineering, Bergamo, Italy; General Chair

ICSM 2012
International Conference on Software Maintenance, Riva del Garda, Italy; General Chair

ICSM 2011
International Conference on Software Maintenance, Timisoara, Romania; Program Chair

ISSTA 2010
International Symposium on Software testing and Analysis, Trento, Italy; General Chair

ICPC 2007
International Conference on Program Comprehension , Banff, Canada; Program Chair

INTERNATIONAL COLLABORATIONS

I have been actively involved in several international collaborations, which resulted in exchange of researchers, joint publications and research visits. I have co-supervised a PhD student with Prof. Mark Harman and Prof. David Clark from University College London, UK, where I regularly spend part of my research time. Among others, I have also worked with Prof. Gregg Rothermel from NC State University, Raleigh, USA; Prof. Alessandro Orso from Georgia Institute of Technology, Atlanta, USA. I am currently collaborating with Iowa State University (Prof. Hridesh Rajan), Mondragon University (Prof. Aitor Arrieta Marcos), University of Auckland (Dr. Valerio Terragni), University of Naples (Prof. Sergio Di Martino, Prof. Stefano Russo), Zurich University of Applied Science (Prof. Sebastiano Panichella), University of Genova (Prof. Alessio Merlo), University of Verona (Dr. Mariano Ceccato).

Major Scientific Achievements

SUMMARY OF RESEARCH CONTRIBUTIONS AND IMPACT

I have given foundational contributions to Software Engineering in the areas of code analysis and software testing. My work on object-oriented code analysis, published in the comprehensive book "Reverse Engineering of Object-Oriented Code", Springer, 2005, laid the foundations for the reverse engineering of object-oriented systems. My ICSE MIP award winning paper, "Analysis and Testing of Web Applications", initiated a new stream of research devoted to the development of testing techniques tailored to the specific features of web applications. My ISSTA 2004 paper "Evolutionary Testing of Classes" is recognized as a milestone for the automated generation of object oriented test cases, taking the form of method invocation sequences. One of the most widely used Java test case generators, *EvoSuite*, can be traced back to this seminal ISSTA paper and to the associated tool, *eToc*, developed by me. My recent ERC project Precrime has laid the foundations for testing and self-healing of deep learning components under unexpected execution scenarios.

LEADERSHIP

At Università della Svizzera italiana (USI), I lead the TAU (Testing AUtomated) research group, which aims at making software testing activities partially or fully automated. The current team consists of 3 postdocs and 6 PhD students, plus several MSc and Summer/internship students carrying out their thesis or Summer/internship project in my lab. When I was at Fondazione Bruno Kessler (2007-2018), I have led the Software Engineering (SE) research unit. The unit consisted of around 15 people. Under my guidance, the unit became a world leader in the areas of software requirements and testing, with publications and contributions in all top-ranked journals and conferences in the field (TSE, TOSEM, ICSE, FSE). The SE group has attracted several industrial and European funds over the years, reaching a self-funding capacity that has been on average above 60%.

I have written 191 peer reviewed conference/workshop papers, among which 31 ICSE/FSE/ISSTA papers, and 84 journal papers, among which 14 TSE/TOSEM papers (source: dblp.org). My H-index is **65** (source: Google Scholar). I was ranked among the top-50 Software Engineering scholars in an article published by the Communications of the ACM (vol. 50, n. 6, pp. 81-85, June 2007). I regularly publish papers at the major software engineering conferences and journals, including ICSE (Int. Conf. on Software Engineering), FSE (Foundations of Software Engineering), TOSEM (ACM Transactions on Software Engineering and Methodology) and TSE (IEEE Transactions on Software Engineering), as well as major software testing venues, such as ISSTA (Int. Symposium on Software Analysis and Testing) and ICST (IEEE Int. Conference on Software Testing, Verification and Validation).

SELECTED PUBLICATIONS

- Tahereh Zohdinasab, Vincenzo Riccio, Alessio Gambi, and Paolo Tonella: *Efficient and effective feature space exploration for testing deep learning systems.* ACM Transactions on Software Engineering and Methodology (**TOSEM**), vol. 32 n. 2, pp. 49:1-49:38, 2023.

- Andrea Stocco, Brian Pulfer, and Paolo Tonella. *Mind the gap! A study on the transferability of virtual versus physical-world testing of autonomous driving systems.* IEEE Transactions on Software Engineering (**TSE**), vol. 49 n. 4, pp. 1928-1940, 2023.

- Vincenzo Riccio and Paolo Tonella. *When and why test generators for deep learning produce invalid inputs: an empirical study.* In Proceedings of the 45th IEEE/ACM International Conference on Software Engineering (**ICSE**), Melbourne, Australia, May 14-20, pages 1161-1173, 2023.

- Tahereh Zohdinasab, Vincenzo Riccio, and Paolo Tonella. *DeepAtash: Focused test generation for deep learning systems.* In Proceedings of the 32nd ACM SIGSOFT International Symposium on Software Testing and Analysis (**ISSTA**), Seattle, WA, USA, July 17-21, pages 954-966, 2023.

- Matteo Biagiola, Paolo Tonella: *Testing the Plasticity of Reinforcement Learning Based Systems.* ACM Transactions on Software Engineering and Methodology (**TOSEM**), vol. 31, n. 4, pp. 80:1-80:46, 2022.

- Andrea Romdhana, Alessio Merlo, Mariano Ceccato, and Paolo Tonella. *Deep reinforcement learning for black-box testing of android apps.* ACM Transactions on Software Engineering and Methodology (**TOSEM**), vol. 31, n. 4, pp. 65:1-65:29, 2022.

- Michael Weiss and Paolo Tonella. *Simple techniques work surprisingly well for neural network test prioritization and active learning (replicability study).* In Proceedings of the 31st ACM SIGSOFT International Symposium on Software Testing and Analysis (**ISSTA**), July 18-22, pp. 139-150, 2022.

- Héctor D. Menéndez, Gunel Jahangirova, Federica Sarro, Paolo Tonella, and David Clark. *Diversifying focused testing for unit testing.* ACM Transactions on Software Engineering and Methodology (**TOSEM**), vol. 30, n. 4, pp. 44:1-44:24, 2021.

- Gunel Jahangirova, David Clark, Mark Harman, Paolo Tonella: *An Empirical Validation of Oracle Improvement.* IEEE Transactions on Software Engineering (**TSE**), vol. 47, n. 8, pp. 1708-1728, 2021.

- Nargiz Humbatova, Gunel Jahangirova, and Paolo Tonella. *DeepCrime: mutation testing of deep learning systems based on real faults.* In Proceedings of the 30th ACM SIGSOFT International Symposium on Software Testing and Analysis (**ISSTA**), July 11-17, pp. 67-78, 2021.

- Tahereh Zohdinasab, Vincenzo Riccio, Alessio Gambi, and Paolo Tonella. *DeepHyperion: exploring the feature space of deep learning-based systems through illumination search.* In Proceedings of the 30th ACM SIGSOFT International Symposium on Software Testing and Analysis (**ISSTA**), July 11-17, pp. 79-90, 2021.

- Nargiz Humbatova, Gunel Jahangirova, Gabriele Bavota, Vincenzo Riccio, Andrea Stocco, Paolo Tonella: *Taxonomy of Real Faults in Deep Learning Systems.* Proceedings of the 42nd International Conference on Software Engineering (**ICSE**), 2020

- Andrea Stocco, Michael Weiss, Paolo Tonella: *Misbehaviour Prediction for Autonomous Driving Systems.* Proceedings of the 42nd International Conference on Software Engineering (**ICSE**), 2020

- Annibale Panichella, Fitsum Kifetew, Paolo Tonella: *Automated Test Case Generation as a Many-Objective Optimisation Problem with Dynamic Selection of the Targets.* IEEE Transactions on Software Engineering (**TSE**), vol. 44, n.2, pp. 122-158, 2018.

ICSE Keynote 2023
The Road Toward Dependable AI Based Systems, 45th IEEE/ACM International Conference on Software Engineering, May 19h, 2023

ICST Keynote 2022
Misconceptions in deep learning testing, 15th IEEE International Conference on Software Testing, Verification and Validation, April 6th, 2022

RAISE Keynote 2020
Ensuring quality and dependability of systems based on deep learning, 8th International Workshop on Realizing Artificial Intelligence Synergies in Software Engineering, June 29th, 2020

CHOOSE Invited Talk 2019
How to test a system based on deep learning, CHOOSE Forum, Zurich, Switzerland, November 2019

COW Invited Talk 2019
What is a bug in deep learning applications? 61st CREST Open Workshop (COW) on Statistics, Learning, Genetic Improvement and Testing for Programs. London, UK, October 2019

Distinguished Lecture 2014
Model-based Testing in the Era of Web 2.0, at the University of Luxembourg, June 2014 (available at: https://www.youtube.com/watch?v=TnuiEGS6iyc)

Summer School Lecture 2012 – 2018
Search Based Test Case Generation, at ISSSE (Int. Summer School on Software Engineering), TAROT (Training And Research On Testing), SIESTA (Int. Summer School on Software Engineering), GASES (International Genoa Software Engineering PhD School)

INDUSTRIAL IMPACT AND TOOL DEVELOPMENT

- **SEAC** (2014-2016): Industrial project with SEAC, a company that has reengineered its software system from the current platform (Cobol/ISAM) to the .NET platform with Microsoft SQL Server. Such reengineering effort was supported by FBK with the introduction of an agile development process and of automated tools for testing. Project leader.
- **IBT** (2007-2010): Industrial project with IBT (Informatica Bancaria Trentina), for the reengineering of a large (8 million lines of code) legacy application and its migration toward a modern, object-oriented architecture. Project leader.
- **FITTEST** (2010-2013): Development of the model based testing techniques for future internet applications and of the associated tool *ReAjax*, within the FITTEST FP7 European project n. 257574. Workpackage leader.
- **CERN** (2000-2007): Development of the C++ static analysis tool RuleChecker for CERN, Geneva, within the Alice Large Hadron Collider (LHC) experiment. Project leader.
- **UncertaintyWizard** (2021): A tool for fast and user-friendly neural network uncertainty quantification. https://github.com/testingautomated-usi/uncertainty-wizard

The most widely used search-based test generator for Java, *EvoSuite* (http://www.evosuite.org), includes the MOSA (Many Objective Sorting Algorithm) algorithm developed by my collaborators and me, among the available test generation engines. According to the experimental results, MOSA is the best performing engine among those available in EvoSuite.

Publication List (2018-2023)

[1] Andrea Romdhana, Alessio Merlo, Mariano Ceccato, and Paolo Tonella. Assessing the security of inter-app communications in android through reinforcement learning. *Comput. Secur.*, 131:103311, 2023.

[2] Andrea Stocco, Brian Pulfer, and Paolo Tonella. Model vs system level testing of autonomous driving systems: a replication and extension study. *Empir. Softw. Eng.*, 28(3):73, 2023.

[3] Tahereh Zohdinasab, Vincenzo Riccio, Alessio Gambi, and Paolo Tonella. Efficient and effective feature space exploration for testing deep learning systems. *ACM Trans. Softw. Eng. Methodol.*, 32(2):49:1–49:38, 2023.

[4] Andrea Stocco, Brian Pulfer, and Paolo Tonella. Mind the gap! A study on the transferability of virtual versus physical-world testing of autonomous driving systems. *IEEE Trans. Software Eng.*, 49(4):1928–1940, 2023.

[5] Nargiz Humbatova, Gunel Jahangirova, and Paolo Tonella. Deepcrime: from real faults to mutation testing tool for deep learning. In *45th IEEE/ACM International Conference on Software Engineering: ICSE 2023 Companion Proceedings, Melbourne, Australia, May 14-20, 2023*, pages 68–72. IEEE, 2023.

[6] Vincenzo Riccio and Paolo Tonella. When and why test generators for deep learning produce invalid inputs: an empirical study. In *45th IEEE/ACM International Conference on Software Engineering, ICSE 2023, Melbourne, Australia, May 14-20, 2023*, pages 1161–1173. IEEE, 2023.

[7] Sajad Khatiri, Sebastiano Panichella, and Paolo Tonella. Simulation-based test case generation for unmanned aerial vehicles in the neighborhood of real flights. In *IEEE Conference on Software Testing, Verification and Validation, ICST 2023, Dublin, Ireland, April 16-20, 2023*, pages 281–292. IEEE, 2023.

[8] Jinhan Kim, Nargiz Humbatova, Gunel Jahangirova, Paolo Tonella, and Shin Yoo. Repairing DNN architecture: Are we there yet? In *IEEE Conference on Software Testing, Verification and Validation, ICST 2023, Dublin, Ireland, April 16-20, 2023*, pages 234–245. IEEE, 2023.

[9] Tahereh Zohdinasab, Vincenzo Riccio, and Paolo Tonella. Deepatash: Focused test generation for deep learning systems. In René Just and Gordon Fraser, editors, *Proceedings of the 32nd ACM SIGSOFT International Symposium on Software Testing and Analysis, ISSTA 2023, Seattle, WA, USA, July 17-21, 2023*, pages 954–966. ACM, 2023.

[10] Tahereh Zohdinasab, Vincenzo Riccio, Alessio Gambi, and Paolo Tonella. Deephyperion: Exploring the feature space of deep learning-based systems through illumination search. In Gregor Engels, Regina Hebig, and Matthias Tichy, editors, *Software Engineering 2023, Fachtagung des GI-Fachbereichs Softwaretechnik, 20.-24. Februar 2023, Paderborn*, volume P-332 of *LNI*, pages 131–132. Gesellschaft für Informatik e.V., 2023.

[11] Antonia Bertolino, Pietro Braione, Guglielmo De Angelis, Luca Gazzola, Fitsum Meshesha Kifetew, Leonardo Mariani, Matteo Orrù, Mauro Pezzè, Roberto Pietrantuono, Stefano Russo, and Paolo Tonella. A survey of field-based testing techniques. *ACM Comput. Surv.*, 54(5):92:1–92:39, 2022.

[12] Andrea Stocco and Paolo Tonella. Confidence-driven weighted retraining for predicting safety-critical failures in autonomous driving systems. *J. Softw. Evol. Process.*, 34(10), 2022.

[13] Matteo Biagiola and Paolo Tonella. Testing the plasticity of reinforcement learning-based systems. *ACM Trans. Softw. Eng. Methodol.*, 31(4):80:1–80:46, 2022.

[14] Andrea Romdhana, Alessio Merlo, Mariano Ceccato, and Paolo Tonella. Deep reinforcement learning for black-box testing of android apps. *ACM Trans. Softw. Eng. Methodol.*, 31(4):65:1–65:29, 2022.

[15] Jon Ayerdi, Valerio Terragni, Aitor Arrieta, Paolo Tonella, Goiuria Sagardui, and Maite Arratibel. Evolutionary generation of metamorphic relations for cyber-physical systems. In Jonathan E. Fieldsend and Markus Wagner, editors, *GECCO '22: Genetic and Evolutionary Computation Conference, Companion Volume, Boston, Massachusetts, USA, July 9 - 13, 2022*, pages 15–16. ACM, 2022.

[16] Andrea Romdhana, Mariano Ceccato, Alessio Merlo, and Paolo Tonella. IFRIT: focused testing through deep reinforcement learning. In *15th IEEE Conference on Software Testing, Verification and Validation, ICST 2022, Valencia, Spain, April 4-14, 2022*, pages 24–34. IEEE, 2022.

[17] Michael Weiss and Paolo Tonella. Simple techniques work surprisingly well for neural network test prioritization and active learning (replicability study). In Sukyoung Ryu and Yannis Smaragdakis, editors, *ISSTA '22: 31st ACM SIGSOFT International Symposium on Software Testing and Analysis, Virtual Event, South Korea, July 18 - 22, 2022*, pages 139–150. ACM, 2022.

[18] Andrea Stocco, Paulo J. Nunes, Marcelo d'Amorim, and Paolo Tonella. Thirdeye: Attention maps for safe autonomous driving systems. In *37th IEEE/ACM International Conference on Automated Software Engineering, ASE 2022, Rochester, MI, USA, October 10-14, 2022*, pages 102:1–102:12. ACM, 2022.

[19] Chiara Di Francescomarino and Paolo Tonella. The BPMN visual query language and process querying framework. In Artem Polyvyanyy, editor, *Process Querying Methods*, pages 181–218. Springer, 2022.

[20] Maurizio Leotta, Filippo Ricca, and Paolo Tonella. Sidereal: Statistical adaptive generation of robust locators for web testing. *Softw. Test. Verification Reliab.*, 31(3), 2021.

[21] Héctor D. Menéndez, Gunel Jahangirova, Federica Sarro, Paolo Tonella, and David Clark. Diversifying focused testing for unit testing. *ACM Trans. Softw. Eng. Methodol.*, 30(4):44:1–44:24, 2021.

[22] Gunel Jahangirova, David Clark, Mark Harman, and Paolo Tonella. An empirical validation of oracle improvement. *IEEE Trans. Software Eng.*, 47(8):1708–1728, 2021.

[23] Valerio Terragni, Gunel Jahangirova, Mauro Pezzè, and Paolo Tonella. Improving assertion oracles with evolutionary computation. In Krzysztof Krawiec, editor, *GECCO '21: Genetic and Evolutionary Computation Conference, Companion Volume, Lille, France, July 10-14, 2021*, pages 45–46. ACM, 2021.

[24] Michael Weiss, Rwiddhi Chakraborty, and Paolo Tonella. A review and refinement of surprise adequacy. In *3rd IEEE/ACM International Workshop on Deep Learning for Testing and Testing for Deep Learning, DeepTest@ICSE 2021, Madrid, Spain, June 1, 2021*, pages 17–24. IEEE, 2021.

[25] Valerio Terragni, Gunel Jahangirova, Paolo Tonella, and Mauro Pezzè. Gassert: A fully automated tool to improve assertion oracles. In *43rd IEEE/ACM International Conference on Software Engineering: Companion Proceedings, ICSE Companion 2021, Madrid, Spain, May 25-28, 2021*, pages 85–88. IEEE, 2021.

[26] Gunel Jahangirova, Andrea Stocco, and Paolo Tonella. Quality metrics and oracles for autonomous vehicles testing. In *14th IEEE Conference on Software Testing, Verification and Validation, ICST 2021, Porto de Galinhas, Brazil, April 12-16, 2021*, pages 194–204. IEEE, 2021.

[27] Dario Olianas, Maurizio Leotta, Filippo Ricca, Matteo Biagiola, and Paolo Tonella. STILE: a tool for parallel execution of E2E web test scripts. In *14th IEEE Conference on Software Testing, Verification and Validation, ICST 2021, Porto de Galinhas, Brazil, April 12-16, 2021*, pages 460–465. IEEE, 2021.

[28] Andrea Romdhana, Mariano Ceccato, Gabriel Claudiu Georgiu, Alessio Merlo, and Paolo Tonella. COSMO: code coverage made easier for android. In *14th IEEE Conference on Software Testing, Verification and Validation, ICST 2021, Porto de Galinhas, Brazil, April 12-16, 2021*, pages 417–423. IEEE, 2021.

[29] Emanuele Viglianisi, Mariano Ceccato, and Paolo Tonella. Summary of: A federated society of bots for smart contract testing. In *14th IEEE Conference on Software Testing, Verification and Validation, ICST 2021, Porto de Galinhas, Brazil, April 12-16, 2021*, pages 282–283. IEEE, 2021.

[30] Michael Weiss and Paolo Tonella. Fail-safe execution of deep learning based systems through uncertainty monitoring. In *14th IEEE Conference on Software Testing, Verification and Validation, ICST 2021, Porto de Galinhas, Brazil, April 12-16, 2021*, pages 24–35. IEEE, 2021.

[31] Michael Weiss and Paolo Tonella. Uncertainty-wizard: Fast and user-friendly neural network uncertainty quantification. In *14th IEEE Conference on Software Testing, Verification and Validation, ICST 2021, Porto de Galinhas, Brazil, April 12-16, 2021*, pages 436–441. IEEE, 2021.

[32] Nargiz Humbatova, Gunel Jahangirova, and Paolo Tonella. Deepcrime: mutation testing of deep learning systems based on real faults. In Cristian Cadar and Xiangyu Zhang, editors, *ISSTA '21: 30th ACM SIGSOFT International Symposium on Software Testing and Analysis, Virtual Event, Denmark, July 11-17, 2021*, pages 67–78. ACM, 2021.

[33] Tahereh Zohdinasab, Vincenzo Riccio, Alessio Gambi, and Paolo Tonella. Deephyperion: exploring the feature space of deep learning-based systems through illumination search. In Cristian Cadar and Xiangyu Zhang, editors, *ISSTA '21: 30th ACM SIGSOFT International Symposium on Software Testing and Analysis, Virtual Event, Denmark, July 11-17, 2021*, pages 79–90. ACM, 2021.

[34] Vincenzo Riccio, Nargiz Humbatova, Gunel Jahangirova, and Paolo Tonella. Deepmetis: Augmenting a deep learning test set to increase its mutation score. In *36th IEEE/ACM International Conference on Automated Software Engineering, ASE 2021, Melbourne, Australia, November 15-19, 2021*, pages 355–367. IEEE, 2021.

[35] Jon Ayerdi, Valerio Terragni, Aitor Arrieta, Paolo Tonella, Goiuria Sagardui, and Maite Arratibel. Generating metamorphic relations for cyber-physical systems with genetic programming: an industrial case study. In Diomidis Spinellis, Georgios Gousios, Marsha Chechik, and Massimiliano Di Penta, editors, *ESEC/FSE '21: 29th ACM Joint European Software Engineering Conference and Symposium on the Foundations of Software Engineering, Athens, Greece, August 23-28, 2021*, pages 1264–1274. ACM, 2021.

[36] Vincenzo Riccio, Gunel Jahangirova, Andrea Stocco, Nargiz Humbatova, Michael Weiss, and Paolo Tonella. Testing machine learning based systems: a systematic mapping. *Empir. Softw. Eng.*, 25(6):5193–5254, 2020.

[37] Alessio Viticchié, Leonardo Regano, Cataldo Basile, Marco Torchiano, Mariano Ceccato, and Paolo Tonella. Empirical assessment of the effort needed to attack programs protected with client/server code splitting. *Empir. Softw. Eng.*, 25(1):1–48, 2020.

[38] Emanuele Viglianisi, Mariano Ceccato, and Paolo Tonella. A federated society of bots for smart contract testing. *J. Syst. Softw.*, 168:110647, 2020.

[39] Andrea Stocco, Michael Weiss, Marco Calzana, and Paolo Tonella. Misbehaviour prediction for autonomous driving systems. In Gregg Rothermel and Doo-Hwan Bae, editors, *ICSE '20: 42nd International Conference on Software Engineering, Seoul, South Korea, 27 June - 19 July, 2020*, pages 359–371. ACM, 2020.

[40] Nargiz Humbatova, Gunel Jahangirova, Gabriele Bavota, Vincenzo Riccio, Andrea Stocco, and Paolo Tonella. Taxonomy of real faults in deep learning systems. In Gregg Rothermel and Doo-Hwan Bae, editors, *ICSE '20: 42nd International Conference on Software Engineering, Seoul, South Korea, 27 June - 19 July, 2020*, pages 1110–1121. ACM, 2020.

[41] Antonia Bertolino, Guglielmo De Angelis, Breno Miranda, and Paolo Tonella. Run java applications and test them in-vivo meantime. In *13th IEEE International Conference on Software Testing, Validation and Verification, ICST 2020, Porto, Portugal, October 24-28, 2020*, pages 454–459. IEEE, 2020.

[42] Matteo Biagiola, Andrea Stocco, Filippo Ricca, and Paolo Tonella. Dependency-aware web test generation. In *13th IEEE International Conference on Software Testing, Validation and Verification, ICST 2020, Porto, Portugal, October 24-28, 2020*, pages 175–185. IEEE, 2020.

[43] Mariano Ceccato, Davide Corradini, Luca Gazzola, Fitsum Meshesha Kifetew, Leonardo Mariani, Matteo Orrù, and Paolo Tonella. A framework for in-vivo testing of mobile applications. In *13th IEEE International Conference on Software Testing, Validation and Verification, ICST 2020, Porto, Portugal, October 24-28, 2020*, pages 286–296. IEEE, 2020.

[44] Gunel Jahangirova and Paolo Tonella. An empirical evaluation of mutation operators for deep learning systems. In *13th IEEE International Conference on Software Testing, Validation and Verification, ICST 2020, Porto, Portugal, October 24-28, 2020*, pages 74–84. IEEE, 2020.

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