Francesca Cairoli

Personal info

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Research Interest

My main research interest is to leverage the great computational power of **deep learning** to tackle the **scalability issues** of **formal methods** and **simulation** of **complex system**. In particular, the main focus is to investigate the use of deep learning tools to create data-driven digital twins or to improve the scalability of simulation, verification, monitoring and control of complex cyber-physical systems such as digital twins. I have a special interest in stochastic systems as their analysis is inevitably complex. Another important direction is toward improving the reliability of safety-critical systems. To this end, I focus on designing approximate solutions enriched with statistically sound quantifications of uncertainty.

Keywords: Machine Learning; Formal Methods; Formal Languages; Verification; Cyber Physical Systems; Digital Twins; Uncertainty Quantification; Control Theory; Scalability; Stochastic Systems.

Research Activity

- **Junior Assistant Professor (RTD-A)**   from March 2023

  Department of Mathematics and Geoscience, University of Trieste (Italy)

  Project: Interconnected Nord-Est Innovation (INEST).

- **Research Fellowship**   March 2022 - Feb. 2023

  Department of Mathematics and Geoscience, University of Trieste (Italy)

  Project: Machine Learning for the verification and synthesis of cyber-physical systems.
  Supervisor: Luca Bortolussi

- **Research Fellowship**   July 2017 - July 2018

  POR FESR 2014-2020, Department of Engineering and Architectures, University of Trieste (Italy)

  Project: Dynamical models for Multi Device Closed Loop System.
  Supervisor: Felice Andrea Pellegrino

Education

- **PhD in Computer Science**   Nov. 2018 - Oct. 2022

  PhD course in "Earth Science, Fluid-Dynamics and Mathematics. Interactions and Methods.", University of Trieste (Italy)

  Research field: Computational and data-based modeling
  Thesis title: "Deep Learning for Abstraction, Control and Monitoring of Complex Cyber-Physical Systems".
  Supervisor: Luca Bortolussi.
  Grade: Excellent Cum Laude

- **Master Degree in Mathematics**   Oct. 2014- March 2017

  University of Trieste (Italy)

  Thesis title: "Non-linear whole-genome analysis of DNA methylation fidelity".
  Supervisor: Luca Bortolussi.
  Grade: 110/110L

- **Bachelor Degree in Mathematics**   Sept. 2010- July 2013

  University of Milano-Bicocca (Italy)

  Thesis title: "Applicazioni computazionali delle basi di Groebner su equazioni polinomiali".
  Supervisor: Andrea Previtali.
  Grade: 104/110

- **High School**   Sept. 2005- July 2010

  Liceo Scientifico "Enrico Fermi", Cantù (Italy)

  Grade: 95/100

- **Erasmus Program**   Sept. 2012- March 2013
  Graz University of Technology (Austria)

Publications

📕 **Cairoli, F.**; Anselmi, F.; d'Onofrio, A.; Bortolussi, L. *Generative abstraction of Markov population processes.* Theoretical Computer Science, 977, 114169, 2023. https://doi.org/10.1016/j.tcs.2023.114169

📕 Anselmi, F.; Manzoni, L.; D'onofrio, A.; Rodriguez, A.; Caravagna, G.; Bortolussi, L.; **Cairoli, F.**. *Data symmetries and Learning in fully connected neural networks.* IEEE Access, 11, 47282-47290, 2023. https://doi.org/10.1109/ACCESS.2023.3274938

📕 Bortolussi, L.; **Cairoli, F.**; Paoletti, N.; Smolka, S. A.; Stoller, S. D.; *Neural predictive monitoring and a comparison of frequentist and Bayesian approaches*; International Journal on Software Tools for Technology Transfer, 1-26, 2021, Springer Berlin Heidelberg. https://doi.org/10.1007/s10009-021-00623-1

📕 **Cairoli, F.**; Fenu, G.; Pellegrino, F. A.; Salvato, E.; *Model Predictive Control of Glucose Concentration Based on Signal Temporal Logic Specifications with Unknown-Meals Occurrence*; Cybernetics and Systems 51 4, 426-441, 2020, Taylor & Francis. https://doi.org/10.1080/01969722.2020.1758463

⊕ **Cairoli, F.**; Bortolussi, L.; Paoletti, N.; *Learning-Based Approaches to Predictive Monitoring with Conformal Statistical Guarantees.* International Conference on Runtime Verification, 2023. `https://doi.org/10.1007/978-3-031-44267-4_26`

⊕ Bortolussi, L.; **Cairoli, F.**; Carbone, G.; Pulcini, P.; *Scalable Stochastic Parametric Verification with Stochastic Variational Smoothed Model Checking.* International Conference on Runtime Verification, 2023. `https://doi.org/10.1007/978-3-031-44267-4_3`

⊕ Bortolussi, L.; **Cairoli, F.**; Giacomarra, F.; Scassola, D.; *Model Abstraction and Conditional Sampling with Score-Based Diffusion Models.* International Conference on Quantitative Evaluation of Systems, 2023. `https://doi.org/10.1007/978-3-031-43835-6_21`

⊕ Bortolussi, L.; **Cairoli, F.**; Klein, J.; Petrov, T.; *Data-Driven Inference of Chemical Reaction Networks via Graph-Based Variational Autoencoders.* International Conference on Quantitative Evaluation of Systems, 2023. `https://doi.org10.1007/978-3-031-43835-6_10`

⊕ **Cairoli, F.**; Paoletti, N.: Bortolussi; L.; *Conformal Quantitative Predictive Monitoring of STL Requirements for Stochastic Processes.* Proceedings of the 26th ACM International Conference on Hybrid Systems: Computation and Control, 2022. `https://doi.org/10.1145/3575870.3587113`

⊕ **Cairoli, F.**; Paoletti, N.; Bortolussi, L.; *Neural predictive monitoring for collective adaptive systems*; International Symposium on Leveraging Applications of Formal Methods (pp. 30-46). Springer, Cham, 2022. `https://doi.org/10.1007/978-3-031-19759-8_3`

⊕ **Cairoli, F.**; Bortolussi, L.; Paoletti, N.; *Neural predictive monitoring under partial observability*; International Conference on Runtime Verification, 121-141, Springer, Cham, 2021. `https://doi.org/10.1007/978-3-030-88494-9_7`

⊕ **Cairoli, F.**; Carbone, G.; Bortolussi, L.; *Abstraction of Markov Population Dynamics via Generative Adversarial Nets*; International Conference on Computational Methods in Systems Biology, 19-35, Springer, Cham, 2021. `https://doi.org/10.1007/978-3-030-85633-5_2`

⊕ Bortolussi, L.; **Cairoli, F.**; Carbone, G.; Franchina, F.; Regolin, E.; *Adversarial Learning of Robust and Safe Controllers for Cyber-Physical Systems*; IFAC-PapersOnLine 54 5, 223-228, Elsevier, 2021. `https://doi.org/10.1016/j.ifacol.2021.08.502`

⊕ Bortolussi, L.; **Cairoli, F.**; *Bayesian abstraction of Markov population models*; International Conference on Quantitative Evaluation of Systems, 259-276, Springer, Cham, 2019. `https://doi.org/10.1007/978-3-030-30281-8_15`

⊕ **Cairoli, F.**; Fenu, G.; Pellegrino, F. A.; *Clinical Decision Support Using Colored Petri Nets: a Case Study on Cancer Infusion Therapy*; 6th International Conference on Control, Decision and Information Technologies (CoDIT), 314-319, IEEE, 2019 `https://doi.org/10.1109/CoDIT.2019.8820456`

⊕ **Cairoli, F.**; Fenu, G.; Pellegrino, F. A.; Salvato, E.; *Model predictive control of glucose concentration based on signal temporal logic specifications*; 6th International Conference on Control, Decision and Information Technologies (CoDIT), 714-719, IEEE, 2019. `https://doi.org/10.1109/CoDIT.2019.8820492`

🌐 Bortolussi, L.; **Cairoli, F.**; Paoletti, N.; Smolka, S. A.; Stoller, S. D.; *Neural predictive monitoring*; International Conference on Runtime Verification, 129-147, Springer, Cham, 2019. `https://doi.org/10.1007/978-3-030-32079-9_8`

🌐 Bortolussi, L.; **Cairoli, F.**; Paoletti, N.; Stoller, S. D.; *Conformal predictions for hybrid system state classification From Reactive Systems to Cyber-Physical Systems*; 225-241, Springer, Cham, 2019. `https://doi.org/10.1007/978-3-030-31514-6_13`

Teaching

- **Teacher** - Preparatory Course of "Computer Programming", Master Degrees in Data Science and Artificial Intelligence and in Scientific and Data Intensive Computing, 2023/24.

- **Teaching Assistant** - Course of "Stochastic Modeling and Simulation", Master Degree in Data Science and Scientific Computing, 2021/22.

- **Teaching Assistant** - Course of "Stochastic Modeling and Simulation", Master Degree in Data Science and Scientific Computing, 2020/21.

- **Teaching Assistant** - Course of "Stochastic Modeling and Simulation", Master Degree in Data Science and Scientific Computing, 2019/20.

- **Teaching Assistant** - Course of "Stochastic Modeling and Simulation", Master Degree in Data Science and Scientific Computing, 2018/19.

Academic Supervision

- **Co-advisor** - Master thesis of Davide Bartole: "Model abstraction using Temporal Difference Variational Auto Encoders". Master Degree in Statistics (March 2022).

- **Co-advisor** - Internship of Paolo Pulcini and Matilde Castelli.

- **Co-advisor** - Master thesis of Gaia Saveri: "Graph Neural Networks for Propositional Model Counting". Master Degree in Data Science and Scientific Computing (Sept. 2021).

- **Co-advisor** - Bachelor thesis of Matteo Boi: "Adversarial Learning on Model of Artificial Pancreas". Bachelor Degree in Physics (March 2021).

- **Co-advisor** - Master thesis of Francesco Franchina: "Adversarial Learning of Robust and Safe Controllers for Cyber-Physical Systems". Master Degree in Data Science and Scientific Computing (May 2020).

- **Co-advisor** - Master thesis of Laura Falciani: "Bayesian Abstraction for Chemical Reaction Networks". Master Degree in Mathematics (March 2019).

Visiting

- **Scientific Collaboration**   May 2023-Aug. 2023

University of Southern California, Department of Computer Science, CPS-Vida Lab, Los Angeles (California, USA)

- **Scientific Collaboration**   Feb. 2022-Mar. 2022

  University of Konstanz, Department of Computer Science and Centre for the Advanced Study of Collective Behaviour, Konstanz (Germany)

- **PhD Collaboration**   Jan. 2020-Feb. 2020

  Royal Holloway University, Department of Computer Science, London (U.K.)

- **Master Thesis Collaboration**   Oct. 2016

  Saarland University, Department of Modeling and Simulation, Saarbrucken (Germany)

Talks Given at Conferences and Workshops

- **RV 2023 - International Conference on Runtime Verification**, Thessaloniki (Greece)

  Contributed Talk: "Learning-Based Approaches to Predictive Monitoring with Conformal Statistical Guarantees" *Contributed Talk*: "Scalable Stochastic Parametric Verification with Stochastic Variational Smoothed Model Checking"

- **HSCC 2023 - CPS-IoT Week**, San Antonio (Texas, USA)

  Contributed Talk: "Conformal Quantitative Predictive Monitoring of STL Requirements for Stochastic Processes"

- **ISoLA 2022 - International Symposium On Leveraging Applications of Formal Methods, Verification and Validation**, Rhodes (Greece)

  Contributed Talk: "Neural Predictive Monitoring for Collective Adaptive Systems".

- **RV 2021 - International Conference on Runtime Verification**, online

  Contributed Talk: "Neural Predictive Monitoring under Partial Observability"

- **CMSB 2021 - International Conference on Computational Methods in System Biology**, online

  Contributed Talk: "Abstraction of Markov Population Dynamics via Generative Adversarial Nets"

- **LiVE 2020 - Workshop on Learning in Verification**, online

  Contributed Talk: "Neural Predictive Monitoring and a Comparison of Frequentist and Bayesian Approaches"

- **OVERLAY 2020 - Workshop on Artificial Intelligence and fOrmal VERification, Logic, Automata, and sYnthesis**, online

  Contributed Talk: "Bayesian Neural Predictive Monitoring"

- **HSB 2020 - Workshop on Hybrid Systems Biology**, online

  Contributed Talk: "Neural Predictive Monitoring"
  Contributed Talk: "Abstraction of Markov population models via Generative Adversarial Nets"

- **QEST 2019 - International Conference on Quantitative Evaluation of Systems**, Glasgow (Scotland, UK)

  Contributed Talk: "Bayesian Abstraction of Markov population models"

- **CoDIT 2019 - International Conference on Control, Decision and Information Technologies**, Paris (France)

  Contributed Talk: "Clinical Decision Support Using Colored Petri Nets: a Case Study on Cancer Infusion Therapy".

Seminars

- **DSSC Seminar**, University of Trieste, 2021

  Invited Speaker: "Abstraction of Markov Population Dynamics via Generative Adversarial Nets", 2021
  Invited Speaker: "Variational Auto-Encoders", 2020
  Invited Speaker: "Conformal Predictions", 2020 and 2022

- **Analysis Junior Seminar**, SISSA Trieste 2020

  Invited Speaker: "Abstraction of Markov Population Dynamics via Generative Adversarial Nets"

Attended Conferences, Workshops and Schools

- **RV 2023 - International Conference on Runtime Verification**, Thessaloniki, Greece (2023)

- **CPS-IoT Week 2023**, San Antonio, Texas, USA (2023)

- **ISoLA 2022 - International Symposium On Leveraging Applications of Formal Methods, Verification and Validation**, Rhodes, Greece (2022)

- **School**: "Science Communication", Montagnana (2022)

- **Summer school**: "Deep Learning", Gran Canaria (2022)

- **PhD Courses**: Advanced Programming; Foundations of High Performance Computing; Cyber-Physical Systems; Data Visualization; Population-Based Optimization Methods; Variational Inference

- **Workshop**: "AI for Security and Security for AI", King Cross College, London (2020)

- **Bootcamp**: "Theory of Reinforcement Learning", online (2020)

- **Winter School**: "Quantitative System Biology: Learning and Artificial Intelligence", International Centre for Theoretical Physics, Trieste (2019)

- **CMSB 2019 - International Conference on Computational Methods in System Biology**, Trieste (*Co-organizer*)

- **24 CFU for Teaching**: Pedagogia, Pedagogia speciale e didattica dell'inclusione; Psicologia; Antropologia; Metodologie e tecniche didattiche generali (Didattica delle scienze).

Reviewer

- **PC Member**: QEST/FORMATS 2024, FORMATS AE 2023.

- **International Conferences**: subreviewer for TACAS 2024, RV 2023, QEST 2020, QEST 2021, QEST 2022, QEST 2023, AAAI 2021, AAAI 2022, AAAI 2023, CMSB 2019, CMSB 2021, ADHS 2021, ATVA 2020, CDC 2019.

- **Journals**: reviewer for "TOMACS", "NeuroComputing", "Information and Computation" and "Leibniz Transactions on Embedded Systems".

Personal skills

Languages	Italian (native) English (proficiency) German (basic)
Programming Languages	Python (PyTorch, Tensorflow), MATLAB, R, C++, Java
Software	Excel, LaTeX

Autorizzo il trattamento dei dati personali contenuti nel mio curriculum vitae ai sensi del Decreto Legislativo 30 giugno 2003, n. 196 "Codice in materia di protezione dei dati personali", e del GDPR (Regolamento UE 2016/679) relativo alla protezione delle persone fisiche riguardo al trattamento dei dati personali.

Trieste, 09/01/2024

Francesca Cairoli