Riccardo Gozzi

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Personal informations

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Sex: Male | Date of birth: 18/05/1992 | Nationality: Italian

Education

- Scientific high school 2006-2011

Grade: 100/100

Liceo Ariosto Spallanzani, Reggio Emilia, Italy

- BSc in Physics 2011-2014

University of Modena & Reggio Emilia, Italy

During these years I learned the foundations of classical physics, thermodynamics and quantum mechanics. I have also learned the mathematical concepts necessary for mastering these subjects, with a particular attention for differential geometry, that has been the argument of my thesis.

➢ MSc in Theoretical Physics 2014-2016

Grade: 110/110 with honors

University of Bologna, Italy

At the university of Bologna, I focused my studies on theoretical physics, and became acquainted with topics such as fields theory, statistical thermodynamics, general relativity and super-symmetry. My interests took me to improve my mathematical expertise, taking exams concerning group theory and advanced differential geometry.

In my master thesis I did work connected with the study of open systems. More concretely, I studied the evolutions of these type of systems for Q-tris, or three level quantum systems. In this work I found a particular solution to the differential equation called Lindblad equation, that using the Markovian approximation simulates the time evolution of a Q-bit free to interact with his environment. I also analyzed the geometrical consequences of such an evolution, observing the orbits created by the system into the Kahler manifolds of the states. This thesis work has then been further analyzed from a more strictly mathematical point of view, investigating the action of the operators describing these trajectories, the Kraus operators, defined by means of representations of the symmetric groups.

This research has led to the production of the article: **Cattabriga, Alessia, et al. "Kraus operators and symmetric groups." International Journal of Geometric Methods in Modern Physics 18.09 (2021): 2150142.**

The work done in my master thesis has deep connections with the world of Quantum computation and Quantum information.

➢ PhD in Information security 2017-2022

Grade: Pass with distinction

Instituto Superior Tecnico, Lisbon, Portugal

In the first year and a half of my PhD, following the programme and my interests, I attended several courses on different topics and areas such as Quantum information, information security, and computer science. In particular I have developed a passion and curiosity for Computability and Complexity theory. Here follows a list of the courses I have completed:

- Theory of Computability, Complexity & Information
- Physics of Classical and Quantum Information
- Statistical Learning
- Cryptography and security protocol
- Computational Models in Security
- Computability and Complexity

University of Algarve, Faro, Portugal

In the remaining time, under the guide of assistant professor Daniel S. Graça, I focused my studies on the topic of dynamical systems. More precisely, we established a new result that provides a purely continuous characterization for exponential complexity classes FEXPTIME and EXPTIME by means of system of polynomial ODEs. This result represented an important extension of other works like: "**Polynomial time corresponds to solutions of polynomial ordinary differential equations of polynomial length.**" ***Journal of the ACM (JACM)*** **64.6 (2017): 1-76.**, where the treatment was limited to polynomial complexity classes FP and P. Moreover, together with Daniel S. Graça we had been able to extend the characterization procedure for a wider set of classes. Indeed, this process led us to fully characterize the Grzegorczyk hierarchy with the use of dynamical systems described by polynomial ODEs.

These particular results are presented in the article: **Gozzi, Riccardo, and Daniel Graça. "Characterizing time computational complexity classes with polynomial differential equations." Computability (2022).**

Finally, we turned our attention to polynomial space complexity classes. These classes required a very different intuition to be characterized with continuous dynamical systems due to robustness requirements and the necessity of keeping close track of the length of the tape of the simulated machines. Nonetheless, by modifying the notion of encoding used to a more suitable one, we had been able to obtain complete characterizations of the polynomial space complexity classes FPSPACE and PSPACE. This has been done by means of a new notion of space emulation.

This particular result is presented in the article: **Bournez, Olivier, Riccardo Gozzi, Daniel S. Graça, and Amaury Pouly. "A continuous characterization of PSPACE using polynomial ordinary differential equations." Journal of Complexity (2023): 101755.**

Thanks to the results described above, we could define a continuous version of the well known separation problem PSPACE vs EXPTIME, where any solution of the separation problem stated for the two new analog classes that we defined implies as a consequence the same solution for the discrete problem.

Future ideas for the upcoming work involve the possibility of extending the obtained results to the context of computable analysis, following what it was done for polynomial classes in the original article from O. Bournez, D. S. Graça, and A. Pouly. Another interesting direction for future work could be to include a continuous description of nondeterminism into the picture, which is still lacking in this approach.

Grants

- PhD Grant PD/BD/135190/2017 2017

  Obtained from Fundação para a Ciência e a Tecnologia, (FCT) from a competitive open call

- Grants JP18H03203 and JP20H05967 2021-2022

  Obtained from JSPS KAKENHI

- Grant ANR-20-CE48-0002-01 2022-Present

  Obtained from ANR Project

Visits to other institutions and scientific collaborations during the PhD

- Kyushu University, Fukuoka, Japan & Kyoto University, Kyoto, Japan, 2020

In the course of three months, from january until march, I had a scientific collaboration with professor Akitoshi Kawamura, from Kyoto university. The collaboration started in Fukuoka, Japan, where I stayed one month, and then continued in Kyoto, at Kyoto university, for the two remaining months. In the course of this collaboration we studied an approach for computing the logarithm function and the square root function defined over certain kind of complex domains, in the spirit of computable analysis. Our work was inspired by the article: **K. I. Ko and F. Yu, "On the complexity of computing the logarithm and square root functions on a complex domain."Journal of Complexity 23.1 (2007): 2-24**. , where the authors designed an algorithm that can compute the logarithm and the square root function on simply connected domains under complexity classes $P^{\#P}$ and P^{MP} respectively. Our goal was to improve the complexity of the square root algorithm to the class $P^{PARITY\ P}$.

Post-doctoral experiences:

- Kyoto University, Kyoto, Japan, 2021-2022

In the course of five months, from november 2021 until march 2022, I worked as external researcher under the supervision of professor Akitoshi Kawamura, from Kyoto university. The work conducted during this period of time was the continuation of the collaboration started in 2020 in Fukuoka, Japan, The main topic was related to the article **"On the complexity of computing the logarithm and square root functions on a complex domain." Journal of Complexity 23.1 (2007): 2-24** and we achieved our goal of improving the complexity of the square root algorithm to the class $P^{PARITY\ P}$. In the present days this is ongoing work in order to polish and submit the results.

- École Polytechnique / Université Paris-Est Créteil Val de Marne (UPEC), Paris, France 2022-Present

From May 2022 until the present day I worked as a post-doctoral research under the supervision of professor Olivier Bournez, from École Polytechnique, and professor Florent Madelaine, from Université Paris-Est Créteil Val de Marne (UPEC). We have been able to describe a transfinite procedure that can analytically obtain the solution of systems of ODEs with discontinuous right-hand term and unique solution. Such procedure establishes a hierarchy that classifies the hardness of these solutions and relates them with the hyperarithmetical hierarchy. Building on the possibility of systems of polynomial ODEs to successfully simulate Turing machine computations, this study provides an insteresting connection between discontinuous dynamical systems of ODEs and transfinite computing. The inspiration for the work came from the two articles **"Collins, Pieter, and Daniel Graça. "Effective computability of solutions of differential inclusions-the ten thousand monkeys approach." Journal of Universal Computer Science 15 (2009): 1162-1185** and **"Kechris, Alexander S. "The complexity of antidifferentiation, Denjoy totalization, and hyperarithmetic reals." (1987): 307-313.** This particular result is presented in the paper: **Bournez, Olivier, and Riccardo Gozzi. "Solving Discontinuous Initial Value Problems with Unique Solutions Is Equivalent to Computing over the Transfinite." 41st International Symposium on Theoretical Aspects of Computer Science (STACS 2024). Schloss Dagstuhl–Leibniz-Zentrum für Informatik, 2024**. Extensions on the same research topic are under preparation for one, or possibly two, journal papers to be soon submitted.

Publications

Journals:

- Title: Kraus operators and symmetric groups

  Authors: A.Cattabriga, E.Ercolessi, R.Gozzi, E.Meucci

  Journal: International Journal of Geometric Methods in Modern Physics, 2150142

  Year: 2021

- Title: Characterizing time computational complexity classes with polynomial differential equations

  Authors: R.Gozzi, D.Graça

  Journal: Computability vol. 12, no. 1, pp. 23-57, 2023.

  Year: 2023

- Title: A continuous characterization of PSPACE using polynomial ordinary differential equations

  Authors: O.Bournez, R.Gozzi, D.Graça, A. Pouly

  Journal: Journal of Complexity: 101755.

  Year: 2023

Conferences with a selecting committee:

- Title: Using differential equations to characterize complexity classes

  Location: virtual (originally planned for Faro, Portugal)

  Conference: Continuity, Computability, Constructivity

  Year: 2020

- Title: Analog characterization of complexity classes

  Location: virtual

  Conference: Computability and Complexity in Analysis

  Year: 2021

- Title: Discontinuous IVPs with unique solutions

  Location: Dubrovnik, Croatia

  Conference: Computability and Complexity in Analysis

  Year: 2023

- Title: Discontinuous IVPs with unique solutions

  Location: Kyoto, Japan

  Conference: Continuity, Computability, Constructivity

  Year: 2023

- Title: Solving discontinuous initial value problems with unique solutions is equivalent to computing over the transfinite

  Authors: O.Bournez and R.Gozzi.

  Location: Clermont-Ferrand

  Conference: International Symposium on Theoretical Aspects of Computer Science (STACS)

  Year: 2024

In preparation:

- Title: Complexity of computing the complex square root on connected domains

  Authors: A.Kawamura and R.Gozzi.

- Title: Hyperarithmetical reals and discontinuous ODEs with unique solutions

  Authors: O.Bournez and R.Gozzi.

Theses

- Title: Open dynamics of su (3) quantum systems

  Authors: E.Ercolessi and R.Gozzi.

  Link: http://amslaurea.unibo.it/id/eprint/12395

- Title: Analog characterization of complexity classes

  Authors: R.Gozzi.

  Citation: Gozzi, Riccardo, *Analog characterization of complexity classes*. Diss. Ph. D. thesis, Instituto Superior Técnico, Lisbon, 2022,

  https://scholar.tecnico.ulisboa.pt/api/records/eQCtqawlw3sb-UklVdtD8gkBmFIHud3r3Ptg/file/4ce8a8dc534ad948f22c6a95028001f9e1220e4faac0935424dd49817c14a8a3.pdf

Teaching experiences

- Supply teacher for primary school "Marco Emilio Lepido", Reggio Emilia, Italy, 22/02/2017 - 28/02/2017

- Supply teacher for the primary school "Don Pasquino Borghi", Reggio Emilia, Italy, 24/04/2017 - 10/06/2017 :