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# Coalgebraic Methods in Computer Science

Daniela Petrişan, Jurriaan Rot

► **To cite this version:**

Daniela Petrişan, Jurriaan Rot. Coalgebraic Methods in Computer Science: 15th IFIP WG 1.3 International Workshop, CMCS 2020, Colocated with ETAPS 2020, Dublin, Ireland, April 25–26, 2020, Proceedings. Springer International Publishing, LNCS-12094, 2020, Lecture Notes in Computer Science, 978-3-030-57200-6. 10.1007/978-3-030-57201-3 . hal-03232344

**HAL Id: hal-03232344**

**<https://inria.hal.science/hal-03232344>**

Submitted on 3 Jul 2023

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# Coalgebraic Methods in Computer Science

15th IFIP WG 1.3 International Workshop, CMCS 2020

Colocated with ETAPS 2020

Dublin, Ireland, April 25–26, 2020

Proceedings

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ISSN 0302-9743                      ISSN 1611-3349 (electronic)  
Lecture Notes in Computer Science  
ISBN 978-3-030-57200-6              ISBN 978-3-030-57201-3 (eBook)  
<https://doi.org/10.1007/978-3-030-57201-3>

LNCS Sublibrary: SL1 – Theoretical Computer Science and General Issues

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# Preface

The 15th International Workshop on Coalgebraic Methods in Computer Science (CMCS 2020) was originally planned to be held on April 25–26, 2020, in Dublin, Ireland, as a satellite event of the European Joint Conferences on Theory and Practice of Software (ETAPS 2020). Due to the 2020 COVID-19 pandemic, it was canceled, and held in alternative form as a series of online seminars, ranging over several weeks in the fall of 2020.

The aim of the workshop is to bring together researchers with a common interest in the theory of coalgebras, their logics, and their applications. Coalgebras allow for a uniform treatment of a large variety of state-based dynamical systems, such as transition systems, automata (including weighted and probabilistic variants), Markov chains, and game-based systems. Over the last two decades, coalgebra has developed into a field of its own interest, presenting a deep mathematical foundation, a growing field of applications, and interactions with various other fields such as reactive and interactive system theory, object-oriented and concurrent programming, formal system specification, modal and description logics, artificial intelligence, dynamical systems, control systems, category theory, algebra, analysis, etc.

Previous workshops of the CMCS series were held in Lisbon (1998), Amsterdam (1999), Berlin (2000), Genova (2001), Grenoble (2002), Warsaw (2003), Barcelona (2004), Vienna (2006), Budapest (2008), Paphos (2010), Tallinn (2012), Grenoble (2014), Eindhoven (2016), and Thessaloniki (2018). Since 2004, CMCS has been a biennial workshop, alternating with the International Conference on Algebra and Coalgebra in Computer Science (CALCO).

The CMCS 2020 program featured a keynote talk by Yde Venema (ILLC, University of Amsterdam, The Netherlands), an invited talk by Nathanaël Fijalkow (CNRS, LaBRI, University of Bordeaux, France), and an invited talk by Koko Muroya (RIMS, Kyoto University, Japan). In addition, a special session on probabilistic couplings was planned, featuring invited tutorials by Marco Gaboardi (Boston University, USA) and Justin Hsu (University of Wisconsin-Madison, USA). This volume contains revised regular contributions (9 papers were accepted out of 13 submissions; 1 submission was conditionally accepted but unfortunately had to be rejected ultimately as the author did not agree to implement the changes required by the Program Committee) and the abstracts of 3 keynote/invited talks. All regular contributions were refereed by three reviewers. We wish to thank all the authors who submitted to CMCS 2020, and the external reviewers and the Program Committee members for their thorough reviewing and help in improving the papers accepted at CMCS 2020.

July 2020

Daniela Petrişan  
Jurriaan Rot

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## **Abstracts of Invited Talks**

# Logic and Automata: A Coalgebraic Perspective

Yde Venema

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**Abstract.** In Theoretical Computer Science, the area of *Logic and Automata* combines a rich mathematical theory with many applications in for instance the specification and verification of software. Of particular relevance in this area is the design of formal languages and derivation systems for describing and reasoning about nonterminating or *ongoing behavior*, and the study of such formalisms through the theory of automata operating on potentially infinite objects.

We will take a foundational approach towards these issues using insights from Universal Coalgebra and Coalgebraic Logic. Specifically, we will review the basic theory of *coalgebraic modal fixpoint logic* and its link with *coalgebra automata* – finite automata that operate on coalgebras. We will show that much of the theory linking logic and automata in the setting of streams, trees or transition systems, transfers to the coalgebraic level of generality, and we will argue that this theory is essentially coalgebraic in nature.

Topics that will be covered include closure properties of classes of coalgebra automata, expressive completeness results concerning fixpoint logics, and the design of sound and complete derivation systems for modal fixpoint logics. The key instruments in our analysis will be those of a coalgebraic modal signature and its associated one-step logic. As we will see, many results in the theory of logic and automata are ultimately grounded in fairly simple observations on the underlying one-step logic.

**Keywords:** Coalgebra · Modal logic · Fixed points · Automata

# The Theory of Universal Graphs for Games: Past and Future

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**Abstract.** This paper surveys recent works about the notion of universal graphs. They were introduced in the context of parity games for understanding the recent quasipolynomial time algorithms, but they are defined for arbitrary objectives yielding a new approach for constructing efficient algorithms for solving different classes of games.

**Keywords:** Games · Parity games · Universal graphs

# Hypernet Semantics and Robust Observational Equivalence

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**Abstract.** In semantics of programming languages, *observational equivalence* [6] is the fundamental and classical question, asking whether two program fragments have the same behaviour in any program context. Establishing observational equivalence is vital in validating compiler optimisation and refactoring, and there have been proposed proof methodologies for observational equivalence, such as logical relations [9, 10] and applicative bisimulations [1]. A challenge is, however, to establish *robustness* of observational equivalence, namely to prove that observational equivalence is preserved by a language extension. In this talk I will discuss how *hypernet semantics* can be used to reason about such robustness. The semantics was originally developed for cost analysis of program execution [8], in particular for analysis of a trade-off between space and time efficiency. It has been used to model exotic programming features [2, 7] inspired by Google’s TensorFlow<sup>1</sup>, a machine learning library, and also to design a dataflow programming language [3]. In hypernet semantics, program execution is modelled as dynamic rewriting of a *hypernet*, that is, graph representation of a program. Inspired by Girard’s Geometry of Interaction [4], the rewriting process is notably guided and controlled by a dedicated object (*token*) of the graph. The use of graphs together with the token enables a direct proof of observational equivalence. The key step of the proof is to establish *robustness* of observational equivalence relative to language features, using step-wise reasoning enriched with the so-called *up-to* technique [5].

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<sup>1</sup> <https://www.tensorflow.org/>.

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