# Universiteit <br> Leiden <br> The Netherlands 

## Enhanced Coinduction

Rot, J.C.

## Citation

Rot, J. C. (2015, October 15). Enhanced Coinduction. IPA Dissertation Series. Retrieved from https://hdl.handle.net/1887/35814

Version: Not Applicable (or Unknown)
License:
Downloaded from:
Leiden University Non-exclusive license
https://hdl.handle.net/1887/35814

Note: To cite this publication please use the final published version (if applicable).

## Bibliography

[AC14] Davide Ancona and Andrea Corradi. Sound and complete subtyping between coinductive types for object-oriented languages. In Richard Jones, editor, ECOOP 2014 - Object-Oriented Programming - 28th European Conference, Proceedings, volume 8586 of Lecture Notes in Computer Science, pages 282-307. Springer, 2014. (Cited on page 9.)
[ACI12] Luca Aceto, Matteo Cimini, and Anna Ingólfsdóttir. Proving the validity of equations in GSOS languages using rule-matching bisimilarity. Mathematical Structures in Computer Science, 22(2):291-331, 2012. (Cited on page 160.)
[Acz88] Peter Aczel. Non-well-founded Sets. Center for the Study of Language and Information Publication Lecture Notes. Cambridge University Press, 1988. (Cited on page 11.)
[AFV01] Luca Aceto, Wan Fokkink, and Chris Verhoef. Structural operational semantics. In Handbook of Process Algebra, pages 197-292. Elsevier Science, 2001. (Cited on pages 9 and 14.)
[AGJJ12] Robert Atkey, Neil Ghani, Bart Jacobs, and Patricia Johann. Fibrational induction meets effects. In Lars Birkedal, editor, Foundations of Software Science and Computational Structures - 15th International Conference, FoSSaCS 2012, proceedings, volume 7213 of Lecture Notes in Computer Science, pages 42-57. Springer, 2012. (Cited on page 52,)
[AKV00] Jiří Adámek, Václav Koubek, and Jiří Velebil. A duality between infinitary varieties and algebraic theories. Commentationes Mathematicae Universitatis Carolinae, 41(3):529-542, 2000. (Cited on pages 86 and 143.)
[AM89] Peter Aczel and Nax Mendler. A final coalgebra theorem. In Category Theory and Computer Science, 1989, proceedings, volume 389 of LNCS, pages 357-365. Springer, 1989. (Cited on pages 11, 46, 79, and 84.)
[APTS13] Andreas Abel, Brigitte Pientka, David Thibodeau, and Anton Setzer. Copatterns: programming infinite structures by observations. In Giacobazzi and Cousot [GC13], pages 27-38. (Cited on page 9.)
[Awo10] Steve Awodey. Category Theory. Oxford Logic Guides. OUP Oxford, 2010. (Cited on page 41.)
[Bar03] Falk Bartels. Generalised coinduction. Mathematical Structures in Computer Science, 13(2):321-348, 2003. (Cited on page 93.)
[Bar04] Falk Bartels. On generalised coinduction and probabilistic specification formats. PhD thesis, CWI, Amsterdam, April 2004. (Cited on pages 14 , 15, 16, 41, 60, 62, 64, 65, 82, 117, and 121,)
$\left[\mathrm{BBB}^{+} 12\right]$ Filippo Bonchi, Marcello Bonsangue, Michele Boreale, Jan Rutten, and Alexandra Silva. A coalgebraic perspective on linear weighted automata. Information and Computation, 211:77-105, 2012. (Cited on pages $44,46,48,63,68,84$, and 87 .)
[BH98] Michael Brandt and Fritz Henglein. Coinductive axiomatization of recursive type equality and subtyping. Fundamenta Informaticae, 33(4):309-338, 1998. (Cited on page 9.)
[BHKR13] Marcello Bonsangue, Helle Hvid Hansen, Alexander Kurz, and Jurriaan Rot. Presenting distributive laws. In Reiko Heckel and Stefan Milius, editors, CALCO, volume 8089 of Lecture Notes in Computer Science, pages 95-109. Springer, 2013. (Cited on page 18.)
[BHKR15] Marcello Bonsangue, Helle Hvid Hansen, Alexander Kurz, and Jurriaan Rot. Presenting distributive laws. Logical Methods in Computer Science, 11(3), 2015. (Cited on page 18.)
[BIM95] Bard Bloom, Sorin Istrail, and Albert Meyer. Bisimulation can't be traced. Journal of the ACM, 42(1):232-268, 1995. (Cited on pages 14 and 64.)
[BK01] Peter Buchholz and Peter Kemper. Quantifying the dynamic behavior of process algebras. In Luca de Alfaro and Stephen Gilmore, editors, PAPM-PROBMIV, volume 2165 of Lecture Notes in Computer Science, pages 184-199. Springer, 2001. (Cited on pages 87 and 132.)
[BM02] Maria Grazia Buscemi and Ugo Montanari. A first order coalgebraic model of pi-calculus early observational equivalence. In Lubos Brim, Petr Jancar, Mojmír Kretínský, and Antonín Kucera, editors, CONCUR 2002 - Concurrency Theory, 13th International Conference, proceedings, volume 2421 of Lecture Notes in Computer Science, pages 449-465. Springer, 2002. (Cited on page 139.)
[BP12] Thomas Braibant and Damien Pous. Deciding kleene algebras in coq. Logical Methods in Computer Science, 8(1), 2012. (Cited on page 38.)
[BP13] Filippo Bonchi and Damien Pous. Checking NFA equivalence with bisimulations up to congruence. In Giacobazzi and Cousot [GC13], pages 457-468. (Cited on pages $9,13,38,70$, and 73 .)
[BP15] Filippo Bonchi and Damien Pous. Hacking nondeterminism with induction and coinduction. Communications of the ACM, 58(2):87-95, 2015. (Cited on page 13.)
[BPPR14] Filippo Bonchi, Daniela Petrisan, Damien Pous, and Jurriaan Rot. Coinduction up-to in a fibrational setting. In Thomas Henzinger and Dale Miller, editors, Joint Meeting of the Twenty-Third EACSL Annual Conference on Computer Science Logic (CSL) and the Twenty-Ninth Annual ACM/IEEE Symposium on Logic in Computer Science (LICS), CSLLICS 2014, proceedings, page 20. ACM, 2014. (Cited on pages 17, 18 , and 117.)
[BPT15] Jasmin Christian Blanchette, Andrei Popescu, and Dmitriy Traytel. Witnessing (co)datatypes. In Jan Vitek, editor, Programming Languages and Systems - 24th European Symposium on Programming, ESOP 2015, Proceedings, volume 9032 of Lecture Notes in Computer Science, pages 359-382. Springer, 2015. (Cited on page 9.)
[Brz64] Janusz Brzozowski. Derivatives of regular expressions. Journal of the ACM, 11(4):481-494, 1964. (Cited on pages 21, 22, and 30.)
[BW05] Michael Barr and Charles Wells. Toposes, theories, and triples. Reprints in Theory and Applications of Categories, No. 12, 2005. Available at http://www.tac.mta.ca/tac/reprints/articles/12/ tr12abs.html. (Cited on pages 41, 85, and 143.)
[CHM02] Andrea Corradini, Reiko Heckel, and Ugo Montanari. Compositional SOS and beyond: a coalgebraic view of open systems. Theoretical Computer Science, 280(1-2):163-192, 2002. (Cited on page 139.)
[Con71] John Conway. Regular Algebra and Finite Machines. Chapman and Hall, 1971. (Cited on pages 21 and 22.)
[CS11] Thierry Coquand and Vincent Siles. A decision procedure for regular expression equivalence in type theory. In Jean-Pierre Jouannaud and Zhong Shao, editors, Certified Programs and Proofs - First International Conference, CPP 2011, proceedings, volume 7086 of Lecture Notes in Computer Science, pages 119-134. Springer, 2011. (Cited on pages 19 and 38.)
[DK09] Manfred Droste and Werner Kuich. Semirings and formal power series. In Handbook of Weighted Automata, pages 3-28. Springer, 2009. (Cited on page 122.)
[EHB13] Jörg Endrullis, Dimitri Hendriks, and Martin Bodin. Circular coinduction in Coq using bisimulation-up-to techniques. In Sandrine Blazy, Christine Paulin-Mohring, and David Pichardie, editors, Interactive Theorem Proving - 4th International Conference, ITP 2013, proceedings,
volume 7998 of Lecture Notes in Computer Science, pages 354-369. Springer, 2013. (Cited on pages 13 and 38 .)
[FS10] Marcelo Fiore and Sam Staton. Positive structural operational semantics and monotone distributive laws. In Coalgebraic Methods in Computer Science - 10th International Workshop, CMCS 2012, Short Contributions, page 8, 2010. (Cited on pages 116 and 123.)
[FS12] Simon Foster and Georg Struth. Automated analysis of regular algebra. In Bernhard Gramlich, Dale Miller, and Uli Sattler, editors, Automated Reasoning - 6th International Joint Conference, IJCAR 2012, proceedings, volume 7364 of Lecture Notes in Computer Science, pages 271-285. Springer, 2012. (Cited on page 25.)
[GC13] Roberto Giacobazzi and Radhia Cousot, editors. The 40th Annual ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages, POPL 2013, proceedings. ACM, 2013. (Cited on pages 161 , 162, and 165.)
[GJF13] Neil Ghani, Patricia Johann, and Clément Fumex. Indexed induction and coinduction, fibrationally. Logical Methods in Computer Science, 9(3), 2013. (Cited on page 52.)
[GR62] Seymour Ginsburg and H. Gordon Rice. Two families of languages related to ALGOL. Journal of the ACM, 9(3):350-371, 1962. (Cited on page 26 .)
[Gra05] Clemens Grabmayer. Using proofs by coinduction to find "traditional" proofs. In José Fiadeiro, Neil Harman, Markus Roggenbach, and Jan Rutten, editors, Algebra and Coalgebra in Computer Science: First International Conference, CALCO 2005, proceedings, volume 3629 of Lecture Notes in Computer Science, pages 175-193. Springer, 2005. (Cited on page 38.)
[GS00] H. Peter Gumm and Tobias Schröder. Coalgebraic structure from weak limit preserving functors. Electronic Notes Theoretical Computer Science, 33:111-131, 2000. (Cited on page 80.)
[GS01] H. Peter Gumm and Tobias Schröder. Monoid-labeled transition systems. Electronic Notes Theoretical Computer Science, 44(1):185-204, 2001. (Cited on pages 48,68 , and 84 .)
[HCKJ13] Ichiro Hasuo, Kenta Cho, Toshiki Kataoka, and Bart Jacobs. Coinductive predicates and final sequences in a fibration. Electronic Notes Theoretical Computer Science, 298:197-214, 2013. (Cited on pages 12 , 41, 51, 52, and 56,)
[HJ97] Ulrich Hensel and Bart Jacobs. Proof principles for datatypes with iterated recursion. In Eugenio Moggi and Giuseppe Rosolini, editors, Category Theory and Computer Science, 7th International Conference, CTCS 1997, Proceedings, volume 1290 of Lecture Notes in Computer Science, pages 220-241. Springer, 1997. (Cited on page 9.)
[HJ98] Claudio Hermida and Bart Jacobs. Structural induction and coinduction in a fibrational setting. Information and Computation, 145(2):107-152, 1998. (Cited on pages 12, 41, 50, 52, 56, and 104.)
[HJ04] Jesse Hughes and Bart Jacobs. Simulations in coalgebra. Theoretical Computer Science, 327(1-2):71-108, 2004. (Cited on pages 92,113 , 114, and 115.)
[HK71] John Hopcroft and Richard Karp. A linear algorithm for testing equivalence of finite automata. Technical Report 114, Cornell University, December 1971. (Cited on page 70.)
[HK11] Helle Hvid Hansen and Bartek Klin. Pointwise extensions of gsosdefined operations. Mathematical Structures in Computer Science, 21(2):321-361, 2011. (Cited on page 141.)
[HKP09] Helle Hvid Hansen, Clemens Kupke, and Eric Pacuit. Neighbourhood structures: Bisimilarity and basic model theory. Logical Methods in Computer Science, 5(2), 2009. (Cited on page 68.)
[HKR14] Helle Hvid Hansen, Clemens Kupke, and Jan Rutten. Stream differential equations: Specification formats and solution methods. Technical Report No. FM-1404, CWI, 2014. (Cited on pages 11, 14, 26, 27, 32, 38, 45, 47, and 65,)
[HMSW11] Tony Hoare, Bernhard Möller, Georg Struth, and Ian Wehrman. Concurrent kleene algebra and its foundations. Journal of Logic and Algebraic Programming, 80(6):266-296, 2011. (Cited on page 36.)
[HN11] Fritz Henglein and Lasse Nielsen. Regular expression containment: coinductive axiomatization and computational interpretation. In Thomas Ball and Mooly Sagiv, editors, 38th ACM SIGPLAN-SIGACT Symposium on Principles of Programming Languages, POPL 2011, proceedings, pages 385-398. ACM, 2011. (Cited on page 38.)
[HNDV13] Chung-Kil Hur, Georg Neis, Derek Dreyer, and Viktor Vafeiadis. The power of parameterization in coinductive proof. In Giacobazzi and Cousot [GC13], pages 193-206. (Cited on page 9.)
[HR15] Thomas Henzinger and Jean-François Raskin. The equivalence problem for finite automata: technical perspective. Communications of the ACM, 58(2):86, 2015. (Cited on page 38.)
[HU79] John Hopcroft and Jeffrey Ullman. Introduction to Automata Theory, Languages and Computation. Addison-Wesley, 1979. (Cited on page 19.)
[Jac99] Bart Jacobs. Categorical Logic and Type Theory. Elsevier, 1999. (Cited on pages 52, 53, 54, 98, and 99.)
[Jac06a] Bart Jacobs. A bialgebraic review of deterministic automata, regular expressions and languages. In Kokichi Futatsugi, Jean-Pierre Jouannaud, and José Meseguer, editors, Essays Dedicated to Joseph A. Goguen, volume 4060 of LNCS, pages 375-404. Springer, 2006. (Cited on page 9 )
[Jac06b] Bart Jacobs. Distributive laws for the coinductive solution of recursive equations. Information and Computation, 204(4):561-587, 2006. (Cited on pages 14, 15, 62, 139, and 141,)
[Jac12] Bart Jacobs. Introduction to coalgebra. Towards mathematics of states and observations, 2012. Draft. (Cited on pages 12, 41, 50, 51, 103, and 149.)
[JNRS11] Bart Jacobs, Milad Niqui, Jan Rutten, and Alexandra Silva. Preface. Theoretical Computer Science, 412(38):4967-4968, 2011. (Cited on page 12.)
[Joh75] Peter Johnstone. Adjoint lifting theorems for categories of algebras. Bulletin of the London Mathematical Society, 7:294-297, 1975. (Cited on page 62.)
[JR12] Bart Jacobs and Jan Rutten. An introduction to (co)algebras and (co)induction. In Advanced Topics in Bisimulation and Coinduction [SR12], pages 38-99. (Cited on pages 11, 41, and 43.)
[JSS12] Bart Jacobs, Alexandra Silva, and Ana Sokolova. Trace semantics via determinization. In Dirk Pattinson and Lutz Schröder, editors, Coalgebraic Methods in Computer Science - 11th International Workshop, CMCS 2012, Revised Selected Papers, volume 7399 of Lecture Notes in Computer Science, pages 109-129. Springer, 2012. (Cited on pages 14 , 46, 60, 62, and 63.)
[Kel80] Max Kelly. A unified treatment of transfinite constructions for free algebras, free monoids, colimits, associated sheaves, and so on. Bulletin of the Australian Mathematical Society, 22:1-84, 1980. (Cited on page 145.)
[KKV12] Clemens Kupke, Alexander Kurz, and Yde Venema. Completeness for the coalgebraic cover modality. Logical Methods in Computer Science, 8(3), 2012. (Cited on page 51.)
[Kli04] Bartek Klin. Adding recursive constructs to bialgebraic semantics. Journal of Logic and Algebraic Programming, 60-61:259-286, 2004. (Cited on pages 16 and 139.)
[Kli07] Bartek Klin. Bialgebraic methods in structural operational semantics: Invited talk. Electronic Notes Theoretical Computer Science, 175(1):3343, 2007. (Cited on pages 15 and 121.)
[Kli09] Bartek Klin. Structural operational semantics for weighted transition systems. In Jens Palsberg, editor, Semantics and Algebraic Specification, Essays Dedicated to Peter D. Mosses on the Occasion of His 60th Birthday, volume 5700 of Lecture Notes in Computer Science, pages 121-139. Springer, 2009. (Cited on pages $14,48,68$, and 84 .)
[Kli11] Bartek Klin. Bialgebras for structural operational semantics: An introduction. Theoretical Computer Science, 412(38):5043-5069, 2011. (Cited on pages 14, 41, 60, 61, 63, 64, 65, 132, 139, and 156,)
[KN12] Alexander Krauss and Tobias Nipkow. Proof pearl: Regular expression equivalence and relation algebra. Journal of Automated Reasoning, 49(1):95-106, 2012. (Cited on pages 19 and 38.)
[KN14] Bartek Klin and Beata Nachyla. Distributive laws and decidable properties of SOS specifications. In Johannes Borgström and Silvia Crafa, editors, Combined 21st International Workshop on Expressiveness in Concurrency and 11th Workshop on Structural Operational Semantics, EXPRESS/SOS 2014, proceedings, volume 160 of EPTCS, pages 79-93, 2014. (Cited on page 139.)
[KNR11] Clemens Kupke, Milad Niqui, and Jan Rutten. Stream differential equations: concrete formats for coinductive definitions. Technical Report No. RR-11-10, Oxford University, 2011. (Cited on pages 27 and 32, )
[Koz90] Dexter Kozen. On Kleene algebras and closed semirings. In Branislav Rovan, editor, MFCS, volume 452 of Lecture Notes in Computer Science, pages 26-47. Springer, 1990. (Cited on page 26.)
[KS14] Dexter Kozen and Alexandra Silva. Practical coinduction. To appear in Mathematical Structures in Computer Science, 2014. (Cited on page 9.)
[Lan98] Saunders Mac Lane. Categories for the Working Mathematician. Graduate Texts in Mathematics. Springer New York, 1998. (Cited on pages 41 and 98.)
[Len98] Marina Lenisa. Themes in Final Semantics. PhD thesis, Università di Pisa-Udine, 1998. (Cited on page 41.)
[Len99] Marina Lenisa. From set-theoretic coinduction to coalgebraic coinduction: some results, some problems. Electronic Notes Theoretical Computer Science, 19:2-22, 1999. (Cited on pages 15, 16, and 117.)
[LGCR09] Dorel Lucanu, Eugen-Ioan Goriac, Georgiana Caltais, and Grigore Rosu. CIRC: A behavioral verification tool based on circular coinduction. In Alexander Kurz, Marina Lenisa, and Andrzej Tarlecki, editors, Algebra and Coalgebra in Computer Science, Third International Conference, CALCO 2009, proceedings, volume 5728 of Lecture Notes in Computer Science, pages 433-442. Springer, 2009. (Cited on pages 9 , 19, and 38.)
[LLYL14] Lingyun Luo, Xinxin Liu, Xiaohua Yang, and Zhiming Liu. Up-to technique for product functorâŃE. Journal of Computational Information Systems, 10(22):9597-9607, 2014. (Cited on page 94.)
[LPW00] Marina Lenisa, John Power, and Hiroshi Watanabe. Distributivity for endofunctors, pointed and co-pointed endofunctors, monads and comonads. Electronic Notes Theoretical Computer Science, 33:230-260, 2000. (Cited on pages 15, 93, and 117.)
[LPW04] Marina Lenisa, John Power, and Hiroshi Watanabe. Category theory for operational semantics. Theoretical Computer Science, 327(1-2):135-154, 2004. (Cited on pages 16, 64, 139, and 160.)
[Luo06] Lingyun Luo. An effective coalgebraic bisimulation proof method. Electronic Notes Theoretical Computer Science, 164(1):105-119, 2006. (Cited on pages 16 and 117.)
[Mil80] Robin Milner. A Calculus of Communicating Systems, volume 92 of LNCS. Springer, 1980. (Cited on pages 10 and 47.)
[Mil83] Robin Milner. Calculi for synchrony and asynchrony. Theoretical Computer Science, 25:267-310, 1983. (Cited on pages 13, 15, 39, 67 , and 71.)
[Mil89] Robin Milner. Communication and concurrency. PHI Series in computer science. Prentice Hall, 1989. (Cited on pages 9 and 15.)
[Mil92] Robin Milner. Functions as processes. Mathematical Structures in Computer Science, 2(2):119-141, 1992. (Cited on page 120.)
[Mis15] Michael Mislove. Semantics column. SIGLOG News, 2(2), 2015. (Cited on page 12.)
[MM07] Ernie Manes and Philip Mulry. Monad compositions I: General constructions and recursive distributive laws. Theory and Applications of Categories, 18(7):172-208, 2007. (Cited on pages 16, 152, and 160.)
[MMS13] Stefan Milius, Lawrence S. Moss, and Daniel Schwencke. Abstract gsos rules and a modular treatment of recursive definitions. Logical Methods in Computer Science, 9(3:28):52 pp., 2013. (Cited on pages 14 and 139.)
[MPdS12] Nelma Moreira, David Pereira, and Simão de Sousa. Deciding regular expressions (in-)equivalence in Coq. In Wolfram Kahl and Timothy Griffin, editors, Relational and Algebraic Methods in Computer Science - 13th International Conference, RAMiCS 2012, proceedings, volume 7560 of Lecture Notes in Computer Science, pages 98-113. Springer, 2012. (Cited on page 38.)
[MR05] Mohammad Reza Mousavi and Michel Reniers. Congruence for structural congruences. In Sassone [Sas05], pages 47-62. (Cited on pages $15,16,120,133,134,135$, and 138 .)
[NR09] Milad Niqui and Jan Rutten. Coinductive predicates as final coalgebras. In 6th Workshop on Fixed Points in Computer Science, FICS 2009, proceedings, pages 79-85, 2009. (Cited on page 51.)
[NR11] Milad Niqui and Jan Rutten. A proof of moessner's theorem by coinduction. Higher-Order and Symbolic Computation, 24(3):191-206, 2011. (Cited on pages 10 and 13.)
[NT14] Tobias Nipkow and Dmitriy Traytel. Unified decision procedures for regular expression equivalence. Archive of Formal Proofs, 2014, 2014. (Cited on page 38.)
[Okh13] Alexander Okhotin. Conjunctive and boolean grammars: The true general case of the context-free grammars. Computer Science Review, 9:27-59, 2013. (Cited on page 30.)
[Par81] David Park. Concurrency and automata on infinite sequences. In Peter Deussen, editor, Theoretical Computer Science, volume 104 of LNCS, pages 167-183. Springer, 1981. (Cited on pages $9,10,20$, and 47.)
[Plo01] Gordon Plotkin. Bialgebraic semantics and recursion (extended abstract). Electronic Notes Theoretical Computer Science, 44(1):285-288, 2001. (Cited on pages 16 and 139 .)
[Pou07] Damien Pous. Complete lattices and up-to techniques. In Zhong Shao, editor, Programming Languages and Systems, 5th Asian Symposium, APLAS 2007, proceedings, volume 4807 of Lecture Notes in Computer Science, pages 351-366. Springer, 2007. (Cited on pages 13, 15, 67, and 75.)
[PS12] Damien Pous and Davide Sangiorgi. Enhancements of the bisimulation proof method. In Advanced Topics in Bisimulation and Coinduction
[SR12], pages 233-289. (Cited on pages 13, 15, 27, 67, 68, 72, 75, 81, 82, 83, 119, 120, and 139,
[PW02] John Power and Hiroshi Watanabe. Combining a monad and a comonad. Theoretical Computer Science, 280(1-2):137-162, 2002. (Cited on page 148.)
[RB14] Jurriaan Rot and Marcello Bonsangue. Combining bialgebraic semantics and equations. In Anca Muscholl, editor, Foundations of Software Science and Computation Structures - 17th International Conference, FoSSaCS 2014, Proceedings, volume 8412 of Lecture Notes in Computer Science, pages 381-395. Springer, 2014. (Cited on pages 17 18, and 122,)
[RB15] Jurriaan Rot and Marcello Bonsangue. Structural congruence for bialgebraic semantics. Submitted, 2015. (Cited on pages 17 and 83.)
[RBB ${ }^{+}$15] Jurriaan Rot, Filippo Bonchi, Marcello Bonsangue, Damien Pous, Jan Rutten, and Alexandra Silva. Enhanced coalgebraic bisimulation. To appear in Mathematical Structures in Computer Science, 2015. (Cited on pages 17, 18, and 80, )
[RBR13a] Jurriaan Rot, Marcello Bonsangue, and Jan Rutten. Coalgebraic bisimulation-up-to. In Peter van Emde Boas, Frans Groen, Giuseppe Italiano, Jerzy Nawrocki, and Harald Sack, editors, 39th International Conference on Current Trends in Theory and Practice of Computer Science, SOFSEM 2013, proceedings, volume 7741 of Lecture Notes in Computer Science, pages 369-381. Springer, 2013. (Cited on pages 17 and 18.)
[RBR13b] Jurriaan Rot, Marcello Bonsangue, and Jan Rutten. Coinductive proof techniques for language equivalence. In Adrian Horia Dediu, Carlos Martín-Vide, and Bianca Truthe, editors, Language and Automata Theory and Applications - 7th International Conference, LATA 2013, proceedings, volume 7810 of Lecture Notes in Computer Science, pages 480-492. Springer, 2013. (Cited on pages 16 and 18.)
[RBR15] Jurriaan Rot, Marcello Bonsangue, and Jan Rutten. Proving language inclusion and equivalence by coinduction. To appear in Information and Computation, 2015. (Cited on pages 16 and 18.)
[RT93] Jan Rutten and Daniele Turi. Initial algebra and final coalgebra semantics for concurrency. In Jaco de Bakker, Willem de Roever, and Grzegorz Rozenberg, editors, A Decade of Concurrency, Reflections and Perspectives, REX School/Symposium, 1993, Proceedings, volume 803 of Lecture Notes in Computer Science, pages 530-582. Springer, 1993. (Cited on page 14.)
[Rut98a] Jan Rutten. Automata and coinduction (an exercise in coalgebra). In Davide Sangiorgi and Robert de Simone, editors, CONCUR 1998: Concurrency Theory, 9th International Conference, proceedings, volume 1466 of Lecture Notes in Computer Science, pages 194-218. Springer, 1998. (Cited on pages 9, 13, 19, 21, 22, 26, 37, and 39,)
[Rut98b] Jan Rutten. Relators and metric bisimulations. Electronic Notes Theoretical Computer Science, 11:252-258, 1998. (Cited on page50.)
[Rut00] Jan Rutten. Universal coalgebra: a theory of systems. Theoretical Computer Science, 249(1):3-80, 2000. (Cited on pages 11, 41, 43, 46, 47, 78, 79, 80, 84, and 138,)
[Rut03] Jan Rutten. Behavioural differential equations: a coinductive calculus of streams, automata, and power series. Theoretical Computer Science, 308(1-3):1-53, 2003. (Cited on pages $9,10,11,19,26,28,45,47$, and 75.)
[Rut05] Jan Rutten. A coinductive calculus of streams. Mathematical Structures in Computer Science, 15(1):93-147, 2005. (Cited on page 13.)
[San98] Davide Sangiorgi. On the bisimulation proof method. Mathematical Structures in Computer Science, 8(5):447-479, October 1998. (Cited on pages 13, 15, 67, and 117.)
[San12a] Davide Sangiorgi. An introduction to Bisimulation and Coinduction. Cambridge University Press, 2012. (Cited on pages $9,12,48,49,127$, and 132.)
[San12b] Davide Sangiorgi. Origins of bisimulation and coinduction. In Advanced Topics in Bisimulation and Coinduction [SR12], pages 1-37. (Cited on page 20.)
[Sas05] Vladimiro Sassone, editor. Foundations of Software Science and Computational Structures, 8th International Conference, FoSSaCS 2005, proceedings, volume 3441 of Lecture Notes in Computer Science. Springer, 2005. (Cited on pages 169 and 172 .)
[SBBR10] Alexandra Silva, Filippo Bonchi, Marcello Bonsangue, and Jan Rutten. Generalizing the powerset construction, coalgebraically. In Kamal Lodaya and Meena Mahajan, editors, IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science, FSTTCS 2010, Proceedings, volume 8 of LIPIcs, pages 272-283. Schloss Dagstuhl - Leibniz-Zentrum für Informatik, 2010. (Cited on pages 13 and 14.)
[SBBR13] Alexandra Silva, Filippo Bonchi, Marcello Bonsangue, and Jan Rutten. Generalizing determinization from automata to coalgebras. Logical

Methods in Computer Science, 9(1), 2013. (Cited on pages 15, 46, 62, and 141.)
[Sch05] Lutz Schröder. Expressivity of coalgebraic modal logic: The limits and beyond. In Sassone [Sas05], pages 440-454. (Cited on page 98.)
[Sil15] Alexandra Silva. A short introduction to the coalgebraic method. SIGLOG News, 2(2), 2015. (Cited on page 12.)
[SR12] Davide Sangiorgi and Jan Rutten. Advanced Topics in Bisimulation and Coinduction. Cambridge University Press, 2012. (Cited on pages 9 , 166, 170, and 171.)
[Sta11] Sam Staton. Relating coalgebraic notions of bisimulation. Logical Methods in Computer Science, 7(1), 2011. (Cited on page50.)
[SW01] Davide Sangiorgi and David Walker. The Pi-Calculus - a theory of mobile processes. Cambridge University Press, 2001. (Cited on page 119.)
[TP97] Daniele Turi and Gordon Plotkin. Towards a mathematical operational semantics. In 12th Annual IEEE Symposium on Logic in Computer Science, 1997, proceedings, pages 280-291. IEEE Computer Society, 1997. (Cited on pages $9,14,26,41,60,62,63,65$, and 82,)
[Trn80] Vera Trnková. General theory of relational automata. Fundamenta Informaticae, 3(2):189-234, 1980. (Cited on page 51.)
[Tur96] Daniele Turi. Functorial Operational Semantics and its Denotational Dual. PhD thesis, Free University, Amsterdam, June 1996. (Cited on page 41.)
[Wat02] Hiroshi Watanabe. Well-behaved translations between structural operational semantics. Electronic Notes Theoretical Computer Science, 65(1):337-357, 2002. (Cited on pages 16, 148, and 160.)
[WBR13] Joost Winter, Marcello Bonsangue, and Jan Rutten. Coalgebraic characterizations of context-free languages. Logical Methods in Computer Science, 9(3), 2013. (Cited on pages 15, 16, 142, 155, 158, and 159,)
[Win14] Joost Winter. Coalgebraic Characterizations of Automata-theoretic Classes. PhD thesis, Radboud Universiteit Nijmegen, 2014. (Cited on page 155 .)
[Win15] Joost Winter. A completeness result for finite $\lambda$-bisimulations. In Andrew Pitts, editor, Foundations of Software Science and Computation Structures - 18th International Conference, FoSSaCS 2015, Proceedings, volume 9034 of Lecture Notes in Computer Science, pages 117-132. Springer, 2015. (Cited on pages 13 and 73.)
[ZLL ${ }^{+}$10] Xiaocong Zhou, Yongji Li, Wenjun Li, Hai-yan Qiao, and Zhongmei Shu. Bisimulation proof methods in a path-based specification language for polynomial coalgebras. In Kazunori Ueda, editor, Programming Languages and Systems - 8th Asian Symposium, APLAS 2010, proceedings, volume 6461 of Lecture Notes in Computer Science, pages 239-254. Springer, 2010. (Cited on pages 16 and 117.)

## Index

( $\rho, E$ )-model, 133
( $\rho, \Delta$ )-model, 124
$F$-invariant, 51
$M(\rho), 123$
$(\mathcal{T}, \mathcal{E})$-Alg, 142
$\mathcal{T}$-Alg, 58
Cat, 98
Fib(-), 98
Id, see also identity functor
M, 42
Pre, 114
Rel, 54
$\operatorname{Rel}(B)$, see also relation lifting
Set, 41
$\Sigma^{*}$, see also free monad
$\widehat{\alpha}, 60$
$T$-alg, 58
be, 84
bhv $_{\delta}, 96$
bis, 70
$\mathrm{b}_{\delta}, 50,56$
-, 77, 100
$\operatorname{cgr}_{\alpha}, 73$
CJSL, 122
$B$-coalg, 43
cst, 76
ctx $_{\alpha}, 71$
diag, 99
$\coprod_{f}$, see also direct image
eq, 69
$\rho^{\dagger}, 63$
inv, 99
$\mathbb{G}, 125$
M, 123

Q, 98
$\mathcal{P}, 42$
$\mathcal{P}_{\omega}, 42$
$\bar{B}_{\delta}, 95$
$\psi, 124$
rfl, 70
slf, 101
sym, 70
$\theta, 133$
tra, 70, 100
$\mathrm{un}_{S}, 71$
$\varphi, 126$
$f$-invariant, 49
$f^{*}$, see also reindexing cfsc, 134
abstract GSOS, 63
monotone, 115, 123
algebra, 58
Arden's rule, 25, 36
assignment rule, 123
base category, 53
BDE , see also behavioural differential equations
behavioural differential equations, 26 28, 45, 65
monotone, 35
behavioural equivalence, 43
bialgebra, 61
bifibration, 53
bisimilarity, see also bisimulation
bisimilarity closure, 70
bisimulation, 46
deterministic automata, 20
bisimulation up-to, 68
bisimilarity, 71
congruence, 73
context, 71
equivalence, 69
languages, 24, 27
soundness, 69
union, 71
Brzozowski, 21
Cartesian lifting, 53
causal function, 32
coalgebra, 42
coinduction, 43, 48
classical, 48
coinductive extension, 43
coinductive predicate, 49,56
compatible, 76
compatible functor, 93
complete lattice, 48
congruence closure, 27, 73
regular expressions, 23
contextual closure, 71, 101
monotone, 110
copointed functor, 63
DA, see also deterministic automata
deterministic automata, 20
bisimulation, 20
simulation, 34,50
deterministic automaton, 44
determinization, 46, 62
diagonal relation, 42
direct image, 42, 54
distributive law, 60
monad over copointed functor, 63
monad over functor, 62
divergence, 52,111
Eilenberg-Moore algebra, 58
equal up to bisimilarity, 83
equations, 132, 142
equivalence closure, 69
fibration, 52
fibration map, 54
fibre, 53
fibred (co)products, 54
final coalgebra, 43
fixed point, 48
free algebra, 59
free monad, 60
GSOS, 64
positive, 116
homomorphism
algebra, 58
bialgebra, 61
coalgebra, 42
identity functor, 42
inductive extension, 58
initial algebra, 58
interpretation
language, 27
of $\rho$ and $\Delta, 124$
invariant, 56
invariant up-to, 76, 92
inverse image, 42
kernel, 42
labelled transition system, 43
language, 20
derivative, 20
lifting, 54, 62
LTS, see also labelled transition system
modality, 97
monad, 58
monad morphism, 59
monotone function, 48
Moore automaton, 44
morphism of distributive laws, 148
non-deterministic automaton, 44
operational model, 64
ordered functor, 114
CJSL, 122
stable, 115
polynomial functor, 58
post-fixed point, 48
predicate bifibration, 54
presentation
distributive law, 152
monad, 147
preservation of equations, 149
product
categories, 42
functors, 42
sets, 41
progression, 68
quotient monad, 145
reflexive closure, 70
reflexive coequalizer, 85
regular epimorphism, 142
reindexing, 53
relation bifibration, 54
relation lifting, 50
lax, 115
replication, 119
semiring, 42
shuffle, 31, 45
shuffle closure, 31
shuffle inverse, 45
signature, 27, 58
simulation
coalgebras, 115
deterministic automata, 34, 50
transition systems, 115
simulation up-to
languages, 35
sound, 76, 92
soundness, 69
stream, 43
stream system, 43
symmetric closure, 70
total category, 53
transfinite induction, 127
transitive closure, 70
weighted automaton, 44
weighted language inclusion, 108
weighted transition system, 44, 122

