PACE project

ANR 12IS02001

Deliverable D2014-123

December 2014[1]

Introduction. We give below a presentation of the results obtained during the second year of PACE (january-december 2014). This corresponds to the actual deliverable. Before that, we present some facts related to the life of the project.

A description of the goals and organisation of the ANR PACE project (*"beyond plain Processes: Analysis techniques, Coinduction and Expressiveness"*) can be found here. The website of the PACE project can be found here.

Life of the project

0.1   Personnel

Funded by PACE.

- **Thomas Given-Wilson** has finished his postdoc, hired by PACE at INRIA Saclay (EPI Comete). His contributions in the project have been mostly in Task 2 (Expressiveness).

Contributing to PACE.

- Valeria Vignudelli has started a PhD in Bologna (INRIA site, EPI Focus), under supervision of D. Sangiorgi. Her work is on Tasks 1.3 and Task 2.

- Paul Brunet has started a PhD in Lyon, under supervision of D. Pous. His work is on Task 3.

- Raphaëlle Crubillé spends the academical year 2014-2015 in Bologna (INRIA site, EPI Focus) as a "pre-PhD" student (*étudiante normalienne en 4ème année*). She studies coinductive equivalences for higher-order languages.

- Matteo Mio has been hired as a CNRS researcher (CR2) in Lyon, in october 2014. His knowledge of probabilistic models can be useful for Task 1.3 of the PACE project.

0.2   Visits, meetings

PACE meeting in Lyon, followed by a workshop   A one-day meeting of the project was organised in Lyon in february 2014. It was followed by a one-week workshop in Lyon on topics covered in the PACE project (the week "Logic, Concurrency and Types", part of the event "Mathematical Structures of Computation"). Several members of PACE gave presentations at this workshop, which was attended by around 50 people, from an international audience.

Visits between PACE partners

- Fu Yuxi, Deng Yuxin, Li Guoqiang, and Xu Xian visited the Lyon site in February 2014 for a week, to attend the PACE meeting and the following workshop.

- Li Guoqiang visited the Lyon site in July 2014 to discuss complexity properties of various kinds of automata models (Task 3).

1 Task 1: Advanced Coinductive Techniques

- L. Pino, A. Aristizabal, F. Bonchi, F. Valencia. Weak CCP Bisimilarity with Strong Procedures. Science of Computer Programming. 2014. (T1.5) (★)

- Yuxin Deng, Rob van Glabbeek, Matthew Hennessy, and Carroll Morgan. Real-Reward Testing for Probabilistic Processes. Theoretical Computer Science. Elsevier, 2014. To appear. (T1.3)

- Yuxin Deng, Rob J. Simmons, and Iliano Cervesato. Relating Reasoning Methodologies in Linear Logic and Process Algebra. Mathematical Structures in Computer Science, pages 1-39. Cambridge University Press, December 2014.

- F. Bonchi, D. Petrisan, D. Pous and J. Rot, Coinduction up-to in a fibrational setting. Proc. of CSL-LICS 2014. (T1)

- Paolo Baldan, Filippo Bonchi, Henning Kerstan, Barbara König, Behavioral Metrics via Functor Lifting. FSTTCS 2014: 403-415

- Ugo Dal Lago, Davide Sangiorgi, and Michele Alberti. On coinductive equivalences for higher-order probabilistic functional programs. In POPL, pages 297–308, 2014. (T1.3)

- Beniamino Accattoli and Ugo Dal Lago. Beta reduction is invariant, indeed. In 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), CSL-LICS '14, Vienna, Austria, July 14 - 18, 2014, page 8, 2014.

- Raphaëlle Crubillé and Ugo Dal Lago. On probabilistic applicative bisimu- lation and call-by-value λ-calculi. In Programming Languages and Systems - 23rd European Symposium on Programming, ESOP 2014, Held as Part of the European Joint Conferences on Theory and Practice of Software, ETAPS 2014, Grenoble, France, April 5-13, 2014, Proceedings, pages 209–228, 2014.

- Ugo Dal Lago and Sara Zuppiroli. Probabilistic recursion theory and implicit computational complexity. In Theoretical Aspects of Computing - ICTAC 2014 - 11th International Colloquium, Bucharest, Romania, September 17- 19, 2014. Proceedings, pages 97–114, 2014. (T1.3)

- Davide Sangiorgi and Xian Xu. Trees from functions as processes. In CONCUR 2014 - Concurrency Theory - 25th International Conference, CONCUR 2014, Rome, Italy, September 2-5, 2014. Proceedings, volume 8704 of Lecture Notes in Computer Science, pages 78–92. Springer, 2014. (★)

- L. Pino, F. Bonchi, F. Valencia. A Behavioural Congruence for Concurrent Constraint Programming with Non-Deterministic Choice. ICTAC 2014 - 11th International Colloquium on Theoretical Aspects of Computing (2014). (T1.5) (★)

- Konstantinos Chatzikokolakis, Daniel Gebler, Catuscia Palamidessi, and Lili Xu. Generalized bisimulation metrics. In Paolo Baldan and Daniele Gorla, editors, CONCUR - 25th Conference on Concurrency Theory, volume 8704 of Lecture Notes in Computer Science, pages 32?46, Rome, Italy, Septem- ber 2014. Springer. (T1.2)

- Yuxin Deng and Hengyang Wu. Model Modal Characterisations of Probabilistic and Fuzzy Bisimulations. In Proceedings of the 16th International Conference on Formal Engineering Methods. Lecture Notes in Computer Science 8829, pages 123-138. Springer, 2014.

We now discuss the announced deliverables for Task 1 (Year 2) in the submission document for PACE:

- D1.2.1 A metatheory of bisimulation enhancements applicable to several higher-order calculi, ranging from the full Higher-Order pi-calculus to the lambda calculus with or without references.

  The paper by Madiot, Pous and Sangiorgi, presented at CONCUR'04, is closely related to this deliverable. Work remains to be done in the follow-up of that contribution.

- D1.2.2 Definition of some abstract criteria for ensuring non-expansiveness of metrics for ensuring compositionality.

  The paper by Paolo Baldan, Filippo Bonchi, Henning Kerstan and Barbara König, presented at FSTTCS 2014, is related to this deliverable. Furthermore, we hope that the advances in other variants of quantitative studies of relations (notably the work based on differential privacy, in Task 2) will be useful to contribute to Task 1.2.

- D1.2.3 A form of environmental bisimulation for the probabilistic lambda-calculus and for the higher-order pi-calculus.

  The paper by Marco Bernardo, Davide Sangiorgi and Valeria Vignudelli, presented at CLS-LICS'14, defines a variant of environmental bisimulation, *coupled logical bisimulation* for a probabilistic higher-order λ-calculus. The paper by Crubillé and Dal Lago, presented at ESOP'14, studies related questions.

- D1.2.4 Weak versions of the symbolic bisimulation for quantum CCS.

  The paper by Yuan Feng, Yuxin Deng and Mingsheng Ying, published in ACM TOCL, studies symbolic bisimulation for quantum processes.

- D1.2.5 Definition of labelled transition system and of a contextual form of bisimulation (barbed congruence) for the spatial-epistemic CCP.

  We are working on questions related to this deliverable, but we did not achieve the expected results yet.

2 Task 2: Expressiveness

- T. Given-Wilson; D. Gorla; B. Jay. A Concurrent Pattern Calculus. Logical Methods in Computer Science (2014). (T2.1)

- E. ElSalamouny. K. Chatzikokolakis, C. Palamidessi. Generalized differential privacy: regions of priors that admit robust optimal mechanisms. Horizons of the Mind. A Tribute to Prakash Panangaden Springer International Publishing (Ed.) (2014) 292-318. (T2.3)

- K. Chatzikokolakis, C. Palamidessi, C. Braun. Compositional Methods for Information-Hiding. Mathematical Structures in Computer Science, Cambridge University Press, 2014. (T2.3)

- Yuxi Fu. Nondeterministic Structure of Computation. Mathematical Structures in Computer Science, to appear, 2014. (T2.1)

- F. Bonchi, P. Sobocinski, F. Zanasi. Interacting Bialgebras are Frobenius. In the proc. of the 15th International Conference on Foundations Of Software Science And Computation Structures LNCS 8412, pp. 351-365. Springer, 2014. (T2)

- P. Baldan, F. Bonchi, F. Gadducci, and G. V. Monreale. Encoding Synchronous Interactions using Labelled Petri Nets. In COORDINATION 2014. LNCS 8459, pp. 1-16. (T2)

- Facundo Carreiro, Alessandro Facchini, Yde Venema, and Fabio Zanasi. Weak MSO: Automata and expressiveness modulo bisimilarity. In CSL-LICS, 2014.

- Filippo Bonchi, Stefan Milius, Alexandra Silva, Fabio Zanasi, How to Kill Epsilons with a Dagger - A Coalgebraic Take on Systems with Algebra Label Structure. CMCS 2014, LNCS 8446: 53-74

- Filippo Bonchi, Pawel Sobocinski, Fabio Zanasi, A Categorical Semantics of Signal Flow Graphs. CONCUR 2014, LNCS 8704: 435-450

- Marco Bernardo, Davide Sangiorgi, and Valeria Vignudelli. On the discrviminating power of passivation and higher-order interaction. In 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), CSL-LICS '14, Vienna, Austria, July 14 - 18, 2014, page 14. ACM, 2014.

- Marco Bernardo, Davide Sangiorgi, and Valeria Vignudelli. On the discriminating power of testing equivalences for reactive probabilistic systems: Results and open problems. In Quantitative Evaluation of Systems - 11th International Conference, QEST 2014, Florence, Italy, September 8-10, 2014. Proceedings, volume 8657 of Lecture Notes in Computer Science, pages 281– 296. Springer, 2014.

- Ugo Dal Lago, Claudia Faggian, Ichiro Hasuo, and Akira Yoshimizu. The geometry of synchronization. In 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), CSL-LICS '14, Vienna, Austria, July 14 - 18, 2014, page 35, 2014.

- T. Given-Wilson. An Intensional Concurrent Faithful Encoding of Turing Machines. 7th Interaction and Concurrency Experience (ICE 2014) (2014). (T2.1)

- T. Given-Wilson. Expressiveness via Intensionality and Concurrency. ICTAC 2014 - 11th International Colloquium on Theoretical Aspects of Computing (2014). (T2.2)

- Chatzikokolakis, Konstantinos and Palamidessi, Catuscia and Stronati, Marco. A Predictive Differentially-Private Mechanism for Mobility Traces. Proceedings of the 14th International Symposium on Privacy Enhancing Technologies (PETS 2014). (T2.2)

- Kawamoto, Yusuke and Chatzikokolakis, Konstantinos and Palamidessi, Catuscia. Compositionality Results for Quantitative Information Flow. Proceedings of the 11th International Conference on Quantitative Evaluation of SysTems (QEST 2014). (T2.3)

- Nicolas E. Bordenabe, Konstantinos Chatzikokolakis, and Catuscia Palamidessi. Optimal Geo-Indistinguishable Mechanisms for Location Privacy. In Gail-Joon Ahn, Moti Yung, and Ninghui Li, editors, CCS - 21st ACM Conference on Computer and Communications Security, pages 251?262, Scottsdale, Arizona, United States, November 2014. Gail-Joon Ahn, ACM. (T2.3)

- Thomas Given-Wilson. On the Expressiveness of Intensional Communication. In Johannes Borgstrom and Silvia Crafa, editors, Combined 21th International Workshop on Expressiveness in Concurrency and 11th Workshop on Structural Operational Semantics, volume 160 of Electronic Proceedings in Theoretical Computer Science, pages 30?46, Rome, Italy, September 2014. Open Publishing Association. (T2.2)

- Qiang Yin, Yuxi Fu, Chaodong He, Mingzhang Huang, Xiuting Tao. Branching Bisimilarity Checking for PRS. J. Esparza et al. (Eds.): ICALP 2014, Part II, Lecture Notes in Computer Science 8573, 363–374, 2014. (T2)

- Mizuhito Ogawa and Xiaojuan Cai. Well-structured pushdown system: Case of Dense Timed Pushdown Automata. In Proceedings of the 12th International Symposium on Functional and Logic Programming (FLOPS'14). LNCS. 2014 (T2)

We now discuss the announced deliverables for Task 2 (Year 2) in the submission document for PACE:

- D2.2.1 Extend Fu's expressiveness framework to other paradigms, including quantum processes and spatial-epistemic processes.

  We are working on the expressiveness framework, but we have not been able yet to extend it to the aforementioned kinds of "non standard computation".

- D2.2.2 Proof systems for absolute equality on some of the PACE paradigms.

  We do not have contributions on this deliverable yet.

- D2.2.3 Expressiveness results for PACE paradigms (e.g., on higher-order concurrency or probabilistic processes) using subbisimilarity.

  Several works published in 2014 address expressiveness questions for higher-order concurrent and probabilistic processes. These include works by Crubillé and Dal Lago (ESOP'14), by Bernardo, Vignudelli and Sangiorgi (CSL-LICS'14), by Yuxin Deng, Rob van Glabbeek, Matthew Hennessy, and Carroll Morgan (TCS'14), by Yuxin Deng, Rob J. Simmons, and Iliano Cervesato (MSCS'14), by Yuxin Deng and Hengyang Wu (ICFEM'14), by Dal Lago, Sangiorgi and Alberti (POPL'14).

- D2.2.4 Comparisons between Fu's expressiveness framework and more traditional frameworks.

  We do not have contributions on this deliverable yet.

- D2.2.5 A first classification of the interaction mechanisms typical of social networks based on expressiveness.

  We do not have contributions on this deliverable yet.

A few remarks are in order about the work in Task 2 in the second year of PACE.

A series of works by C. Palamidessi and coauthors, actually addresses subtasks T2.2 and T2.3, using an approach inspired from Differential Privacy. The resulting notion of geo-indistinguishability, although it was not foreseen in the submission of the project, is clearly related to the topics announced for T2.2 and T2.3 (location-awareness, protection of information).

Fu and coauthors have established important decidability and complexity results regarding branching bisimilarity, by studying known results about branching bisimilarity. An interesting aspect of these works is that it appears that branching bisimilarity often has better properties than weak bisimilarity. Again, although this in-depth study of branching bisimilarity, and the resulting comparison with weak bisimilarity, were not planned, they clearly belong to Task 2.

3   Task 3: Analysis techniques

- Yuxin Deng and Yu Zhang. Program Equivalence in Linear Contexts. Theoretical Computer Science. Elsevier, 2014. To appear. (T3)

- Yuan Feng, Yuxin Deng, and Mingsheng Ying. Symbolic bisimulation for quantum processes. ACM Transactions on Computational Logic, Vol. 15, No. 2, Article 14, April 2014. (T3)

- Yang Fei, Huang Hao, A Polynomial Time Algorithm for Checking Regularity of Totally Normed Process Algebra, J. Shanghai Jiaotong Univ. (Sci.), 2014,DOI: 10.1007/s12204-014-1555-x.

- F. Bonchi, S. Millius, A. Silva and F. Zanasi. How to Kill Epsilons with a Dagger: A Coalgebraic Take on Systems with Algebraic Label Structure. Prooceedings of CMCS 2014. (T3)

- F. Bonchi, M. Bonsangue, H.H. Hansen, P. Panangaden, J. Rutten and A. Silva. Algebra-coalgebra duality in Brzozowski's minimization algorithm. In ACM Transactions on Computational Logic, 15(1): 3 (2014). (T3.1)

- Paul Brunet, Damien Pous: Kleene Algebra with Converse. In Proc. RAMICS 2014, LNCS 8428, Springer, 2014.

- Jean-Marie Madiot, Damien Pous, Davide Sangiorgi: Bisimulations up-to: beyond first-order transition systems. Proc. CONCUR 2014, Springer, 2014. (★)

- Jingcheng Liu, Pinyan Lu, and Chihao Zhang. FPTAS for Counting Weighted Edge Covers. In Proceedings of the 22nd European Symposium on Algorithms (ESA'14), pp.654-665, 2014.

- Jingcheng Liu, Pinyan Lu, and Chihao Zhang. The Complexity of Ferromagnetic Two-spin Systems with External Fields. In Approximation, Randomization, and Combinatorial Optimization. Algorithms and Techniques (APPROX/RANDOM'14), pp.843-856, 2014.

- Jingcheng Liu, Pinyan Lu, and Chihao Zhang. FPTAS for Weighted Fibonacci Gates and Its Applications. In Proceedings of the 41st International Colloquium on Automata, Languages and Programming (ICALP'14), pp.787-799, 2014.

- Yunqing Wen, Guoqiang Li, Shoji Yuen. An Over-Approximation Forward Analysis for Nested Timed Automata. In Proceedings of the 4th International Workshop on SOFL + MSVL (SOFL+MSVL'14), LNCS, 2014

We now discuss the announced deliverables for Task 3 (Year 2) in the submission document for PACE:

- D3.2.1 Mechanised tools for standard up-to techniques in higher-order languages

  The paper by Madiot, Pous and Sangiorgi, presented at CONCUR'04, is a contribution towards the goal of this deliverable.

- D3.2.2 Basic algorithms for metric bisimulations

  We do not have contributions for this deliverable yet (see also Deliverable D1.2.2 above).

- D3.2.3 Basic algorithms for symbolic strong bisimulation on a quantum CCS

  We do not have contributions for this deliverable yet.

- D3.2.4 Algorithms for branching bisimulation and codivergence checking

  We do not have contributions for this deliverable yet.

Regarding Task 3, we should highlight the impact of the work on coinductive approaches for algorithms on automata: the work by Bonchi and Pous published at POPL'13 has been invited for publication in Communications of the ACM, and has had several follow-up papers: from a theoretical point of view, the paper by F. Bonchi, D. Petrisan, D. Pous and J. Rot presented at CSL-LICS 2014 studies coalgebraic-based generalisations of this approach. From a more practical point of view, the algorithm has been adapted to symbolic automata, with applications to KAT (Kleene Algebra with Tests). The latter subject is also related with the PhD thesis of P. Brunet, with first results published in RAMICS'14.

As mentioned above, we have been studying branching bisimilarity from the point of view of decidability and complexity. Beyond the comparison with weak bisimilarity, which belongs to Task 2, this kind of results is also useful to study algorithms and analysis methods for branching bisimilarity (Task 3).