ERCIM "Alain Bensoussan"
Fellowship Scientific Report

Fellow: Filippo Bonchi
Visited Location : Comète team at INRIA - LIX (France)
Duration of Visit: 9 months (from 5th of October 2009 to 5th of July 2010)

I - Scientific activity

At INRIA - LIX, with the group Comète, I worked on several topics, all of them closely related to those carried on during the first part of the fellowship and to my Ph.D thesis.

Symbolic Semantics for Concurrent Constraint Programming. When I arrived in Comète, part of the team was investigating abstract semantics for the Concurrent Constraint Programming. I proposed them to use the general approach that I have developed in my Ph.D thesis and as a result we obtained a very "well behaved" abstract semantics. Besides being *compositional*, this semantics is also *fully abstract* and it coincides with the usual *denotational semantics* given in terms of closure operators. All these results will be published soon in [Prep 2] together with Catuscia Palamidessi, Frank Valencia and Andres Aristizabal.
From a general perspective this semantics is an instance of *symbolic bisimilarity* (and thus more abstractly, of *normalized coalgebras*). This fact is extremely important because it gives us the guidelines to develop a *symbolic minimization algorithm* for Concurrent Constrain Programming. This should be developed and implemented by Andres Aristizabal in his Ph.D thesis.
Finally, this work caught the interest of many people: Romain Beauxis (a former Ph.D student in Comète) is planning to extend this semantics to the Probabilistic Concurrent Constaint Programming in order to solve several problems that arise with the denotational semantics in the probabilistic case.

Coalgebras and Behavioural Pseudometrics. At the beginning of my second period, Catuscia Palamidessi (the head of Comète) introduced me to the interesting problem of *behavioural pseudometrics*. I have tried to give a more abstract understanding by means of *coalgebras on metric spaces*. This study have not yet brought new important scientific results, but it has caught the interest (also) of the first hosting team (SEN3 at CWI) that agreed in writing together a research project proposal on these topics.
Moreover I have investigated the use of behavioural pseudometrics for the problem of the *Analysis of rounding errors*. This investigation have been carried on the scope of the "Confidence, Proof and Probabilities" (CPP) project (funded by the French national research agency, as part of the Programme Blanc) together with Catuscia Palamidessi, Dale Miller and Ivan Gazeau. This investigation did not bring new results yet, but it seems to me very promising and I would like to continue it in my future job.

From Bisimilarity to Trace, via coalgebras. Together with Catuscia Palamidessi we tried to exploit some of the ideas of [FSTTCS] in order to give a general way of proving that (different kind of) bisimilarity imply (different kinds of) infinite traces equivalences. This problem has caught also the interest of the first hosting team (SEN3 at CWI), but the investigation did not lead to any important results or further research directions.

II- Publication(s) during your fellowship

Published

[SOS09] F.Bonchi, F. Gadducci and G.V. Monreale. On Barbs and Labels in Reactive Systems. In *Structural Operational Semantics 2009*, CoRR abs/1002.2869: (2010).

Abstract. Reactive systems (RSs) represent a meta-framework aimed at deriving behavioral congruences for those computational formalisms whose operational semantics is provided by reduction rules. RSs proved a flexible specification device, yet so far most of the efforts dealing with their behavioural semantics focused on idem pushouts (IPOs) and saturated (also known as dynamic) bisimulations. In this paper we introduce a novel, intermediate behavioural equivalence: L-bisimilarity, which is able to recast both its IPO and saturated counterparts. The equivalence is parametric with respect to a set L of RSs labels, and it is shown that under mild conditions on L it is indeed a congruence. Furthermore, L-bisimilarity can also recast the notion of barbed semantics for RSs, proposed by the same authors in a previous paper. In order to provide a suitable test-bed, we instantiate our proposal by addressing the semantics of (asynchronous) CCS and of the calculus of mobile ambients.

Accepted for Publication

[IC10] F. Bonchi, M. Bonsangue, J. Rutten and A. Silva. Deriving syntax and axioms for quantitative regular behaviours. Invited for a special issue of *Information and Computation* as one of the best papers of CONCUR 2009.

Abstract. We present a systematic way to generate (1) languages of (generalised) regular expressions, and (2) sound and complete axiomatizations thereof, for a wide variety of quantitative systems. Our quantitative systems include weighted versions of automata and transition systems, in which transitions are assigned a value in a monoid that represents cost, duration, probability, etc. Such systems are represented as coalgebras and (1) and (2) above are derived in a modular fashion from the underlying (functor) type of these coalgebras. In previous work, we applied a similar approach to a class of systems (without weights) that generalizes both the results of Kleene (on rational languages and DFA's) and Milner (on regular behaviours and finite LTS's), and includes many other systems such as Mealy and Moore machines. In the present paper, we extend this framework to deal with quantitative systems. As a consequence, our results now include languages and axiomatizations, both existing and new ones, for many different kinds of probabilistic systems.

[LMCS10] F. Bonchi and U. Montanari. Coalgebraic Symbolic Semantics. Invited for a special issue of *Logical Methods in Computer Science* as one of the best papers of CALCO 2009.

Abstract. The operational semantics of interactive systems is usually described by labeled transition systems. Abstract semantics (that is defined in terms of bisimilarity) is characterized by the final morphism in some category of coalgebras. Since the behaviour of interactive systems is for many reasons infinite, *symbolic semantics* were introduced as a mean to define smaller, possibly finite, transition systems, by employing symbolic actions and avoiding some sources of infiniteness. Unfortunately, symbolic bisimilarity has a different "shape" with respect to ordinary bisimilarity, and thus the standard coalgebraic characterization does not work. In this paper, we introduce its

coalgebraic models. We will use as running examples two asynchronous formalisms: open Petri nets and asynchronous pi-calculus. Indeed, as we have shown in a previous paper, asynchronous bisimilarity can be seen as an instance of symbolic bisimilarity.

[JAR10] F. Bonchi, M.G. Buscemi, V. Ciancia, and F. Gadducci. A presheaf environment for the calculus of explicit fusions. Accepted for *Journal of Automated Reasoning*.

Abstract. Name passing calculi are nowadays one of the preferred formalisms for the specification of concurrent and distributed systems with a dynamically evolving topology. Despite their widespread adoption as a theoretical tool, though, they still face some unresolved semantical issues, since the standard operational, denotational and logical methods often proved inadequate to reason about these formalisms. A domain which has been successfully employed for languages with asymmetric communication, like the pi-calculus, are presheaf categories based on (injective) relabelings, such as Set^{I}. Calculi with *symmetric* binding, in the spirit of the *fusion calculus*, give rise to novel research challenges. In this work we examine the *calculus of explicit fusions*, and propose to model its syntax and semantics using the presheaf category Set^{E}, where E is the category of equivalence relations and equivalence preserving morphisms.

[JSC10] P. Baldan, F. Bonchi, A. Corradini, T. Heindel, B. König. A Lattice-Theoretical Perspective on Adhesive Categories. Accepted for the *Journal of Symbolic Computation*.

Abstract. It is a known fact that the subobjects of an object in an adhesive category form a distributive lattice. Building on this observation, in the paper we show how the representation theorem for finite distributive lattices applies to subobject lattices. In particular, we introduce a notion of irreducible object in an adhesive category, and we prove that any finite object of an adhesive category can be obtained as the colimit of its irreducible subobjects. Furthermore we show that every arrow between finite objects in an adhesive category can be interpreted as a lattice homomorphism between subobject lattices and, conversely, we characterize those homomorphisms between subobject lattices which can be seen as arrows.

[ICGT2010] F. Bonchi, F. Gadducci, G. Monreale, U. Montanari. Saturated LTSs for Adhesive Rewriting Systems. Accepted for the *5th Internation Conference of Graph Transformation 2010*.

Abstract. The theory of reactive systems (RSs) represents a meta-framework aimed at deriving labelled transition systems (LTSs) from a set of unlabelled reaction rules. The key idea is simple: a label for a transition from a state A to a state B is a context C[-]such that C[A] (obtained by inserting the state A into C[-]) may perform a reaction and reach B. Depending if either the set of all possible contexts, or just a set of “minimal” ones, is considered, the resulting LTS is called saturated (IPO, respectively). The borrowed contexts (BCs) technique aims at solving the same problem in the setting of the DPO approach. It also represents a constructive presentation of RSs, since for every adhesive rewriting system (ARSs, generalizing graph transformation systems), an RS can be defined such that DPO derivations correspond to reactions, and BC derivations correspond to transitions of the IPO LTS. In this paper we introduce a technique based on BCs which allows to derive saturated LTSs for ARSs. Furthermore, we propose a set of inference rules for deriving all the transitions of this saturated LTS in terms of those of the underlying, IPO one.

Submitted

[FSTTCS] A. Silva, F. Bonchi, M. Bonsangue and J. Rutten. Generalizing the powerset construction, coalgebraically. Submitted to the *30th Foundations of Software Technology and Theoretical Computer Science*.
[APLAS2010] P. Baldan F.Bonchi, F. Gadducci and G.V. Monreale. Concurrency Can't Be Observed, Asynchronously. Submitted to the *8th ASIAN Symposium on Programming Languages and System.*

[MSCS10] F.Bonchi, F. Gadducci and G.V. Monreale. RPOs Semantics for the Calculus of Mobile Ambients. Submitted to *Mathematical Structures in Computer Science*.

In preparation

[SIIES09] F. Bonchi, D. Gorla, B.Klin. Joint Special Issue of ICE, EXPRESS and SOS 2009 to appear in *Mathematical Structures in Computer Science*.

[Prep1] F. Bonchi, M. Bonsangue, M. Boreale, J.Rutten and A. Silva. Linear Weigheted Automata, Coalgebraically. In Preparation.

[Prep 2] A. Aristizabal, F. Bonchi, C. Palamidessi, F. Valencia. Bisimilarity in Concurrent Constraint Programming. In preparation.

III -Attended Seminars, Workshops, and Conferences

During the second part of my ERCIM fellowship, I attended many talks and seminars organized in the hosting institute (INRIA-Saclay, LIX) by the team Comète. Moreover, I attended a lot of seminars in several different universities and research centers of computer science in Paris.

In order to give more continuity to my research project, the two hosting teams (CWI, team SEN3 and INRIA-LIX, team Comète) meet twice. In the 14th December 2009, me, Catuscia Palamidessi (the head of Comète), Ivan Gazeau (a ph.D student in Comète) met Jan Rutten, Marcello Bonsange and Alexandra Silva (all my coauthors in SEN3) at CWI. In the 25th and 26th of April 2010, we had a second meeting in Paris.

Furthermore, some of my previous collaborators come to visit me in Paris and gave a talk at LIX.

During the second part of my ERCIM fellowship, I have also attended the following workshops

1. CHOCO – April 22, 2010, Lyon, France
2. ICE - *June 10th, 2010, Amsterdam, Netherlands*
3. *QAPL* - June 21-26, 2010, Bertinoro, Italy
4. CHOCO – June 28-30, 2010, Lyon, France