ERCIM "Alain Bensoussan"
Fellowship Scientific Report

Fellow: Filippo Bonchi
Visited Location : SEN3 group at CWI (The Netherlands)
Duration of Visit: 9 months (from 5th of January to 5th of October 2009)

I - Scientific activity

At CWI, with the group SEN3, I worked on several topics, all of them closely related to my Ph.D thesis.

Symbolic Semantics. Languages for modelling and specifying interactive systems have been widely studied in Theoretical Computer Science. During my Ph.D., I developed a general framework for the definition of symbolic semantics for these languages and I proved its effectiveness by giving symbolic semantics to many well-known formalisms. During my visit in Amsterdam, I have provided a coalgebraic semantics to this framework by mean of *normalized coalgebras*. These are peculiar coalgebraic structures defined on a category of presheaves. The semantics guarantees the existence of a *minimal symbolic automaton* and allows to define a *symbolic minimization algorithm*. This work has been done together with Ugo Montanari and it has brought to the pubblication of two conference papers.

Coalgebras for Quantitative Systems. Closely related to normalized coalgebras are *quantitative coalgebras*, i.e., coalgebras for *monoidal evaluation functors* (in both cases the branching structure of a system is seen as the sum of a monoid). Together with Jan Rutten, Marcello Bonsangue and Alexandra Silva, I have defined a general framework on *regular expressions* for quantitative coalgebras. This allows to systematically derive regular languages for a large variety of quantitative systems. These languages have two nice propeties: (1) they satisfy a generalized version of the Kleene Theorem (i.e., each regular expression specifies a finite system and vice-versa) and (2) they have a sound and complete axiomatization of the associated abstract semantics.
Another way of modelling quantitative systems as coalgebras is through *linear coalgebras*, i.e., coalgebras on *vector spaces*. The resulting abstract semantics are linear, that is they do not take into account the branching structure. In many cases the linear semantics are more interesting the branching ones. For example the ordinary semantics of *weighted automata* is *weighted language equivalence*. All these observations has been carried out working with Alexandra Silva, Marcello Bonsangue, Jan Rutten and Michele Boreale and will be published soon in a journal paper.
Coalgebras could be useful for the modelling and the specification of quantitative systems in a lot of different ways. We have done preliminary studies on a form of *generalized powerset contruction* via linearization (induced by a monad) and on *parametric coalgebras* as coalgebras in a Kleisli category. I am planning to continue these studies and to involve also the next hosting group.

Context dependency and Priorities in Reo. Many people of the SEN3 group at CWI work on the coordination language REO. Together with Alexandra Silva, Jose Proenca and Christan Krause, I tried to give a compositional abstract to Reo with priorities and context dependency. I would like to work further on this, maybe involving the next hosting group.

II- Publication(s) during your fellowship

1. Filippo Bonchi, Ugo Montanari: Coalgebrac Symbolic Semantics. CALCO 2009: 173-190

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 a previous paper, we have introduced an abstract theory of symbolic semantics. In this paper, we introduce its coalgebraic models.

2. Filippo Bonchi, Marcello M. Bonsangue, Jan J. M. M. Rutten, Alexandra Silva: Deriving Syntax and Axioms for Quantitative Regular Behaviours. CONCUR 2009: 146-162

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.

3. Paolo Baldan, Filippo Bonchi, Fabio Gadducci: Encoding Asynchronous Interactions Using Open Petri Nets. CONCUR 2009: 99-114

Abstract : We present an encoding for (bound) processes of the asynchronous CCS with replication into open Petri nets: ordinary Petri nets equipped with a distinguished set of *open* places. The standard token game of nets models the reduction semantics of the calculus; the exchange of tokens on open places models the interactions between processes and their environment. The encoding preserves strong and weak CCS asynchronous bisimilarities: it thus represents a relevant step in establishing a precise correspondence between asynchronous calculi and (open) Petri nets. The work is intended as fostering the technology transfer between these formalisms: as an example, we discuss how some results on expressiveness can be transferred from the calculus to nets and back.

4. Filippo Bonchi, Ugo Montanari: Minimization Algorithm for Symbolic Bisimilarity. ESOP 2009: 267-284

Abstract : The operational semantics of interactive systems is usually described by labeled transition systems. Abstract semantics is defined in terms of bisimilarity that, in the finite case, can be computed via the well-known *partition refinement algorithm*. However, the behaviour of interactive

systems is in many cases infinite and thus checking bisimilarity in this way is unfeasible. *Symbolic semantics* allows to define smaller, possibly finite, transition systems, by employing symbolic actions and avoiding some sources of infiniteness. Unfortunately, the standard partition refinement algorithm does not work with symbolic bisimilarity.

5. Filippo Bonchi, Fabio Gadducci, Giacoma Valentina Monreale: Reactive Systems, Barbed Semantics, and the Mobile Ambients. FOSSACS 2009: 272-287

Abstract: Reactive systems, proposed by Leifer and Milner, represent a meta-framework aimed at deriving behavioral congruences for those specification formalisms whose operational semantics is provided by rewriting rules. Despite its applicability, reactive systems suffered so far from two main drawbacks. First of all, no technique was found for recovering a set of inference rules, e.g. in the so-called SOS style, for describing the distilled observational semantics. Most importantly, the efforts focused on strong bisimilarity, tackling neither weak nor barbed semantics.
Our paper addresses both issues, instantiating them on a calculus whose semantics is still in a flux: Cardelli and Gordon's mobile ambients.
While the solution to the first issue is tailored over our case study, we provide a general framework for recasting (weak) barbed equivalence in the reactive systems formalism. Moreover, we prove that our proposal captures the behavioural semantics for mobile ambients proposed by Rathke and Sobociński and by Merro and Zappa Nardelli.

6. Filippo Bonchi, Ugo Montanari: Reactive systems, (semi-)saturated semantics and coalgebras on presheaves. Theor. Comput. Sci. 410(41): 4044-4066 (2009)

Abstract:The semantics of process calculi has traditionally been specified by labelled transition systems (ltss), but, with the development of name calculi, it turned out that reaction rules (i.e., unlabelled transition rules) are often more natural. This leads to the question of how behavioral equivalences (bisimilarity, trace equivalence, etc.) defined for lts can be transferred to unlabelled transition systems. Recently, in order to answer this question, several proposals have been made with the aim of automatically deriving an lts from reaction rules in such a way that the resulting equivalences are congruences. Furthermore, these equivalences should agree with the standard semantics, whenever one exists.

In this paper, we propose saturated semantics, based on a weaker notion of observation and orthogonal to all the previous proposals, and we demonstrate the appropriateness of our semantics by means of two examples: logic programming and open Petri nets. We also show that saturated semantics can be efficiently characterized through the so called semi-saturated games. Finally, we provide coalgebraic models relying on presheaves.

III -Attended Seminars, Workshops, and Conferences

In Amsterdam I had the opportunity of attending many interesting seminars. Amongst these I want to mention:

- ACG Seminars, i.e., biweekly seminars of SEN3 group that are organized by Alexandra Silva and Frank de Boer
- Algebra and Coalgebra Seminars, i.e., biweekly seminars at ILLC (UVA) organized by Yde Venema.
- Coalgebra Day (2th of March 2009) at CWI (Amsterdam)

I have attended the following conferences:

- ESOP09, 25-27 March 2009, York, United Kingdom
- FOSSACS09, 25-27 March 2009, York, United Kingdom
- CONCUR09, 1-4 September 2009, Bologna, Italy
- CALCO09, 6-10 September 2009, Udine, Italy
- ICTCS09, 28-30 September 2009, Cremona, Italy (Invited Speaker)

I have organized the following workshops:

- ICE09, 31 August 2009, Bologna, Italy