Scientific Report

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Period of the fellowship	01/04/2014 to 31/03/2015

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

During my fellowship at the Institute of Computer Science at the University of Wrocław I worked on two main topics. Bisimilarity for a Timed Concurrent Constraint Language and Bisimulations for Advanced Delimited Control Operators.

Bisimilarity for a Timed Concurrent Constraint Language
During the first couple of months I continued the research I started while I was at Universidad Javeriana in Colombia, the previous year.

The main idea of the project was to give TCC (Timed Concurrent Constraint Programming) an adequate notion of bisimilarity, thus, providing this calculus with an alternative co-inductive proof method for verifying behavioural equivalences in concurrency.

Concurrent Constraint Programming is a well-established formalism for concurrency in which processes interact with each other by telling and asking partial information (namely constraints) in a global medium. TCC extends CCP with the addition of temporal constructs in order to model time and reactive systems.

Input/output bisimilarity, as far as we know, is one of the few notions of bisimilarity for TCC. Unfortunately, this concept is not adequate since it is not a congruence. We showed that the fact of this definition being based on observable reductions is the reason why it is not a congruence. That is the price to pay for not taking internal reductions into account. The problem arises from some processes that can be hung in an internal computation. Those processes cannot be observed, but when plugged in a context, they can react, thus becoming observable.

Based on the fact that internal reductions are just CCP transitions we defined a congruent barbed equivalence based on these (saturated barbed bisimilarity), then, we derived some labels for those internal reductions, thus turning them into observable sub-time unit transitions. We showed that this LTS is sound and complete with respect to the reduction semantics. Finally based on these labelled sub-time unit transitions we introduced a notion of labelled bisimilarity that fully corresponds to the barbed congruence (saturated barbed bisimilarity).

Bisimulations for Advanced Delimited-Control Operators
The rest of my fellowship I have been working with Dariusz Biernacki on the use of different notions of bisimulation to characterize contextual equivalence for lambda calculi extended with delimited control operators.

The principal goal of this project was to find easier-to-use behavioural equivalences such as bisimilarities in order to characterize the Morris-style contextual equivalence for lambda calculus extended with delimited-control operators.

Continuations are an abstract representation of the control state of a program. They reify the program control state. Meanwhile, a delimited continuation is a slice of a continuation frame that has been reified into a function. Unlike regular continuations, delimited ones

return a value and can be reused and composed. Delimited control operators enable the manipulation of the control of a program in a concise way.

Based on previous works by Biernacki and Lenglet, we worked on giving a normal form bisimulation to a lambda calculus extended with $shift_0$/$reset_0$ and proved that it is sound with respect to contextual equivalence. Although this notion is not complete with respect to contextual equivalence, normal form relations are much more convenient in practice (do not involve universal quantifications), therefore making this concept viable as a contextual equivalence characterization.

Finally, and with help of Piotr Polesiuk, we worked on finding an applicative bisimulation, which could be sound and complete with respect to contextual equivalence for several versions of the lambda calculus extended with different delimited control operators. We started our research with the lambda calculus with named prompts and aborts and we continued with a more interesting and challenging version, a lambda calculus for handling exceptions.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

C. Rueda, F. Valencia and A. Aristizabal. Deriving Labels and Bisimilarity for Timed Concurrent constraint Programming. *Pending.*

Abstract. Timed concurrent constraint programming (tcc) is a well-established extension of the Concurrent Constraint Programming (ccp), which allows agents to be constrained by time requirements. Bisimilarity is one of the central reasoning techniques in concurrency. The standard definition of bisimilarity, however, is practically inexistent for tcc. By building upon recent foundational investigations, we introduce a labelled transition semantics for the internal reductions and novel notions of bisimilarity for tcc, based upon the adequate definition of bisimilarity for ccp

By the end of my fellowship, alongside Dariusz Biernacki and Piotr Polesiuk, we have been working on applicative bisimulations on lambda calculi extended with exceptions and multiple prompts. We expect to have a publication later on.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

- 11 April 2014 Programming Languages Seminar, Uniwersytet Wrocławski, Instytut Informatyki, Wrocław, Poland.
- 13-15 October 2014. 10th European Computer Science Summit ECSS, Institute of Computer Science, Wroclaw, Poland.
- 23-24 October 2014. ABCDE Seminar IV, CNR, Pisa, Italy.
- 5 November 2014. CS Colloquium Series UCY, University of Cyprus, Nicosia, Cyprus.
- 30-31 January 2015. Forum Informatyki Teoretycznej FIT, Warsaw, Poland.

Given Talks:

- "Bisimulation Techniques and Algorithms for CCP" (University of Wrocław).
- "Deriving Labels and Bisimilarity for TCC" (Universidad Politécnica de Valencia, University of Cyprus, FIT 2015 Warsaw).
- "Bisimulations for Advanced Delimited Control Operators" (ABCDE Seminar IV, CNR, Pisa).

IV – RESEARCH EXCHANGE PROGRAMME (REP)

First Stay

I visited the Computer Science Department at Universidad Politécnica de Valencia, Spain, from the 22nd until the 26th of October of 2014. My visit was supervised by Professor Maria Alpuente, leader of the Extensions of Logic Programming group. I gave a talk about my work at their seminar, on Deriving Labels and Bisimilarity for Timed Concurrent Constraint Programming. I had some fruitful meetings with Professor Alpuente and Alicia Villanueva regarding possible collaborations on automated software engineering on timed concurrent constraint languages.

Second Stay

I visited the Computer Science Department at the University of Cyprus in Nicosia, from the 3rd to 7th of November of 2014. My visit was supervised by Professor Anna Philippou. I gave a talk about bisimilarity for timed concurrent constraint languages at their Colloquium. I discussed several ideas for collaborations with Professor Philippou regarding type checking privacy policies in the timed pi calculus with groups.