Scientific Report

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Nationality	Indian
Name of the *Host Organisation*	Inria Saclay - Île-de-France
First Name / family name of the *Scientific Coordinator*	Luc Segoufin
Period of the fellowship	02/01/2012 to 01/01/2013

I – SCIENTIFIC ACTIVITY DURING YOUR FELLOWSHIP

I worked with the INRIA research team DAHU at Laboratoire Spécification et Vérification (LSV), ENS Cachan. As mentioned in the ABCDE research training programme established at the beginning of my fellowship, my work focused on verification of infinite-state systems manipulating data.

I collaborated with Stéphane Demri at LSV and Diego Figueira at University of Edinburgh. We studied the logic of repeating values that is a formalism suitable for specifying properties of sequences of data values. We began by establishing the link between deciding this logic and the coverability problem for Vector Addition Systems (VAS). We continued the work further establishing close connections among problems related to logic of repeating values, VAS and classical logics for data words. A paper based on this work has been submitted to a top ranking conference in the area of theoretical computer science.

Apart from the work described above identified at the beginning of the fellowship period, I also identified a related common area of interest with Alain Finkel and Rémi Bonnet, two other members of LSV. This work relates to extending the Rackoff technique, widely used for establishing complexity of problems related to VAS. A paper based on this work was presented at IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science, December 15 - 17, 2012.

Another common area of interest with members in LSV is descriptive complexity, which explores the relationship between logical formalisms and computational complexity of problems expressed in the logical formalism. I was part of a group headed by Luc Segoufin studying the book *Descriptive Complexity,Canonisation, and Definable Graph Structure Theory* authored by Martin Grohe. Apart from Luc Segoufin and myself, Wojciech Kazana and Nadime Francis, two PhD students in LSV were part of this group. We studied different parts of the book individually and presented our understanding to the entire group.

II – PUBLICATION(S) DURING YOUR FELLOWSHIP

1. **Reasoning about Data Repetitions with Counter Systems**
   Authors: Stéphane Demri, Diego Figueira, M. Praveen
   Status: Pending
   Abstract: We study linear-time temporal logics interpreted over data words with multiple attributes. We restrict the atomic formulas to equalities of attribute values in successive positions and to repetitions of attribute values in the future or past. We demonstrate correspondences between satisfiability problems for logics and reachability-like decision problems for counter systems. We show that allowing/disallowing atomic formulas expressing repetitions of values in the past corresponds to the reachability/coverability problem in Petri nets. This gives us 2EXPSPACE upper bounds for several satisfiability problems. We prove matching lower bounds by reduction from a reachability problem for a newly introduced class of counter systems. This new class is a succinct version of vector

addition systems with states in which counters are accessed via pointers, a potentially useful feature in other contexts. We strengthen further the correspondences between data logics and counter systems by characterizing the complexity of fragments, extensions and variants of the logic. For instance, we precisely characterize the relationship between the number of attributes allowed in the logic and the number of counters needed in the counter system.

2. **Extending the Rackoff technique to Affine nets**

Authors: Rémi Bonnet, Alain Finkel, M. Praveen

Status: Published at IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science, December 15 to 17, 2012.

Abstract: We study the possibility of extending the Rackoff technique to Affine nets, which are Petri nets extended with affine functions. The Rackoff technique has been used for establishing Expspace upper bounds for the coverability and boundedness problems for Petri nets. We show that this technique can be extended to strongly increasing Affine nets, obtaining better upper bounds compared to known results. The possible copies between places of a strongly increasing Affine net make this extension non-trivial. One cannot expect similar results for the entire class of Affine nets since coverability is Ackermann-hard and boundedness is undecidable. Moreover, it can be proved that model checking a logic expressing generalized coverability properties is undecidable for strongly increasing Affine nets, while it is known to be Expspace-complete for Petri nets.

3. **ω-Petri nets**

Authors: G. Geeraerts, A. Heußner, M. Praveen, J.-F. Raskin

Status: Pending

Abstract: We introduce ω-Petri nets (ωPN), an extension of plain Petri nets with ω-labeled input and output arcs, that is well-suited to analyse parametric concurrent systems with dynamic thread creation. Most techniques (such as the Karp and Miller tree or the Rackoff technique) that have been proposed in the setting of plain Petri nets do not apply directly to ωPN because ωPN define transition systems that have infinite branching. This motivates a thorough analysis of the computational aspects of ωPN. We show that an ωPN can be turned into an plain Petri net that allows to recover the reachability set of the ωPN, but that does not preserve termination. This yields complexity bounds for the reachability, (place) boundedness and coverability problems on ωPN. We provide a practical algorithm to compute a coverability set of the ωPN and to decide termination by adapting the classical Karp and Miller tree construction. We also adapt the Rackoff technique to ωPN, to obtain the exact complexity of the termination problem. Finally, we consider the extension of ωPN with reset and transfer arcs, and show how this extension impacts the decidability and complexity of the aforementioned problems.

III – ATTENDED SEMINARS, WORKHOPS, CONFERENCES

1. **Name of the seminar:** ABCDE Seminar II
   Date: 24-25 October 2012
   Place: Inria Sophia Antipolis, France

2. **Name of the conference:** IARCS Annual Conference on Foundations of Software Technology and Theoretical Computer Science
   Date: 15-17 December 2012
   Place: IIIT Hyderabad, India.

IV – RESEARCH EXCHANGE PROGRAMME (REP)

1. **Name of REP organisation:** SpaRCIM
   Country: Spain
   Department: The IMDEA Software Institute
   Local scientific coordinator: Pierre Ganty
   Date: 10-14 September 2012
   Experience: We discussed potential practical applications of a theoretical result we had proved about context free grammars. Context free grammars play a crucial role in analysing recursive programmes. We had found an efficient way to compute a finite state automaton that accepts a language with Parikh image equal to the Parikh image of the language generated by a given context free grammar. One week of discussion was short to plan submission of any papers, but we hope to continue collaborating in the future.

2. **Name of REP organisation:** FNRS
   Country: Belgium
   Department: Université libre de Bruxelles
   Local scientific coordinator: Jean-Francois Raskin
   Date: 8-12 October 2012
   Experience: I gave a talk about the work I had done in LSV about extending the Rackoff technique. This was of interest to Jean-Francois Raskin and some of his team members, who wanted to explore the applicability of the Rackoff technique to some extensions of Petri nets they were working on. We discussed about it and after a follow-up visit in November 2012, we submitted a paper based on this work to a top ranking conference in this topic.