ERCIM "Alain Bensoussan" Fellowship Scientific Report

Fellow: Florian Horn
Visited Location : CWI (Amsterdam)
Duration of Visit: 9 months

I - Scientific activity

In my thesis, I studied stochastic games as models for the verification of reactive open processes: one player represents the controller which is to be verified of synthetised, while the other represents the (hostile) environment. The system evolves through the actions of the players, supplemented by random choices. The winning condition describes the satisfying infinite behaviour that the system should respect.

During my fellowship in CWI, I worked with Prof. Krzysztof Apt on mechanical design, in which games are design to provide good decision rules between rational agents with incompatible objective. These rules should always select the best option and encourage agents to disclose honestly their personal informations. As this is not always possible -Arrow's famous "impossibility theorem"-, trade-offs of various nature have to be made.

With Dominik Wojtczak, another post-doc of Prof. Apt, we focused on the routing problem, in which a path has to be selected in a graph where each edge has a cost and belongs to a different agent. Unfortunately, we were not able to find results suitable for publication on this subject.

I also continued my work on graph games in verification, and published four papers on the subject while I was in Amsterdam:

1. a journal version of a new approach to the solution of simple stochastic games;
2. a paper in FSTTCS'08 studying games of ordinal length;
3. a paper in FSTTCS'08 describing a new polynomial algorithm for explicit Muller games;
4. a paper in STACS'09 on memory savings through the use of randomised strategies.

II- Publication(s) during your fellowship

Hugo Gimbert and Florian Horn. ***Solving Simple Stochastic Games with Few Random Vertices***. In *Logical Methods in Computer Science, LMCS,* volume 5(2): 9th. International Federation for Computational Logic, 2009.
Simple stochastic games are two-player zero-sum stochastic games with turn-based moves, perfect information, and reachability winning conditions.
We present two new algorithms computing the values of simple stochastic games. Both of them rely on the existence of optimal permutation strategies, a class of positional strategies derived from permutations of the random vertices. The ``permutation-enumeration'' algorithm performs

an exhaustive search among these strategies, while the ``permutation-improvement'' algorithm is based on successive improvements, à la Hoffman-Karp.
Our algorithms run in polynomial time when the number of random vertices is fixed, so the problem of solving simple stochastic games is fixed-parameter tractable when the parameter is the number of random vertices. Furthermore, our algorithms do not require the input game to be transformed into a stopping game. Finally, the permutation-enumeration algorithm does not use linear programming, while the permutation-improvement algorithm may run in polynomial time.

Florian Horn. ***Explicit Muller Games are PTIME.*** In *Proceedings of the 28th Conference on Foundations of Software Technology and Theoretical Computer Science, FSTTCS'08,* volume 2 of Leibniz International Proceedings in Informatics, pages 235-243. Dagstuhl Research Online Publication Server, 2008.
Regular games provide a very useful model for the synthesis of controllers in reactive systems. The complexity of these games depends on the representation of the winning condition: if it is represented through a win-set, a coloured condition, a Zielonka-DAG or Emerson-Lei formulae, the winner problem is PSPACE-complete; if the winning condition is represented as a Zielonka tree, the winner problem belongs to NP and co-NP. In this paper, we show that explicit Muller games can be solved in polynomial time, and provide an effective algorithm to compute the winning regions.

Julien Cristau and Florian Horn. ***Graph Games on Ordinals.*** In *Proceedings of the 28th Conference on Foundations of Software Technology and Theoretical Computer Science, FSTTCS'08*, volume 2 of Leibniz International Proceedings in Informatics, pages 143-154. Dagstuhl Research Online Publication Server, 2008.
We consider an extension of Church's synthesis problem to ordinals by adding limit transitions to the graph games used in verification. Such games of ordinal length are determined for plays of length less than ω^ω *and the winner problem is PSPACE-complete. However, the proof uses a rather involved reduction to classical Muller games, and the resulting strategies need infinite memory.*
In this paper, we consider first arenas with priority transitions, and provide an algorithm computing the winning regions of both players in time n^d*. Its analysis yields three interesting results: determinacy without hypothesis on the length of the plays, existence of memoryless strategies, and membership of the winner problem in the classes NP and co-NP*
We show then how to relate these results to McNaughton games of ordinal length, and we adapt the LAR reduction in order to prove the determinacy of these games on arbitrary arenas.

Florian Horn. ***Random Fruits on the Zielonka Tree.*** In *Proceedings of the 26th International Symposium on Theoretical Aspects of Computer Science, STACS'09*, volume 3 of Leibniz International Proceedings in Informatics, pages 541-552. Dagstuhl Research Online Publication Server, 2009.

Stochastic games are a natural model for the synthesis of controllers confronted to adversarial and/or random actions. In particular, ω*-regular games of infinite length can represent reactive systems which are not expected to reach a correct state, but rather to handle a continuous stream of events. One critical resource in such applications is the memory used by the controller. In this paper, we study the amount of memory that can be saved through the use of randomisation in strategies, and present matching upper and lower bounds for stochastic Muller games.*

III -Attended Seminars, Workshops, and Conferences

- *FSTTCS'08 Conference (Bangalore, India): December 9^{th} to 11^{th}.*
- *PCT Workshop (Chennai, India): December 15^{th} to 16^{th}.*
- *LFCS Workshop (Edinburgh, Scotland): February 4^{th} to 6^{th}.*
- *AVERISS Meeting (Paris, France): February 11^{th} to 12^{th}.*
- *STACS'09 Conference (Freiburg, Germany): February 26^{th} to 28^{th}.*
- *GASICS Meeting (Bruxelles, Belgium): March 5^{th} to 6^{th}.*
- *GAMES Spring School (Bertinoro, Italy): May 31^{st} to June 6^{th}.*
- *DOTS Meeting (Rennes, France): July 3^{rd}.*
- *ICALP'09 Conference (Rhodos, Greece): July 5^{th} to $12^{th.}$*