Report of my ERCIM fellowship at the Computer and Automation Research Institute of the Hungarian Academy of Sciences

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The ERCIM fellowship has allowed me to work in the Computer and Automation Research Institute of the Hungarian Academy of Sciences (MTA-SZTAKI) from 11 March 2002 until 11 December 2002. Throughout this period I was a member of the Research Group on Modelling Multi-Agent Systems (MMS) which is headed by dr. Erzsébet Csuhaj-Varjú. I have closely collaborated with both her and dr. György Vaszil, another member of this group. Furthermore, I have worked with several of the many guests visiting this group during these nine months, viz. dr. Markus Holzer and dr. Victor Mitrana.

1 Scientific Activity

I have continued my research on the development and use of formal models and methods to aid in the design and verification of complex computer systems with many interacting components, such as distributed and groupware systems. As such I have profited deeply from the knowledge that the MMS group has on cooperative and distributed models, both from an architectural as from a language-theoretic point of view. This has resulted in four technical reports, one of which has recently been presented at a conference and is about to be published.

2 List and Abstracts of Papers Written

1. M.H. ter Beek, E. Csuhaj-Varjú, and V. Mitrana, Teams of Pushdown Automata. To appear in *Proceedings of the 5th International Conference on Perspectives of System Informatics (PSI'03), Novosibirsk, Akademgorodok, Russia* (A. Zamulin and M. Broy, eds.), Lecture Notes in Computer Science, Springer-Verlag, Berlin, 2003. (extended abstract)

   We introduce team pushdown automata as a theoretical framework capable of modelling various communication and cooperation strategies in complex, distributed systems. Team pushdown automata are

obtained by augmenting distributed pushdown automata with the notion of team cooperation or—alternatively—by augmenting team automata with pushdown memory. Here we study their accepting capacity.

2. M.H. ter Beek, E. Csuhaj-Varjú, and V. Mitrana, Teams of Pushdown Automata, Technical Report 2002/4, Researcg Group on Modelling Multi-Agent Systems, Computer and Automation Research Institute, Hungarian Academy of Sciences, 2002. (full version submitted for journal publication)

   We introduce team pushdown automata as a theoretical framework capable of modelling various communication and cooperation strategies in multi-agent systems. Team pushdown automata are obtained by augmenting distributed pushdown automata with the notion of team cooperation or—alternatively—by augmenting team automata with pushdown memory. In a team pushdown automaton, several pushdown automata work as a team on the input word placed on a common one-way input tape. At any moment in time one team of pushdown automata, each with the same symbol on top of its stack, is active: each pushdown automaton in the active team replaces the topmost symbol of its stack and changes state, while the current input symbol is read from the input tape by a common reading head. The teams are formed according to the team cooperation strategy of the team pushdown automaton and may vary from one moment to the other. Based on the notion of competence, we introduce a variety of team cooperation strategies. If all stacks are empty when the input word has been completely read, then this word is part of the language accepted by the team pushdown automaton. Our initial focus is on the accepting capacity of team pushdown automata. We conclude by providing some directions for future work, including a hint at an application of the enhanced modelling power of team automata obtained through the addition of pushdown memory.

3. M.H. ter Beek, E. Csuhaj-Varjú, M. Holzer, and Gy. Vaszil, On Competence in Cooperating Distributed Grammar Systems. Technical Report 2002/1, Research Group on Modelling Multi-Agent Systems, Computer and Automation Research Institute, Hungarian Academy of Sciences, 2002. (in preparation for journal submission)

   We introduce a very natural cooperation protocol for cooperating distributed (CD) grammar systems with context-free components. Under this protocol, the components of a CD grammar systems are enabled (and disabled) to rewrite the sentential form according to their level of competence on that sentential form and must continue the derivation as long as they have this property. Intuitively, a component is k-competent on a sentential form if it is able to rewrite exactly k (no more and no less) nonterminals appearing in the sentential form. Since CD grammar systems are a language-theoretic

framework for modelling blackboard systems, we thus provide a formal interpretation of the requirement that agents must be competent enough before being able to participate in the problem solving taking place on a blackboard. We show that this cooperation protocol is very powerful. CD grammar systems with 1-competent components can generate all forbidding random context grammars, while already 2-competent components suffice to generate all recursively enumerable languages. By applying the cooperation protocol to a specific type of CD grammar system we shed new light on a longstanding open problem in formal language theory: Is the inclusion of the family of recurrent programmed grammars with appearance checking into the family of programmed grammars with appearance checking strict?

4. M.H. ter Beek, E. Csuhaj-Varjú, M. Holzer, and Gy. Vaszil, On Competence in Cooperating Distributed Grammar Systems, part II. Technical Report 2002/2, Research Group on Modelling Multi-Agent Systems, Computer and Automation Research Institute, Hungarian Academy of Sciences, 2002. (follow-up to Technical Report 2002/1)

   In this paper we continue the investigations of the power of context-free cooperating distributed (CD) grammar systems cooperating under competence-based cooperation protocols. As natural extensions of the $= k$-competence mode of derivation for CD grammar systems, we introduced in [3], we have introduced the $\leq k$-competence mode of derivation and the $\geq k$-competence mode of derivation. A component grammar is said to be k-competent on a sentential form if it is able to rewrite exactly k nonterminals appearing in the sentential form. According to the examined protocols, a component of a CD grammar system is enabled to rewrite a sentential form only if it is $\leq k$-competent or $\geq k$-competent, respectively, on that sentential form and it must continue the derivation as long as it has this property. Both cooperation protocols are very powerful, since CD grammar systems working in the ≤ 2-competence mode of derivation characterize the family of languages generated by random context grammars, while CD grammar systems working in the ≥ 2-competence mode of derivation characterize the family of languages generated by random context ET0L systems. Since CD grammar systems are syntactic models of the blackboard model for problem solving, the results demonstrate that effective problem solving is possible even with cooperating partners of a very low, limited level of competence.

5. M.H. ter Beek, E. Csuhaj-Varjú, M. Holzer, and Gy. Vaszil, On Competence in Cooperating Distributed Grammar Systems, part III. Technical Report 2002/3, Research Group on Modelling Multi-Agent Systems, Computer and Automation Research Institute, Hungarian Academy of Sciences, 2002. (follow-up to Technical Report 2002/2)

Cooperating distributed (CD) grammar systems are grammatical models for the blackboard model of problem solving. In this paper we consider three very natural cooperation protocols for these constructions, introduced in [3] and [4], in the context of CD grammar systems with E0L components, that is, context-free grammars working with a variant of totally parallel derivations. An E0L grammar represents a problem solver which is able perfom several (as many as possible) actions in one step. According to the examined cooperation protocols, a component of the CD grammar system is enabled to rewrite a sentential form only if it is $\leq k$-competent, $= k$-competent, or $\geq k$-competent, respectively, on that sentential form and must continue the derivation as long as it has this property. A component grammar is said to be k-competent on a sentential form if it is able to rewrite exactly k nonterminals appearing in the sentential form. Similarly to the results for context-free CD grammar systems, we obtain that the above cooperation protocols are very powerful in the case of CD grammar systems with E0L component as well, since the grammar systems working in any of the ≤ 2-competence, the $= 2$-competence mode, or the ≥ 2-competence mode of derivation characterize the family of languages generated by random context ET0L systems, a very large, parallel class of languages.

3 List of Workshops/Conferences Attended

I have not participated in any workshops or conferences during this period, but I have presented an article written during this period at PSI'03 (the 5th International Conference on Perspectives of System Informatics) in Novosibirsk, Akademgorodok, Russia, from July 9 - 12, i.e. during the second part of my ERCIM fellowship.

I did attend AFL'02 (the 10th International Conference on Automata and Formal Languages) in Debrecen, Hungary, from August 13 - 18.

Moreover, I have given a talk within the Seminar on Automata Theory at the Department of Computer Science of the University of Szeged in Szeged, Hungary, on April 23, as well as talks at the MTA-SZTAKI in Budapest, Hungary, on May 30, and at the Leiden Institute of Advanced Computer Science (LIACS) of Leiden University in Leiden, The Netherlands, on June 12.