Semantics of Concurrent Logic Languages: report on a visit to ICOT

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1   Introduction

I spent the first three weeks of March 1989, as a visiting researcher at ICOT. I met several researcher of ICOT, in particular those of the First Laboratory, and discussed their and our projects on language design, semantics of concurrent logic languages, and program transformations based on semantics.

My research interests are mainly in the areas of *semantics of concurrent logic languages, concurrency* and *program transformations*.

I think that the role of semantics in the definition of programming languages is essential for many reasons. Semantics can be a guide to the implementors, and the basis to define any possible correct program transformation rules. Hence its role is central, for istance, in designing compilers and to define program optimization tecniques.

The First Laboratory is a place where the design of languages and the definition of their semantics are carried out in parallel. Moreover, there is a strong interaction between people working in the first laboratory, and people working in different areas, such as implementation of the new languages.

On my first day at ICOT, I was welcomed by Doctor Iwata from the Research Planning Department, who introduced me to Doctor Fuchi, Director of the Research Center, gave me an overview of ICOT, and gave me a resume of foreign people currently visiting ICOT. I then got in touch with Doctor Murakami, who, as main host, took in charge all the details of my stay at

ICOT. Then, on my first day, I met Doctor Furukawa, Deputy Director of the Research Center, and I was introduced to Doctor Hasegawa, the chief of the First Laboratory.

I would like to emphasize that my visit was very fruitful, from my viewpoint. I had a strong interaction with Doctor Murakami, with whom I wrote a new paper, and productive discussions with many other researchers of the First and other Laboratories. The paper I wrote together with Doctor Murakami is the result of a continuous cooperation with the other two authors of it, namely Doctor Maurizio Gabbrielli, and Professor Giorgio Levi of the University of Pisa. I hope that this work can contribute to enforce the cooperation between ICOT and the University of Pisa. I would really like to thank the ICOT people for the quality of the welcome I got. I was invited to a welcome dinner by the colleagues of the First Laboratory, to a welcome lunch and to a farewell party. My colleagues Murakami and Ueda took me every day for lunch and for dinner at different restaurants. They also explained me many interesting characteristics of the life in Japan. Thus, I enjoyed the opportunity to understand a bit of this very interesting country. I would like to thank Doctor Furukawa that invited me for a lunch in typical Japanese style. Also, I would really like to thank Doctor Iwata and his secretary, Mrs. Hiromi Chikatsu for their kindness and for having helped me to organize also my free time. I have to thank a lot Masaki Murakami, who, as my host, introduced me to all the ICOT facilities. I can certainly say that the assistance I received for this visit was perfect.

2   My presentations at ICOT

Last year, Professor Giorgio Levi, during his visit to ICOT, already gave some presentations of the research activities done by the logic programming group in Pisa. Also, I already knew the work of some researchers working in ICOT, and especially in the First Laboratory. In fact, I read their publications on international journals. Moreover, I already exchanged ideas with some of them by electronic mail. Thus, it was very easy to explain the general lines of research that we are currently following in Pisa, and to be informed about the most recent results obtained by researchers working in the First Laboratory. Besides this informal discussion, I gave two formal talks.

In the first formal talk, I presented the most recent results obtained by me and the logic programming group of Pisa on defining Equivalence Relations between Logic Programs.

I gave first an introduction based on an extension of the standard seman-

tics of Logic Programs oriented to capture the operational behavior of Logic Programs. Then, I discussed how this semantics has been used by many researchers in Pisa, as a basic tool to give a semantics to concurrent logic languages. The second part of the talk was about the problem of Equivalences (modulo semantics) of Logic Programs.

A basic concept in any programming language is the definition of "useful" notions of equivalences between programs. I explained this problem in the case of languages based on Horn clauses. Thus, I introduced a notion of semantics for Horn clause languages based on the introduction of variables in Herbrand domains. I also discussed the relevance of this semantics for concurrent logic programming languages. Then, I introduced a formalism to compare the semantics introduced in the first part of the talk with the standard semantics, by van Emden and Kowalski, and with another semantics based on the notion of atomic consequences. Each of these semantics allows to define a model; and therefore, a notion of equivalence between programs. The relevance of each of these equivalences was also discussed.

In my second formal talk, I presented a tentative definition of a new language, *Nested Guarded Horn Clauses*, whose definition was inspired by the visit of Professor Giorgio Levi at ICOT First Research Laboratory, last year. At that time, Professor Giorgio Levi had the opportunity to discuss and have a strong insight about the definition of the language Guarded Horn Clauses (GHC), defined by Doctor Ueda of this Laboratory. Thus, he realized that it would have been very useful to investigate on the possibility to define a complete set of unfolding rules and to give a new and easy semantics to the language GHC. Doctor Maurizio Gabbrielli of the University of Pisa and me joined Levi's project, that seemed to be very challenging. Then, my visit to ICOT gave me the chance to present our ideas in, I believe, the right place. I decided to give a talk that was intended as a starting point for discussions. The audience was very careful and interested. Some of them, Dr. David Hawley, Doctor Ueda, Dr. Masaki Murakami and Dr. Jiro Tanaka of Fujitsu IIAS-SIS, immediately started to comment and criticize the language I was defining. I also distributed, for both my talks, a copy of the transparencies to stimulate further discussions. After my second talk, the discussion on my presentations continued, and a strong interaction with Doctor Masaki Murakami started. His careful remarks suggested how to improve the definition and the semantics of the new language. We decided to work together, continuing to cooperate with Professor Giorgio Levi and Doctor Maurizio Gabbrielli.

3   My work at ICOT

As I already told, I worked in a friendly and strongly challenging atmosphere. So, I succeeded in working very well, stimulated by ICOT researchers. My cooperation with Doctor Masaki Murakami was very useful for me. I learned a lot. Discussing with Dr. Murakami and Doctor Ueda, I understood some important points of the programming behavior of GHC. So, I realized that our first definition of the new language had to be improved. Thus, I had the opportunity to work together with Doctor Masaki Murakami. The quality of services available in ICOT made our cooperation with the University of Pisa feasible, and I used the electronic mail and Telefax connections to continuously communicating the results of our discussions in ICOT to Pisa and receiving back the comments and the work done in Pisa. Therefore, I would be honored if the paper of me, Dr. Masaki Murakami, Dr. Maurizio Gabbrielli and Professor Giorgio Levi could appear as an ICOT Technical Report.

I would also like to give a brief description of the content of the paper. The paper "Nested Guarded Horn Clause: a language provided with a complete set of unfolding rules" defines a new language, *Nested Guarded Horn Clauses* (NGHC). The main characteristic of this language is its concept of guard. In fact, guards are trees rather than predicates definitions. This improvement in syntax is directly related to the language semantic definition, given in terms of a complete set of unfolding rules and a fixpoint semantics which are proved equivalent. Apart from the hierarchical structure of guards, NGHC programs are essentially similar to GHC programs. In fact, we define an embedding of FGHC programs in NGHC, and prove the equivalence respect to their success set. NGHC programs are executed in a normalized form (strong normal form). Thus we also provide an algorithm of normalization.

4   Discussions

As I have emphasized in the previous description, the discussions with the researchers of ICOT were many and productive.

I just want to add that I had an interesting discussion with Doctor Jiro Tanaka of Fujitsu IIAS-SIS, talking about his current work on metareflection for GHC programs. We decided to continue to exchange our opinions and ideas also when I will be back in Pisa.

I also had a "panel" discussion with Dr. Tanaka, Dr. Ueda and Dr. Murakami, talking about advantages and disadvantages of the new language

that we wanted to define.

5　Conclusion

My visit at ICOT was very productive from my viewpoint. In fact, I had the chance to discuss with people strongly motivated. Discussions with ICOT researchers have been very useful. I had the chance to write a paper with Doctor Masaki Murakami with whom I will remain in contact, when I will be back in Pisa. I think that the quality of research at ICOT is really high, and the environment very stimulating. Thus, I hope that a cooperation between ICOT and the University of Pisa can start very soon. I think that exchanges of researchers and the organization of joint workshops would be very useful for the University of Pisa and ICOT as well. I hope that my cooperation with the ICOT researchers can continue in the future, maybe taking advantage of the beginning of an official cooperation with the University of Pisa.

Moreno Falaschi

Curriculum vitae et studiorum

-Born on September 13, 1959, in Pontedera (PI), Italy.

-December 1982: <u>Degree in computer science</u> ("110/110 summa cum laude"), dissertation on "Semantics and pragmatics of Generalized Horn Clauses". Advisor: prof. Giorgio Levi

-October 1983: He is admitted to the <u>Doctorate School in computer science</u> at the department of Pisa.

-From December 1987 he is also <u>Assistant Professor</u> in the Department of Computer Science of the University of Pisa.

-October 6, 1988: <u>Ph. D. degree in Computer Science</u> at the University of Pisa, given by Ministero della Pubblica Istruzione (Minister of Education). Dissertation on "Semantics of non determinism in concurrent logic languages" (Advisor: prof. Giorgio Levi).

Research areas: concurrent logic languages (Generalized Horn Clauses), semantics of logic programs with infinite terms, finite failures of concurrent logic languages, non-Herbrand semantics of logic languages.

Research Projects:

Two italian national projects, funded by C.N.R (National Research Council), on "Semantics of Logic Languages", and on "Logic Programming: Extensions and parallel architectures".

An ESPRIT project, funded by the European Community, on "Parallel architectures and languages for advanced information processing: A VLSI-directed approach".

Participation to Advanced International Schools:

"Current trends in concurrency", Noordwijkerhout (Holland), 10-21/6/86.

"Mathematical Models for the Semantics of Parallelism", Roma (Italy), 24/9-1/10/86.

"Foundations of Logic and Functional Programming", Trento (Italy), 15-19/12/86.

"Logic and Computer Science", Montecatini (Italy), 20-28/6/88.

"Advanced school on foundations of Logic Programming", Alghero (Italy), 19-23/9/88.