Constraint Logic Programming
Report on a Visit to ICOT

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My visit to ICOT has been interesting and productive. I was able to contribute to the work of several researchers here and to enhance my own work through interaction with the ICOT people.

My first contact was with Mr. Iwata who brought me to the lab, made a presentation on the work here and explained operations. He then introduced me to Dr. Aiba who was to be in charge of my day-to-day life at ICOT and Miss Nakamura who served as liaison. I was then introduced to Mr. Hiroshige, Executive Director of ICOT, and exchanged greetings with Dr. Furukawa, Deputy Director of ICOT. Later in the week I was introduced to Dr. Fuchi, Director of ICOT.

1 Constraint Programming

Meetings were quickly set up between myself and Dr. Aiba, Mr. Ohsuga, Mr. Sakai and Dr. Sato where we discussed Constraint Logic Programming at great length and where I was introduced to the CAL system. This system implements the CLP scheme with constraints over polynomial rings; the Buchberger algorithm for Gröbner bases is utilized to implement the constraint solver. The group have interesting applications of CAL to non-linear extremal problems using Lagrange's method. Some interesting questions came up such as the independence of negative constraints in this context. At a later time, Dr. Sato made an in-depth presentation of the extension of Buchberger's method to Boolean rings; this is designed to be used on another CLP system which targets circuit design among its applications. Aiba, Sakai and I also have also discussed the topic of a full contraint solver for CLP(R), that is for CLP with Real number constraints. I was able to point them to new work by Ben-Or, Kozen and Reif in this field; this work could yield more efficient algorithms than Collin's Algorithm and has promise of greater parallelism. A related point of discussion was the need for an efficient method of projecting linear arithmetic constraints onto the space of principal variables. This is important for effective garbage collection in constraint languages. We also discussed PDL ("Proof Description Language") and Mr. Fujita of the Mitsubishi Research Institute gave a demonstration of CAP-LA, the proof checking prototype system for Linear Algebra.

In my second week I began my discussions with Drs. Tanaka and Ueda on GHC systems. The subject of the relation between GHC and the CLP languages

was raised. At a later session, after some further analysis on my part, we went into this in detail; the upshot was that, from a theoretical point of view, FGHC by using a constraint based arithmetic, would be able to incorporate important aspects of CLP(R), namely, those applications which do not require backtracking over constraints. What is also interesting is that in a forward chaining constraint based system, canonical form algorithms such as those recently developed for linear constraints by J.L. Lassez and myself, would play an important role. On the other hand, a GHC constraint language would not support certain search programs which exploit backtracking over constraints. However, for this kind of application, typically a generate and test program, Ueda and Okumura have already developed GHC techniques.

In parallel, I talked with Dr. Tick of the Fourth Lab about the parallel implementation of FGHC and the problems of contention that would arise if constraints were implemented in FGHC in various ways. Again, from a high-level point of view, the adjunction of constraint solving mechanisms is perfectly possible but from a systems point of view it would introduce costly overhead. This picture is thus consistent with the analysis done with Drs. Tanaka and Ueda.

During this week I also began some very valuable discussions with Dr. Mukai of the Second Lab on constraint programming, Situation Theory and applications to natural language processing. We went through a proof of Barwise where Löb's Theorem - an extension of the Gödel Incompleteness Theorem - is used to show that Situation Theory has certain natural boundaries to its expressive power. Later we considered the relationship between denotational semantics, functional programming and Situation Semantics and the role of constraint logic programming.

There was also an interesting and lively seminar meeting on partial evaluation of GHC programs based on UR-sets and constraint solving. Mr. Fujita and Dr. Furukawa led the session and contributions were made by Dr. Murukami, Dr. Devienne, Mr. Okumura, Prof. Levi and Dr. Hasegawa. This work has likely application to CLP languages in addition to its use with GHC. Conversely, it is worth considering whether appropriate CLP languages might yield a natural setting for running the algorithm for partial evaluation via constraint solving.

2 ICOT Presentations

In their presentations Mssrs. Sakama and Morita discussed the ongoing projects of the Third Laboratory. Mr. Sakama presented work on program transformation and knowledge bases; using the new technique of representatives for knowledge coded in Horn clause logic, methods are obtained that permit utilization of knowledge in multiple universes and other applications. This work which joint with Mr. H. Itoh, will be presented at the Second International Coinference on Expert Database Systems in April. Mr. Morita described the PHI project which uses innovative relational algebra operations to build and maintain knowledge base management systems; this is a vertically integrated project which goes from data-structure design to actual machine specification. I have also profited from presentations of Mssrs. Sato and Arima at the weekly seminar of the First Lab. Mr. Sato's work is on modelling default reasoning by means of a minimal

model change criterion; Mr. Arima presented a new notion, that of *ascription* which extends the power of current methods for non-monotonic logic such as circumscription. Both papers will be presented at the International Workshop on Machine Learning, Meta-Reasoning and Logics next month.

I also had the opportunity to talk with Mr. Yokota of the Fourth Lab on the Kappa project, this is a very impressive undertaking which is using new relational data-base techniques (*e.g.* nested relations) to manage a very large system; I was able to provide information on some projects at IBM Yorktown for on-line dictionary and text aid that share certain objectives with the Kappa project. Mr. Nagai of the Fifth Lab was also kind enough to describe his work on an Expert System for Machine Design, based on logic programming.

At ICOT I was also able to attend talks and presentations by Prof. Levi, Dr. Autret and Dr. Devienne. Prof. Levi presented his recent work on semantics for parallel logic programming, Dr. Autret talked about parallel architectures being designed in France and Dr. Devienne described the organization of his laboratory in France and talked on his work with weighted graphs and the halting problem for logic programs.

3 Talks

During my second week here I gave a talk on my work with J.L. Lassez on canonical forms for extended linear constraints to the Symbolic Computation Working Group; I was able to complete a draft version of the first three sections of the paper for distribution at the talk. This work is designed to provide CLP(R) with a powerful mechanism for processing output-constraints, but it also has potential application to the design of the constraint solver for CLP languages and for use in constraint propagation over linear arithmetic constraints. The algorithms presented also have strong parallel features. At a later time, I gave a talk on stratification and knowledge base management to the Third Lab seminar. This was on joint work with C. Lassez and G. Port, where we exploited ideas from logic programming with proven computational efficiency to develop a strategy for processing propositional logic knowledge bases by means of a network structure. A copy of the paper was distributed to participants at the seminar and a copy of the overhead transparencies was prepared subsequently. After my talk, I had the opportunity to discuss their work with people from outside ICOT such as Mr. Katsuno of NTT Basic Research Laboratories.

4 Outside ICOT

On Thursday and Friday, January 13 and 14, I represented ICOT at a meeting on Neuroscience and Computing sponsored by the Japan Science Agency and held at Tsukuba City. This was an exciting opportunity to meet with Japanese scientists in a variety of fields and to exchange ideas on emerging technologies. Among other things, I came away with an increased appreciation of the importance of Machine Learning.

I have also been able to have a discussion with Prof. Mizoguchi of Tokyo Science University on applications of Constraint Logic Programming to tightly-

coupled expert systems work. In addition we discussed US-Japan university relations and possibilites for collaborative research.

5 In Conclusion

Most sincere thanks are due Dr. Fuchi for inviting to visit ICOT and participate in the work here. I have been very impressed by the depth and breadth of the research conducted at ICOT. There is a wide range of expertise and one gets quick information and in-depth answers to questions. The lab assembles an elite group of research scientists and has a unified focus. During my stay here a number of new research issues were developped which hopefully will lead to further progress. I myself now have a coherent appreciation for the ICOT projects and a first hand understanding of the work of several research teams.

My thanks begin with Dr. Furukawa who shepherded my initial contacts with ICOT. Moreover, the social reception here has been nothing short of outstanding. From the first, there has been a steady stream of gracious social occasions - dinner with Dr. Furukawa and members of the First Lab, the welcome lunch with Dr. Fuchi, Mr. Hiroshige, Dr. Hasegawa, Mr. Kurozumi, Dr. Furukawa and other ICOT members, the dinner and tea ceremony at Mr. Iwata's and the trips to interesting little restaurants at lunchtime with members of the lab. Moreover, in the workaday situation, the members of the ICOT have been gracious and considerate; a particular note of thanks is due Dr. Aiba who untiringly organized my daily life and was always available. Also, what has been very important to me is the way that the lab received me as a colleague and the way our mutual scientific interests facilitated communication.

Resume

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Experience

1986-87   Visiting scientist, IBM T.J. Watson Research Center

1980-   Professor, Department of Computer and Information Science, Brooklyn College of CUNY; Chairman 1983-84. CUNY Ph.D.

Program in Computer Science; coordinator 1984-1985.
CUNY Ph.D. Program in Mathematics

1976   Visiting professor, Rockefeller University

1969-80   Research professor, Department of Mathematics and
            Computer Science, University of Paris VII and the
            Centre National de la Recherche Scientifique

1967-69   Instructor, Mathematics Department, Princeton University

Education

Fordham University   B.A. Summa Cum Laude 1962
                                        NSF Fellow, Woodrow Wilson Fellow

University of California   Ph.D. in Mathematics 1966
    at Berkeley   NATO Post-doctoral Fellow

Personal Data

Date of Birth 8/23/40   Married, 3 children   Excellent health