ICOT Research Report

Stephen T. C. Wong
UCSF Medical School/UC Berkeley Bioengineering Program

1 Introduction

This report summarizes my work as an invited researcher at ICOT from April 1st to August 18th, 1993. My interests are the theoretical issues and applications of database and knowledge based systems. I had several years of industrial experience at AT&T Bell Laboratories and Hewlett Packard before my Ph.D. study, thus my research has a strong multidisciplinary orientation.

ICOT is the world leader in knowledge information processing (KIP) research. A decade of dedicated research by ICOT has generated not only many original results in this field but also many new hardware and software utilities. The general goal of my stay at ICOT is to collaborate with their researchers in the field of legal reasoning and other KIP applications. This collaboration also requires me to learn and use advanced theories and tools that have been developed here during the past ten years.

This report is organized in the following manner. In Section 2, I discuss my research activities and progress. Section 3 describes my major interactions with ICOT researchers and other external researchers under the auspices of ICOT. Section 4 summarizes the overall progress of my stay.

2 Research Activities and Progress

My major collaboration has been with the legal reasoning group, headed by the manager of the second research department, Dr. Katsumi Nitta. The legal domain is a special challenge for AI because it is intensely linguistic and complex, and only partially logical, adversarial, and analogical. It is midway between the logical domains that are amenable to computer science techniques and the domains of commonsense reasoning and ordinary discourse that AI is targeted to tackle. Study of how knowledge is structured and processed in this partially formalized field may lead to useful insights.

An efficient parallel legal reasoning system, HELIC-II, has been developed at ICOT. This prototype is based on an ingenious blend of case-based and rule-based reasoning paradigms. This system, to my knowledge, is one of the most advanced prototypes in terms of scale and the tools it uses. Its prime focus, however, has been on parallel processing. I found that it lacks clear semantics in representing legal knowledge, and its cognitive model does not capture many important aspects of law, such as, hypothetical reasoning and legal debate.

I reckon law as an interesting domain for experiments in the design and development of advanced KBS. The aim of my research is to derive a formal yet practical computational model for trial reasoning systems. This model will address key research issues in law such as legal knowledge representation, inference structure, and multi-agent debate. The formulation involves a blend of situation semantics and distributed artificial intelligence. I am collaborating with ICOT researchers in the design and development of a large-scale, parallel knowledge-based system based on this model. Different aspects of this model have been reported in two international conferences in AI and Law. If this research proves successful, it will contribute new advances in the field of AI and Law. Details about the approach and methodology used is described in related ICOT technical reports.

Before joining the legal reasoning group, I was attached to the knowledge base management system (KBMS group, headed by the now chief researcher of ICOT, Mr. Kazumasa Yokota. The group was developing QUXIOTE, a database programming language that exhibits features of both deductive object-oriented (DOOD) language and constraint logic programming. It resembles F-logic, in that it is a DOOD language that includes powerful extensions into logic programming such as subsumptions, complex objects, and modules. Professor Micheal Kifer has recently visited ICOT and has a fruitful discussion with us on this topic. In comparison, the work of Kifer's group is concerned with the semantics of deductive object-oriented database systems rather than building practical tools. The other similar effort in deductive object-oriented database, I can recall, is the CHIMERA project, leaded by Professor S. Ceri in Europe, who visited ICOT in the beginning of this year. The development of this project, however, has not yet progressed to the stage of QUIXOTE.

The cross-study beared fruit. In last July, Mr. Satoshi Tojo, a former member of KBMS group now at Mitsubishi Research Institute, and I wrote a paper on how QUXIOTE can be used to implement the situated-theoretic model which I devised for legal reasoning. To our knowledge, this is the first reported work that brings together two previously unrelated fields, namely, deductive object-oriented databases and situation theory, to design knowledge systems for solving complex problems and for modeling human intellectual behavior. It is also the first attempt to enhance the reasoning capability and application scale of the current generation of legal reasoning systems with an advanced database tool.

To a less extent, I also collaborate with Mr. K. Onizuka of the Genetics Information Processing (GIP) group in addressing a long-standing problem faced in biomedicine: how to predict complex protein structures accurately.

In contrast to the legal reasoning project, this research is highly empirical and quantitative. Our method involves a rare mix of the techniques of AI, such as knowledge representation, and those of signal processing, such as wavelet transformation. Traditionally, computational biologists have treated AI and signal processing as orthogonal

approaches. We, however, perceive that there can be a fruitful interplay between the two approaches. The success of such a method will have significant impact on the field of molecular biomedicine.

Our research plan is to build the prediction model in three phases. In the first phase, an effective method to classify protein structures is developed. In the second phase, a scheme to study the constraints between a local protein structure and the primary structure of that region is designed. The constraints found can be used to predict possible protein tertiary structures from amino acid sequences. In the last phase, the results obtained from existing protein databases and laboratory experiments are evaluated. The knowledge gained from analysis can be used to improve the prediction model. Partial results have been reported in international conferences on computational biology. However, due to time constraint, I did not devote as much time as I would like in this project at the later part of my stay.

External technical publications, other then ICOT reports, which are published or accepted during this period (April 1 to August 18) are listed as follows.

1) S. T. C. Wong, "COSMO: a communication scheme for cooperative knowledge based systems," IEEE Trans. on Systems, Man, and Cybernetics, to appear.

2) S. T. C. Wong, "Cooperative decision making based on preferences," ACM Trans. on Information Systems, to appear.

3) S. T. C. Wong, "OPUS: an open system knowledge framework and its application for bridge evaluation," IEEE Trans. on Systems, Man, and Cybernetics, to appear.

4) S. T. C. Wong, "Messages and protocols for cooperative knowledge systems," Multi-agent and cooperative computation II, Lecture notes/software science, Kindai-kagakusha, Japan, July, 1993.

5) with K. Nitta, "The role of massive parallelism in parallel inference applications," AAAI-93 Spring Symposium on Innovative Applications of Massive Parallelism, Stanford, CA, April, 1993.

6) with K. Nitta, I. Oktake, "A computational model for trial reasoning," 4th Int. Conf. on AI and Law, Holland, June, 1993.

7) with K. Onizuka and K. Asai, "A multi-level description scheme of protein conformation," First Int. Conf. on Intelligent Systems for Molecular Biology, July, 1993.

The following papers are currently under peer review:

1) S. T. C. Wong, "Coping with conflict in cooperative information systems," submitted to ACM Trans. on Information Systems, April, 1993.

2) with C. Troy, J. Fu, "A product assembly and restoration planning system for ecologically friendly factory," submitted to JSPE-ISIP WG 5.3, Workshop on "Design of information infrastructure systems for manufacturing," June, 1993.

3) with S. Tojo, "A KBMS for Modeling Situated Inference in Legal Reasoning Systems," submitted to International Conf. on Extended Database Technology, England, July, 1993.

4) with S. Tojo, "A deductive object-oriented database for situation inference in law," submitted to IEEE Trans. on Knowledge and Data Engineering, August, 1993.

3 Interaction with ICOT and External Researchers

Dr. K. Nitta is my host. He has oriented me on the main research activities of ICOT. In general, I found the researchers to be bright, well-informed, and open in sharing information. From the discussions with them, I learnt about a variety of interesting theories, implementations and applications pertaining to the field of knowledge information processing – many of these were entirely new to me. The discussions also helped me to identify the two collaborative projects in law and biomedicine.

It is difficult for me to describe the numerous discussions I have had with the researchers here. Instead, I mentioned the major ones:

- **Knowledge-Based Management System:** The chief researcher, Mr. K. Yokota, explained to me the theory and design of QUIXOTE, an object-oriented deductive system for knowledge representation. This has a strong connection to my research on the knowledge-based management system (KBMS). My view is that the fields of deductive databases and object-oriented databases will be merged in the future. (For me, an object-oriented deductive database (OODB) is, essentially, a knowledge base.) I believe that a purely object-oriented database system must be implemented and shown to be useful. The work of QUIXOTE is important in this aspect. The operational semantics of QUIXOTE, however, has to develop to match its graphic-oriented declarative semantics. This would have as fundamental impact as on OODB research as the linking of SLD resolution to Hebrand models did in the field of logic programming. None of the leading OODB projects, to my knowledge, has offered both operational and declarative semantics for their prototypes.

  I have had productive discussions with the linguistics researchers, especially Mr. Yasukawa (now at Masushita Electric) and Dr. Hasida (now at Electrotechnical Laboratory on situation semantics. Their interpretations changed my previous

negative impression of this field. It motivates me to develop a formal yet practical model of legal reasoning based on situation semantics.

- **Parallel Applications:** Dr. Nitta, and many other researchers in this group presented me with various innovative applications in such areas as protein sequence analysis, legal reasoning, Go-playing board game, and VLSI design layouts. In addition, the working group system of ICOT allows these researchers to cooperate with external experts, such as biologists and lawyers, in these projects. The original emphasis of these applications was to demonstrate the efficiency of parallel inference machines. However, I am not happy with the lack of rigorous theory and pure logical semantics in these applications. It would be very interesting and useful to find formal, logical reconstructions for many of these systems. This would help to generalize results and to make fundamental contributions to selected application domains. I thus designed a formal computation model of legal reasoning based on situation theory. This theory is shown to be implementable in Quixote in a paper which I wrote recently together with S. Tojo.

- **Constraint Logic Programming:** Dr. A. Aiba and Mr. K. Satoh (now at Fujitsu Software Engineering Laboratory) described their recent work on constraint logic programming languages, CAL and GDCC, to me. CAL is a sequential constraint logic language with algebraic, Boolean, set, and linear constraint solvers while GDCC is its parallel extension with the addition of integer solvers. The work seems to be very good and has the potential to extend the computational and expressive power of the logic programming paradigm. I was impressed by the speed of the group's algorithms for solving algebraic constraints, in comparison to existing systems. For practical applications, it comes to my mind that these tools should be used for hardware verification or the generation of test patterns. It also occurs to me that the combination of this paradigm with automated theorem proving may be able to address many hard AI problems.

- **Theorem Proving:** The major result gained from automated reasoning systems was the development of a parallel theorem proving system, MGTP, in the KL1 language on the parallel inference machine (PIM). I have long recognized the importance of high performance automated reasoning systems so it was with great interest that I learned of ICOT's MGTP project. My meetings with Dr. Hasegawa and Mr. Shirai were educational. They explained to me the theory and inner working of this theorem prover. MGTP could be used not only to prove theorems but also to generate models for a satisfiable theory. As an extension of SATCHMO, the theorem prover developed at ECRC, this kind of bottom-up theorem prover seems to be especially appropriate for execution by KL1. The parallel language can handle the generation of ground models efficiently since it uses pattern matching as

its basic method of parameter transfer. In exchange, I showed the significance and possible applications of such a prover ¿from the standpoint of knowledge representation. But I, unfortunately, did not have time to pursue this issue further.

As the preeminent research institute in the world, ICOT experiences a constant stream of visiting international computer scientists. This exposes me to many of the challenging computer research activities being conducted worldwide. Meanwhile, under the auspices of ICOT, I have delivered several lectures on my research to many Japanese laboratories. Through these interactions, I have gained a good understanding of the research infrastructure in Japan and first-hand knowledge in many interesting projects. A list of major external interactions is as follows.

- **Sony Computer Science Laboratory:** This laboratory is headed by Dr. Mario Tokoro, who is also a professor at Keio University. Its focus is on 'Open-System' computing. In May, I presented a seminar on a theory for multi-agent conflict resolution based on free logic semantics. The Sony researchers were so intense that the original one-hour talk ended up being an intensive three-hour debate.

  I made many visits to this laboratory. I have had many productive meetings with their researchers and visitors, especially productive were my discussions with Dr. Alan Bond (UCLA), on the direction and problems of DAI research, Prof. Misbah Deen (University of Keele, England), on the hard issues of cooperative knowledge-based systems (CKBS), and Dr. Shigeru Watari on knowledge representation of multiple perspectives.

- **NTT Communication Science Laboratory:** This is NTT's newest research laboratory, and unlike the others, it is located in Nara, an important cultural and historical city not far from Osaka. One of its major research activities is DAI. I presented a lecture on a communication scheme for cooperative AI systems and talked to NTT researchers about their demonstration systems and research activities. I had a very stimulating and extended discussion (four hours) with the manager of the DAI group, Dr. Ihru Ishida. We exchanged our views on issues about the scientific and economic impact of DAI.

- **NTT Information Science Laboratory:** This is one of NTT's basic research laboratories. I had delivered a talk there. The researchers at this location described to me the recent progress of their research. Especially, I had a stimulating meeting with Mr. Hideki Isozaki, concerning his work on two-dimensional temporal logic. The manager, Mr. Hirfumi Katsuno, also explained to me his interests in cooperative knowledge bases.

- **MITI's Mechanical Engineering Laboratories:** I visited the Manufacturing Information Division in May and June and presented them many advantages of

using knowledge processing techniques to address new manufacturing problems, especially that of environmental concerns. They are now looking into this approach.

- **The Chinese University of Hong Kong:** I have given two seminars in the department of computer science and the department of system engineering in April and in May, 1993. These seminars concern different topics in multiagent problem solving. The discussion with the faculty members (mostly educated in Britain and America) there was stimulating.

One observation I made during those interactions was that many Japanese researchers whom I know are well-versed in individual areas, but show little interest or awareness in research outside their specialities. This differs from the 'broad and deep' education model of the United States.

4 Conclusions

The stay in ICOT kept me busy. I am impressed by the range and depth of research being carried out here. I have learned a lot and found many relationships between my work and the work being conducted by many research groups, especially in legal reasoning, KBMS, and GIP. ICOT provides an excellent, friendly environment for collaborative research. I have also involved in three Post-ICOT projects. All these projects are strongly multidisciplinary. In addition to the study of many core issues in knowledge information processing, these projects have the potential to make significant contributions to database, law, and biomedicine.

One major criticism that is commonly heard about ICOT is that the research conducted is too narrow and specialize. However, I experience otherwise. As indicated in Section 2, I published quite widely during my stay, often in cooperation with ICOT researchers. Meanwhile, an unexpected gain has been a good understanding of the research infrastructure of Japan.

The research at ICOT is so wide-ranging that I saw too much for me to understand it all at once. I will spend a lot of time in the future thinking over some of the questions and issues that were raised here. My current research in biomedicine will apply many techniques learned here. I hope to have opportunity to continue my cooperation with Japanese scientists and researchers in the near future.

5 Acknowledgement

I would like to thank ICOT Research Center for the invitation to collaborate with their researchers. My thanks to the former director of ICOT Center, Fuchi-san, and the current director, Uchida-san for their invitation, and to Nitta-san, and Yokota-san in

whose laboratories I spent most of my time, and to Tojo-san, Ohsaki-san, and Onizuka-san for their open and active cooperation. Special thanks to the people in the Research Planning Department, in particular, Narita-san, Komiko-san, Ogawa-san, and Iwata-san (now at Toshiba R&D Center) for their assistance and kindness during my stay. I would also like to acknowledge the NSF Japan Program, their recommendation made my research at ICOT possible. Finally, I look forward to any future collaboration with the people now in the follow-on project of ICOT.

Resume

Stephen T. C. Wong
email: wong@icot.or.jp

Qualification:

Ph. D. in Computer Science, Lehigh University, 1991.
M. Sc. in Computer Science, Lehigh University, 1989.
B. Eng. in E.E. (Honors IIA), The University of Western Australia, 1983.
Licensed Professional Engineer (Electrical) of USA.

Status: British citizen, USA permanent resident.

Professional Experience:

3/92 –present, ICOT
Parallel knowledge processing for legal and genetics applications.
Knowledge/databases management system.
9/87-2/92, NSF Engineering Research Center at Lehigh
Research in AI and cooperative computing.
Knowledge-based system (BFI) for bridge evaluation.
- (to be adopted by US Federated Highway Administration).
Cooperative information system (CBDN) for building design.
9/85-8/87, AT&T Bell Labs
VLSI factory automation and networking.
1/84-8/85, Hewlett Packard Company
Production and automation for optoelectrics and IC.
2/83-12/83, The University of Western Australia
Design optical time domain reflectometer (OTDR) for Australian Telecom.
10/82-2/83, The Australian National University
Control software development.

Technical knowledge:

Software – Knowledge/database systems; compiler design; UNIX internals; groupware; languages such as Prolog, KR1, C, C++, Fortran, Pascal, Lisp, and Smalltalk; assembly and macro languages; operating systems.

Hardware – Networking (LAN, MAN, WAN, ISDN); optical and signal processing; architecture and digital design; control systems; automation.

General – Project management; system integration; field knowledge in electronics, telecommunication, and construction industries; fabrication and manufacturing process for optics, VLSI, and OEM; quality control; formal techniques in computer science and electrical engineering.

Awards:

STA Award, The Science and Technology Agency, Japan, 1992-93.

NSF Grant No. INT-9123128, 1992-94.

NSF–ERC Scholarship, Lehigh University, 1987-92.

Gleddon Tour Scholarship, The University of Western Australia, 1983.

Vocational Scholarship, The Australian National University, 1982