Constrained Object Hierarchy
—An Architecture for Intelligent Systems

Hongxue Wang
Department of Computer Science
The Australian National University
ACT 0200, AUSTRALIA
Email: hongxue@cs.anu.edu.au

This thesis will report investigations into an architecture for intelligent systems and associated knowledge representation scheme. Such a system is an object containing subobjects like itself, some actions which can be taken and a set of constraints which these must satisfy. The language for programming these systems is quite general, high level and declarative. Our implementation takes advantage of the naturally distributed architecture for concurrent computation.

Any computing system is a kind of abstraction of some part of the real world. Computer scientists have traditionally worked on how to make abstractions from the world, how to encode an abstraction into a computer system and how to manipulate the abstraction inside the system for desired purposes. As a result, special features and micro-structures of many parts of the world are well understood, and many formalisms such as programming languages and knowledge representation schemes have been invented, while many manipulation strategies such as those of calculation and inference have been developed. However, the general features and the macro-structures of the real world have been less investigated and rarely used for abstraction—that is, for the development of computing systems. This is the problem to be addressed in the thesis.

We begin from a generic framework, which we develop by reflecting on generic aspects of the world and some theoretical and technical results in computer science. The following contributions should be made by the thesis:

1. It will address difficulties arising in developing such a representation scheme and problem solving system;
2. The generic formalism will be widely applicable for abstraction and for computer-based intelligent system development;
3. As normal, it will provide a mechanism whereby large scale computing systems can easily be developed from small ones;
4. Distributed and parallel computation can naturally be applied in such a computing system;
5. We may gain better understanding of the structure of real world problems on which our abstraction is based.

In our account, any part of the real world is treated as a constrained object hierarchy(COH), which is made from three kinds of components: relatively static objects, functional actions and relations between object and object, action and action or object and action. Three major issues arise. The *particle problem* is that of ontology: what ground objects, primitive actions and fundamental relations should be used? The *construction problem* is how to combine primitives to introduce new objects, actions and relations for abstracting a specific part of the world. Finally, the *manipulation problem* is how to define the computations needed within a constrained object hierarchy and to determine how these should be carried out.

Investigation of the first two problems has led to the integration of objects from OOP and constraints from CSP, with a mechanism for pushing constraints into object hierarchies. It becomes evident that many different computing systems can be easily formalised as constrained object hierarchies of this kind.

Resolving the third issue has produced a classification of problem solving tasks, a classification of the elementary computations which can be carried out within a constrained object hierarchy. Some strategies for controlling various computations and their interactions have also been proposed.

As part of the research, an implementation of COH theory has been made for a parallel computer. It is being used to evaluate the correctness of the theory and the efficiency of some proposed computation strategies, and to develop algorithms such as for constraint resolution within object hierarchies.

This research cuts across many boundaries within the field of AI, having connections with knowledge representation, constraint-based reasoning, reactive systems and distributed AI. We aim at an enhanced declarative formalism for knowpedge and problem representation, at a powerful engine for solving a wide range of problems and at a generic architecture for developing intelligent systems.