Chapter 8: Conclusions

There are several major aspects to the work reported in this thesis: the formalization of situation theory, using situation theory in knowledge representation, and automating theorem proving for situation theory, beliefs, and perception.

Formalizing Situation Theory

Situation theory as generally propounded is insufficiently specific on a number of issues to use directly as a basis for knowledge representation. However, using the basic postulates of situation theory as a guide, the notion of support is extended in this thesis to provide a foundation for a "full" (if nonclassical) logic of "infons". This logic is full in the sense that there are semantics for versions of all of the common logical connectives and for qualification, making it appropriate for formalizing simple theories of belief and perception. This in turn provides a formal theory appropriate for expressing many problems in knowledge representation. Other infon logics have been sketchy with respect to these common features (e.g. negation and quantification).

The guiding postulates relied on in the development of the infon logic are the persistence of infons, the partiality of situations, and the consistency of situations. The definitions of the support of the '$\Rightarrow$' infon connective, the negation operator, and universal infon quantification which are developed are unique to this work. That is, they are not exactly the definitions found in any other work on situation theory. The justification for this is that they are the definitions which satisfy the minimal postulates about what these things should mean and also obey the guiding postulates.

Thus, the '$\Rightarrow$' connective satisfies the deduction theorem, which is the minimal postulate of what this connective should mean. But, it does *not* satisfy the equivalence a formula using disjunction and negation: '$A \Rightarrow B$' iff '$- A \vee B$'. This is because this equivalence leads to a contradiction of the partiality of situations or the persistence of infons (depending on the definition of negation).

The negation operator is defined to be a "positive" statement about some state of affairs, as opposed to simply a claim that the state of affairs being negated is not supported. This is necessary to support the situation theoretic concept of a "dual" of an infon. The other definition of the negation operator is referred to as "weak" negation and can be defined in terms of the '$\Rightarrow$' connective, strong negation, and the consistency postulate.

The definition of the support for a universal quantification infon is stronger than one might expect, but is just that which is necessary for the persistence of infons. The weaker form of universal quantification can be defined by changing the universally quantified formula to a conditional with a predicate that restricts the domain of the bound variable as the antecedent and the original formula as the consequent. The domain of the bound variable can be restricted to the constituents of a particular situation in this fashion, yielding the more common definition of universal quantification found in the situation theory literature. This latter approach, restricting a variable's domain to the constituents of some situation, is one which was never needed in any of the problems addressed by this thesis.

Formalizing Theories of Perception and Belief

The simplified theory of perception which Barwise developed as a situation theoretic account of perception is given a formal expression in the logic developed in this thesis. This theory of perception successfully addresses certain problems not handled in other, more traditional, approaches to perception.

A simplified theory of belief based on commonly accepted postulates is given a situation theoretic formulation in this thesis. This theory allows the expression of various ideas about beliefs not possible in the more traditional approaches, due to the added "degrees of freedom" present in explicitly representing the situations involved in the beliefs, and the partial nature of situations.

Situation Theory and Knowledge Representation

Using situation theory as a basis for representing knowledge provides a richer analysis of knowledge than a traditional approach based on classical logic. A few possibilities of this richer representation have been explored in reasoning about beliefs and perception. This richer representation exposes some issues in defining the principles of belief which are not apparent in a classically oriented formulation. Particularly, the principles of Knowledge and Consistency are independent in the situation theoretic formulation, but are not independent classically. A major benefit of this richer representation is that one can account for phenomena which cannot be described classically. In the belief theory for instance, one can be precise about the situations which an agent believes support particular infons, and avoid drawing inferences about what the "perfectly rational" agent should believe which are not warranted by that agent's partial comprehension of its world.

A price one pays for the richer representation is greater complexity in the system which employs such a representation, and greater complexity in formalizations in such a representation. Even though the situation theoretic formalizations of the poker game problems and the wise men problem are greatly simplified by eliminating the explicit location arguments and by combining situations, the representations are still complex. In the case of the poker game, since no other formalization has been produced for this problem, and three authors argued that there may not *be* a classical formulation of this problem, the complexity is just that which is appropriate to the problem. In the case of the wise men problem, there are many classical formulations which appear much simpler than the one used in this thesis. However, the analysis used here indicates that the classical formulation *oversimplifies* the problem, leaving out an important piece of information (i.e. that wise man A believes the situation B sees determines whether or not A has a white dot). This piece of information must be left out since there is no way to say it in the classical formulation. Thus, it is not until one attempts the richer formulation in situation theoretic terms that one discovers this otherwise implicit information. This information stems from the nature of perception and A's assumptions about what B perceives, something which can be formalized in terms of the theory of perception used in this thesis, but which is problematic to formalize classically, as discussed in chapter 5.

There are many knowledge representation issues which this thesis does not explore; time, substances, and actions to name a few. These are of course areas for future research.

FELIX: Automating Theorem Proving for Situation Theory, Beliefs, and Perception

The natural deduction style theorem prover produces proofs which are reasonably comprehensible, in contrast with those produced by other automated theorem proving methods. This is the intended situation. FELIX is complicated in several ways; there are many inference rules (about 40), the search algorithm interleaves two different kinds of searches - backward AND/OR tree problem decomposition and forward breadth first reasoning, suppositional reasoning, and multiple intensional contexts. These complexities are the price for the comprehensibility of the resulting proof and the reasonably efficient nature of the search. A resolution-based theorem prover uses a comparatively simple search algorithm. It will generally produce a proof which involves many more steps than the natural deduction style theorem prover. Each of these inference steps is made very efficiently, so the two approaches can be of similar efficiency overall. Pollock's implementation of OSCAR is more efficient than many resolution-based theorem provers on many theorems.

FELIX's interest-driven, suppositional reasoning lends itself to the significant extension to handling multiple intensional contexts. Reasoning in multiple intensional contexts effectively supports various kinds of "intensional" reasoning. In this thesis, examples of "intensional" reasoning include the supports relation and beliefs. Other kinds of "intensional" reasoning include reasoning about knowledge, doubts, and hopes.

The Implementation of FELIX

FELIX is implemented in LPA MacProlog on a Macintosh II. This provided an adequate development environment, although there are many ways in which it can be improved. The author finds the Prolog language easy to use for implementing large complex systems such as FELIX, although a richer suite of tools for the development environment would be much appreciated. Some Prolog implementations have more such tools than LPA MacProlog does, but these don't run on the Macintosh or were not available when this project was begun.

This implementation of FELIX is not as efficient as that of Pollock. Pollock's FELIX is implemented in LISP on a Symbolics. The LPA MacProlog is not a very fast implementation of Prolog, and the Macintosh II is not a very fast machine. The optimizing compilation in LPA MacProlog decreases the running time of FELIX (compared to non-optimized compilation) by about a factor of 2 for all of the test cases. It's not known how the algorithms used in the implementations (data structures, search techniques, etc.) compare, thus there may be a difference in efficiency due to implementation differences (aside from simply the different language paradigms).