grammar and purely linguistic theory with parsing techniques; it is a pity that their articles in this book make no suggestion of such a combination.)

In summary, this book is not systematic enough for an introductory text, and it surveys too much familiar work for a research collection. Although the book is not suitable as a primary textbook, parts of it would make good supplementary reading for a course in AI or computational linguistics.

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Automated Theorem Proving: A Logical Basis

D.W. Loveland

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To determine whether someone understands a text, such as a story, essay, or poem, he is asked questions that require him to draw inferences from what he has read. Since the text, questions, and answers are all in natural language, a theory of natural language understanding is not satisfactory if it cannot support a model of how questions are answered. When linguists propose explanations for natural language, therefore, they must consider the inference procedures that will be needed to extract information from the representations in their theories.

The inference process associated with the answering of questions can be formally characterized as theorem proving, the subject of Loveland's book. Loveland presents mostly various methods of theorem proving by resolution, but the most attractive method he presents is a non-resolution approach that extends the problem reduction method in artificial intelligence. In the problem reduction method, a question Q is reduced to a set of subquestions P1, P2, ..., Pn by application of the assertion

$$P1 \; \& \; P2 \; \& \; \ldots \; \& \; Pn \supset Q$$

which is called an implication. The terms Pi and Q are atomic statements or their negations. Loveland points out that the problem reduction method is not complete, i.e., that it cannot always answer answerable questions. From the assertions

$$P \supset Q, \quad \sim P \supset Q$$

for example, the question Q cannot be answered yes (shown to be a theorem) even though that is logically implied. (The incompleteness comes from the fact that negation is a primitive in first order logic. See Black [1] and Smullyan [3] for systems that do not have negation as a primitive and for which problem reduction is complete.)

Loveland's extension to the problem reduction method, named the MESON format (called a format because many design choices are left to the implementer), adds several rules to the problem reduction method which make it complete. These rules do not complicate the method very much; the most important new rule, for instance, states that when answering a question Q, if one of the resulting subquestions is ~Q, then that subquestion is considered to be successfully answered in the affirmative. (This rule is essentially proof by contradiction.) The MESON format is partially described elsewhere (Loveland and Stickel [2]), but this book is the source for a full description and a proof of its completeness.

The book is divided into six chapters. The first two chapters review the basic concepts of first order logic and explain the basic resolution procedure. Chapter 3 presents several refinements of resolution, including unit preference, set-of-support, linear refinements, and model elimination. Chapter 4 discusses subsumption, a technique that removes redundant expressions from further consideration. Chapter 5 adds paramodulation, the inference rule that handles equality in the context of a resolution-based theorem proving system. The last chapter is devoted to the MESON format. In a sense Chapter 6 is the climax of the book because the MESON format is justified on the basis of theorems about resolution in the preceding five chapters.

This book is a well organized and well written reference for mechanical theorem proving methods presented at the algorithmic level. More than this should not be expected. It assumes that the reader has an acquaintance with formal logic. It proves rigorously nearly every theorem presented, and there are many. Many technical terms are defined throughout the book, as is typical of mathematical treatments. Although theorem proving consists of two parts, a mechanism that defines a search space and a control that guides the search in that space, the techniques described in the book are only the space defining mechanisms. Details of the guiding controls are still the subject of research.

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References

1. Black, F. A deduction question-answering system, *Semantic Information Processing,* Marvin Minsky, ed., MIT Press, Cambridge, MA (1968), 354-402.
2. Loveland, D. W. and Stickel, M. E. A hole in goal trees: Some guidance from resolution theory, *Proc. Third IJCAI,* Stanford, Calif. (August 1973), 153-161. Also in *IEEE Trans. on Computers* C-25 (April 1976), 335-341.
3. Smullyan, R. M. *Theory of Formal Systems.* Annals of Mathematics Studies, No. 47, Princeton University Press, Princeton, N.J., 1961.