SEMANTIC INFORMATION PROCESSING

Semantic Information Processing

Marvin Minsky, Editor

The MIT Press
Massachusetts Institute of Technology
Cambridge, Massachusetts, and London, England

Set in IBM Press Roman. Printed and bound in the
United States of America by Publication Press, Inc.

Library of Congress catalog card number: 68-18239

Preface

How can one make machines understand things? This body is a collection of studies in *artificial intelligence*, the science of making machines do things that would require intelligence if done by men.

Most of the chapters are slightly edited Ph.D. theses, and the book is to serve two purposes: to make the results of these dissertations more available to scientists, and to exhibit the work to students searching for new problems in this area. Abbreviated versions of such studies, as usually presented in scientific journals, rarely suffice as a basis either for further work or for critical evaluation. Besides, the uncompressed original dissertations are usually easier to read and understand.

Each of the projects described in this book has already inspired more ambitious attacks. I hope to collect reports of those that succeed into a second volume within the next year or two.

In the long introduction that is Chapter 1, there are scattered remarks about contributors to this work. I want to acknowledge explicitly the influence of my own collaborators, John McCarthy and Seymour Papert, on the work that was done at M.I.T., and the support of that work, in its early years, by the M.I.T. Research Laboratory of Electronics and the M.I.T. Computation Center and, in recent years, by the Advanced Research Projects Agency through M.I.T.'s Project MAC. I want also to thank Edmund C. Berkeley for demanding and helping to get the papers collected and published.

Cambridge, Mass. Marvin Minsky
July 1968

Contents

Preface v

1. Introduction, Marvin L. Minsky 1

1.1 Survey 1
1.2 Organization of the Book 3
1.3 Artificial Intelligence and its Cybernetic Background 6
1.4 The Period between 1955 and 1962 8
1.5 Formality 11
1.6 Generality 13
1.7 Learning 13
1.8 Knowledge 17
1.9 Grammar, Syntax, and Parsing Programs 20
1.10 Machine Translation of Languages 24
1.11 How Much Semantic? 25
1.12 Relevance and Structure 26
1.13 Practical Problems of Mechanizing Large Models 27

2. SIR: A Computer Program for Semantic Information Retrieval, Bertram Raphael 33

2.1 Introduction 33
2.2 Semantic Information Retrieval Systems 37
2.3 Representations for Semantic Information 48
2.4 SIR Treatment of Restricted Natural Language 58
2.5 Behavior and Operation of SIR 64
2.6 Formalization and Generalization of SIR 90
2.7 Conclusions 110

3. Natural Language Input for a Computer Problem-Solving System, Daniel G. Bobrow 146

3.1 Introduction 146

3.2 Semantic Generation and Analysis of Discourse 155
3.3 Programming Formalisms, and Language Manipulation 167
3.4 Transformation of English to the STUDENT Deductive Model 172
3.5 Storage of Global Information 195
3.6 Solution of Simultaneous Equations 197
3.7 Conclusion 201
4. Semantic Memory, M. Ross Quillian 227
4.1 The Role of Semantic Memory 227
4.2 The Memory Model 234
4.3 Use of the Memory Model in a Simulation Program 246
4.4 The Memory Model as Basis for a Theory of How People Comprehend Language 256
4.5 Some Final Implications and Relations to Linguistic Theory 259
5. A Program for the Solution of Geometric-Analogy Intelligence Test Questions, Thomas G. Evans 271
5.1 Introduction 271
5.2 The Complete Solution Process: Two Examples 288
5.3 Analogy: Part 1 297
5.4 Analogy: Part 2 317
5.5 Results and Discussion 327
5.6 Conclusions 341
6. A Deductive Question-Answering System, Fischer Black 354
6.1 Introduction 354
6.2 Statement, Question, and Answer 357
6.3 Deduction 363
6.4 Stopping Endless Deduction 371
6.5 Avoiding Endless Deduction 378
6.6 Examples 384
6.7 Efficiency 391
7. Programs with Common Sense, John McCarthy 403
7.1 The Advice Taker 403
7.2 Situation, Actions, and Causal Laws 410
8. Descriptive Languages and Problem Solving, Marvin L. Minsky 419
8.1 Introduction 419
8.2 The Need for Analysis 420
8.3 Conclusion 423
9. Matter, Mind, and Models, Marvin L. Minsky 425
9.1 Introduction 425
9.2 Knowledge and Models 425
9.3 Models of Models 426
9.4 Dimorphism of our World Models 427
9.5 The Central Argument: Belief in Dualism 428
9.6 Heuristic Value of Quasi-Separate Models 428
9.7 Interpreters 430
9.8 Free Will 431
9.9 Conclusion 431
Subject Index 433
Name Index 437

1. Introduction

Marvin L. Minsky

1.1 Survey

This book presents a group of experiments directed toward making intelligent machines. Each of the computer programs described here demonstrates some aspects of behavior that everyone would agree require some intelligence.

Each program solves different kinds of problems. These include resolving ambiguities in word meanings, finding analogies between things, making logical and nonlogical inferences, resolving inconsistencies in information, engaging in coherent discourse with a person, and building internal models for representing newly acquired information. The programs are very limited in the range of situations they can handle. This survey will attempt a perspective for viewing these achievements and limitations.

Within the small domain in which each program operates, the performance is not too bad compared with some human activities. Thus Bobrow's STUDENT program (Chapter 3) rivals, within its algebraic scope, the average high-school student. Evans's ANALOGY program (Chapter 5) works also at this respectable level. The reasoning abilities of the programs of Black and Raphael (Chapters 6 and 2) could perhaps be compared with those of slightly younger children, and we simply do not know enough about how powerful Quillian's methods (Chapter 4) would be when provided with a more substantial knowledge bank. But much more important than what these particular experiments achieve are the methods they use to achieve what they do, *for each is a first trial of previously untested ideas.*

These programs work by setting up goals, trying to fit data into previously acquired patterns, forming and testing hypotheses, and so forth, often by using the meanings of statements that have been made to them.