# Contents

# PREFACE xi

## Chapter 1

1.3

## Introduction to Natural Language Understanding

- 1.1 The Study of Language 1
- 1.2 Applications of Natural Language Understanding 3
  - Evaluating Language Understanding Systems 6
- 1.4 The Different Levels of Language Analysis 9
- 1.5 Representations and Understanding 11
- 1.6 The Organization of Natural Language Understanding Systems 15

# PART I SYNTACTIC PROCESSING

## Chapter 2

#### Linguistic Background: An Outline of English Syntax

- 2.1 Words 23
- 2.2 The Elements of Simple Noun Phrases 25
- 2.3 Verb Phrases and Simple Sentences 28
- 2.4 Noun Phrases Revisited 33
- 2.5 Adjective Phrases 35
- 2.6 Adverbial Phrases 35

## Chapter 3

## **Grammars and Parsing**

- 3.1 Grammars and Sentence Structure 41
- 3.2 What Makes a Good Grammar 44
- 3.3 A Top-Down Parser 47
- 3.4 A Bottom-Up Chart Parser 53
- 3.5 Transition Network Grammars 61
- 3.6 Top-Down Chart Parsing 65
- 3.7 Finite State Models and Morphological Processing 70
- 3.8 Grammars and Logic Programming 72

(o-optional topic)

#### Chapter 4 Features and Augmented Grammars

- 4.1 Feature Systems and Augmented Grammars 83
- 4.2 Some Basic Feature Systems for English 86
- 4.3 Morphological Analysis and the Lexicon 90
- 4.4 A Simple Grammar Using Features 94
- 4.5 Parsing with Features 98
- 4.6 Augmented Transition Networks 101
- 4.7 Definite Clause Grammars 106
- 4.8 Generalized Feature Systems and Unification Grammars 109

#### Chapter 5

#### **Grammars for Natural Language**

- 5.1 Auxiliary Verbs and Verb Phrases 123
- 5.2 Movement Phenomena in Language 127
- 5.3 Handling Questions in Context-Free Grammars 132
- 5.4 Relative Clauses 141
  - 5.5 The Hold Mechanism in ATNs 144
  - 5.6 Gap Threading 148

#### Chapter 6

#### **Toward Efficient Parsing**

- 6.1 Human Preferences in Parsing 159
- 6.2 Encoding Uncertainty: Shift-Reduce Parsers 163
- 6.3 A Deterministic Parser 170
- 6.4 Techniques for Efficient Encoding of Ambiguity 176
- 6.5 Partial Parsing 180

#### Chapter 7

#### **Ambiguity Resolution: Statistical Methods**

- 7.1 Basic Probability Theory 189
- 7.2 Estimating Probabilities 192
- 7.3 Part-of-Speech Tagging 195
- 7.4 Obtaining Lexical Probabilities 204
- 7.5 Probabilistic Context-Free Grammars 209
- 7.6 Best-First Parsing 213
- 7.7 A Simple Context-Dependent Best-First Parser 216

## PART II SEMANTIC INTERPRETATION

#### Chapter 8 Semantics and Logical Form

- 8.1 Semantics and Logical Form 227
- 8.2 Word Senses and Ambiguity 231
- 8.3 The Basic Logical Form Language 233
- 8.4 Encoding Ambiguity in the Logical Form 238
- 8.5 Verbs and States in Logical Form 241
- 8.6 Thematic Roles 244
- 8.7 Speech Acts and Embedded Sentences 250
- 8.8 Defining Semantic Structure: Model Theory 251

## Chapter 9

### Linking Syntax and Semantics

- 9.1 Semantic Interpretation and Compositionality 263
- 9.2 A Simple Grammar and Lexicon with Semantic Interpretation 267
- 9.3 Prepositional Phrases and Verb Phrases 271
- 9.4 Lexicalized Semantic Interpretation and Semantic Roles 275
- 9.5 Handling Simple Questions 280
- 9.6 Semantic Interpretation Using Feature Unification 283
- 9.7 Generating Sentences from Logical Form 286

#### Chapter 10

#### **Ambiguity Resolution**

- 10.1 Selectional Restrictions 295
- 10.2 Semantic Filtering Using Selectional Restrictions 302
- 10.3 Semantic Networks 305
- 10.4 Statistical Word Sense Disambiguation 310
- 10.5 Statistical Semantic Preferences 314
- 10.6 Combining Approaches to Disambiguation 318

#### Chapter 11

#### **Other Strategies for Semantic Interpretation**

- 11.1 Grammatical Relations 328
- 11.2 Semantic Grammars 332
- 11.3 Template Matching 334
- 11.4 Semantically Driven Parsing Techniques 341

## Chapter 12 Scoping and the Interpretation of Noun Phrases

- 12.1 Scoping Phenomena 351
- 12.2 Definite Descriptions and Scoping 359
- 12.3 A Method for Scoping While Parsing 360
- 12.4 Co-Reference and Binding Constraints 366
- 12.5 Adjective Phrases 372
- 12.6 Relational Nouns and Nominalizations 375
- 12.7 Other Problems in Semantics 378

## PART III CONTEXT AND WORLD KNOWLEDGE

#### Chapter 13

#### **Knowledge Representation and Reasoning**

- 13.1 Knowledge Representation 392
- 13.2 A Representation Based on FOPC 397
- 13.3 Frames: Representing Stereotypical Information 400
- 13.4 Handling Natural Language Quantification 404
- 13.5 Time and Aspectual Classes of Verbs 406
- 13.6 Automating Deduction in Logic-Based Representations 410
- 13.7 Procedural Semantics and Question Answering 414
- 13.8 Hybrid Knowledge Representations 419

#### Chapter 14

#### Local Discourse Context and Reference

- 14.1 Defining Local Discourse Context and Discourse Entities 429
- 14.2 A Simple Model of Anaphora Based on History Lists 433
- 14.3 Pronouns and Centering 435
- 14.4 Definite Descriptions 440
- 14.5 Definite Reference and Sets 445
  - 14.6 Ellipsis 449
  - 14.7 Surface Anaphora 455

#### Chapter 15 Using World Knowledge

- 15.1 Using World Knowledge: Establishing Coherence 465
- 15.2 Matching Against Expectations 466
- 15.3 Reference and Matching Expectations 471
- 15.4 Using Knowledge About Action and Causality 473
- 15.5 Scripts: Understanding Stereotypical Situations 477
- 15.6 Using Hierarchical Plans 480
- 15.7 Action-Effect-Based Reasoning 483
- 15.8 Using Knowledge About Rational Behavior 490

#### Chapter 16

#### **Discourse Structure**

- 16.1 The Need for Discourse Structure 503
- 16.2 Segmentation and Cue Phrases 504
- 16.3 Discourse Structure and Reference 510
- 16.4 Relating Discourse Structure and Inference 512
- 16.5 Discourse Structure, Tense, and Aspect 517
- 16.6 Managing the Attentional Stack 524
- 16.7 An Example 530

#### Chapter 17

#### **Defining a Conversational Agent**

- 17.1 What's Necessary to Build a Conversational Agent? 541
- 17.2 Language as a Multi-Agent Activity 543
- 17.3 Representing Cognitive States: Beliefs 545
- 17.4 Representing Cognitive States: Desires, Intentions, and Plans 551
- 17.5 Speech Acts and Communicative Acts 554
- 17.6 Planning Communicative Acts 557
- 17.7 Communicative Acts and the Recognition of Intention 561
- 17.8 The Source of Intentions in Dialogue 564
- 17.9 Recognizing Illocutionary Acts 567
- 17.10 Discourse-Level Planning 570

#### APPENDIX A

#### An Introduction to Logic and Model-Theoretic Semantics

- A.1 Logic and Natural Language 579
- A.2 Model-Theoretic Semantics 584
- A.3 A Semantics for FOPC: Set-Theoretic Models 588

#### APPENDIX B

#### **Symbolic Computation**

- B.1 Symbolic Data Structures 595
- B.2 Matching 598
- B.3 Search Algorithms 600
- B.4 Logic Programming 603
- B.5 The Unification Algorithm 604

# **APPENDIX C**

#### Speech Recognition and Spoken Language

- C.1 Issues in Speech Recognition 611
- C.2 The Sound Structure of Language 613
- C.3 Signal Processing 616
- C.4 Speech Recognition 619
- C.5 Speech Recognition and Natural Language Understanding 623
- C.6 Prosody and Intonation 625

#### **BIBLIOGRAPHY** 629

#### INDEX 645