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Frontmatter
More Information

Sentiment Analysis

Sentiment analysis is the computational study of people's opinions, sentiments, emotions, moods, and attitudes. This fascinating problem offers numerous research challenges, but promises insights useful to anyone interested in opinion analysis and social media analysis. This comprehensive introduction to the topic takes a natural-language-processing point of view to help readers understand the underlying structure of the problem and the language constructs commonly used to express opinions, sentiments, and emotions. The book covers core areas of sentiment analysis as well as related topics such as debate analysis, intention mining, and fake-opinion detection. It will be a valuable resource for researchers and practitioners in natural language processing, computer science, management sciences, and the social sciences.

In addition to traditional computational methods, this second edition includes recent deep learning methods to analyze and summarize sentiments and opinions, and also new material on emotion and mood analysis techniques, emotion-enhanced dialogues, and multimodal emotion analysis.

BING LIU is a distinguished professor of computer science at the University of Illinois at Chicago. His current research interests include sentiment analysis, lifelong machine learning, natural language processing, and data mining. He has published extensively in top conferences and journals, and his research has been cited on the front page of *The New York Times*. Three of his research papers also received Test-of-Time awards. He was the recipient of the ACM SIGKDD Innovation Award in 2018, and he is a Fellow of the ACM, AAAI, and IEEE. He served as the Chair of ACM SIGKDD from 2013 to 2017.

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Sentiment Analysis

Mining Opinions, Sentiments, and Emotions

Second Edition

Bing Liu

University of Illinois at Chicago, and Peking University

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2nd Edition
Frontmatter
More Information

Contents

Preface *page* xi
Acknowledgments xvi

1 Introduction 1
1.1 Sentiment Analysis Applications 5
1.2 Sentiment Analysis Research 9
1.2.1 Different Levels of Analysis 9
1.2.2 Sentiment Lexicon and Its Issues 11
1.2.3 Analyzing Debates and Comments 12
1.2.4 Mining Intent 13
1.2.5 Opinion Spam Detection and Quality of Reviews 14
1.3 Sentiment Analysis As Mini-NLP 15
1.4 My Approach to Writing This Book 16

2 The Problem of Sentiment Analysis 18
2.1 Definition of Opinion 19
2.1.1 Opinion Definition 20
2.1.2 Sentiment Target 21
2.1.3 Sentiment of Opinion 22
2.1.4 Opinion Definition Simplified 24
2.1.5 Reason and Qualifier for Opinion 26
2.1.6 Objective and Tasks of Sentiment Analysis 28
2.2 Definition of Opinion Summary 32
2.3 Affect, Emotion, and Mood 34
2.3.1 Affect, Emotion, and Mood in Psychology 35
2.3.2 Emotion 37
2.3.3 Mood 40
2.3.4 Feeling 41
2.3.5 Affect, Emotion, and Mood in Sentiment Analysis 43
2.4 Different Types of Opinions 46
2.4.1 Regular and Comparative Opinions 46
2.4.2 Subjective and Fact-Implied Opinions 47
2.4.3 First-Person and Non-First-Person Opinions 51
2.4.4 Meta-Opinions 52
2.5 Author and Reader Standpoint 52
2.6 Summary 53

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CAMBRIDGE

Cambridge University Press
978-1-108-48637-8 — Sentiment Analysis
2nd Edition
Frontmatter
More Information

3 Document Sentiment Classification 55
3.1 Supervised Sentiment Classification 57
3.1.1 Classification Using Traditional Machine Learning Algorithms 57
3.1.2 Classification Using a Custom Score Function 66
3.1.3 Classification Using Deep Learning 67
3.1.4 Classification Based on Lifelong Learning 70
3.2 Unsupervised Sentiment Classification 74
3.2.1 Classification Using Syntactic Patterns and Web Search 74
3.2.2 Classification Using Sentiment Lexicons 76
3.3 Sentiment Rating Prediction 79
3.4 Cross-Domain Sentiment Classification 81
3.5 Cross-Language Sentiment Classification 84
3.6 Emotion Classification of Documents 86
3.7 Summary 88

4 Sentence Subjectivity and Sentiment Classification 89
4.1 Subjectivity 91
4.2 Sentence Subjectivity Classification 92
4.3 Sentence Sentiment Classification 96
4.3.1 Assumption of Sentence Sentiment Classification 96
4.3.2 Traditional Classification Methods 97
4.3.3 Deep Learning–Based Methods 99
4.4 Dealing with Conditional Sentences 102
4.5 Dealing with Sarcastic Sentences 104
4.6 Cross-Language Subjectivity and Sentiment Classification 107
4.7 Using Discourse Information for Sentiment Classification 109
4.8 Emotion Classification of Sentences 110
4.9 Multimodal Sentiment and Emotion Classification 112
4.10 Summary 113

5 Aspect Sentiment Classification 115
5.1 Aspect Sentiment Classification 116
5.1.1 Supervised Learning 117
5.1.2 Lexicon-Based Approach 121
5.1.3 Pros and Cons of the Two Approaches 125
5.2 Rules of Sentiment Composition 126
5.2.1 Sentiment Composition Rules 128
5.2.2 DECREASE and INCREASE Expressions 135
5.2.3 SMALL_OR_LESS and LARGE_OR_MORE Expressions 138
5.2.4 Emotion and Sentiment Intensity 141
5.2.5 Senses of Sentiment Words 142
5.2.6 Survey of Other Approaches 144
5.3 Negation and Sentiment 146
5.3.1 Negation Words 146
5.3.2 Never 149
5.3.3 Some Other Common Sentiment Shifters 151
5.3.4 Shifted or Transferred Negations 152
5.3.5 Scope of Negations 152

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CAMBRIDGE

Cambridge University Press
978-1-108-48637-8 — Sentiment Analysis
2nd Edition
Frontmatter
More Information

5.4 Modality and Sentiment 153
5.5 Coordinating Conjunction *But* 158
5.6 Sentiment Words in Non-Opinion Contexts 160
5.7 Rule Representation 162
5.8 Word Sense Disambiguation and Coreference Resolution 164
5.9 Summary 166

6 Aspect and Entity Extraction 168
6.1 Frequency-Based Aspect Extraction 169
6.2 Exploiting Syntactic Relations 171
6.2.1 Using Opinion and Target Relations 172
6.2.2 Using Part-of and Attribute-of Relations 179
6.3 Using Supervised Learning 182
6.3.1 Hidden Markov Model 182
6.3.2 Conditional Random Fields 183
6.3.3 Deep Learning–Based Methods 186
6.4 Mapping Implicit Aspects 188
6.4.1 Corpus-Based Approach 188
6.4.2 Dictionary-Based Approach 189
6.5 Grouping Aspects into Categories 192
6.6 Exploiting Topic Models 194
6.6.1 Latent Dirichlet Allocation 196
6.6.2 Using Unsupervised Topic Models 199
6.6.3 Using Prior Domain Knowledge in Modeling 205
6.6.4 Lifelong Topic Models: Learn As Humans Do 207
6.6.5 Using Phrases As Topical Terms 211
6.7 Entity Extraction and Resolution 216
6.7.1 The Problem of Entity Extraction and Resolution 217
6.7.2 Entity Extraction 220
6.7.3 Entity Linking 222
6.7.4 Entity Search and Linking 224
6.8 Opinion Holder and Time Extraction 224
6.9 Summary 225

7 Sentiment Lexicon Generation 227
7.1 Dictionary-Based Approach 228
7.2 Corpus-Based Approach 232
7.2.1 Identifying Sentiment Words from a Corpus 232
7.2.2 Dealing with Context-Dependent Sentiment Words 233
7.2.3 Lexicon Adaptation 236
7.2.4 Some Other Related Work 237
7.3 Sentiment Word Embedding 238
7.4 Desirable and Undesirable Facts 239
7.5 Summary 241

8 Analysis of Comparative Opinions 243
8.1 Problem Definition 243
8.2 Identifying Comparative Sentences 247
8.3 Identifying the Preferred Entity Set 248
8.4 Special Types of Comparisons 250

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CAMBRIDGE

Cambridge University Press
978-1-108-48637-8 — Sentiment Analysis
2nd Edition
Frontmatter
More Information

8.4.1 Nonstandard Comparisons 250
8.4.2 Cross-Type Comparison 253
8.4.3 Single-Entity Comparison 254
8.4.4 Sentences Involving *Compare* or *Comparison* 255
8.5 Entity and Aspect Extraction 257
8.6 Summary 258

9 Opinion Summarization and Search 259
9.1 Aspect-Based Opinion Summarization 260
9.2 Enhancements to Aspect-Based Summaries 262
9.3 Contrastive View Summarization 266
9.4 Traditional Summarization 266
9.5 Summarization of Comparative Opinions 267
9.6 Opinion Search 267
9.7 Existing Opinion Retrieval Techniques 269
9.8 Summary 271

10 Analysis of Debates and Comments 273
10.1 Recognizing Stances in Debates 274
10.2 Modeling Debates/Discussions 277
10.2.1 JTE Model 279
10.2.2 JTE-R Model: Encoding Reply Relations 284
10.2.3 JTE-P Model: Encoding Pair Structures 286
10.2.4 Analysis of Tolerance in Online Discussions 288
10.3 Modeling Comments 290
10.4 Summary 292

11 Mining Intent 294
11.1 The Problem of Intent Mining 294
11.2 Intent Classification 298
11.3 Fine-Grained Mining of Intent 301
11.4 Summary 302

12 Detecting Fake or Deceptive Opinions 304
12.1 Different Types of Spam 307
12.1.1 Harmful Fake Reviews 308
12.1.2 Types of Spammers and Spamming 309
12.1.3 Types of Data, Features, and Detection 311
12.1.4 Fake Reviews versus Conventional Lies 313
12.2 Supervised Fake Review Detection 315
12.3 Supervised Yelp Data Experiment 318
12.3.1 Supervised Learning Using Linguistic Features 319
12.3.2 Supervised Learning Using Behavioral Features 321
12.4 Automated Discovery of Abnormal Patterns 322
12.4.1 Class Association Rules 322
12.4.2 Unexpectedness of One-Condition Rules 324
12.4.3 Unexpectedness of Two-Condition Rules 327
12.5 Model-Based Behavioral Analysis 329
12.5.1 Spam Detection Based on Atypical Behaviors 330
12.5.2 Spam Detection Using Review Graphs 331

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CAMBRIDGE

Cambridge University Press
978-1-108-48637-8 — Sentiment Analysis
2nd Edition
Frontmatter
More Information

12.5.3 Spam Detection Using Bayesian Models 332
12.6 Group Spam Detection 333
12.6.1 Group Behavior Features 337
12.6.2 Individual Member Behavior Features 340
12.7 Identifying Reviewers with Multiple Userids 341
12.7.1 Learning in a Similarity Space 342
12.7.2 Training Data Preparation 343
12.7.3 *d*-Features and *s*-Features 344
12.7.4 Identifying Userids of the Same Author 345
12.8 Exploiting Burstiness in Reviews 348
12.9 Future Research Directions 351
12.10 Summary 352

13 Quality of Reviews 354
13.1 Quality Prediction As a Regression Problem 354
13.2 Other Methods 356
13.3 Some New Frontiers 358
13.4 Summary 359

14 Conclusion 360

Appendix 365
Bibliography 376
Index 427

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CAMBRIDGE

Cambridge University Press
978-1-108-48637-8 — Sentiment Analysis
2nd Edition
Frontmatter
More Information

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2nd Edition
Frontmatter
More Information

Preface

Since the first edition of the book was published in 2015, we have witnessed the rapid rise of deep learning, which has resulted in a huge amount of work on using deep learning models to perform sentiment analysis tasks. The goal of this second edition is mainly to update the first edition with the deep learning methods published in the past few years. In addition, many other sections of the book have been updated.

Opinion and sentiment and their related concepts, such as evaluation, appraisal, attitude, affect, emotion, and mood, are about our subjective feelings and beliefs. They are central to human psychology and are key influencers of our behaviors. Our beliefs and perceptions of reality, as well as the choices we make, are to a considerable degree conditioned on how others see and perceive the world. For this reason, our views of the world are very much influenced by others' views. Whenever we need to make a decision, we often seek out others' opinions. This is true not only for individuals but also for organizations. From an application point of view, we naturally want to mine people's opinions and feelings toward any subject matter of interest, which is the task of sentiment analysis. More precisely, sentiment analysis – also called opinion mining – is a field of study that aims to extract opinions and sentiments from natural language text using computational methods.

The inception and rapid growth of sentiment analysis coincide with those of social media on the web, such as reviews, forum discussions, blogs, and microblogs, because for the first time in human history, we have a huge volume of opinionated data recorded in digital forms. These data, also called *user-generated content,* prompted researchers to mine them to discover useful knowledge. This endeavor naturally led to the problem of sentiment analysis or opinion mining because these data are full of opinions. This is not surprising, because the primary reason that people post messages on social media platforms is to express their views and opinions; therefore, sentiment analysis is at the very core of social media analysis. Since the early 2000s, sentiment analysis has grown to be one of the most active research areas in natural language processing. It is also widely studied in the context of data mining,

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2nd Edition
Frontmatter
More Information

web mining, and information retrieval. In fact, this line of research has expanded from computer science to management science and social science because of its importance to business and society as a whole. Industrial activities surrounding sentiment analysis have also thrived. Numerous start-ups have emerged. Many large corporations – for example, Microsoft, Google, Facebook, Hewlett-Packard, IBM, Adobe, Alibaba, Baidu, and Tencent – have also built their own in-house systems. Sentiment analysis systems have found applications in almost every business, health, government, and social domain.

Although no silver bullet algorithm can solve the sentiment analysis problem, many deployed systems are able to provide useful information to support real-life applications. I believe it is now a good time to document the knowledge that we have obtained through research – and, to some extent, in practice – in a book. Obviously, I don't claim to know everything that is happening in the industry, as businesses do not publish or disclose their algorithms. However, I have built a sentiment analysis system myself in a start-up company and served clients on projects involving social media data sets in a large variety of domains. Over the years, many developers of sentiment analysis systems in the industry have also told me roughly what algorithms they were using. Thus, I have a reasonable knowledge of practical systems and their capabilities and firsthand experience in solving real-life problems. I try to pass along those nonconfidential pieces of information and knowledge in this book.

In writing this book, I aimed to take a balanced approach, analyzing the sentiment analysis problem from a linguistic angle to help readers understand the underlying structure of the problem and the language constructs commonly used to express opinions and sentiments, and presenting computational methods to analyze and summarize opinions. Like many natural language processing tasks, most published computational techniques use machine learning or data mining algorithms with the help of text-specific clues or features. However, if we focus solely on such computational algorithms, we will miss the deep insights of the problem, which in turn will hinder our progress on the computational front. Most existing machine learning algorithms are black boxes; they do not produce human-interpretable models. In turn, when something goes wrong, it is hard to know the cause and how to fix it.

In presenting linguistic constructs and perspectives, I do not follow the linguistic tradition in writing, because the knowledge and the way that the knowledge is presented in the traditional linguistics literature are mainly for people to understand, rather than for computers to operationalize to solve real-life problems. Although the knowledge of human beings and instructions for computers can largely intersect, they also have major differences. As a case in point, when I was working on the problem of mining opinions from conditional sentences, I read several linguistics books about conditionals. To my

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2nd Edition
Frontmatter
More Information

surprise, I found almost no linguistic knowledge that could be operationalized computationally to help solve the problem. I believe this is partly because the current computation technologies are not mature enough to have the same understanding capability as people and partly because much of the linguistic knowledge was not meant for computers to use.

Another feature of this book is that it is not just about studying the language for human understanding per se, as much of the traditional linguistic literature is; it is also about practical applications of mining sentiment and opinion expressed in natural language, for which we want not only to recognize sentiment or opinion expressions and their polarities (or orientations) but also to extract several other pieces of important information associated with sentiment or opinion. For example, we want to identify the real-world entities or topics that a sentiment or opinion is about. These entities or topics are called *opinion* (or *sentiment*) *targets*. Extracting opinion targets is extremely important in practice. For example, in the sentence "I am disgusted by the tax increase for the poor," if we find only that the sentence expresses a negative sentiment and/or the emotion of *disgust* from the sentence author, it is not that useful in practice. But if we also find that the negative sentiment is toward "tax increase for the poor," which is the target of the negative sentiment or emotion, the information becomes much more valuable. I hope this book can also serve to encourage linguists to develop a comprehensive theory about sentiment, opinion, and emotion, as well as their associated concepts.

I wrote this book as an introductory text for the field of sentiment analysis and as a research survey. In many places, it is one or the other; in other places, it is a mixture of both. The reason for this mixed or somewhat unusual presentational style is that there are few truly mature techniques or algorithms for sentiment analysis, although numerous researchers have attempted to solve each subproblem using many techniques. In many cases, we can see from the accuracy of results of the published papers that they are not yet ready for prime time.

Another reason for the mixed presentational style of this book is that most existing research methods are direct applications of machine learning and data mining algorithms employing text features or the raw text itself. Because many books on machine learning and data mining cover these algorithms extensively, the algorithms are not detailed in this book. This book also does not detail the basics of linguistics or natural language processing, such as part-of-speech tagging, syntactic parsing, shallow parsing, and grammar. Although these topics are very important to sentiment analysis, once again they have been covered in numerous books on natural language processing. This book thus assumes that readers know the basics of machine leaning and natural language processing.

I tried to cover all major developments of the field in this book. It is thus quite comprehensive. Evidence of this is that the book cites more than seven

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More Information

hundred publications from all major conferences and journals. I organized the book as follows.

Chapter 1 introduces the book and gives the motivations for the study of sentiment analysis. We see that sentiment analysis is a fascinating, yet challenging problem with almost unlimited practical applications.

Chapter 2 defines the sentiment analysis problem and discusses many of its related issues. Here we see that although sentiment analysis is a natural language processing problem, it can be defined structurally. Through this definition, we can transform unstructured text to structured data. This facilitates subsequent qualitative and quantitative analyses, which are critical for real-life applications. We also see that sentiment analysis is a multifaceted problem with many challenging and interrelated subproblems.

Chapter 3 studies the popular topic of document-level sentiment classification, which classifies an opinion document (e.g., a product review) as expressing a positive or negative opinion. Chapter 4 studies the same classification problem but focuses on each individual sentence. Related problems of sentiment rating prediction, transfer learning, and multilingual sentiment classification are also discussed in these two chapters.

Chapters 5 and 6 go to a fine-grained level to study the enormously important topic of aspect-based sentiment analysis, which not only classifies sentiment but also identifies the target of sentiment or opinion. Most practical sentiment analysis or opinion mining systems in industry are based on this fine-grained level of analysis. Chapter 5 focuses on aspect sentiment classification, and Chapter 6 addresses aspect or target extraction.

Chapter 7 describes research that compiles sentiment lexicons. A sentiment lexicon is a list of words and phrases (e.g., *good*, *amazing*, *bad*, *horrible*) that people often use to express positive or negative opinions. Chapter 8 studies opinions expressed in comparative sentences. Chapter 9 focuses on opinion summarization and opinion search. Chapter 10 looks into a different type of sentiment (agreement and disagreement) expressed in online debates and discussions, which involve extensive interactive exchanges among participants. Chapter 11 investigates intent mining, which aims to discover intentions expressed in language.

Chapter 12 switches to a very different topic: the detection of fake or deceptive online opinions. Chapter 13 studies the problem of ranking online reviews based on their usefulness so that users can view the most useful reviews first. Chapter 14 concludes the book and discusses some future research.

This book is suitable for students, researchers, and practitioners who are interested in social media analysis and natural language processing in general, and sentiment analysis or opinion mining in particular. It is written not only for the computer science audience, but also for researchers and practitioners in

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Frontmatter
More Information

management sciences and social sciences. Consumer sentiments and public opinions are central to many management and social science areas such as marketing, economics, communication, political science, and even history. Lecturers can readily use the book in class for courses on natural language processing, social media analysis, social computing, and text and data mining. Lecture slides are available online.

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2nd Edition
Frontmatter
More Information

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2nd Edition
Frontmatter
More Information

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