

contents

foreword xiii
preface xv
acknowledgments xxi
about this book xxiv
about the authors xxvii
about the cover illustration xxix

PART I WORDY MACHINES 1

I *Packets of thought (NLP overview)* 3

- 1.1 Natural language vs. programming language 4
- 1.2 The magic 4
 - Machines that converse* 5 ▪ *The math* 6
- 1.3 Practical applications 8
- 1.4 Language through a computer's "eyes" 9
 - The language of locks* 10 ▪ *Regular expressions* 11
 - A simple chatbot* 12 ▪ *Another way* 16
- 1.5 A brief overflight of hyperspace 19
- 1.6 Word order and grammar 21
- 1.7 A chatbot natural language pipeline 22
- 1.8 Processing in depth 25
- 1.9 Natural language IQ 27

Build your vocabulary (word tokenization) 30

- 2.1 Challenges (a preview of stemming) 32
- 2.2 Building your vocabulary with a tokenizer 33
 - Dot product* 41 ▪ *Measuring bag-of-words overlap* 42
 - A token improvement* 43 ▪ *Extending your vocabulary with n-grams* 48 ▪ *Normalizing your vocabulary* 54
- 2.3 Sentiment 62
 - VADER—A rule-based sentiment analyzer 64 ▪ *Naive Bayes* 65

Math with words (TF-IDF vectors) 70

- 3.1 Bag of words 71
- 3.2 Vectorizing 76
 - Vector spaces* 79
- 3.3 Zipf's Law 83
- 3.4 Topic modeling 86
 - Return of Zipf* 89 ▪ *Relevance ranking* 90 ▪ *Tools* 93
 - Alternatives* 93 ▪ *Okapi BM25* 95 ▪ *What's next* 95

4 Finding meaning in word counts (semantic analysis) 97

- 4.1 From word counts to topic scores 98
 - TF-IDF vectors and lemmatization* 99 ▪ *Topic vectors* 99
 - Thought experiment* 101 ▪ *An algorithm for scoring topics* 105
 - An LDA classifier* 107
- 4.2 Latent semantic analysis 111
 - Your thought experiment made real* 113
- 4.3 Singular value decomposition 116
 - U—left singular vectors* 118 ▪ *S—singular values* 119
 - VT—right singular vectors* 120 ▪ *SVD matrix orientation* 120
 - Truncating the topics* 121
- 4.4 Principal component analysis 123
 - PCA on 3D vectors* 125 ▪ *Stop horsing around and get back to NLP* 126 ▪ *Using PCA for SMS message semantic analysis* 128
 - Using truncated SVD for SMS message semantic analysis* 130
 - How well does LSA work for spam classification?* 131
- 4.5 Latent Dirichlet allocation (LDiA) 134
 - The LDiA idea* 135 ▪ *LDiA topic model for SMS messages* 137
 - LDiA + LDA = spam classifier* 140 ▪ *A fairer comparison: 32 LDiA topics* 142

- 4.6 Distance and similarity 143
- 4.7 Steering with feedback 146
 - Linear discriminant analysis* 147
- 4.8 Topic vector power 148
 - Semantic search* 150 ▪ *Improvements* 152

PART 2 DEEPER LEARNING (NEURAL NETWORKS) 153

5 *Baby steps with neural networks (perceptrons and backpropagation)* 155

- 5.1 Neural networks, the ingredient list 156
 - Perceptron* 157 ▪ *A numerical perceptron* 157 ▪ *Detour through bias* 158 ▪ *Let's go skiing—the error surface* 172
 - Off the chair lift, onto the slope* 173 ▪ *Let's shake things up a bit* 174 ▪ *Keras: neural networks in Python* 175 ▪ *Onward and deepward* 179 ▪ *Normalization: input with style* 179

6 *Reasoning with word vectors (Word2vec)* 181

- 6.1 Semantic queries and analogies 182
 - Analogy questions* 183
- 6.2 Word vectors 184
 - Vector-oriented reasoning* 187 ▪ *How to compute Word2vec representations* 191 ▪ *How to use the gensim.word2vec module* 200 ▪ *How to generate your own word vector representations* 202 ▪ *Word2vec vs. GloVe (Global Vectors)* 205
 - fastText* 205 ▪ *Word2vec vs. LSA* 206 ▪ *Visualizing word relationships* 207 ▪ *Unnatural words* 214 ▪ *Document similarity with Doc2vec* 215

7 *Getting words in order with convolutional neural networks (CNNs)* 218

- 7.1 Learning meaning 220
- 7.2 Toolkit 221
- 7.3 Convolutional neural nets 222
 - Building blocks* 223 ▪ *Step size (stride)* 224 ▪ *Filter composition* 224 ▪ *Padding* 226 ▪ *Learning* 228
- 7.4 Narrow windows indeed 228
 - Implementation in Keras: prepping the data* 230 ▪ *Convolutional neural network architecture* 235 ▪ *Pooling* 236
 - Dropout* 238 ▪ *The cherry on the sundae* 239 ▪ *Let's get to*

learning (training) 241 ▪ *Using the model in a pipeline* 243
Where do you go from here? 244

8 **Loopy (recurrent) neural networks (RNNs)** 247

8.1 Remembering with recurrent networks 250

Backpropagation through time 255 ▪ *When do we update what?* 257 ▪ *Recap* 259 ▪ *There's always a catch* 259
Recurrent neural net with Keras 260

8.2 Putting things together 264

8.3 Let's get to learning our past selves 266

8.4 Hyperparameters 267

8.5 Predicting 269

Statefulness 270 ▪ *Two-way street* 271 ▪ *What is this thing?* 272

9 **Improving retention with long short-term memory networks** 274

9.1 LSTM 275

Backpropagation through time 284 ▪ *Where does the rubber hit the road?* 287 ▪ *Dirty data* 288 ▪ *Back to the dirty data* 291
Words are hard. Letters are easier. 292 ▪ *My turn to chat* 298
My turn to speak more clearly 300 ▪ *Learned how to say, but not yet what* 308 ▪ *Other kinds of memory* 308 ▪ *Going deeper* 309

10 **Sequence-to-sequence models and attention** 311

10.1 Encoder-decoder architecture 312

Decoding thought 313 ▪ *Look familiar?* 315 ▪ *Sequence-to-sequence conversation* 316 ▪ *LSTM review* 317

10.2 Assembling a sequence-to-sequence pipeline 318

Preparing your dataset for the sequence-to-sequence training 318
Sequence-to-sequence model in Keras 320 ▪ *Sequence encoder* 320 ▪ *Thought decoder* 322 ▪ *Assembling the sequence-to-sequence network* 323

10.3 Training the sequence-to-sequence network 324

Generate output sequences 325

10.4 Building a chatbot using sequence-to-sequence networks 326

Preparing the corpus for your training 326 ▪ *Building your character dictionary* 327 ▪ *Generate one-hot encoded training sets* 328 ▪ *Train your sequence-to-sequence chatbot* 329

Assemble the model for sequence generation 330 ▪ *Predicting a sequence* 330 ▪ *Generating a response* 331 ▪ *Converse with your chatbot* 331

10.5 Enhancements 332

Reduce training complexity with bucketing 332 ▪ *Paying attention* 333

10.6 In the real world 334

PART 3 GETTING REAL (REAL-WORLD NLP CHALLENGES) 337

11 **Information extraction (named entity extraction and question answering) 339**

11.1 Named entities and relations 339

A knowledge base 340 ▪ *Information extraction* 343

11.2 Regular patterns 343

Regular expressions 344 ▪ *Information extraction as ML feature extraction* 345

11.3 Information worth extracting 346

Extracting GPS locations 347 ▪ *Extracting dates* 347

11.4 Extracting relationships (relations) 352

Part-of-speech (POS) tagging 353 ▪ *Entity name normalization* 357
Relation normalization and extraction 358 ▪ *Word patterns* 358
Segmentation 359 ▪ *Why won't split('!.?!') work?* 360
Sentence segmentation with regular expressions 361

11.5 In the real world 363

12 **Getting chatty (dialog engines) 365**

12.1 Language skill 366

Modern approaches 367 ▪ *A hybrid approach* 373

12.2 Pattern-matching approach 373

A pattern-matching chatbot with AIML 375 ▪ *A network view of pattern matching* 381

12.3 Grounding 382

12.4 Retrieval (search) 384

The context challenge 384 ▪ *Example retrieval-based chatbot* 386 ▪ *A search-based chatbot* 389

- 12.5 Generative models 391
 - Chat about NLP/A 392* ▪ *Pros and cons of each approach 394*
- 12.6 Four-wheel drive 395
 - The Will to succeed 395*
- 12.7 Design process 396
- 12.8 Trickery 399
 - Ask questions with predictable answers 399* ▪ *Be entertaining 399*
 - When all else fails, search 400* ▪ *Being popular 400* ▪ *Be a connector 400* ▪ *Getting emotional 400*
- 12.9 In the real world 401

13 *Scaling up (optimization, parallelization, and batch processing) 403*

- 13.1 Too much of a good thing (data) 404
- 13.2 Optimizing NLP algorithms 404
 - Indexing 405* ▪ *Advanced indexing 406* ▪ *Advanced indexing with Annoy 408* ▪ *Why use approximate indexes at all? 412*
 - An indexing workaround: discretizing 413*
- 13.3 Constant RAM algorithms 414
 - Gensim 414* ▪ *Graph computing 415*
- 13.4 Parallelizing your NLP computations 416
 - Training NLP models on GPUs 416* ▪ *Renting vs. buying 417*
 - GPU rental options 418* ▪ *Tensor processing units 419*
- 13.5 Reducing the memory footprint during model training 419
- 13.6 Gaining model insights with TensorBoard 422
 - How to visualize word embeddings 423*
- appendix A Your NLP tools 427*
- appendix B Playful Python and regular expressions 434*
- appendix C Vectors and matrices (linear algebra fundamentals) 440*
- appendix D Machine learning tools and techniques 446*
- appendix E Setting up your AWS GPU 459*
- appendix F Locality sensitive hashing 473*
 - resources 481*
 - glossary 490*
 - index 497*