

# Contents

List of Contributors.....	xv
About the Editors.....	xix
Preface.....	xxi
Acknowledgments.....	xxv

## **PART I BIG DATA SCIENCE**

<b>CHAPTER 1 BDA = ML + CC</b> .....	<b>3</b>
<b>1.1</b> Introduction.....	<b>3</b>
<b>1.2</b> A Historical Review of Big Data.....	<b>4</b>
1.2.1 The Origin of Big Data.....	4
1.2.2 Debates of Big Data Implication.....	5
<b>1.3</b> Historical Interpretation of Big Data.....	<b>7</b>
1.3.1 Methodology for Defining Big Data.....	7
1.3.2 Different Attributes of Definitions.....	7
1.3.3 Summary of 7 Types Definitions of Big Data.....	10
1.3.4 Motivations Behind the Definitions.....	10
<b>1.4</b> Defining Big Data From 3Vs to 3 <sup>2</sup> Vs.....	<b>11</b>
1.4.1 Data Domain.....	11
1.4.2 Business Intelligent (BI) Domain.....	11
1.4.3 Statistics Domain.....	13
1.4.4 3 <sup>2</sup> Vs Definition and Big Data Venn Diagram.....	13
<b>1.5</b> Big Data Analytics and Machine Learning.....	<b>14</b>
1.5.1 Big Data Analytics.....	14
1.5.2 Machine Learning.....	15
<b>1.6</b> Big Data Analytics and Cloud Computing.....	<b>18</b>
<b>1.7</b> Hadoop, HDFS, MapReduce, Spark, and Flink.....	<b>18</b>
1.7.1 Google File System (GFS) and HDFS.....	20
1.7.2 MapReduce.....	24
1.7.3 The Origin of the Hadoop Project.....	25
1.7.4 Spark and Spark Stack.....	27
1.7.5 Flink and Other Data Process Engines.....	27
1.7.6 Summary of Hadoop and Its Ecosystems.....	32
<b>1.8</b> ML + CC → BDA and Guidelines.....	<b>34</b>
<b>1.9</b> Conclusion.....	<b>35</b>
References.....	35



<b>CHAPTER 2 Real-Time Analytics</b> .....	<b>39</b>
2.1 Introduction.....	39
2.2 Computing Abstractions for Real-Time Analytics .....	40
2.3 Characteristics of Real-Time Systems .....	41
2.3.1 Low Latency .....	42
2.3.2 High Availability.....	42
2.3.3 Horizontal Scalability .....	43
2.4 Real-Time Processing for Big Data — Concepts and Platforms.....	43
2.4.1 Event.....	43
2.4.2 Event Processing.....	44
2.4.3 Event Stream Processing and Data Stream Processing .....	44
2.4.4 Complex Event Processing .....	44
2.4.5 Event Type .....	45
2.4.6 Event Pattern.....	45
2.5 Data Stream Processing Platforms.....	45
2.5.1 Spark.....	46
2.5.2 Storm.....	47
2.5.3 Kafka.....	47
2.5.4 Flume .....	48
2.5.5 Amazon Kinesis.....	48
2.6 Data Stream Analytics Platforms.....	48
2.6.1 Query-Based EPSs.....	48
2.6.2 Rule-Oriented EPSs .....	49
2.6.3 Programmatic EPSs .....	50
2.7 Data Analysis and Analytic Techniques .....	53
2.7.1 Data Analysis in General .....	53
2.7.2 Data Analysis for Stream Applications .....	53
2.8 Finance Domain Requirements and a Case Study .....	54
2.8.1 Real-Time Analytics in Finance Domain .....	54
2.8.2 Selected Scenarios .....	55
2.8.3 CEP Application as a Case Study .....	55
2.9 Future Research Challenges .....	58
References.....	59
<b>CHAPTER 3 Big Data Analytics for Social Media</b> .....	<b>63</b>
3.1 Introduction.....	63
3.2 NLP and Its Applications.....	63
3.2.1 Language Detection .....	64
3.2.2 Named Entity Recognition .....	68
3.3 Text Mining.....	72



3.3.1 Sentiment Analysis .....	72
3.3.2 Trending Topics .....	77
3.3.3 Recommender Systems.....	81
<b>3.4 Anomaly Detection.....</b>	<b>85</b>
Acknowledgments .....	88
References.....	89
<b>CHAPTER 4 Deep Learning and Its Parallelization .....</b>	<b>95</b>
<b>4.1 Introduction.....</b>	<b>95</b>
4.1.1 Application Background.....	95
4.1.2 Performance Demands for Deep Learning .....	96
4.1.3 Existing Parallel Frameworks of Deep Learning.....	96
<b>4.2 Concepts and Categories of Deep Learning .....</b>	<b>96</b>
4.2.1 Deep Learning .....	96
4.2.2 Mainstream Deep Learning Models .....	99
<b>4.3 Parallel Optimization for Deep Learning.....</b>	<b>104</b>
4.3.1 Convolutional Architecture for Fast Feature Embedding.....	104
4.3.2 DistBelief.....	111
4.3.3 Deep Learning Based on Multi-GPUs.....	112
<b>4.4 Discussions .....</b>	<b>115</b>
4.4.1 Grand Challenges of Deep Learning in Big Data.....	115
4.4.2 Future Directions .....	116
References.....	117
<b>CHAPTER 5 Characterization and Traversal of Large Real-World Networks.....</b>	<b>119</b>
<b>5.1 Introduction.....</b>	<b>119</b>
<b>5.2 Background.....</b>	<b>120</b>
<b>5.3 Characterization and Measurement .....</b>	<b>121</b>
<b>5.4 Efficient Complex Network Traversal .....</b>	<b>124</b>
5.4.1 HPC Traversal of Large Networks.....	124
5.4.2 Algorithms for Accelerating AS-BFS on GPU .....	125
5.4.3 Performance Study of AS-BFS on GPU's.....	126
<b>5.5 <i>k</i>-Core-Based Partitioning for Heterogeneous Graph Processing.....</b>	<b>128</b>
5.5.1 Graph Partitioning for Heterogeneous Computing.....	129
5.5.2 <i>k</i> -Core-Based Complex-Network Unbalanced Bisection .....	129
<b>5.6 Future Directions .....</b>	<b>133</b>
<b>5.7 Conclusions.....</b>	<b>133</b>
Acknowledgments .....	134
References.....	134



## PART II BIG DATA INFRASTRUCTURES AND PLATFORMS

<b>CHAPTER 6 Database Techniques for Big Data</b> .....	<b>139</b>
6.1 Introduction.....	139
6.2 Background.....	139
6.2.1 Navigational Data Models .....	139
6.2.2 Relational Data Models .....	140
6.3 NoSQL Movement.....	143
6.4 NoSQL Solutions for Big Data Management.....	144
6.5 NoSQL Data Models .....	150
6.5.1 Key-Value Stores .....	150
6.5.2 Column-Based Stores .....	151
6.5.3 Graph-Based Stores .....	153
6.5.4 Document-Based Stores.....	154
6.6 Future Directions .....	156
6.7 Conclusions.....	157
References.....	157
<b>CHAPTER 7 Resource Management in Big Data Processing Systems</b> .....	<b>161</b>
7.1 Introduction.....	161
7.2 Types of Resource Management.....	162
7.2.1 CPU and Memory Resource Management .....	162
7.2.2 Storage Resource Management .....	163
7.2.3 Network Resource Management.....	163
7.3 Big Data Processing Systems and Platforms .....	163
7.3.1 Hadoop.....	163
7.3.2 Dryad .....	164
7.3.3 Pregel .....	164
7.3.4 Storm.....	164
7.3.5 Spark .....	165
7.3.6 Summary .....	165
7.4 Single-Resource Management in the Cloud .....	166
7.4.1 Desired Resource Allocation Properties .....	166
7.4.2 Problems for Existing Fairness Policies .....	167
7.4.3 Long-Term Resource Allocation Policy .....	168
7.4.4 Experimental Evaluation.....	170
7.5 Multiresource Management in the Cloud .....	171
7.5.1 Resource Allocation Model.....	172
7.5.2 Multiresource Fair Sharing Issues .....	174
7.5.3 Reciprocal Resource Fairness.....	175
7.5.4 Experimental Evaluation.....	179



..... 139  
 ..... 139  
 ..... 139  
 ..... 139  
 ..... 140  
 ..... 143  
 ..... 144  
 ..... 150  
 ..... 150  
 ..... 151  
 ..... 153  
 ..... 154  
 ..... 156  
 ..... 157  
 ..... 157  
 ..... 161  
 ..... 161  
 ..... 162  
 ..... 162  
 ..... 163  
 ..... 163  
 ..... 163  
 ..... 163  
 ..... 164  
 ..... 164  
 ..... 164  
 ..... 164  
 ..... 165  
 ..... 165  
 ..... 166  
 ..... 166  
 ..... 167  
 ..... 168  
 ..... 170  
 ..... 171  
 ..... 172  
 ..... 174  
 ..... 175  
 ..... 179

7.6	Related Work on Resource Management.....	182
7.6.1	Resource Utilization Optimization .....	182
7.6.2	Power and Energy Cost Saving Optimization .....	182
7.6.3	Monetary Cost Optimization .....	182
7.6.4	Fairness Optimization.....	183
7.7	Open Problems.....	183
7.7.1	SLA Guarantee for Applications .....	183
7.7.2	Various Computation Models and Systems .....	183
7.7.3	Exploiting Emerging Hardware .....	184
7.8	Summary.....	184
	References.....	184
<b>CHAPTER 8</b>	<b>Local Resource Consumption Shaping: A Case for MapReduce .....</b>	<b>189</b>
8.1	Introduction.....	189
8.2	Motivation.....	191
8.2.1	Pitfalls of Fair Resource Sharing .....	192
8.3	Local Resource Shaper .....	194
8.3.1	Design Philosophy .....	194
8.3.2	Splitter.....	195
8.3.3	The Interleave MapReduce Scheduler .....	195
8.4	Evaluation .....	198
8.4.1	Experiments With Hadoop 1.x.....	198
8.4.2	Experiments With Hadoop 2.x.....	204
8.5	Related Work .....	210
8.6	Conclusions.....	211
	Appendix CPU Utilization With Different Slot Configurations and LRS.....	212
	References.....	213
<b>CHAPTER 9</b>	<b>System Optimization for Big Data Processing .....</b>	<b>215</b>
9.1	Introduction.....	215
9.2	Basic Framework of the Hadoop Ecosystem.....	217
9.3	Parallel Computation Framework: MapReduce.....	218
9.3.1	Improvements of MapReduce Framework .....	218
9.3.2	Optimization for Task Scheduling and Load Balancing of MapReduce .....	219
9.4	Job Scheduling of Hadoop.....	220
9.4.1	Built-In Scheduling Algorithms of Hadoop .....	220
9.4.2	Improvement of the Hadoop Job Scheduling Algorithm.....	221
9.4.3	Improvement of the Hadoop Job Management Framework .....	223
9.5	Performance Optimization of HDFS .....	224
9.5.1	Small File Performance Optimization .....	224
9.5.2	HDFS Security Optimization.....	226



**9.6 Performance Optimization of HBase** .....228

    9.6.1 HBase Framework, Storage, and Application Optimization .....228

    9.6.2 Load Balancing of HBase .....229

    9.6.3 Optimization of HBase Configuration .....230

**9.7 Performance Enhancement of Hadoop System** .....230

    9.7.1 Efficiency Optimization of Hadoop .....231

    9.7.2 Availability Optimization of Hadoop .....232

**9.8 Conclusions and Future Directions** .....233

    References .....233

**CHAPTER 10 Packing Algorithms for Big Data Replay on Multicore** .....239

**10.1 Introduction** .....239

**10.2 Performance Bottlenecks** .....241

    10.2.1 Hadoop/MapReduce Performance Bottlenecks .....241

    10.2.2 Performance Bottlenecks Under Parallel Loads .....243

    10.2.3 Parameter Spaces for Storage and Shared Memory .....244

    10.2.4 Main Storage Performance .....245

    10.2.5 Shared Memory Performance .....248

**10.3 The Big Data Replay Method** .....250

    10.3.1 The Replay Method .....250

    10.3.2 Jobs as Sketches on a Timeline .....251

    10.3.3 Performance Bottlenecks Under Replay .....252

**10.4 Packing Algorithms** .....253

    10.4.1 Shared Memory Performance Tricks .....253

    10.4.2 Big Data Replay at Scale .....255

    10.4.3 Practical Packing Models .....256

**10.5 Performance Analysis** .....256

    10.5.1 Hotspot Distributions .....256

    10.5.2 Modeling Methodology .....258

    10.5.3 Processing Overhead Versus Bottlenecks .....259

    10.5.4 Control Grain for Drop Versus Drag Models .....261

**10.6 Summary and Future Directions** .....262

    References .....264

**PART III BIG DATA SECURITY AND PRIVACY**

**CHAPTER 11 Spatial Privacy Challenges in Social Networks** .....269

    11.1 Introduction .....269

    11.2 Background .....269

    11.3 Spatial Aspects of Social Networks .....271

CHAPTER

1  
1  
1  
12  
12

12

12

12  
12

CHAPTER 13

13  
13

13.3

13.4



.....228  
 .....228  
 .....229  
 .....230  
 .....230  
 .....231  
 .....232  
 .....233  
 .....233  
  
 .....239  
 .....239  
 .....241  
 .....241  
 .....243  
 .....244  
 .....245  
 .....248  
 .....250  
 .....250  
 .....251  
 .....252  
 .....253  
 .....253  
 .....255  
 .....256  
 .....256  
 .....256  
 .....258  
 .....259  
 .....261  
 .....262  
 .....264  
  
 .....269  
 .....269  
 .....269  
 .....271

11.4 Cloud-Based Big Data Infrastructure .....273  
 11.5 Spatial Privacy Case Studies.....275  
 11.6 Conclusions.....281  
     Acknowledgments .....282  
     References.....282  
**CHAPTER 12 Security and Privacy in Big Data .....285**  
 12.1 Introduction.....285  
 12.2 Secure Queries Over Encrypted Big Data .....287  
     12.2.1 System Model .....287  
     12.2.2 Threat Model and Attack Model.....288  
     12.2.3 Secure Query Scheme in Clouds .....289  
     12.2.4 Security Definition of Index-Based Secure Query Techniques .....291  
     12.2.5 Implementations of Index-Based Secure Query Techniques .....291  
 12.3 Other Big Data Security.....295  
     12.3.1 Digital Watermarking .....295  
     12.3.2 Self-Adaptive Risk Access Control .....296  
 12.4 Privacy on Correlated Big Data .....296  
     12.4.1 Correlated Data in Big Data .....296  
     12.4.2 Anonymity .....298  
     12.4.3 Differential Privacy .....300  
 12.5 Future Directions .....304  
 12.6 Conclusions.....305  
     References.....305  
**CHAPTER 13 Location Inferring in Internet of Things and Big Data .....309**  
 13.1 Introduction.....309  
 13.2 Device-Based Sensing Using Big Data .....310  
     13.2.1 Introduction.....310  
     13.2.2 Approach Overview .....310  
     13.2.3 Trajectories Matching .....311  
     13.2.4 Establishing the Mapping Between Floor Plan and RSS Readings.....314  
     13.2.5 User Localization .....318  
     13.2.6 Graph Matching Based Tracking .....318  
     13.2.7 Evaluation .....318  
 13.3 Device-Free Sensing Using Big Data .....319  
     13.3.1 Customer Behavior Identification.....319  
     13.3.2 Human Object Estimation.....328  
 13.4 Conclusion .....334  
     Acknowledgements.....334  
     References.....334



**PART IV BIG DATA APPLICATIONS**

<b>CHAPTER 14 A Framework for Mining Thai Public Opinions</b> .....	<b>339</b>
14.1 Introduction.....	339
14.2 XDOM.....	340
14.2.1 Data Sources.....	340
14.2.2 DOM System Architecture.....	341
14.2.3 MapReduce Framework.....	342
14.2.4 Sentiment Analysis.....	343
14.2.5 Clustering-Based Summarization Framework.....	344
14.2.6 Influencer Analysis.....	349
14.2.7 AskDOM: Mobile Application.....	350
14.3 Implementation.....	350
14.3.1 Server.....	350
14.3.2 Core Service.....	351
14.3.3 I/O.....	351
14.4 Validation.....	352
14.4.1 Validation Parameter.....	352
14.4.2 Validation method.....	352
14.4.3 Validation results.....	352
14.5 Case Studies.....	353
14.5.1 Political Opinion: #prayforthailand.....	353
14.5.2 Bangkok Traffic Congestion Ranking.....	353
14.6 Summary and Conclusions.....	354
Acknowledgments.....	354
References.....	355
<b>CHAPTER 15 A Case Study in Big Data Analytics: Exploring Twitter Sentiment Analysis and the Weather</b> .....	<b>357</b>
15.1 Background.....	357
15.2 Big Data System Components.....	358
15.2.1 System Back-End Architecture.....	358
15.2.2 System Front-End Architecture.....	359
15.2.3 Software Stack.....	360
15.3 Machine-Learning Methodology.....	360
15.3.1 Tweets Sentiment Analysis.....	361
15.3.2 Weather and Emotion Correlation Analysis.....	371
15.4 System Implementation.....	373
15.4.1 Home Page.....	373
15.4.2 Sentiment Pages.....	374
15.4.3 Weather Pages.....	374

CHAPTER

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1

1



**15.5 Key Findings**..... 378

    15.5.1 Time Series ..... 378

    15.5.2 Analysis with Hourly Weather Data ..... 378

    15.5.3 Analysis with Daily Weather Data..... 380

    15.5.4 DBSCAN Cluster Algorithm..... 382

    15.5.5 Straightforward Weather Impact on Emotion..... 383

**15.6 Summary and Conclusions** ..... 384

    Acknowledgments ..... 387

    References..... 387

**CHAPTER 16 Dynamic Uncertainty-Based Analytics for Caching Performance Improvements in Mobile Broadband Wireless Networks**..... 389

**16.1 Introduction**..... 389

    16.1.1 Big Data Concerns ..... 391

    16.1.2 Key Focus Areas ..... 391

**16.2 Background**..... 392

    16.2.1 Cellular Network and VoD ..... 392

    16.2.2 Markov Processes ..... 393

**16.3 Related Work** ..... 395

**16.4 VoD Architecture** ..... 396

**16.5 Overview**..... 398

**16.6 Data Generation** ..... 399

**16.7 Edge and Core Components** ..... 400

**16.8 INCA Caching Algorithm**..... 401

**16.9 QoE Estimation**..... 403

**16.10 Theoretical Framework**..... 403

**16.11 Experiments and Results**..... 404

    16.11.1 Cache Hits With  $N_U$ ,  $N_C$ ,  $N_M$  and  $k$ ..... 405

    16.11.2 QoE Impact With Prefetch Bandwidth ..... 407

    16.11.3 User Satisfaction With Prefetch Bandwidth ..... 409

**16.12 Synthetic Dataset** ..... 409

    16.12.1 INCA Hit Gain..... 410

    16.12.2 QoE Performance..... 410

    16.12.3 Satisfied Users ..... 412

**16.13 Conclusions and Future Directions**..... 413

    References..... 414

**CHAPTER 17 Big Data Analytics on a Smart Grid: Mining PMU Data for Event and Anomaly Detection**..... 417

**17.1 Introduction**..... 417

**17.2 Smart Grid With PMUs and PDCs** ..... 418



17.3 Improving Traditional Workflow.....418

17.4 Characterizing Normal Operation.....419

17.5 Identifying Unusual Phenomena.....420

17.6 Identifying Known Events.....423

17.7 Related Efforts.....426

17.8 Conclusion and Future Directions.....427

    Acknowledgments.....428

    References.....428

**CHAPTER 18 eScience and Big Data Workflows in Clouds:  
A Taxonomy and Survey.....431**

18.1 Introduction.....431

18.2 Background.....432

    18.2.1 History.....432

    18.2.2 Grid-Based eScience.....434

    18.2.3 Cloud Computing.....435

18.3 Taxonomy and Review of eScience Services in the Cloud.....436

    18.3.1 Infrastructure.....437

    18.3.2 Ownership.....437

    18.3.3 Application.....438

    18.3.4 Processing Tools.....439

    18.3.5 Storage.....439

    18.3.6 Security.....440

    18.3.7 Service Models.....441

    18.3.8 Collaboration.....441

18.4 Resource Provisioning for eScience Workflows in Clouds.....442

    18.4.1 Motivation.....442

    18.4.2 Our Solution.....445

18.5 Open Problems.....451

18.6 Summary.....452

    References.....452

Index.....457

List of

- T. Achalak**  
King Mong
- P. Ameri**  
Karlsruhe
- A. Berry**  
Deontik, B
- N. Bojja**  
Machine Z
- R. Buyya**  
The Univer  
Australia
- W. Chen**  
University o
- C. Deerosej**  
King Mongk
- A. Diaz-Pere**  
Cinvestav-Ta
- H. Ding**  
Xi'an Jiaoton
- X. Dong**  
Huazhong U
- H. Duan**  
The Univers
- S. Dutta**  
Max Planck
- A. Garcia-Ro**  
Cinvestav-Ta
- V. Gramoli**  
University of
- X. Gu**  
Huazhong U
- J. Han**  
Xi'an Jiaotong
- B. He**  
Nanyang Tec