

Contents

	<i>List of Figures</i>	<i>page ix</i>
	<i>List of Tables</i>	<i>xi</i>
1	Introduction	1
	1.1 Background	1
	1.2 From Cloud Learning to Edge Learning	2
	1.2.1 From Cloud Computing to Edge Computing	2
	1.2.2 From Distributed Machine Learning to Edge Learning	3
	1.3 Edge Learning and Edge Intelligence	4
	1.4 Challenges of Edge Learning	5
	1.4.1 Hard to Train Due to Constrained and Heterogeneous Edge Resources	6
	1.4.2 Hard to Protect Due to Vulnerable Edge Devices	7
	1.4.3 Hard to Manage Due to Complex Edge Environment	8
	1.4.4 Hard to Collaborate Due to Lack of Participant	8
	1.5 The Scope and Organization of This Book	9
2	Preliminary	11
	2.1 Background of Edge Computing	11
	2.1.1 Edge Computing Paradigms	11
	2.2 Deep Learning Models and Collaborative Training Approaches	14
	2.2.1 Deep Learning Models	14
	2.2.2 Collaborative Training Approaches	15
	2.3 Basic Machine Learning Algorithms	16
	2.3.1 Learning Problem Statement	16
	2.3.2 Basic Machine Learning Algorithms	17
	2.4 Learning Architectures: Parameter Server and Decentralized Learning	20
	2.5 Synchronization Modes	22
	2.5.1 Bulk Synchronous Parallel (BSP)	23
	2.5.2 Asynchronous Parallel (ASP)	23
	2.5.3 Stale Synchronous Parallel (SSP)	23

3	Fundamental Theory and Algorithms of Edge Learning	24
3.1	Distributed Machine Learning and the Convergence Theory	24
3.2	Advanced Training Algorithm and Corresponding Theory	27
3.2.1	Regularization and Loss Function	27
3.2.2	Direction Based Optimization	29
3.2.3	Algorithms Based on Hyper-Parameters	32
3.2.4	Co-designed Algorithms	34
3.2.5	Optimization Algorithms for DNN	37
3.3	Theoretical Framework for Flexible Synchronization in Edge Learning	38
4	Communication-Efficient Edge Learning	42
4.1	Introduction to Communication-Efficient Edge Learning	42
4.2	Communication Data Compression in Edge Learning	43
4.2.1	Quantization	43
4.2.2	Sparsification	46
4.2.3	Low Rank	48
4.2.4	Error Compensation Techniques for Communication Compression	48
4.2.5	Communication Compression in Decentralized Training	50
4.3	Lazy Synchronization	51
4.3.1	Large Batch Size	51
4.3.2	Periodic Averaging	52
4.3.3	Fine-Grained Aggregation	52
4.3.4	A Communication-Efficient Edge Learning Framework with Quantized and Period Averaging	53
4.4	Overlap Synchronization Parallel with Quantization	57
4.4.1	Algorithm Description	58
4.4.2	Theoretical Results	60
4.5	Wireless Network Optimization for Edge Learning	62
4.5.1	Scheduling Policy for Communication-Efficient Edge Learning in Wireless Environments	63
4.5.2	MIMO and Over-the-Air Computation for Fast Aggregation in Edge Learning	66
4.6	Conclusion and Future Directions	70
4.6.1	Two-Pass Compression Method for Edge Learning	71
4.6.2	Gradient Compression Robust to Byzantine Workers	71
4.6.3	Communication Compression for Two-Order Optimization Algorithm	72
5	Computation Acceleration	73
5.1	Introduction to Computation Acceleration	73
5.2	Model Compression and Hardware Acceleration	74
5.2.1	model compression	74
5.2.2	Hardware Acceleration	79

5.3	Straggler Tolerance	82
5.3.1	Framework of Gradient Coding	83
5.3.2	Construction Encoding and Decoding Matrix	84
5.3.3	Construct B in the General Case	87
5.3.4	Recent Methods of Gradient Coding	90
5.4	Improving the Inference Performance in the Edge Environment	91
5.4.1	Key Performance Indicators in Inference	91
5.4.2	Enabling Technologies for Inference	92
5.5	Conclusion and Future Directions	95
5.5.1	Jointly Optimize Learning Algorithm and Hardware Implementation in Edge Environments	95
5.5.2	Green and Sustainable Model Training among Heterogeneous Hardware Platforms	96
5.5.3	Approximate Gradient Coding to Deal with Stragglers	97
6	Efficient Training with Heterogeneous Data Distribution	98
6.1	Introduction to Federated Learning	98
6.2	Training with Non-IID Data	101
6.2.1	What Does Non-IID Mean?	102
6.2.2	Enabling Technologies for Training Non-IID Data	102
6.3	Conclusion and Future Directions	107
6.3.1	Tackle the Non-IID Data via Learning-based Data Selection	108
6.3.2	Adaptive Parameter Setting for Non-IID Data	109
6.3.3	Straggler-Tolerant Federated Learning Algorithms	110
7	Security and Privacy Issues in Edge Learning Systems	112
7.1	Security Guarantee	112
7.1.1	Data-Oriented Attacks	113
7.1.2	Defense Technologies for Data-Oriented Attacks	116
7.1.3	Model-Oriented Attacks	119
7.1.4	Defense Technologies for Model-Oriented Attacks	120
7.2	Privacy Protection	121
7.2.1	Introduction to Privacy Attacks in Edge Learning	121
7.2.2	Enabling Technologies for Private Edge Learning	122
7.3	Conclusion and Future Directions	128
7.3.1	Multi-level Privacy-Protection for Efficient Edge Learning	128
7.3.2	Hierarchical Outlier Detection for Security Guarantee	128
7.3.3	Attack Detection in Communication-Compressed Training	130
7.3.4	Computation Offloading for Encrypted Data Training	130
8	Edge Learning Architecture Design for System Scalability	131
8.1	Introduction to the Learning Architecture	131
8.1.1	Parallelism Schemes: Data Parallelism and Model Parallelism	131

viii	Contents	
	8.1.2 Large-Scale Model Training Architecture	137
	8.2 Edge Learning Frameworks over the Hierarchical Architecture	139
	8.2.1 Introduction to the Hierarchical Architecture	140
	8.2.2 Community-Based Synchronization Parallel over the Hierarchical Architecture	143
	8.2.3 Convergence Rate of Community-Based Synchronization Parallel	145
	8.3 Extension of Community-Based Synchronization Parallel	150
	8.3.1 A Hybrid Synchronization Mechanism over the Hierarchical Architecture	150
	8.3.2 Abstract of Community and Communication-Aware Parameter Servers	151
	8.3.3 Convergence Result of Hybrid Community-Based Synchronization Parallel	152
	8.4 Conclusion and Future Directions	157
9	Incentive Mechanisms in Edge Learning Systems	159
	9.1 Fundamental Theory of Incentive Mechanisms	159
	9.2 Related Works	161
	9.2.1 Incentive Mechanisms	161
	9.2.2 Incentive Mechanisms for Edge Learning	161
	9.3 A Learning-Based Incentive Mechanism for Edge Learning	162
	9.3.1 Problem Description	164
	9.3.2 System Model	165
	9.3.3 Equilibrium Analysis	166
	9.3.4 A Deep Reinforcement Learning-Based Incentive Mechanism	168
	9.4 Conclusion and Future Directions	169
10	Edge Learning Applications	171
	10.1 APIs, Libraries, and Platforms for Edge Learning	171
	10.1.1 General Programming Frameworks for Machine Learning	171
	10.2 Application Scenarios	175
	10.2.1 Smart Transportation	175
	10.2.2 Smart Healthcare	179
	10.2.3 Intelligent Blockchain + Edge AI	180
	10.2.4 Intelligent Financial Risk Control	182
	10.2.5 Edge AI + IoT	184
	10.2.6 Virtual Reality	186
	10.3 The Dr. Body System for Posture Detection and Rehabilitation Tracking	188
	<i>Bibliography</i>	190
	<i>Index</i>	215