## **BIG DATA**

## **CONCEPTS, WAREHOUSING, AND ANALYTICS**

MARIBEL YASMINA SANTOS

CARLOS COSTA





## **CONTENTS**

List	st of Figures				X	
List	st of Tables					
The	ne Authors					
Ack	cknowledgments >					
For	eword				XXIII	
Not	ation				XXV	
1.	Introduction					
	1.1.	Object	ives of this	Book	4	
	1.2.	Intende	ed Audien	ce	7	
	1.3.	Book Structure				
2.	Big Data Concepts, Techniques, and Technologies				9	
	2.1.	Big Da	Data Relevance			
	2.2.	Big Da	ata Characteristics			
	2.3.	. Big Data Challenges				
		2.3.1.	Big Data	General Dilemmas	16	
		2.3.2.	Challeng	es in the Big Data Life Cycle	17	
		2.3.3.	Big Data	in Secure, Private, and Monitored Environments	19	
		2.3.4.	Organiza	tional Change	20	
	2.4.	Techniques for Big Data Solutions			21	
		2.4.1.	Big Data	Life Cycle and Requirements	23	
			2.4.1.1.	General Steps to Process and Analyze Big Data	23	
			2.4.1.2.	Architectural and Infrastructural Requirements	25	

		2.4.2.	The Lam	bda Architecture	27
		2.4.3.		Standardization: the NIST Reference	
			Architect		28
	2.5. Big Data Technologies				30
			•	and Related Projects	30
		2.5.2.		pe of Distributed SQL Engines	32
		2.5.3.	Other le	chnologies for Big Data Analytics	35
3.	OLT	P-orien	ted Datab	pases for Big Data Environments	37
	3.1.	NoSQL	and New	/SQL: an Overview	38
	3.2.	NoSQL	_ Databas	es	41
		3.2.1.	Key-valu	e Databases	41
			3.2.1.1.	Overview	41
			3.2.1.2.	Redis	42
		3.2.2.	Column-	oriented Databases	49
			3.2.2.1.	Overview	50
			3.2.2.2.	HBase	51
			3.2.2.3.	From Relational Models to HBase Data Models	57
		3.2.3.		nt-oriented Databases	69
				Overview	69
				MongoDB	71
		3.2.4.	•		79
			3.2.4.1.	Overview	79
			3.2.4.2.		82
	3.3.	NewS(	QL Databa	ises and Translytical Databases	88
4.	OLA	P-orien	ted Datal	pases for Big Data Environments	93
	4.1.	Hive: the De Facto SQL-on-Hadoop Engine			94
		4.1.1.	Data Sto	rage Formats	98
			4.1.1.1.	Text File	99
			4.1.1.2.	Sequence File	100
			4.1.1.3.	RCFile	105
			4.1.1.4.	ORC File	107
			4.1.1.5.	Avro File	111
			4.1.1.6.	Parquet	112
		4.1.2.	Partitions	s and Buckets	113

		4.2.1.	Primary	Data Tables	121	
		4.2.2.	Derived	Data Tables	125	
	4.3.	Optimi	zing OLAF	P workloads with Druid	131	
5.	Desi	sign and Implementation of Big Data Warehouses				
	5.1.	Big Data Warehousing: an Overview			144	
	5.2.	Model	of Logical	Components and Data Flows	147	
		5.2.1.	Data Pro	ovider and Data Consumer	149	
		5.2.2.	Big Data	Application Provider	149	
		5.2.3.	Big Data	Framework Provider	151	
			5.2.3.1.	Messaging/Communications, Resource		
				Management, and Infrastructures	152	
			5.2.3.2.	Processing	153	
			5.2.3.3.	Storage: Data Organization and Distribution	154	
		5.2.4.	System	Orchestrator and Security, Privacy, and		
			Manage		157	
	5.3.			ological Infrastructure	158	
	5.4.		Method for Data Modeling			
		5.4.1.	•	al Objects and their Related Concepts	164	
		5.4.2.	_	Uniting, and Materializing Analytical Objects	167	
		5.4.3.	Dimensional Big Data with Outsourced Descriptive Families 169			
		5.4.4.		deling Best Practices	171	
			5.4.4.1.	Using Null Values	171	
			5.4.4.2.	Date, Time, and Spatial Objects vs. Separate		
			<b>5440</b>	Temporal and Spatial Attributes	172	
		- 4-	5.4.4.3.		173	
		5.4.5.	Data Mo	deling Advantages and Disadvantages	174	
6.	Big	Data Wa	arehouse	s Modeling: From Theory to Practice	177	
	6.1.	Multina	ational Bic	ycle Wholesale and Manufacturing	178	
		6.1.1.	Fully Flat	t or Fully Dimensional Data Models	180	
		6.1.2.	Nested A	Attributes	181	
		6.1.3.	Streamir	ng and Random Access on Mutable Analytical		
			Objects		182	
	6.2.		age Firm		183	
		6.2.1.		ssary Complementary Analytical Objects and	183	
		Update Problems				

			6.2.1.1.	The Traditional Way of Handling SCD-like			
				Scenarios	185		
			6.2.1.2.	A New Way of Handling SCD-like Scenarios	185		
		6.2.2.	Joining C	Complementary Analytical Objects	186		
		6.2.3.	Data Science Models and Insights as a Core Value				
		6.2.4.	Partition	Keys for Streaming and Batch Analytical Objects	187		
	6.3.	Retail			188		
		6.3.1.	Simpler [	Data Models: Dynamic Partitioning Schemas	189		
		6.3.2.	Consider	rations for Spatial Objects	189		
		6.3.3.	Analyzing	g Non-Existing Events	190		
		6.3.4.	Wide De	scriptive Families	190		
		6.3.5.	The Nee	d for Joins in Data CPE Workloads	191		
	6.4.	Code Version Control System					
	6.5.	A Glob	al Databa	se of Society – The GDELT Project	193		
	6.6.	Air Qua	ality		194		
7.	Fueling Analytical Objects in Big Data Warehouses						
	7.1.	From T	raditional	Data Warehouses	198		
	7.2.	From C	DLTP NoSQL Databases				
	7.3.	From S	Semi-structured Data Sources 2				
	7.4.	From S	Streaming Data Sources 2				
	7.5.	Using Data Science Models					
		7.5.1.	Data Min	ing/Machine Learning Models for Structured Data	211		
		7.5.2.	Text Mini	ng, Image Mining, and Video Mining Models	216		
8.	Evaluating the Performance of Big Data Warehouses 21						
	8.1.	The SSB+ Benchmark			220		
		8.1.1.	Data Mo	del and Queries	220		
		8.1.2.	System A	Architecture and Infrastructure	221		
	8.2.	Batch	OLAP		223		
		8.2.1.	Compari	ng Flat Analytical Objects with Star Schemas	223		
		8.2.2.	Improving	g Performance with Adequate Data Partitioning	227		
		8.2.3.	The Impa	act of Dimensions' Size in Star Schemas	230		
		8.2.4.	The Impa	act of Nested Structures in Analytical Objects	232		
		8.2.5.	Drill Acro	ss Queries and Window and Analytics Functions	234		

	8.3.	Streaming OLAP							
		8.3.1.	The Impact of Data Volume in the Streaming Storage						
			Component	236					
		8.3.2.	Considerations for Effective and Efficient Streaming OLAP	239					
	8.4.	SQL-or	n-Hadoop Systems under Multi-User Environments	242					
9.	Big [	Big Data Warehousing in Smart Cities 24							
	9.1.	Logical	Components, Data Flows, and Technological Infrastructure	246					
		9.1.1.	SusCity Architecture	247					
		9.1.2.	SusCity Infrastructure	250					
	9.2.	SusCity Data Model							
		9.2.1.	Buildings Characteristics as an Outsourced Descriptive						
			Family	254					
		9.2.2.	Nested Structures in Analytical Objects	255					
	9.3.	3. The Inter-storage Pipeline							
	9.4.	The Su	sCity Data Visualization Platform	256					
		9.4.1.	City's Energy Consumption	257					
		9.4.2.	City's Energy Grid Simulations	258					
		9.4.3.	Buildings' Performance Analysis and Simulation	258					
		9.4.4.	Mobility Patterns Analysis	260					
10.	Co	Conclusion							
	10.	1. Syn	opsis of the Book	265					
	10.	<b>2.</b> Con	tributions to the State of the Art	270					
Refe	erence	S		271					
Inde	ex			281					