

Hasso Plattner · Alexander Zeier

# In-Memory Data Management

Technology and Applications

Second Edition

 Springer

# Contents

6

## Part I An Inflection Point for Enterprise Applications

<b>1</b>	<b>Desirability, Feasibility, Viability: The Impact of In-Memory . . . .</b>	<b>3</b>
1.1	Information in Real Time: Anything, Anytime, Anywhere . . . .	3
1.1.1	Response Time at the Speed of Thought. . . . .	4
1.1.2	Real-Time Analytics and Computation on the Fly . . . .	6
1.2	The Impact of Recent Hardware Trends . . . . .	6
1.2.1	Database Management Systems for Enterprise Applications. . . . .	7
1.2.2	Main Memory is the New Disk . . . . .	10
1.2.3	From Maximizing CPU Speed to Multi-Core Processors. . . . .	11
1.2.4	Increased Bandwidth Between CPU and Main Memory . . . . .	13
1.3	Reducing Cost Through In-Memory Data Management . . . . .	16
1.3.1	Total Cost of Ownership. . . . .	16
1.3.2	Cost Factors in Enterprise Systems. . . . .	17
1.3.3	In-Memory Performance Boosts Cost Reduction . . . . .	18
1.4	Conclusion . . . . .	19
<b>2</b>	<b>Why Are Enterprise Applications So Diverse? . . . . .</b>	<b>21</b>
2.1	Current Enterprise Applications . . . . .	22
2.2	Examples of Enterprise Applications . . . . .	23
2.3	Enterprise Application Architecture . . . . .	25
2.4	Data Processing in Enterprise Applications . . . . .	26
2.5	Data Access Patterns in Enterprise Applications . . . . .	27
2.6	Conclusion . . . . .	27

<b>3</b>	<b>SanssouciDB: Blueprint for an In-Memory Enterprise</b>	
	<b>Database System</b> . . . . .	29
3.1	Targeting Multi-Core and Main Memory . . . . .	30
3.2	Designing an In-Memory Database System . . . . .	31
3.3	Organizing and Accessing Data in SanssouciDB . . . . .	33
3.4	Conclusion . . . . .	35



## Part II SanssouciDB: A Single Source of Truth Through In-Memory

<b>4</b>	<b>The Technical Foundations of SanssouciDB</b> . . . . .	39
4.1	Understanding Memory Hierarchies . . . . .	40
4.1.1	Introduction to Main Memory . . . . .	40
4.1.2	Organization of the Memory Hierarchy . . . . .	44
4.1.3	Trends in Memory Hierarchies . . . . .	45
4.1.4	Memory from a Programmer's Point of View . . . . .	46
4.2	Parallel Data Processing Using Multi-Core and Across Servers. . . . .	53
4.2.1	Increasing Capacity by Adding Resources. . . . .	54
4.2.2	Parallel System Architectures . . . . .	56
4.2.3	Parallelization in Databases for Enterprise Applications . . . . .	58
4.2.4	Parallel Data Processing in SanssouciDB . . . . .	60
4.3	Compression for Speed and Memory Consumption . . . . .	64
4.3.1	Light-Weight Compression . . . . .	65
4.3.2	Heavy-Weight Compression . . . . .	69
4.3.3	Data-Dependent Optimization . . . . .	70
4.3.4	Compression-Aware Query Execution. . . . .	70
4.3.5	Compression Analysis on Real Data. . . . .	71
4.4	Column, Row, Hybrid: Optimizing the Data Layout. . . . .	72
4.4.1	Vertical Partitioning . . . . .	72
4.4.2	Finding the Best Layout . . . . .	76
4.4.3	Challenges for Hybrid Databases . . . . .	78
4.4.4	Application Scenarios . . . . .	79
4.5	The Impact of Virtualization . . . . .	79
4.5.1	Virtualizing Analytical Workloads . . . . .	80
4.5.2	Data Model and Benchmarking Environment. . . . .	80
4.5.3	Virtual Versus Native Execution . . . . .	81
4.5.4	Response Time Degradation with Concurrent VMs . . . . .	82
4.6	Summarizing the Technical Concepts . . . . .	84
4.7	Conclusion . . . . .	95

<b>5</b>	<b>Organizing and Accessing Data in SanssouciDB</b>	97
5.1	SQL for Accessing In-Memory Data	98
5.1.1	The Role of SQL	98
5.1.2	The Lifecycle of a Query	99
5.1.3	Stored Procedures	99
5.1.4	Data Organization and Indices	100
5.1.5	Any Attributes as Index	101
5.2	Increasing Performance with Data Aging	103
5.2.1	Active and Passive Data	104
5.2.2	Implementation Considerations for an Aging Process	105
5.2.3	The Use Case for Horizontal Partitioning of Leads	106
5.3	Efficient Retrieval of Business Objects	108
5.3.1	Retrieving Business Data from a Database	109
5.3.2	Object Data Guide	109
5.4	Efficient Execution of Business Functions	111
5.4.1	Separating Business Functions from Application Functions	111
5.4.2	Comparing Business Functions	112
5.5	Handling Data Changes in Read-Optimized Databases	114
5.5.1	The Impact on SanssouciDB	115
5.5.2	The Merge Process	116
5.5.3	Improving Performance with Single Column Merge	120
5.6	Append, Never Delete, to Keep the History Complete	123
5.6.1	Insert-Only Implementation Strategies	123
5.6.2	Minimizing Locking Through Insert-Only	125
5.6.3	The Impact on Enterprise Applications	128
5.6.4	Feasibility of the Insert-Only Approach	130
5.7	Enabling Analytics on Transactional Data	132
5.7.1	Aggregation on the Fly	133
5.7.2	Analytical Queries without a Star Schema	142
5.8	Extending Data Layout Without Downtime	149
5.8.1	Reorganization in a Row Store	149
5.8.2	On-The-Fly Addition in a Column Store	150
5.9	Business Resilience Through Advanced Logging Techniques	151
5.9.1	Recovery in Column Stores	152
5.9.2	Differential Logging for Row-Oriented Databases	154
5.9.3	Providing High Availability	155
5.10	The Importance of Optimal Scheduling for Mixed Workloads	156
5.10.1	Introduction to Scheduling	156
5.10.2	Characteristics of a Mixed Workload	159

5.10.3	Scheduling Short and Long Running Tasks . . . . .	160
5.11	Conclusion . . . . .	163

### Part III How In-Memory Changes the Game

<b>6</b>	<b>Application Development . . . . .</b>	<b>167</b>
6.1	Optimizing Application Development for SanssouciDB . . . . .	167
6.1.1	An In-Memory Application Programming Model . . . . .	168
6.1.2	Application Architecture . . . . .	172
6.1.3	Moving Business Logic into the Database . . . . .	173
6.1.4	Best Practices . . . . .	175
6.1.5	Graphical Creation of Views . . . . .	176
6.2	Innovative Enterprise Applications . . . . .	178
6.2.1	New Analytical Applications . . . . .	179
6.2.2	Operational Processing to Simplify Daily Business . . . . .	182
6.2.3	Information at Your Fingertips with Innovative User-Interfaces . . . . .	185
6.2.4	Combining Analytics and Textsearch . . . . .	190
6.2.5	Basic Types of Search . . . . .	191
6.2.6	Features for Enterprise Search . . . . .	191
6.3	Conclusion . . . . .	194
<b>7</b>	<b>Finally, A Real Business Intelligence System is at Hand . . . . .</b>	<b>195</b>
7.1	Analytics on Operational Data . . . . .	195
7.1.1	Yesterday's Business Intelligence . . . . .	196
7.1.2	Today's Business Intelligence . . . . .	199
7.1.3	Drawbacks of Separating Analytics from Daily Operations . . . . .	201
7.1.4	Dedicated Database Designs for Analytical Systems . . . . .	202
7.1.5	Analytics and Query Languages . . . . .	205
7.1.6	Enablers for Changing Business Intelligence . . . . .	206
7.1.7	Tomorrow's Business Intelligence . . . . .	208
7.2	How to Evaluate Databases After the Game has Changed . . . . .	209
7.2.1	Benchmarks in Enterprise Computing . . . . .	210
7.2.2	Changed Benchmark Requirements for a Mixed Workload . . . . .	211
7.2.3	A New Benchmark for Daily Operations and Analytics . . . . .	213
7.3	Conclusion . . . . .	216
<b>8</b>	<b>Scaling SanssouciDB in the Cloud . . . . .</b>	<b>219</b>
8.1	What Is Cloud Computing? . . . . .	220
8.2	Types of Cloud Applications . . . . .	221

8.3	Cloud Computing from the Provider Perspective . . . . .	223
8.3.1	Multi-Tenancy . . . . .	223
8.3.2	Low-End Versus High-End Hardware . . . . .	228
8.3.3	Replication . . . . .	229
8.3.4	Energy Efficiency by Employing In-Memory Technology . . . . .	230
8.4	Conclusion . . . . .	231
<b>9</b>	<b>In-Memory Revolution has Begun . . . . .</b>	<b>233</b>
9.1	Risk-Free Transition to In-Memory Data Management . . . . .	233
9.1.1	Operating In-Memory and Traditional Systems Side by Side . . . . .	234
9.1.2	System Consolidation and Extensibility . . . . .	235
9.2	Customer Proof Points . . . . .	236
9.2.1	Charité—Universitätsmedizin Berlin . . . . .	237
9.2.2	Hilti . . . . .	239
9.3	Conclusion . . . . .	241
	<b>About the Authors . . . . .</b>	<b>243</b>
	<b>Glossary . . . . .</b>	<b>245</b>
	<b>References . . . . .</b>	<b>255</b>
	<b>Index . . . . .</b>	<b>263</b>