Next Generation Analytics
Oracle Database In-Memory and Oracle Converged Database

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In-Memory Computing Summit 2020

@dbinmemory
Safe harbor statement

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What is a Real-Time Enterprise?

Data Driven
Agile
Efficient
What is a Real-Time Enterprise?

- **Data-Driven**: Uses metrics and calculations based on actual data
What is a Real-Time Enterprise?

- **Data-Driven**: Uses metrics and calculations based on actual data
- **Agile**: Rapidly adapts to changes in observed data
What is a Real-Time Enterprise?

- **Data-Driven:** Uses metrics and calculations based on actual data
- **Agile:** Rapidly adapts to changes in observed data
- **Efficient:** Continuously optimizes business processes to maximize revenue and profit
Real-Time Enterprise Examples

INSURANCE

Improve portfolios and reduce cost with real-time analytics for pricing
Real-Time Enterprise Examples

**INSURANCE**

Improve portfolios and reduce cost with real-time analytics for pricing

**RETAILERS**

Use location-based analytics to send personalized mobile coupons to customers
Real-Time Enterprise Examples

- **INSURANCE**
  - Improve portfolios and reduce cost with real-time analytics for pricing

- **RETAILERS**
  - Use location-based analytics to send personalized mobile coupons to customers

- **MANUFACTURING**
  - Use real-time analytics to monitor quality and adjust parameters

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Real-Time Enterprise Examples

**INSURANCE**
Improve portfolios and reduce cost with real-time analytics for pricing

**RETAILERS**
Use location-based analytics to send personalized mobile coupons to customers

**MANUFACTURING**
Use real-time analytics to monitor quality and adjust parameters

**FINTECH**
Perform risk/fraud analysis across channels in real-time, not after the event occurs
## Real-Time Enterprise Examples

<table>
<thead>
<tr>
<th>INSURANCE</th>
<th>RETAILERS</th>
<th>MANUFACTURING</th>
<th>FINTECH</th>
<th>TELECOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve portfolios and reduce cost with real-time analytics for pricing</td>
<td>Use location-based analytics to send personalized mobile coupons to customers</td>
<td>Use real-time analytics to monitor quality and adjust parameters</td>
<td>Perform risk/fraud analysis across channels in real-time, not after the event occurs</td>
<td>Use real-time congestion metrics to optimize their networks</td>
</tr>
</tbody>
</table>

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The Enemy of the Real Time Enterprise: Complexity

- Multiple systems, different technologies, different implementations, etc.
- Hurts security, administration, diagnosability
- Disrupts agility and efficiency
Real-World Macro-Complexity: Die By DIY

**Macro-Complexity**

- Multiple technologies
- Multiple data stores
- Data copied multiple times to do analytics
- Compromises security
- Compromises data consistency
- Complex to maintain
- Need highly skilled developers to build & keep running
Example of Application Evolution: **Magna Cart**

- **Online Delivery App**
  - **Customers**: place orders
  - **Stores**: process orders
  - **Delivery Service**: delivers orders
  - **Analyst**: Checks business metrics

- **App logic includes**:
  - Transactions for Orders and Delivery
  - Analytics for instant decisions and for continuous business optimization
Magna Cart: Transactional (OLTP) Workload

- Browse Items, Add Items to Order, Place Order, ...
- Process Order, Ship Order, Restock Products, ...
- Schedule Delivery Pick up from Store, Deliver to Customer, ...

Customer

Store

Delivery Service

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## Define OLTP Tables and Relationships

<table>
<thead>
<tr>
<th>CUSTOMERS</th>
<th>id</th>
<th>email</th>
<th>name</th>
<th>address</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORDERS</td>
<td>id</td>
<td>customer_id</td>
<td>order_datetime</td>
<td>store_id</td>
</tr>
<tr>
<td>ITEMS</td>
<td>id</td>
<td>order_id</td>
<td>Shipment_id</td>
<td>product_id</td>
</tr>
<tr>
<td>STORES</td>
<td>id</td>
<td>name</td>
<td>URL</td>
<td>address</td>
</tr>
<tr>
<td>PRODUCTS</td>
<td>id</td>
<td>name</td>
<td>category</td>
<td>rating</td>
</tr>
<tr>
<td>INVENTORY</td>
<td>store_id</td>
<td>product_id</td>
<td>product_inventory</td>
<td></td>
</tr>
</tbody>
</table>
Define **OLTP Tables and Relationships**

<table>
<thead>
<tr>
<th>CUSTOMERS</th>
<th>ORDERs</th>
<th>ITEMS</th>
<th>DELIVERIES</th>
<th>STORES</th>
<th>PRODUCTS</th>
<th>INVENTORY</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>id</td>
<td>id</td>
<td>id</td>
<td>id</td>
<td>id</td>
<td>store_id</td>
</tr>
<tr>
<td>email</td>
<td>customer_id</td>
<td>order_id</td>
<td>store_id</td>
<td>name</td>
<td>name</td>
<td>category</td>
</tr>
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<td>URL</td>
<td>rating</td>
</tr>
<tr>
<td>address</td>
<td>store_id</td>
<td>product_id</td>
<td>Delivery_address</td>
<td>address</td>
<td>unit_price</td>
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- A **Customer** has multiple **Orders**
## Define OLTP Tables and Relationships

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<tbody>
<tr>
<td>id</td>
<td>id</td>
<td>id</td>
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<td>id</td>
<td>store_id</td>
</tr>
<tr>
<td>email</td>
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<td>category</td>
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</tr>
<tr>
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<td>product_id</td>
<td>URL</td>
<td>rating</td>
<td>store_id</td>
</tr>
<tr>
<td></td>
<td>order_status</td>
<td>quantity</td>
<td>address</td>
<td>unit_price</td>
<td>store_id</td>
</tr>
</tbody>
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- A **Customer** has multiple **Orders**
- An **Order** has multiple **Items** and a single **Store**
Define **OLTP Tables and Relationships**

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<td>id</td>
<td>id</td>
<td>store_id</td>
</tr>
<tr>
<td>email</td>
<td>customer_id</td>
<td>order_id</td>
<td>store_id</td>
<td>name</td>
<td>name</td>
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<tr>
<td>name</td>
<td>order_datetime</td>
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<td>category</td>
<td>URL</td>
<td>category</td>
<td>product_inventory</td>
</tr>
<tr>
<td>address</td>
<td>store_id</td>
<td>product_id</td>
<td>rating</td>
<td>address</td>
<td>rating</td>
<td></td>
</tr>
<tr>
<td></td>
<td>order_status</td>
<td>quantity</td>
<td>unit_price</td>
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- A **Customer** has multiple **Orders**
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- An **Item** has a single **Delivery** and **Product**
Define OLTP Tables and Relationships

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  - email
  - name
  - address

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  - order_datetime
  - store_id
  - order_status

- **ITEMS**
  - id
  - order_id
  - Shipment_id
  - product_id
  - quantity

- **DELIVERIES**
  - id
  - store_id
  - customer_id
  - Delivery_address
  - Delivery_status

- **STORES**
  - id
  - name
  - URL
  - address

- **PRODUCTS**
  - id
  - name
  - category
  - rating
  - unit_price

- **INVENTORY**
  - store_id
  - product_id
  - product_inventory

- **A Customer** has multiple **Orders**
- **An Order** has multiple **Items** and a single **Store**
- **An Item** has a single **Delivery** and **Product**
- **A Delivery** has multiple **Items** and a single **Store** and **Customer**
Define **OLTP Tables and Relationships**

- A **Customer** has multiple **Orders**
- An **Order** has multiple **Items** and a single **Store**
- An **Item** has a single **Delivery** and **Product**
- A **Delivery** has multiple **Items** and a single **Store** and **Customer**
- A **Store** has an inventory of each **Product** via the many-many **Inventory** Table
Relationships Correspond to OLTP Indexes

• Primary Key Indexes for each table
  Customers(id)  
  Orders(id)  
  Items(id)  
  etc.

• Indexes on all Foreign keys
  Orders(Customer_id)  
  Items(order_id)  
  Deliveries(store_id)  
  etc.
Magna Cart: Up and Running with Transactions!

- Single Database
- Simple Schema
- Simple Architecture
- Fast Transactions
Magna Cart: **Real-Time Analytics**

- What is the top rated phone? Which stores carry it in my region? What other accessories do I need?
- What other products and promotions should we offer a customer based on their current order items and location?
- What deliveries could be combined within a single trip? Which stores and customers have the most pending deliveries?

These queries run slowly without analytic indexes.
Without indexes, analytic queries perform poorly (perform full table scans)

- Many columns require analytic indexes:
  - Orders: **status, datetime**
  - Products: **name, rating, category, price**
  - Inventory: **product_inventory**
  - Customer: **name, email, address**
  - Deliveries: **address, status**
  - Items: **quantity**
Magna Cart: **Still Simple, But ...**

- Still a Single Database
- Still a Simple Schema
- But analytic indexes add overheads:
  - Slow down Transactions
  - Increase database size
  - Require knowledge of workload
Magna Cart: Longer Term Analytics

Which products give us our highest margins?

What are the top 10 stores in the northwest region this month?

If we offer a 20% discount on flour, how much could our margins improve?

These queries typically access large amounts of historical data and are usually better offloaded to a Reporting Database.
Define **Reporting Database (Star) Schema**

- Required for longer running queries on large historical data
- Maintains history of all sales, by customer, store, product
- Different schema from the OLTP database:
  - **Central “Fact” table:** SALES
  - **“Dimension” tables:** Customers, Products, Stores
  - Indexes on all key columns
  - Plus Analytic indexes on most columns

<table>
<thead>
<tr>
<th>CUSTOMERS</th>
<th>STORES</th>
<th>PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>id</td>
<td>id</td>
</tr>
<tr>
<td>email</td>
<td>store_name</td>
<td>name</td>
</tr>
<tr>
<td>full_name</td>
<td>web_address</td>
<td>category</td>
</tr>
<tr>
<td>address</td>
<td>physical_address</td>
<td>rating</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SALES</th>
<th>price</th>
<th>quantity</th>
<th>sale_date</th>
</tr>
</thead>
<tbody>
<tr>
<td>sale_id</td>
<td>customer_id</td>
<td>store_id</td>
<td>product_id</td>
</tr>
</tbody>
</table>

- Indexes on all key columns
- Plus Analytic indexes on most columns

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Magna Cart: Reporting Database *Doubles* Complexity

Operational Database

- OLTP Tables
  - Customers
  - Orders
  - Products
  - Stores
  - OTLP indexes
  - Analytic indexes

Reporting Database

- Extract, Transform, Load
- Star Schema Tables
  - Customers
  - Sales
  - Products
  - Stores
  - Star Schema Indexes

Business Analyst

Customer

Store

Delivery Service

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Magna Cart: Analytic “Dashboard” Reports

What is my YTD sales?  
What is my YoY growth?  
What are my top 10 products this month?

How many deliveries were made last week in the North East region?  
How many customers were served last month?

These queries are typically frequently run, resource intensive, and usually require pre-computed summaries for good performance
Define **Pre-Computed Summaries**

- Reports are of various types, from short term to long term
- Pre-computed summaries are often needed for frequent reports, e.g.
  - **Quarterly Sales by Store**
  - **Monthly Deliveries by Store**
  - **Top 10 Products in Store by Month**

- Typically maintained as Materialized Views that are periodically refreshed from the star schema
Magna Cart: Complexity Grows Further ...

- Customer
- Store
- Delivery Service
- Business Analyst

Operational Database

OLTP Tables
- Customers
- Orders
- Products
- Stores
- OTLP indexes
- Analytic indexes

Reporting Database

Star Schema Tables
- Customers
- Sales
- Products
- Stores
- Pre-Computed Summaries
  - Qtrly_Sales
  - Monthly_Deliveries
  - Top_Products

Extract, Transform, Load
Sources of Complexity and Inefficiency

- **Reporting Databases** add major complexity:
  - Adds a new system to manage
  - Requires complex ETL logic
  - Usually lags Operational database

- **Analytic Indexes** add overheads:
  - Requires advance knowledge of workload
  - Slow down transactions and data ingest
  - Increases Database Size

- **Pre-computed summaries** add complexity:
  - Usually lag the source tables
  - Summaries adds additional load and DB size
What We Really Want is **Simple**

- A reporting database should not be required unless it is aggregating data from multiple sources

- No predefined indexes or precomputed summaries should be needed for Analytics

- Transactions and all Analytics should be able to run on the Operational Database

*Is this possible?*
YES
Introducing Database In-Memory

What’s your favorite data format?

**Row Format**
*Fast for OLTP!*
*Slower for Analytics*

**Column Format**
*Fast for Analytics!*
*REALLY slow for OLTP!*

**Dual Format**
*Best for both Fast Analytics and fast OLTP (No need for Analytic indexes)*

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Database In-Memory: Real-Time Analytics with Fast OLTP

- Row format is ideal for OLTP and Column format for Analytics
- **BOTH** row and column format can be enabled for same table
  - Simultaneously active and consistent
- OLTP uses highly concurrent row format
  - **Tens of millions of transactions** per second
- Analytics uses in-Memory column format
  - SIMD vector instructions allow multiple values to be processed per instruction
  - **Billions of Rows per second** scan speeds
Database In-Memory: In-Memory Columnar Format

- Pure in-memory column format
- In-memory maintenance: Fast OLTP
- No changes to disk format
- Available on all platforms
- All enterprise features (security, availability) work transparently
- Does not require whole database to be in-memory
  - Can be enabled for hot data, at tablespace, table, partition, sub-partition level
In-Memory Enables SIMD Vector Processing

- Column format benefit: Need to access only needed columns
- Process multiple values with a single SIMD Vector Instruction
- Billions of rows/sec scan rate per CPU core
  - Row format is millions/sec

Example: Find sales in State of California

> 100x Faster
In-Memory Technology Summary

Greatly Accelerate Analytic Data Access

Columnar Format
- Access only the columns you need

SIMD Vector Processing
- Process multiple column values in a single CPU instruction

Storage Indexes
- Prune out any unnecessary data from the column

Compression
- Scan & filter data in compressed format
In-Memory Processing **Summary**
Greatly Accelerate all Aspects of Analytic Data Processing

**In-Memory Scans**
- Speed of memory
- Scan and Filter only the needed Columns
- Vector Instructions

**In-Memory Joins**
- Scan and Filter large table for values that match small table
- Convert Star Joins into 10X Faster Column Scans

**In-Memory Reporting**
- Create In-Memory Report Outline that is Populated during Fast Scan
- Runs complex reports 10x faster

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In-Memory Reporting

Example: Report sales of Swimwear in California Stores

- First create in-memory report outline by scanning dimension tables
  - One cell per (California Store, Swimwear Product) combo
- Outline then populated by in-memory scan of fact table
- Report runs 10x faster
Accelerates Mixed Workloads **like Magna Cart**

- Inserting one row into a table requires updating 10-20 analytic indexes: **Slow!**
- Fast analytics **only on** indexed columns
- Analytic indexes **increase** database size

- Column Store not persistent so updates are: **Fast!**
- Fast analytics on **any** columns
- No analytic indexes: **Reduces** database size
In-Memory **Extended to Flash**

- In-Memory column format also available in in Exadata Smart Columnar Flash
  - Extends in-memory from DRAM in DB compute servers to Flash in storage servers
  - Enables **SAME** in-memory optimizations on data in Storage servers as on DB compute servers

- **Massive** increase in In-Memory Columnar capacity *500TB on full rack X8*) for large tables that do not fit in DRAM

- Exadata smart query offload to storage replaces need to offload workload to reporting database

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Database In-Memory Innovations

12.1
- Pure In-Memory column format
- Scan & Filter on compressed data
- Fast joins
- Data pruning via storage indexes
- SIMD vector processing
- In-Memory aggregation

12.2
- Join Groups
- In-Memory Expressions
- JSON/OSON support
- Massive capacity - In-Memory on Exadata flash
- Auto population policies
- Fast-Start
- Active Data Guard

18c
- Automatic In-Memory
- In-Memory Dynamic Scans
- In-Memory External tables
- In-Memory Optimized Arithmetic
- Memoptimized Rowstore – Fast Lookup

19c
- Performance
- External Tables: Hive & HDFS
- Memoptimized Rowstore – Fast Ingest

20c
- Self Managing In-Memory
- In-Memory Spatial Analytics
- In-Memory Text Analytics
- Hybrid Scans
- Vector Joins

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Database In-Memory Transforms Enterprise Architecture

• Air travel was not just faster— it transformed society
  • Travel in hours not days
  • Changed business, trade, politics, education, media, sports, defense, tourism, employment ...
  • No sea sickness (only jetlag) 😊
Database In-Memory Transforms Enterprise Architecture

- Air travel was not just faster—it transformed society
  - Travel in hours not days
  - Changed business, trade, politics, education, media, sports, defense, tourism, employment …
  - No sea sickness (only jetlag) 😊
- Database In-Memory does not just improve performance
  - Instant business results → **Faster decisions**
  - No additional systems for reporting → **Lower costs**
  - Far **simpler**, more **agile** enterprise architecture
Magna Cart: Database In-Memory Brings Simplicity

- Entire workload can run on Operational database:

OLTP Tables
- Customers
- Orders
- Products
- Stores

+ OLTP Indexes

Operational Database
Magna Cart: Database In-Memory Brings Simplicity

- Entire workload can run on Operational database:
  - In-Memory Column Store replaces Analytic Indexes

OLTP Tables
- Customers
- Orders
- Products
- Stores
- Deliveries
- Inventory

+ OLTP Indexes

Operational Database

In-Memory Column Store

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Magna Cart: Database In-Memory Brings Simplicity

- Entire workload can run on Operational database:
  - In-Memory Column Store replaces Analytic Indexes
  - In-Flash Column Store replaces reporting database
Magna Cart: Database In-Memory Brings Simplicity

- Entire workload can run on Operational database:
  - In-Memory Column Store replaces Analytic Indexes
  - In-Flash Column Store replaces reporting database
  - In-Memory Reporting replaces Pre-Computed Summaries

OLTP Tables:
- Customers
- Orders
- Products
- Stores
+ OLTP Indexes

In-Memory Column Store

In-Flash Column Store

Operational Database

In-Memory Reporting

Customer
Store
Delivery Service
Business Analyst
Magna Cart: **Database In-Memory Brings Simplicity**

- Entire workload can run on **Operational database**:
  - In-Memory Column Store replaces Analytic Indexes
  - In-Flash Column Store replaces Reporting Database
  - In-Memory Reporting replaces Pre-Computed Summaries

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Superfast transactions and analytics on **all data, without prior knowledge** of workload, all on a **single** database
How Customers Use Database In-Memory

Mankind Pharma – Mixed Workload
• Analytical reports 11x faster
• Dropping indexes improved OLTP
• 90% reduction in database size

Shanghai Customs
Mixed Workload
• Processes Clearance 43x Faster
• Improves Declaration-Services Efficiency
• Reduced Costs

Lufthansa – Reporting Application
• Analytic queries up to 100x faster
• Improved data ingest performance
• Reduction in database size

Die Mobiliar – Mixed Workload
• Analytic queries 50-200X faster
• Database size reduced considerably
• Phase out of Netezza and mainframe systems

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**How Customers Use Database In-Memory**

**AT&T WiFi – reporting database**
- Business Objects reports **100X** faster
- ETL processes improved by **50%** faster
- No changes to SAP Business Objects reports

**Villeroy & Boch – SAP BW**
- SAP BW COPA queries **30 – 33X** faster
- SAP Transaction list queries **4 – 4,800X** faster
- Avoided expensive & risky upgrade to S4/Hana

**BOSCH – SAP CRM**
- Dropped all custom indexes
- Analytic queries **2-20X** faster, DML **2-3X** faster
- No changes to application required

**LION – SAP ERP**
- Analytic queries **4X** faster
- Transactions **2X** faster
- Analytic queries now possible on 100s of Millions of Point-of-Sales Transactions

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Oracle **Converged Database**
Path to Simpler Application Evolution

- As applications evolve, they often need other algorithms: Document, Graph, AI/ML. etc.
Oracle Converged Database
Path to Simpler Application Evolution

- As applications evolve, they often need other algorithms: Document, Graph, AI/ML, etc.
- Oracle converged database enables any type of workloads against any type of data
  - Relational, Document, Graph, Spatial, Files, etc.
  - Class leading Machine Learning portfolio
- Converged DB is: Simpler, Lower Cost, More Reliable
  - Same security management across all data
  - Prevents data fragmentation and copy contagion
  - Eliminates multi-database integration costs
Autonomous Database
Ultimate Converged Platform

Self-Driving
• Scale-out database with fault-tolerance and DR
• Runs on enterprise-proven Exadata platform
• Full compatibility with existing enterprise databases

Self-Securing
• Automatically applies security updates online
• Secure configuration with full database encryption
• Sensitive data hidden from Oracle or customer admins

Self-Repairing
• Recovers automatically from any failure
• 99.995% uptime including maintenance
• Elastically scales compute or storage as needed
Oracle Cloud Free Tier: Easy On-Ramp to Autonomous DB
Overview » Autonomous Database » Autonomous Database Details

ATPTESTDB2  Always Free

DB Connection  Performance Hub  Service Console  Scale Up/Down  More Actions

Autonomous Database Information  Tools  Tags

Database administration and developer tools for Autonomous Database

SQL Developer Web
Oracle SQL Developer Web provides an integrated development environment and a database administration interface for Oracle Database. Learn more.

Oracle Application Express
Oracle Application Express (APEX) is a low-code development platform that enables you to build scalable, secure enterprise apps that can be deployed anywhere. Learn more.

Oracle ML User Administration
Oracle Machine Learning is a development environment that uses a web-based interface to enable you to perform data analytics, data discovery and data visualizations. Learn more.

SODA Drivers
Simple Oracle Document Access (SODA) is a set of APIs that let you work with JSON documents managed by the Oracle Database without needing to use SQL. SODA drivers are available for REST, Java, Node.js, Python, PL/SQL, and C. Learn more.
Five Stages of Complexity

**Denial:** It’s actually very simple …
**Pain:** It is broken!
**Anxiety:** When will it break next?
**Depression:** It always breaks …
**Substance Abuse:** Just once more, for this escalation …
Five Stages of Complexity

Denial: It’s actually very simple …
Pain: It is broken!
Anxiety: When will it break next?
Depression: It always breaks …
Substance Abuse: Just once more, for this escalation …

“Simplicity is Complexity Resolved”

JUST SAY NO!!

“Simplicity is Complexity Resolved”
Getting Started With Database In-Memory

• Download Free Oracle Express Edition
  https://tinyurl.com/oracle18cXE
  Includes Database In-Memory with up to 2GB in-memory column store

• Try out free Exadata Express on Oracle Cloud
  https://tinyurl.com/exadataexpress
  Includes Database In-Memory with up to 5GB in-memory column store

• Free In-Memory Base Level in Oracle Enterprise Edition 19.8 onwards
  https://tinyurl.com/dbimbibaselevel
  Enables an in-memory column store of up to 16GB per DB instance
For More Information

Visit the Database In-Memory Blog
https://blogs.oracle.com/in-memory/

Read the Database In-Memory Overview

Try out Autonomous DB for Free!
https://www.oracle.com/cloud/free/