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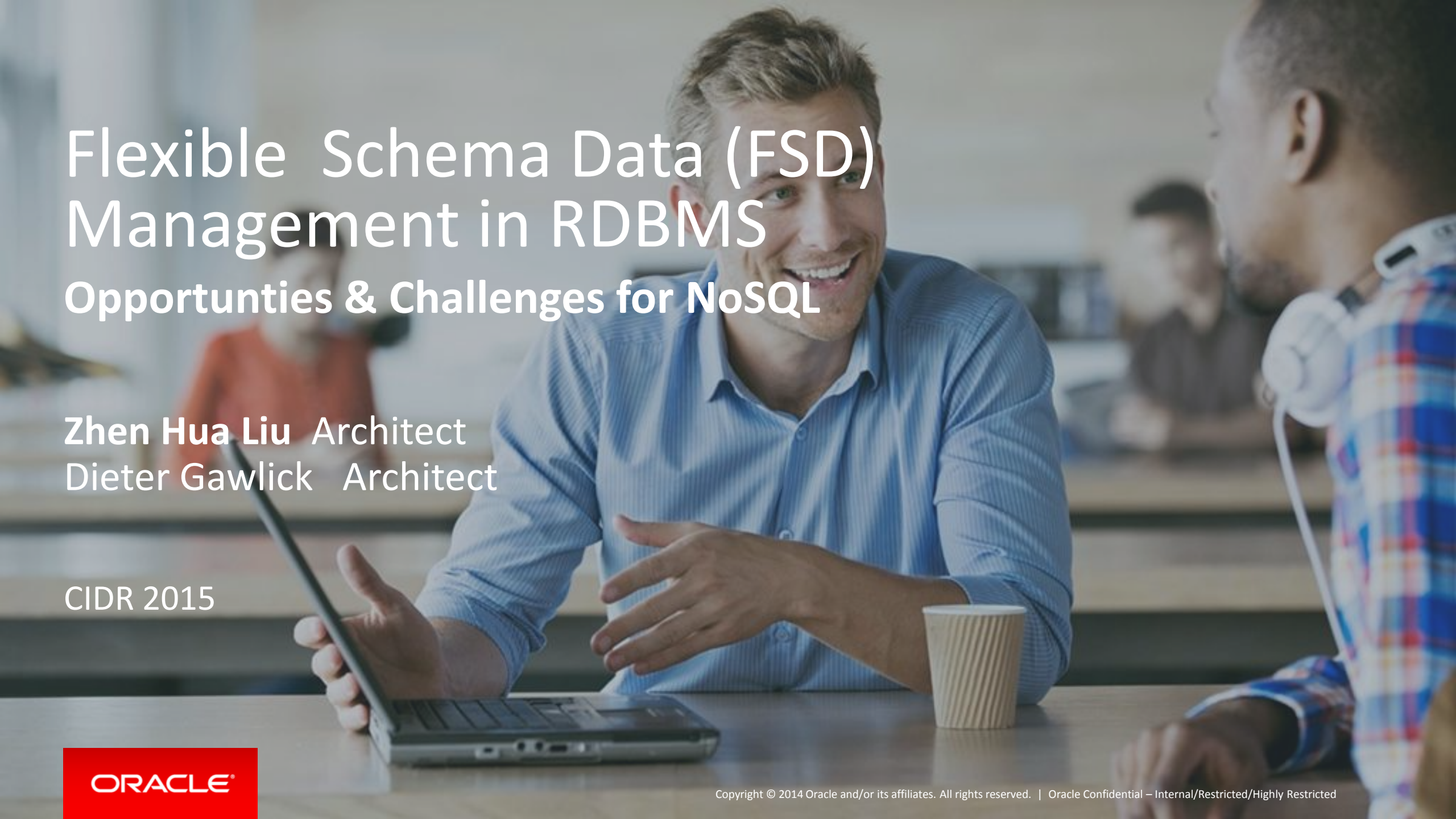

Flexible Schema Data (FSD) Management in RDBMS

Opportunties & Challenges for NoSQL

Zhen Hua Liu Architect
Dieter Gawlick Architect

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Program Agenda

1. **DBMS Generational Gap: Need Support of Flexible Schema Data**
2. Requirements & Challenges of FSD management
3. Engineering Practices&Principles of FSD management
4. Each FSD Principle with Opportunities & Challenges Analysis
5. Related Work & Conclusion
6. Q & A

DBMS Generational Gap

Upfront Schema Design becomes bottleneck!

- My Father's RDBMS: Classical Bank Record Keep Application
  - Process Statically Shaped Data
  - DBA Style: Schema First, Data Later
  - Every New Shaped Data demands Schema Evolution
- My Generation's DBMS: Flexible Schema Data Management
  - Process Semi-Structured/Unstructured Dynamically Shaped Data: Web Data, Diversity Data
  - Agile Style: Data First, Schema Later/Never
  - **On Write: No Schema for Store; On Read: Soft Schema for Query**

Simple & Popular FSD Example - JSON

```
{
    "firstName": "John“,
    "lastName" : "Smith“,
    "age": 25,
    "address": {
        "streetAddress": "21 2nd Street“,
        "city": "New York“,
        "state": "NY“,
        "postalCode": "10021“,
        "isBusiness" : false
    },
    "phoneNumbers": [
        {"type": "home“, "number": "212 555-1234“},
        {"type": "fax“, "number": "646 555-4567“ }
    ],
    "creditHistory": [
        {"year": 2011,"creditScore": 650}
    ],
    "bankruptcies " : null
}
```

- Each FSD instance is a set of key-value pairs organized hierarchically
- FSD collection: a set of FSD instances
- Schema is considered **unbounded** for the entire FSD collection
- Storing FSD using relational tables requires **Constant Schema Evolution**
- Storing FSD using vertical table requires many self-joins & suboptimal object retrieval time

FSD Management Requirements

Conventional Schema-based RDBMS Wisdoms are being Challenged!

- **Storage Requirement:** How to store data without upfront schema definition ?
- **Query Requirement:** How to query data without upfront schema definition ?
- **Indexing Requirement:** How to index data without upfront schema definition ?

NoSQL ? Does this imply SQL is dead ?

- **Consolidated Data Management Platform Requirement:** How to query both my data and my father's data together ?

Think Out of Box here means **THINK OUT OF SCHEMA !**

New Engineering Practises/Principles for managing FSD

My Data & My Father's Data are jointly queried together via NoSQL

- **Storage Principle**: Schema-less Storage
  - **Document Object Storage Model:** Not relying on schema to decompose & shred data.
  - **DataGuide**: dynamically computed SOFT Schema to support **schema on read** capability
- **Query Principle**: Declarative Query (Central Dogma of DBMS)
  - **NoSQL**: **N**aturally **o**pen SQL as **S**et **Q**uery **L**anguage with embedded FSD domain language
  - **Declarative FSD Domain Language**: for query both FSD schema & data together
- **Index Principle**: Schema-less Indexing
  - **Search Index** : Data First/Schema Never Indexing – Ad-hoc workload
  - **Table index**: Data First/Schema Later Indexing – known workload

My Principles are inspired from My Father's RDBMS Extensibility Ideas (UDT/UDF/UDI)

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FSD Storage principle in RDBMS

Storage Principle – Document Object Store without shredding

- Each FSD instance is **self-contained** without relying on central schema definition
  - Schema & Data are stored together in each FSD instance
- Each domain specific FSD can be stored as varchar/varbinary/CLOB/BLOB **without a new SQL datatype**!
  - JSON as FSD Example: FSD Check Constraint/Soft Schema Validation
  - *CREATE TABLE PERSON_JTAB (jcol VARCHAR(32000) CONSTRAINT jcon CHECK (jcol IS JSON));*
- 100% operational completeness support for FSD
  - Transactions, Replication, Partition, Security, Temporial, Provenance, Export/Export, Fault Tolerance, Client APIs, …

FSD Query Principle in RDBMS

Query Principle: SQL: **S**et **Q**uery **L**anguage with FSD Domain Language

- Leveraging SQL as **Inter-Document S**et **Q**uery **L**anguage
- Leveraging FSD Domain Language as **Intra-Document** query language
- FSD Domain language for each FSD instance to do
  - path navigation, extracting scalar values & fragments, searching content, transforming and updating fragments. JSON as an example

```
SELECT JSON_VALUE(T.jcol, '$.person.name'),
       JSON_QUERY(T.jcol, '$.person.address')
FROM PERSON_JTAB T
WHERE JSON_EXISTS(T.jcol, '$.person.creditHistory?(score >=
700)') AND
JSON_TEXTCONTAINS(T.jcol, '$.person..experiences', 'semi-
structured data processing')
ORDER BY JSON_VALUE(T.jcol, '$.person.address.zip')
```

FSD Query Principle in RDBMS

JSON_TABLE() for Relational View Projection – UNNEST array

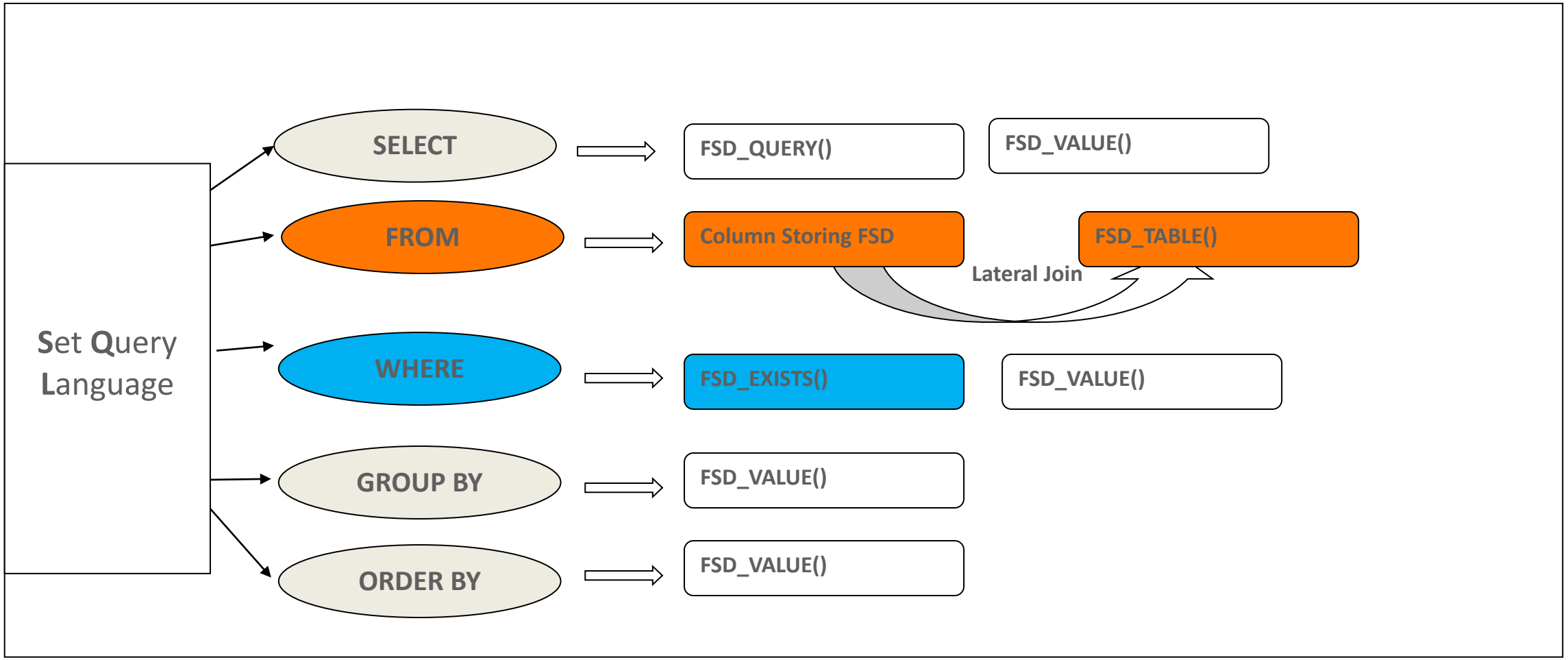
- Project FSD data as relational table
- Objects inside array become ROWS
- Values inside object become COLUMNS

PH_TYPE	PH_NUM
home	212 555-1234
fax	646 555-4567

```
SELECT jrv.*
FROM Person_Jtab, JSON_TABLE (jcol, '$.person.phoneNumbers[*]'
             COLUMNS
                    PH_TYPE   VARCHAR2(10) PATH '$.type',
                    PH_NUM    VARCHAR2(10) PATH '$.number') jrv;
```

FSD Query Principle in RDBMS

FSD UDFs to Set Query Language without a brand new query language!



FSD Index principle in RDBMS

Search Index: Data First/Schema Never Indexing

- Schema and data are indexed together for ad-hoc exploratory and search queries over FSD collection
- Generalized Inverted Index (FSD_EXISTS(), FSD_TEXTCONTAINS())
  - Classical SIGIR: Full Text Search for Document Content
  - **Beyond classical SIGIR**:
    - Range Value Search for leaf Scalar Value (auto detecting and indexing number, dates, timestamps)
    - Hierarchical Path Containment for both full text search & range value

```
SELECT JSON_VALUE(T.jcol, '$.person.name)
FROM PERSON_JTAB T
WHERE JSON_EXISTS(T.jcol, '$.person.creditHistory?(score >= 700)')
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structured data processing')
```

FSD Index principle in RDBMS

Table Index: Data First/Schema Later as Indexing

- Table Index based on Dataguide & known query workload
- FSD_VALUE() Scalar Value Functional Index
- FSD_TABLE() Table Index/Materialized view
- Table Index brings relational model back into FSD as secondary view & indexing structures instead of primary storage structures
  - Provide maximum flexibility because table index is secondary structure that can be dropped and recreated without impacting primary storage structures
  - No schema evolution & management Issue
  - Enables Paradigm of **Data First, Schema Later as table Index**

FSD Data Model Challenges

What's wrong with a single tree model ?

- **Single Hierarchy issue** for document storage Model
  - Document Storage Model imposes single hierarchy restriction whereas relational Model provides flexible hierarchies access
- Your father can do multi-hierarchical access of relational data & you are re-inventing IMS !
- Need DataGuide to E/R Model EcoSystem ?
  - Given students taking courses hierarchy, it shall infer courses being taken by students hierarchy
- Need Declarative Hierarchy Transformation Language for FSD
  - Leverage Category Theory Providing Hierarchy Equivalency Transformation & Query Access ?

FSD Layout Challenges

Row & Columnar Dual FSD Data Format

- **FSD Instance layout** for both efficient path query and piece-wise update (Avro, BSON, Tree encoding)
- **FSD Set Columnar layout of FSD** for Efficient Vector based Set processing query over FSD collection (Parquet, Dremel)
- Which is Better Storage Model ?
- Leveraging idea of InSitu Query Processing for FSD
  - **Exploit instance/set query friendly Data Layout as secondary Just-In-Time In-Memory structures!**
  - **Never Getting Stale with a storage model**

FSD Layout Challenges

Keeping Dual Formats In-Synch in Real Time

- Tension between dual formats:
  - Ingestion/update friendly instance oriented format
    - Optimal for OLTP workload
    - Not so good for query
  - Search & Analytic query friendly set oriented format:
    - columnar & inverted index favors compression & Batch loading, good for OLAP query
    - Not optimal for OLTP workload
- Keeping dual formats transactionally consistent – LSF/LSM/MVCC

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Related Work

Common Theme: Break strong dependency of using schema to store data

- Research:
  - Stanford LOREL Semi-Structured DB
  - XMLDB
  - Argo/SQL, NoBench benchmark from University of Wisconsin
  - SiNew/TeraData from Yale University Research
- Industry:
  - DB2, Oracle, Microsoft, TeraData SQL/JSON, SQL/XML Support
  - No-SQL DB Products: MongoDB, MarkLogic

Conclusion

Take Home Message for FSD: What would happen if I do not depend on schema to store data ?

- Engineering Practises & Principles for FSD
  - **Storage** – Native Store without shredding, Just-in-time secondary structures for both instance & set friendly access patterns
  - **Query** – SQL As Set Query Language with FSD domain Language embedded
  - **Index** – Search Index and Table index
- The underlying philosophy is very simple:
  - **Treat Schema as if it were data:** Store, Index and Query schema along with the data
- ***My Data & My Father's Data can be queried together by Naturally openning Set Query Language (NoSQL) !***

Questions

Hardware and Software
Engineered to Work Together