Flexible Schema Data (FSD) Management in RDBMS
Opportunities & Challenges for NoSQL

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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

```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**: Naturally open SQL as *Set Query Language* 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, Temporal, Provenance, Export/Export, Fault Tolerance, Client APIs, ...
FSD Query Principle in RDBMS

Query Principle: SQL: **Set Query Language** with FSD Domain Language

- Leveraging SQL as **Inter-Document Set Query Language**
- 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

```sql
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

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

<table>
<thead>
<tr>
<th>PH_TYPE</th>
<th>PH_NUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>home</td>
<td>212 555-1234</td>
</tr>
<tr>
<td>fax</td>
<td>646 555-4567</td>
</tr>
</tbody>
</table>
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 search

```sql
SELECT JSON_VALUE(T.jcol, '$.person.name')
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```
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 opening Set Query Language (NoSQL)!**
Questions
Hardware and Software
Engineered to Work Together