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Concepts for Specialised Databases
Document Stores: MongoDB

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Objectives

As Yogi Berra said, "In theory there's no difference between theory and practice. But in practice, there is." This statement is especially true for NOSQL databases.
This is a hands-on lab to get familiar with Document Stores. The main goals are as follows. Given a database schema and a query workload, you are supposed to:

- Decide how to design the database,
- Query the database created in order to answer each of the queries.

Try not to think relational-wise and also grasp the subtle details. That is, get familiar with the pros and cons of such systems so that in the future you can decide when to use them.

Lab organization

On session 1, the lecturer will be present at the lab and will help you out. Thus, it is a session to solve your doubts and help you to prepare the final delivery.

On session 2, you must hand in (upload) the deliverables specified in the corresponding section of this document.

Important: You are highly advised to attend the first session. Furthermore, if you do not work on this lab during the first week, expect a heavy workload for the last one (we estimate 6h of work per week). Thus, you are the ultimate responsible for a reasonable scheduling of this session.

Required knowledge

This practice session subsumes the entire course but, specially, sessions on key-value and document-stores. **Your team mate will be that of the team creation event.**

Tools

This lab requires MongoDB. We assume you can install MongoDB in your own laptop. If this is not possible, contact us.

Training (Activities to do beforehand)

- First, set MongoDB up in your laptop. There are plenty of manuals with lots of information about this, for example, this is the most basic one: `http://docs.mongodb.org/manual/installation/`
- Play a bit with the shell and get used with the basics. For example, follow the get started tutorial: `http://docs.mongodb.org/manual/tutorial/getting-started/`
- Next, decide what API you want to use: `http://docs.mongodb.org/manual/applications/drivers/`.
  Python happens to be the language better coupled with MongoDB. Nevertheless, the Java API is available out there, among many others.
- Now, refresh what we discussed in the lecture about how to model documents and decide their structure (according to the database and query workload given below in the session statement). You can find further information at: `http://docs.mongodb.org/manual/applications/data-models/`
- Get familiar about how to query MongoDB databases. You have three options: the find() and findOne() methods defined in the API, the Aggregation Framework (also available by means of the API) and MapReduce. Avoid the third one (meant for large databases) and we strongly suggest to use the Aggregation Framework: `http://docs.mongodb.org/manual/core/aggregation-pipeline/`

Anyway, this training is up to you; decide which manuals suit better your needs. Maybe some other manuals help you better (a comprehensive list of the official manuals can be found here: `http://docs.mongodb.org/manual/contents/`). You are expected to need a couple of hours to set the environment and get familiar with the basics.

Session statement

Once you are familiar with MongoDB, solve the following exercise.

For this lab we will consider the TPC-H benchmark (`http://www.tpc.org/tpch/`). The schema of the TPC-H benchmark is introduced in Appendix A. **You must design this database in MongoDB (i.e., in terms of documents) in such a way the performance of the queries in Appendix B is optimal**. For this reason, you may want to consider indexes. Thus:

- First, create **a PDF explanation document (2 pages long)** showing the chosen structure for your MongoDB documents (i.e., model your own MongoDB database).
  - You should clearly (i.e., quantitatively) justify the choice of documents as well as their internal structure.
- Then, **create a file (in Java, Python, etc.) with your solution**. Specifically, this file must contain:
  - Some inserts of sample documents meeting the structure described in your explanation document,
  - Your code to implement the 4 queries introduced in Appendix B. You are strongly advised to use the Aggregation Framework for this purpose.

Delivery

Upload the two files asked for this practice (the explanation/justification document and the Java/Python/etc. file) into the corresponding Moodle activity BEFORE the end of the second lab session. Failing to send these files will invalidate the whole session. If you do not use the aggregation framework to implement the queries the maximum mark you can obtain for this lab is 8 (out of 10).

The second lab session, is merely a deadline for the submission of the solutions/deliverables to the first lab session. Thus, there will be no second lab session with the teacher.

Appendix A

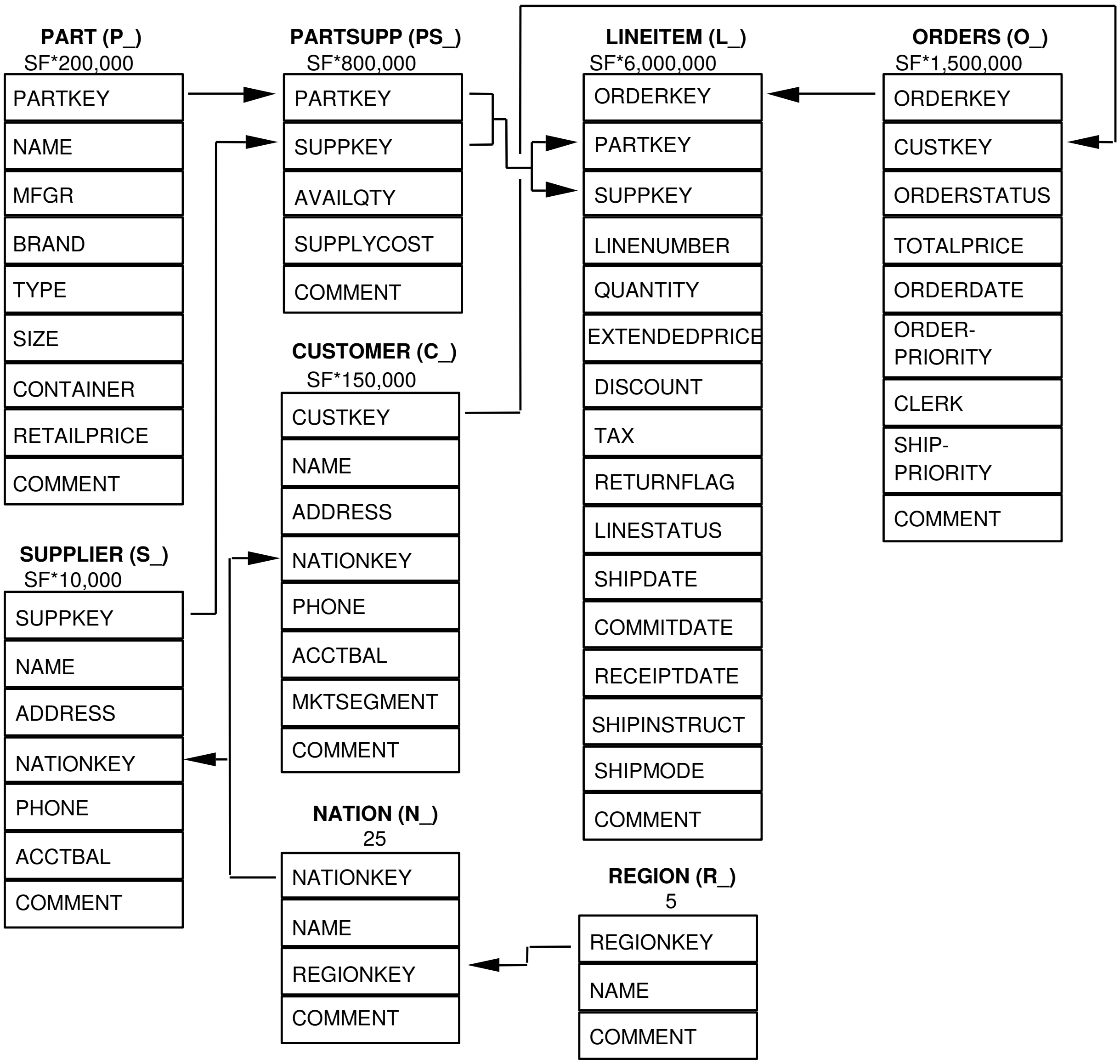
In this appendix you will find a graphical representation of the TPC-H schema and further explanations on the schema you may want to check.

IMPORTANT NOTE: This appendix introduces you to the TPC-H benchmark. This is just for your information (for better understanding each attribute and table), so do not consider the additional information about insertion rules, etc. you may find there.

1.2 Database Entities, Relationships, and Characteristics

The components of the TPC-H database are defined to consist of eight separate and individual tables (the Base Tables). The relationships between columns of these tables are illustrated in Figure 2: The TPC-H Schema.

Figure 2: The TPC-H Schema



Legend:

- The parentheses following each table name contain the prefix of the column names for that table;
- The arrows point in the direction of the one-to-many relationships between tables;
- The number/formula below each table name represents the cardinality (number of rows) of the table. Some are factored by SF, the Scale Factor, to obtain the chosen database size. The cardinality for the LINEITEM table is approximate (see Clause 4.2.5).

1.3 Datatype Definitions

1.3.1 The following datatype definitions apply to the list of columns of each table:

- **Identifier** means that the column must be able to hold any key value generated for that column and be able to support at least 2,147,483,647 unique values;

Comment: A common implementation of this datatype will be an integer. However, for SF greater than 300 some column values will exceed the range of integer values supported by a 4-byte integer. A test sponsor may use some other datatype such as 8-byte integer, decimal or character string to implement the identifier datatype;

- **Integer** means that the column must be able to exactly represent integer values (i.e., values in increments of 1) in the range of at least -2,147,483,646 to 2,147,483,647.
- **Decimal** means that the column must be able to represent values in the range -9,999,999,999.99 to +9,999,999,999.99 in increments of 0.01; the values can be either represented exactly or interpreted to be in this range;
- **Big Decimal** is of the Decimal datatype as defined above, with the additional property that it must be large enough to represent the aggregated values stored in temporary tables created within query variants;
- **Fixed text, size N** means that the column must be able to hold any string of characters of a fixed length of N.

Comment: If the string it holds is shorter than N characters, then trailing spaces must be stored in the database or the database must automatically pad with spaces upon retrieval such that a CHAR_LENGTH() function will return N.

- **Variable text, size N** means that the column must be able to hold any string of characters of a variable length with a maximum length of N. Columns defined as "variable text, size N" may optionally be implemented as "fixed text, size N";
- **Date** is a value whose external representation can be expressed as YYYY-MM-DD, where all characters are numeric. A date must be able to express any day within at least 14 consecutive years. There is no requirement specific to the internal representation of a date.

Comment: The implementation datatype chosen by the test sponsor for a particular datatype definition must be applied consistently to all the instances of that datatype definition in the schema, except for identifier columns, whose datatype may be selected to satisfy database scaling requirements.

1.3.2 The symbol SF is used in this document to represent the scale factor for the database (see Clause 4:).

1.4 Table Layouts

1.4.1 Required Tables

The following list defines the required structure (list of columns) of each table.

The annotations ‘Primary Key’ and ‘Foreign Key’, as used in this Clause, are for information only and do not imply additional requirements to implement **primary key** and **foreign key** constraints (see Clause 1.4.2).

PART Table Layout

Column Name	Datatype Requirements	Comment
P_PARTKEY	identifier	SF*200,000 are populated
P_NAME	variable text, size 55	
P_MFGR	fixed text, size 25	

P_BRAND	fixed text, size 10	
P_TYPE	variable text, size 25	
P_SIZE	integer	
P_CONTAINER	fixed text, size 10	
P_RETAILPRICE	decimal	
P_COMMENT	variable text, size 23	

Primary Key**:** P_PARTKEY

SUPPLIER Table Layout

Column Name	Datatype Requirements	Comment
S_SUPPKEY	identifier	SF*10,000 are populated
S_NAME	fixed text, size 25	
S_ADDRESS	variable text, size 40	
S_NATIONKEY	Identifier	Foreign Key to N_NATIONKEY
S_PHONE	fixed text, size 15	
S_ACCTBAL	decimal	
S_COMMENT	variable text, size 101	

Primary Key**:** S_SUPPKEY

PARTSUPP Table Layout

Column Name	Datatype Requirements	Comment
PS_PARTKEY	Identifier	Foreign Key to P_PARTKEY
PS_SUPPKEY	Identifier	Foreign Key to S_SUPPKEY
PS_AVAILQTY	integer	
PS_SUPPLYCOST	Decimal	
PS_COMMENT	variable text, size 199	

Primary Key**:** PS_PARTKEY, PS_SUPPKEY

CUSTOMER Table Layout

Column Name	Datatype Requirements	Comment
C_CUSTKEY	Identifier	SF*150,000 are populated

C_NAME	variable text, size 25	
C_ADDRESS	variable text, size 40	
C_NATIONKEY	Identifier	Foreign Key to N_NATIONKEY
C_PHONE	fixed text, size 15	
C_ACCTBAL	Decimal	
C_MKTSEGMENT	fixed text, size 10	
C_COMMENT	variable text, size 117	

Primary Key**:** C_CUSTKEY

ORDERS Table Layout

Column Name	Datatype Requirements	Comment
O_ORDERKEY	Identifier	SF*1,500,000 are sparsely populated
O_CUSTKEY	Identifier	Foreign Key to C_CUSTKEY
O_ORDERSTATUS	fixed text, size 1	
O_TOTALPRICE	Decimal	
O_ORDERDATE	Date	
O_ORDERPRIORITY	fixed text, size 15	
O_CLERK	fixed text, size 15	
O_SHIPPRIORITY	Integer	
O_COMMENT	variable text, size 79	

Primary Key**:** O_ORDERKEY

Comment: Orders are not present for all customers. In fact, one-third of the customers do not have any order in the database. The orders are assigned at random to two-thirds of the customers (see Clause 4:). The purpose of this is to exercise the capabilities of the DBMS to handle "dead data" when joining two or more tables.

LINEITEM Table Layout

Column Name	Datatype Requirements	Comment
L_ORDERKEY	identifier	Foreign Key to O_ORDERKEY
L_PARTKEY	identifier	Foreign key to P_PARTKEY, first part of the compound Foreign Key to (PS_PARTKEY, PS_SUPPKEY) with L_SUPPKEY
L_SUPPKEY	Identifier	Foreign key to S_SUPPKEY, second part of the compound Foreign Key to (PS_PARTKEY,

		PS_SUPPKEY) with L_PARTKEY
L_LINENUMBER	integer	
L_QUANTITY	decimal	
L_EXTENDEDPRICE	decimal	
L_DISCOUNT	decimal	
L_TAX	decimal	
L_RETURNFLAG	fixed text, size 1	
L_LINESTATUS	fixed text, size 1	
L_SHIPDATE	date	
L_COMMITDATE	date	
L_RECEIPTDATE	date	
L_SHIPINSTRUCT	fixed text, size 25	
L_SHIPMODE	fixed text, size 10	
L_COMMENT	variable text size 44	

Primary Key**:** L_ORDERKEY, L_LINENUMBER

NATION Table Layout

Column Name	Datatype Requirements	Comment
N_NATIONKEY	identifier	25 nations are populated
N_NAME	fixed text, size 25	
N_REGIONKEY	identifier	Foreign Key to R_REGIONKEY
N_COMMENT	variable text, size 152	

Primary Key**:** N_NATIONKEY

REGION Table Layout

Column Name	Datatype Requirements	Comment
R_REGIONKEY	identifier	5 regions are populated
R_NAME	fixed text, size 25	
R_COMMENT	variable text, size 152	

Primary Key**:** R_REGIONKEY

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Appendix B

Find here the queries composing the query workload. This workload is expressed in SQL but you will need to adapt it to MongoDB once you have designed your database.

Query 1

```
SELECT l_returnflag, l_linestatus, sum(l_quantity) as sum_qty,
 sum(l_extendedprice) as sum_base_price,
 sum(l_extendedprice*(1-l_discount)) as sum_disc_price,
 sum(l_extendedprice*(1-l_discount)*(1+l_tax)) as sum_charge, avg(l_quantity) as avg_qty,
 avg(l_extendedprice) as avg_price, avg(l_discount) as avg_disc, count(*) as count_order
FROM lineitem
WHERE l_shipdate <= '[date]'
GROUP BY l_returnflag, l_linestatus
ORDER BY l_returnflag, l_linestatus;
```

Where [date] is a constant that may vary between executions of the query.

Query 2

```
SELECT s_acctbal, s_name, n_name, p_partkey, p_mfgr, s_address, s_phone, s_comment
FROM part, supplier, partsupp, nation, region
WHERE p_partkey = ps_partkey AND s_suppkey = ps_suppkey AND p_size = [SIZE]
 AND p_type like '%[TYPE]' AND s_nationkey = n_nationkey
 AND n_regionkey = r_regionkey AND r_name = '[REGION]'
 AND ps_supplycost =
       (SELECT min(ps_supplycost)
       FROM partsupp, supplier, nation, region WHERE p_partkey = ps_partkey
       AND s_suppkey = ps_suppkey AND s_nationkey = n_nationkey
       AND n_regionkey = r_regionkey AND r_name = '[REGION]')
ORDER BY s_acctbal desc, n_name, s_name, p_partkey;
```

Where [size], [type] and [region] are constants that may vary between executions of the query.

Query 3

```
SELECT l_orderkey, sum(l_extendedprice*(1-l_discount)) as revenue, o_orderdate, o_shippriority
FROM customer, orders, lineitem
WHERE c_mktsegment = '[SEGMENT]' AND c_custkey = o_custkey AND l_orderkey = o_orderkey
 AND o_orderdate < '[DATE1]' AND l_shipdate > '[DATE2]'
GROUP BY l_orderkey, o_orderdate, o_shippriority
ORDER BY revenue desc, o_orderdate;
```

Where [segment], [date1] and [date2] are constants that may vary between executions of the query.

Query 4

```
SELECT n_name, sum(l_extendedprice * (1 - l_discount)) as revenue
FROM customer, orders, lineitem, supplier, nation, region
WHERE c_custkey = o_custkey AND l_orderkey = o_orderkey
 AND l_suppkey = s_suppkey AND c_nationkey = s_nationkey
 AND s_nationkey = n_nationkey AND n_regionkey = r_regionkey
 AND r_name = '[REGION]' AND o_orderdate >= date '[DATE]'
 AND o_orderdate < date '[DATE]' + interval '1' year
GROUP BY n_name
ORDER BY revenue desc;
```

Where [date] and [region] are constants that may vary between executions of the query.