B4M36DS2, BE4M36DS2: **Database Systems 2**

https://cw.fel.cvut.cz/b231/courses/b4m36ds2/

Lecture 7

Wide Column Stores: Cassandra

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Lecture Outline

Wide column stores

- Introduction

Apache Cassandra

- Data model
- Cassandra query language
  - DDL statements
  - DML statements

Wide Column Stores

Data model

- Column family
  - Table is a collection of **similar rows** (not necessarily identical)
- Row
  - Row is a collection of **columns**
    - Should encompass a group of data that is accessed together
  - Associated with a unique **row key**
- Column
  - Column consists of a **column name** and **column value** (and possibly other metadata records)
  - Scalar values, but also **flat sets, lists or maps** may be allowed

Apache Cassandra

Apache Cassandra

Uber

Facebook

Spotify

Netflix

Column-family database

- http://cassandra.apache.org/
- Features
  - Open-source, high availability, linear scalability, sharding (spanning multiple datacenters), peer-to-peer configurable replication, tunable consistency, MapReduce support
- Developed by **Apache Software Foundation**
  - Originally at Facebook
- Implemented in Java
- Operating systems: cross-platform
- Initial release in 2008

Data Model

Database system structure

Instance → **keyspaces** → **tables** → **rows** → **columns**

- Keyspace
- Table (column family)
  - **Collection of (similar) rows**
    - Rows do not need to have exactly the same columns
  - Table schema must be specified, yet can be modified later on
- Row
  - **Collection of columns**
  - Each row is **uniquely identified** by a compulsory primary key
- Column
  - **Name-value pair** + additional data

Data Model

Column values

- Empty value
  - null
- Atomic values
  - **Native data types** such as texts, integers, dates, …
  - **Tuples**
    - Tuple of anonymous fields, each of any type (even different)
  - **User-defined types** (UDT)
    - Set of named fields of any type
- Collections
  - **Lists**, **sets**, and **maps**
    - Nested tuples, UDTs, or collections are also permitted, however, currently only in a frozen mode

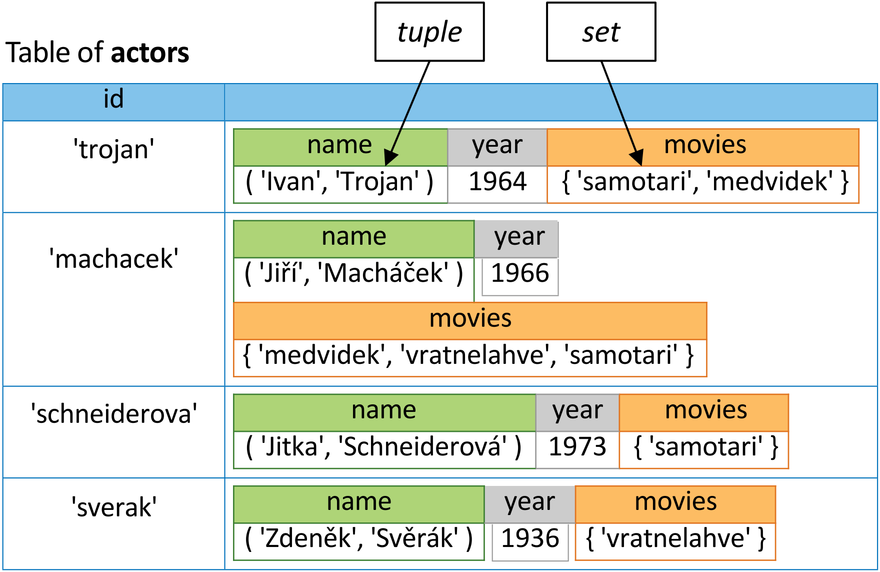
Data Model

Collections

- **List** = **ordered collection of values**
  - This order is based on positions
  - Values do not need to be unique
- **Set** = **collection of unique values**
  - Values are internally <u>ordered</u>
- **Map** = **collection of key-value pairs**
  - Keys must be unique
  - Pairs are internally <u>ordered</u> based on keys

Sample Data

Table of **actors**



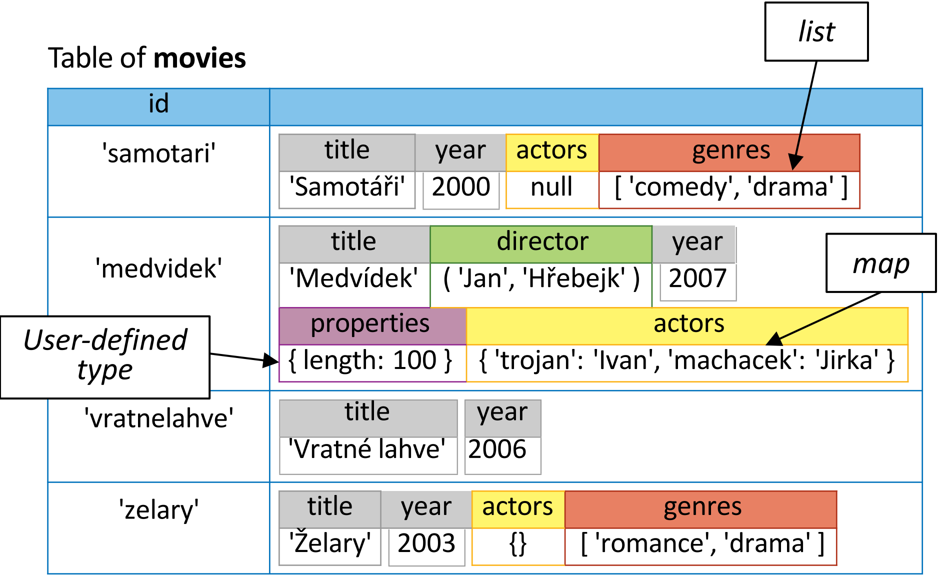
tuple

set

id	
'trojan'	name ('Ivan', 'Trojan') year 1964 movies { 'samotari', 'medvidek' }
'machacek'	name ('Jiří', 'Macháček') year 1966 movies { 'medvidek', 'vratnelahve', 'samotari' }
'schneiderova'	name ('Jitka', 'Schneiderová') year 1973 movies { 'samotari' }
'sverak'	name ('Zdeněk', 'Svěrák') year 1936 movies { 'vratnelahve' }

Sample Data

Table of **movies**



<table>
<tr><th>id</th><th></th></tr>
<tr><td>'samotari'</td><td><table><tr><th>title</th><th>year</th><th>actors</th><th>genres</th></tr><tr><td>'Samotáři'</td><td>2000</td><td>null</td><td>['comedy', 'drama']</td></tr></table></td></tr>
<tr><td>'medvidek'</td><td><table><tr><th>title</th><th>director</th><th>year</th></tr><tr><td>'Medvídek'</td><td>('Jan', 'Hřebejk')</td><td>2007</td></tr></table><table><tr><th>properties</th><th>actors</th></tr><tr><td>{ length: 100 }</td><td>{ 'trojan': 'Ivan', 'machacek': 'Jirka' }</td></tr></table></td></tr>
<tr><td>'vratnelahve'</td><td><table><tr><th>title</th><th>year</th></tr><tr><td>'Vratné lahve'</td><td>2006</td></tr></table></td></tr>
<tr><td>'zelary'</td><td><table><tr><th>title</th><th>year</th><th>actors</th><th>genres</th></tr><tr><td>'Želary'</td><td>2003</td><td>{}</td><td>['romance', 'drama']</td></tr></table></td></tr>
</table>

Data Model

Additional data associated with…

the whole column in case of atomic values, or
each individual element of a collection

- **Time-to-live** (TTL)
  - After a certain period of time (number of seconds) a given column / element is automatically deleted
- **Timestamp** (writetime)
  - Timestamp of the last modification
  - Assigned automatically or manually as well
- Both the records can be queried
  - Unfortunately not in case of collections and their elements

Cassandra API

CQLSH

- **Interactive command line shell**
- `bin/cqlsh`
- Uses **CQL** (*Cassandra Query Language*)

Client drivers

- Provided by the community
- Available for various languages
  - Java, Python, Ruby, PHP, C++, Scala, Erlang, …

Query Language

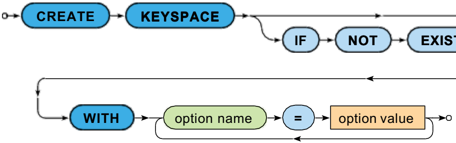
CQL = Cassandra Query Language

- Declarative query language
  - Inspired by SQL
- **DDL statements**
  - CREATE KEYSPACE – creates a new keyspace
  - CREATE TABLE – creates a new table
  - ...
- **DML statements**
  - SELECT – selects and projects rows from a single table
  - INSERT – inserts rows into a table
  - UPDATE – updates columns of rows in a table
  - DELETE – removes rows from a table
  - ...

DDL Statements

Keyspaces

CREATE KEYSPACE



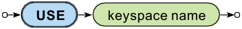
- **Creates a new keyspace**
- **Replication option** is mandatory
  - SimpleStrategy (only one replication factor)
  - NetworkTopologyStrategy
    (individual replication factor for each data center)

```
CREATE KEYSPACE moviedb
WITH replication = {'class': 'SimpleStrategy', 'replication_factor': 3}
```

Keyspaces

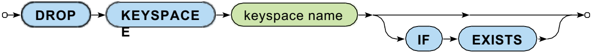
USE

- Changes the current keyspace



DROP KEYSPACE

- Removes a keyspace, all its tables, data etc.



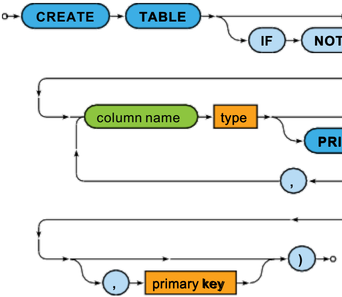
ALTER KEYSPACE

- Modifies options of an existing keyspace

Tables

CREATE TABLE

- **Creates a new table** within the current keyspace
- Each table must have exactly one **primary key** specified



- None of the columns is compulsory (except the primary key)

Tables

Examples: tables for **actors and movies**

```
CREATE TABLE actors  (
   id TEXT PRIMARY KEY,
   name TUPLE<TEXT, TEXT>,
   year SMALLINT,
   movies SET<TEXT>
)
```

```
CREATE TABLE movies (
   id TEXT,
   title TEXT,
   director TUPLE<TEXT, TEXT>,
   year SMALLINT,
   actors MAP<TEXT, TEXT>,
   genres LIST<TEXT>,
   countries SET<TEXT>,
   properties details,
   PRIMARY KEY (id)
)
```

Primary Keys

Primary keys have two parts

- Compulsory **partition key**
    - At least one column
    - Defines how individual rows are distributed between shards
- Optional **clustering columns**
    - Defines the order in which individual rows are locally stored by each shard

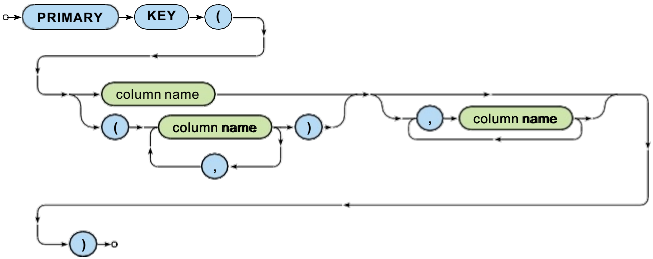
Column-level primary key definition

- A given column (the only one) becomes the partition key
- There are no clustering columns

Primary Keys

Table-level primary key definition

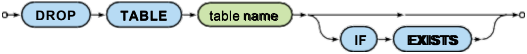
- The first column / all columns in the embedded parentheses become the partition key
- All the remaining ones (if any) form the clustering columns



Tables

DROP TABLE

- Removes a table together with all data it contains



DROP

TABLE

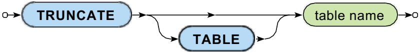
table name

IF

EXISTS

TRUNCATE TABLE

- Preserves a table but removes all data it contains



TRUNCATE

TABLE

table name

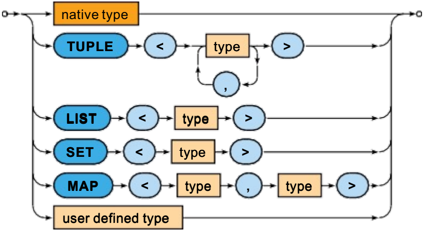
ALTER TABLE

- Allows to alter, add or drop table columns

Data Types

Types of columns

- Native types
- **Tuples**
- Collection types: **lists**, **sets**, and **maps**
- **User-defined types**



Native Data Types

Native types

- `tinyint`, `smallint`, **int**, `bigint`
  - Signed integers (1B, 2B, 4B, 8B)
- **varint**
  - Arbitrary-precision integer
- **decimal**
  - Variable-precision decimal
- `float`, **double**
  - Floating point numbers (4B, 8B)
- **boolean**
  - Boolean values true and false

Native Data Types

Native types

- **text**, varchar
  - UTF8 encoded string
  - Enclosed in single quotes (not double quotes)
    - Escaping sequence: ''
- ascii
  - ASCII encoded string
- **date**, **time**, **timestamp**
  - Dates, times and timestamps
  - E.g. '2016-12-05', '2016-12-05 09:15:00', 1480929300

Native Data Types

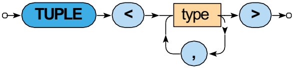
Native types

- **counter** – 8B signed integer
  - Only 2 operations supported: incrementing and decrementing
    - I.e. value of a counter cannot be set to a particular number
  - Restrictions in usage
    - Counters cannot be a part of a primary key
    - Either all table columns (outside the primary key) are counters, or none of them
    - TTL is not supported
    - …
- `blob` – arbitrary bytes
- `inet` – IP address (both IPv4 and IPv6)
- …

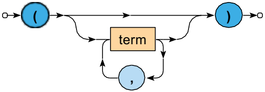
Tuple Data Types

Tuples

- Declaration



- Literals

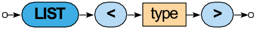


  - E.g. ('Jiří', 'Macháček')

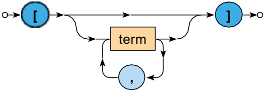
Collection Data Types

Lists

- Declaration



- Literals

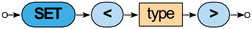


  - E.g. ['comedy', 'drama']

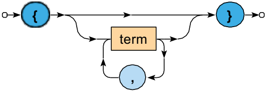
Collection Data Types

Sets

- Declaration



- Literals

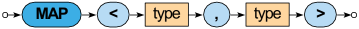


  - E.g. `{ 'medvidek', 'vratnelahve', 'samotari' }`

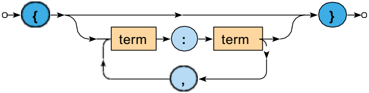
Collection Data Types

Maps

- Declaration



- Literals

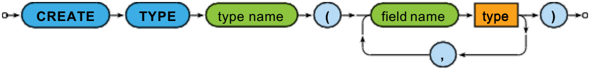


  - E.g. { 'machacek': 'Robert Landa' }

User-Defined Data Types

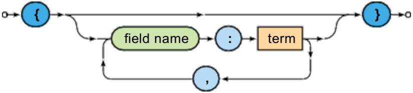
User-defined types (UDT)

- Definition



  - E.g. CREATE TYPE details (length SMALLINT, annotation TEXT)

- Literals



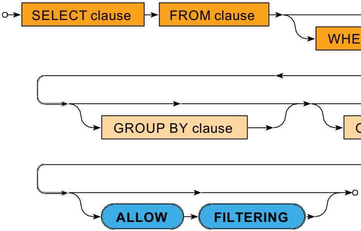
  - E.g. { length: 100 }

DML Statements

Selection

SELECT statement

- **Selects matching rows** from a **<u>single</u> table**



Selection

Clauses of SELECT statements

- SELECT – columns or values to appear in the result
- FROM – **single** table to be queried
- WHERE – filtering conditions to be applied on table rows
- GROUP BY – columns to be used for grouping of rows
- ORDER BY – criteria defining the order of rows in the result
- LIMIT – number of rows to be included in the result

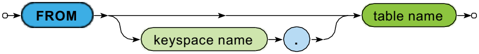
Example

```
SELECT id, title, actors
FROM movies
WHERE year = 2000 AND genres CONTAINS  'comedy'
```

Selection

FROM clause

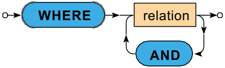
- Defines a **single table to be queried**
  - From the current / selected keyspace
- I.e. joining of multiple tables is not possible



Selection

WHERE clause

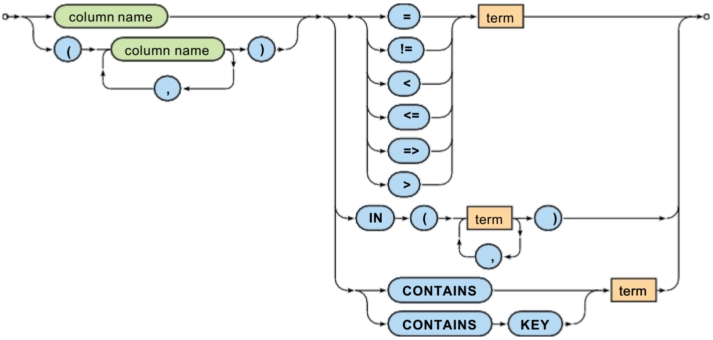
- **One or more relations a row must satisfy** in order to be included in the query result



- Only simple conditions can be expressed and **not all relations are allowed**, e.g.:
  - only primary key columns can be involved unless secondary index structures exist
  - non-equal relations on partition keys are not supported
  - …

Selection

WHERE clause: **relations**



Selection

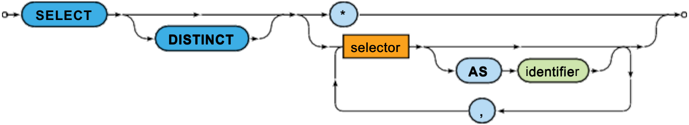
WHERE clause: **relations**

- **Comparisons**
  - =, !=, <, <=, =>, >
- **IN**
  - Returns true when the actual value is one of the enumerated
- **CONTAINS**
  - May only be used on collections (lists, sets, and maps)
  - Returns true when a collection contains a given element
- **CONTAINS KEY**
  - May only be used on maps
  - Returns true when a map contains a given key

Selection

SELECT clause

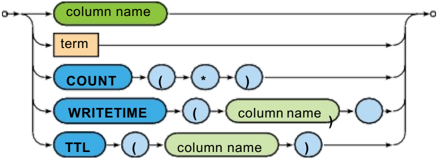
- Defines **columns or values to be included in the result**
  - * = all the table columns
  - Aliases can be defined using AS



- **DISTINCT** – duplicate rows are removed

Selection

SELECT clause: **selectors**

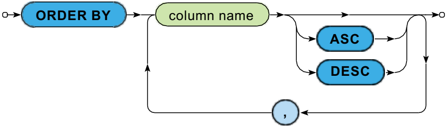


- **COUNT(*)**
  - Number of all the rows in a group (see aggregation)
- **WRITETIME** and **TTL**
  - Selects modification timestamp / remaining time-to-live of a given column
  - Cannot be used on collections and their elements
  - Cannot be used in other clauses (e.g. WHERE)

Selection

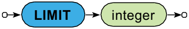
ORDER BY clause

- Defines the **order of rows returned in the query result**
- Only orderings induced by clustering columns are allowed!



LIMIT clause

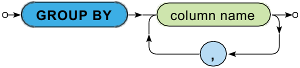
- **Limits the number of rows** returned in the query result



Selection

GROUP BY clause

- **Groups rows of a table** according to certain columns
- Only groupings induced by primary key columns are allowed!



- **When a non-grouping column would be accessed directly** in the SELECT clause (i.e. without being wrapped by an aggregate function), the first value encountered will always be returned

Selection

GROUP BY clause: **aggregates**

- Native aggregates
  - **COUNT**(column)
    - Number of all the values in a given column
    - null values are ignored
  - **MIN**(column), **MAX**(column)
    - Minimal / maximal value in a given column
  - **SUM(**column)
    - Sum of all the values in a given column
  - **AVG(**column)
    - Average of all the values in a given column
- User-defined aggregates

Selection

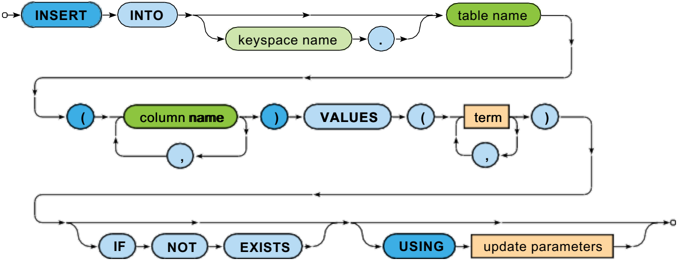
ALLOW FILTERING modifier

- By default, **only non-filtering queries are allowed**
  - I.e. queries where **the number of rows read ~ the number of rows returned**
  - Such queries have predictable performance
    - They will execute in a time that is proportional to the amount of data returned
- `ALLOW FILTERING` **enables (some) filtering queries**

Insertions

INSERT statement

- **Inserts a new row** into a given table
  - When a row with a given primary key already exists, it is updated
- Values of at least primary key columns must be set
- Names of columns must always be explicitly enumerated



Insertions

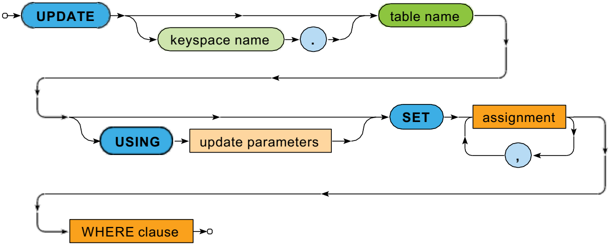
Example

```
INSERT INTO movies (id, title, director, year, actors, genres)  VALUES (
    'stesti',
    'Štěstí',
    ('Bohdan', 'Sláma'),
    2005,
    { 'vilhelmova': 'Monika', 'liska': 'Toník' },
    [ 'comedy', 'drama' ]
)
USING TTL 86400
```

Updates

UPDATE statement

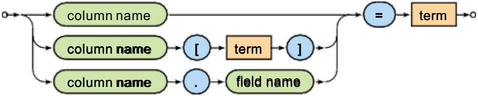
- **Updates existing rows** within a given table
  - When a row with a given primary key does not yet exist, it is inserted
- At least all primary key columns must be specified in the WHERE clause



Updates

UPDATE statement: **assignments**

- Describe modifications to be applied
- Allowed assignments:
  - Value of a whole column is replaced
  - Value of a list or map element is replaced
    - Items of lists are numbered starting with 0
  - Value of a user-defined type field is replaced



Updates

Examples

```
UPDATE
movies  SET
   year = 2006,
   director = ('Jan', 'Svěrák'),
   actors = { 'machacek': 'Robert Landa', 'sverak': 'Josef Tkaloun' },
   genres = [ 'comedy' ],
   countries = { 'CZ' }
WHERE id = 'vratnelahve'
```

```
UPDATE
movies  SET
   actors['vilhelmova'] = 'Helenka',
   genres[1] = 'comedy',
   properties.length = 99
WHERE  id = 'vratnelahve'
```

Updates

Examples: modification of collection elements

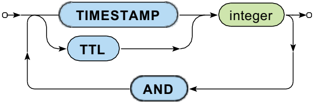
```
UPDATE movies
SET
  actors = actors + { 'vilhelmova': 'Helenka' },
  genres = [ 'drama' ] + genres,
  countries = countries + { 'SK' }
WHERE id = 'vratnelahve'
```

```
UPDATE movies
SET
  actors = actors - { 'vilhelmova', 'landovsky' },
  genres = genres - [ 'drama', 'sci-fi' ],
  countries = countries - { 'SK' }
WHERE id = 'vratnelahve'
```

Insertions and Updates

Update parameters

- **TTL**: time-to-live
  - 0, null or simply missing for persistent values
- **TIMESTAMP**: writetime

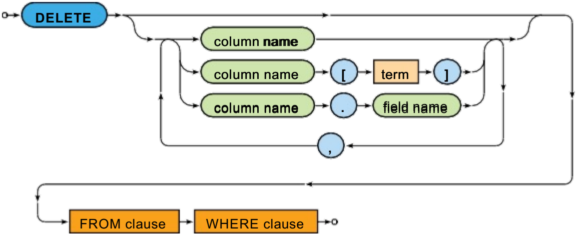


- Only newly inserted / updated values are really affected

Deletions

DELETE statement

- **Removes the matching rows** /
  Preserves these rows but **removes the selected columns** /
  Preserves these columns but **removes elements of collections** or **fields of UDT values**



Lecture Conclusion

Cassandra

- **Wide column store**

Cassandra query language

- DDL statements
- DML statements
  - **SELECT**, **INSERT**, **UPDATE**, **DELETE**