DS
IA

2019

Data Science and AI

Module 2
Part 1:

SQL and Databases

Agenda: Module 2 Part 1

- Introduction to Databases
- The relational database paradigm
- Basic SQL
- RDBMS
- Advanced SQL
- SQL in Python
- NoSQL Databases

Introduction to Databases

- Databases: definition, usage, features, applications
- Database Elements
- Database Principles
- The relational database paradigm
- SQL
- RDBMS

Introduction to Databases

- What is a database?
  - a computer system that manages **storage** and **querying** of data

- How is a database used?
  - data **insertion** & **retrieval** are (typically) performed using a **query language**
    - a compact programming syntax
    - basic operators for data transformation

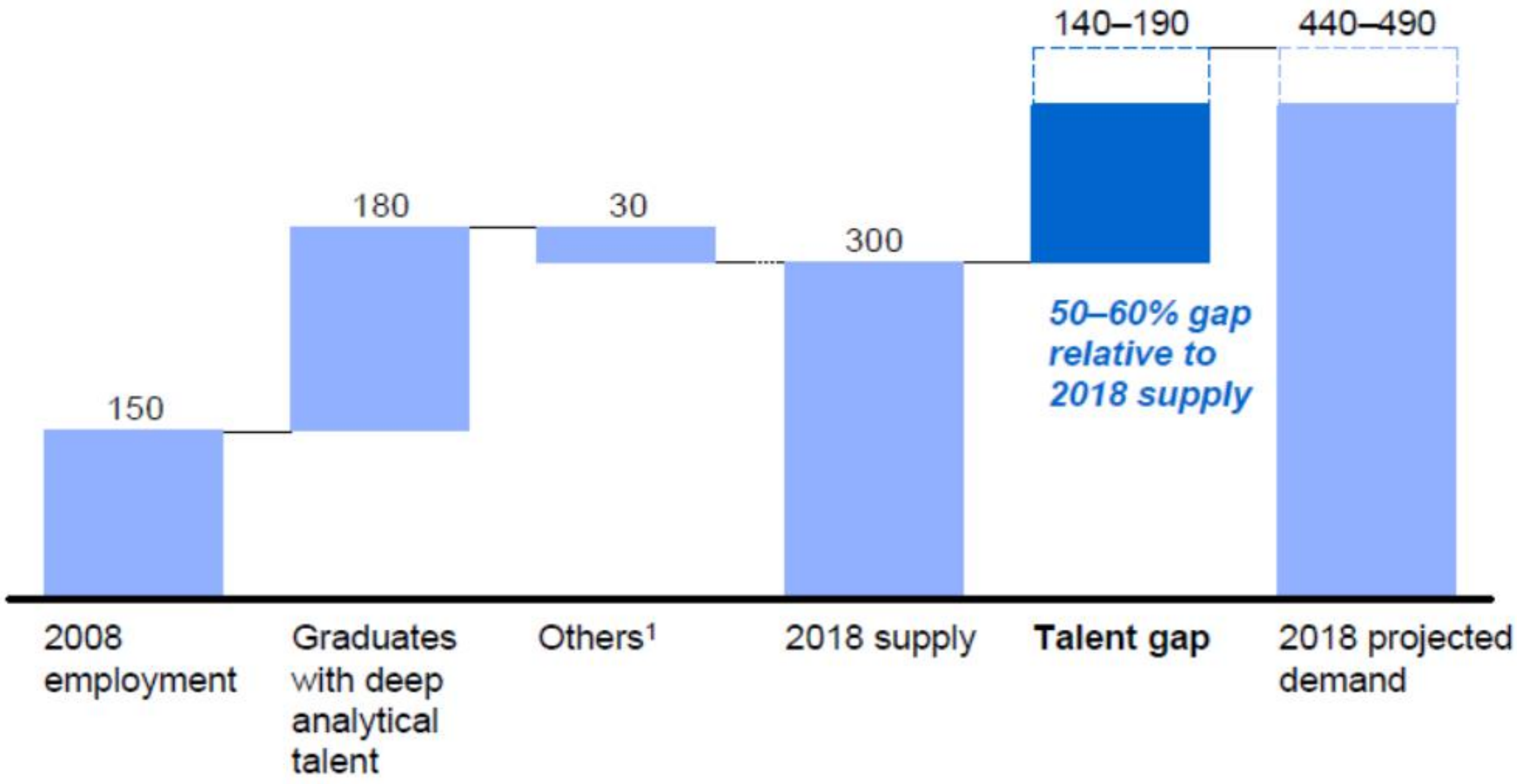
- What are the essential features of a database?
  - practical design for organising data
  - **efficient** methods to retrieve specific information
  - indexing, **performance optimisation**
  - **reliability, security, backup & replication**

Good News: Demand for Data Science!

Demand for deep analytical talent in the United States could be 50 to 60 percent greater than its projected supply by 2018

Supply and demand of deep analytical talent by 2018

Thousand people



1 Other supply drivers include attrition (-), immigration (+), and reemploying previously unemployed deep analytical talent (+).

SOURCE: US Bureau of Labor Statistics; US Census; Dun & Bradstreet; company interviews; McKinsey Global Institute analysis

Why Use a Database?

- The **standard** solution for data storage
- Much more **robust** than text, CSV or JSON files
- Most analyses involve pulling data to and from a resource; in most settings, this means using a **database**
- **Many types and variants** to serve different use cases
- Rules on structure make writing and retrieving data more **reliable and efficient**
- Provide a **central source of “truth”**

Database Application Areas - Examples

- Operations
  - transaction systems
  - data capture
  - inventory management
- Data Warehouse
  - Reporting
  - Analytics
  - Data Science
- Master Data
  - products
  - customers
  - suppliers

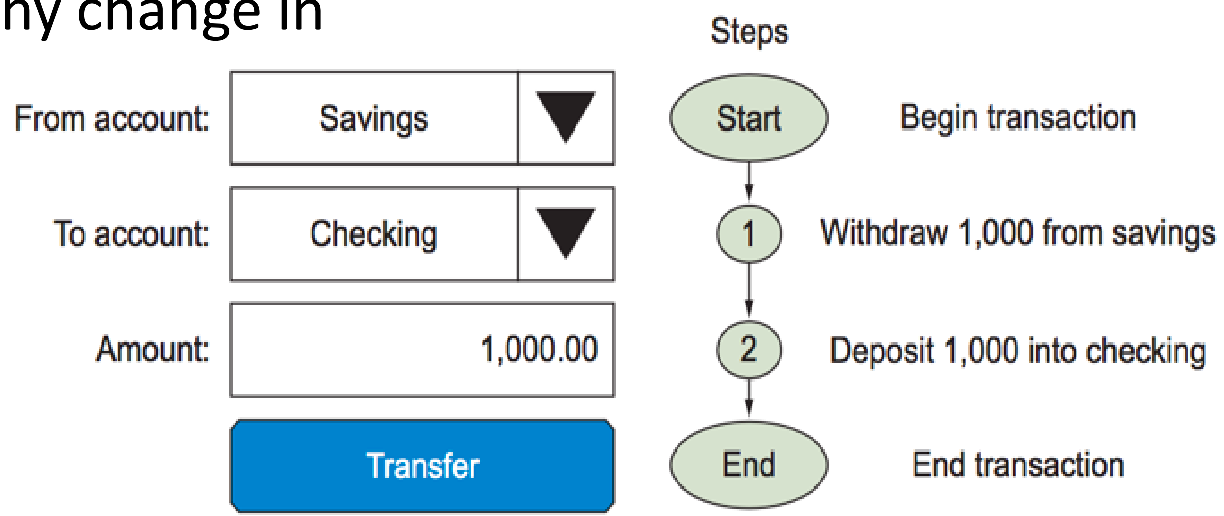
Database Elements

- tables
  - data storage by **columns** (attributes) and **rows** (records)
- keys
  - for matching **indexed** attributes across tables
- queries, views
  - for retrieving, subsetting, aggregating, joining data
- functions, procedures
  - **reusable** code units
- types
  - reusable data structures
- triggers
  - procedures that run automatically when a specific **event** occurs
- jobs
  - batches of procedures that run on a **schedule**

Database Principles: Transactional **Integrity**

def: Transaction

- a unit of work performed against a database
- this term generally represents any change in database
- involves **multiple steps**



Database Principles: ACID

def: ACID is a set of properties that guarantee that database transactions are processed reliably

- **Atomicity**: if one part of the transaction fails, the entire transaction fails; the database state is left unchanged **('all or nothing')**
- **Consistency**: ensures that any transaction will bring the database from one **valid state** to another
- **Isolation**: ensures that the **concurrent** execution of transactions results in a system state that would be obtained if transactions were executed serially (one after the other)
- **Durability**: ensures that once a transaction has been committed it will be unaffected by **power loss, system crashes, or errors**

The relational Database Paradigm

- Each table in a database is devoted to one **domain**
- Keys are used to **connect** tables in a logical manner

Customer

FirstName	LastName	CustID
Elaine	Stevens	101
Mary	Dittman	102
Skip	Stevenson	103
Drew	Lakeman	104
Eva	Plummer	105

Contact

ContactID	CustID	ContactInformation	ContactTypeID
101	101	555-2653	101
102	101	555-0057	102
103	102	555-8816	101
104	104	555-0949	101
105	103	555-0650	101
106	101	555-8855	103
107	105	Plummer@akcomms.com	105
108	101	Stevens@akcomms.com	105
109	101	555-5787	104
110	103	Stevenson@akcomms.com	105
111	105	555-5675	101
112	102	Dittman@akcomms.com	105

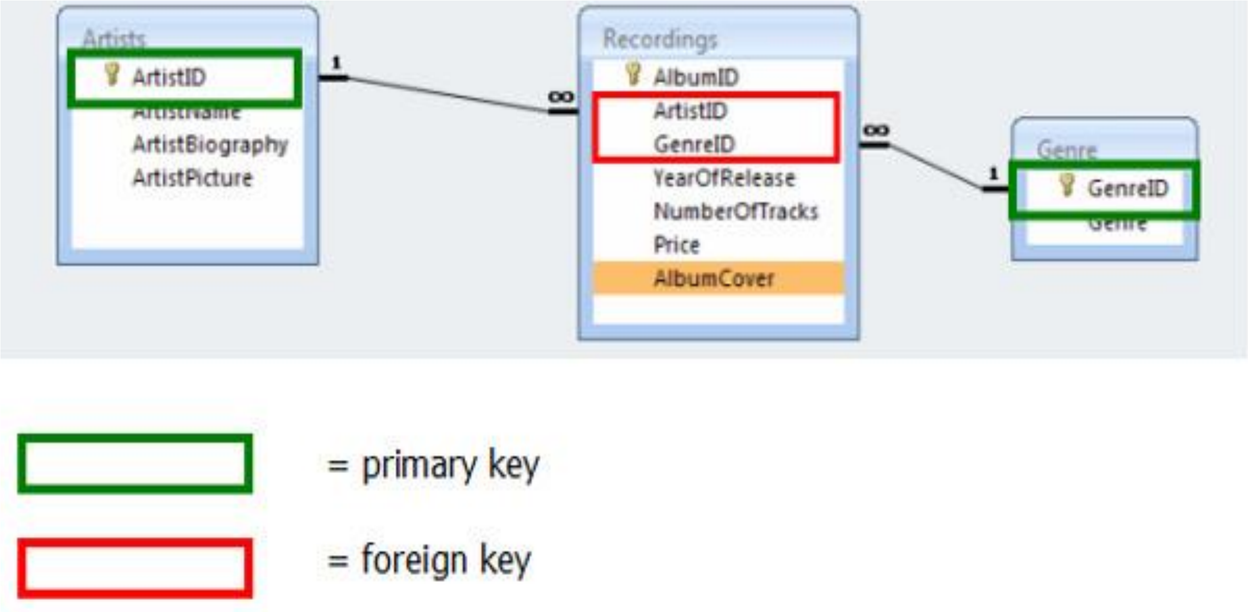
ContactType

Contact TypeID	Contact Type
101	Work
102	Cell
103	Home
104	Fax
105	Email

- customer info in 'Customer' table
- contacts info in 'Contact' table
- contact type lookup in 'ContactType' table

Relational Databases

- Queries can pull together information from multiple tables by matching **foreign keys** to primary keys



- 'ArtistID' is:
  - a foreign key in the 'Recordings' table
  - the primary key in the 'Artists' table
- 'GenreID' is:
  - a foreign key in the 'Recordings' table
  - the primary key in the 'Genre' table

RDBMS

- RDB = ?
  - relational database
- RDBMS = ?
  - relational database management system

RDBMS

The RDBMS is the system, and SQL is the language used to interact with the system.

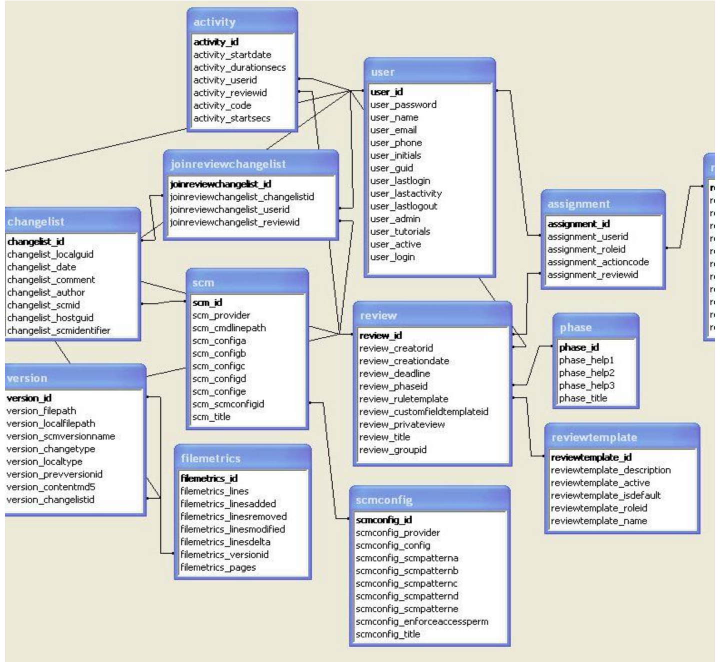
In principle you could have an RDBMS that uses some other language for access, and in principle you could use SQL to interact with some other kind of database system, though in practice the two are closely coupled.

SQLite, MySQL, MariaDB, Postgres, et al are all RDBMSes, and the language you'll use to interact with all of them is SQL.

Database Schema

- table-level
  - columns and primary key
- database-level
  - overall design
    - data model (tables)
    - keys (PK, FK)
  - integrity constraints

- rationale
  - removes tight coupling of database objects and owners
  - improves security administration of database objects



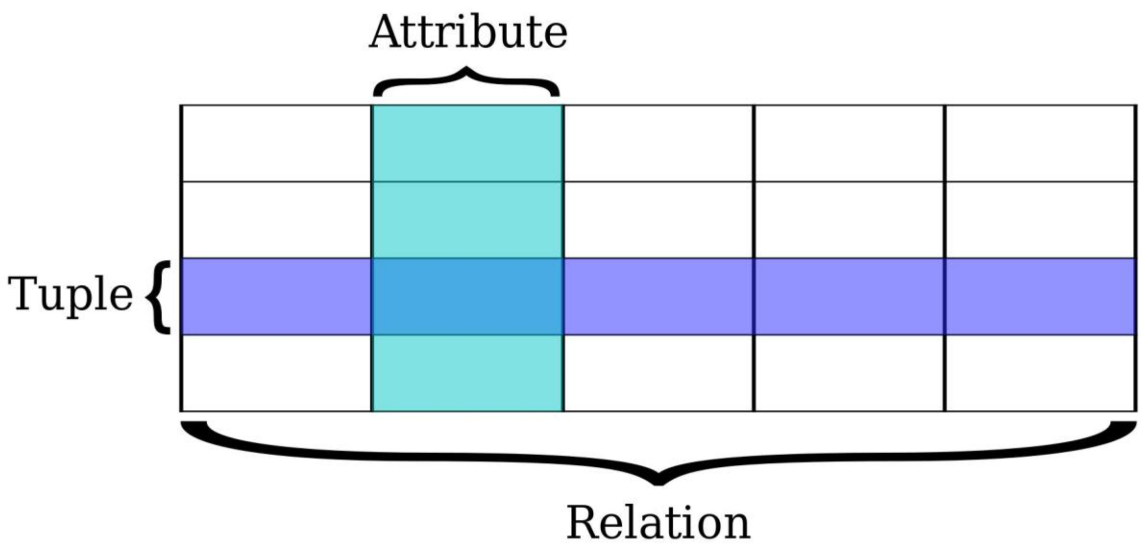
Relation Variables

By using a Data Definition Language (DDL), it is able to define base relation variables. In SQL, CREATE TABLE syntax is used to define base tables. The following is an example.

```
CREATE TABLE List_of_people (
 ID INTEGER,
 Name CHAR(40),
 Address CHAR(200),
 PRIMARY KEY (ID)
)
```

The Data Definition Language (DDL) is also used to define derived relation variables. In SQL, CREATE VIEW syntax is used to define a derived relation variable. The following is an example.

```
CREATE VIEW List_of_Okinawa_people AS (
 SELECT ID, Name, Address
  FROM List_of_people
  WHERE Address LIKE '%, Okinawa'
)
```



SQL (Structured Query Language)

- essentially a **declarative** language
  - data are typically retrieved as **subsets** of the rows and columns in one or more tables: ‘rowsets’
  - the user encodes the kind of rowset to be returned
  - the database engine produces a **plan** for how to execute it
    - **optimised** if possible
    - may accept **hints** from user (e.g. indexes to use)
- 3 functional divisions:
  - data definition language (**DDL**)
    - schema creation and modification
  - data manipulation language (**DML**)
    - insert, update, delete
  - data control language (**DCL**)
    - access, security

SQL – cont'd

simple rowset retrieval:

SELECT *columns* **FROM** *table*

conditional rowset retrieval:

SELECT *columns* FROM *table* **WHERE** *condition*

example (conditional rowset with ordering):

SELECT TOP 10 amount FROM sales WHERE amount > 99.99 **ORDER** BY amount

SQL – cont'd

Syntax

- identifiers with embedded **spaces or punctuation** require implementation-specific delimiters
  - e.g. SQL Server allows "my table" or [my table]

(delimiters are optional, otherwise)

- **namespace hierarchies** are usually delimited with periods (full stops)
  - e.g. (SQL Server): myschema.mytable.mycolumn

SQL – cont'd

Syntax

- SQL is **case-insensitive**
  - best to adopt a style, for readability
    (e.g. uppercase for SQL keywords, lowercase for identifiers)
- Microsoft and others extend the ANSI standard
  - extensions add **power and convenience** to programming
  - many extensions do not readily **port** between versions of SQL

Indices (*aka* 'Indexes')

- An index is a column of unique numbers (one per row) used to speed up query performance
  - reduces number of database data pages that have to be **scanned**
  - can have **> 1** index per table
  - usually based on single columns or **tuples** of columns
- a **clustered index** (e.g. SQL Server) determines physical order of data in a table
  - can only have 1 clustered index per table
- Building / rebuilding an index is an **expensive operation**
  - for inserting a large number of rows, it is usually best to **drop the index**, do the insert, then rebuild the index

Primary and Foreign Keys

- ***primary key*** uniquely refers to each row in a table
  - can have only one per table
  - usually an integer
- ***foreign key*** refers to a row in a different table
  - is a primary key in the other table
  - can have any number per table

- Nb. the use of foreign keys reduces storage and makes database maintenance much easier

Some samples

w3schools:

- ***https://www.w3schools.com/sql/***

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Some of The Most Important SQL Commands

SELECT - ***extracts data from a database***
UPDATE - ***updates data in a database***
DELETE - ***deletes data from a database***
INSERT INTO - ***inserts new data into a database***
CREATE DATABASE - ***creates a new database***
ALTER DATABASE - ***modifies a database***
CREATE TABLE - ***creates a new table***
ALTER TABLE - ***modifies a table***
DROP TABLE - ***deletes a table***
CREATE INDEX - ***creates an index (search key)***
DROP INDEX - ***deletes an index***

SELECT & SELECT DISTINCT

The SELECT statement is used to select data from a database. The data returned is stored in a result table, called the result-set.

SELECT *Syntax*
SELECT *column1, column2, ...*
FROM *table_name;*

SELECT *CustomerName, City* FROM *Customers;*

The following SQL statement lists the number of different (distinct) customer countries:
The SELECT DISTINCT *statement is used to return only distinct (different) values.*

Inside a table, a column often contains many duplicate values; and sometimes you only want to list the different (distinct) values.

SELECT DISTINCT *Syntax*
SELECT DISTINCT *column1, column2, ...*
FROM *table_name;*

SELECT DISTINCT *Country* FROM *Customers;*
SELECT COUNT(DISTINCT *Country)* FROM *Customers;*

SELECT Count*(*) AS DistinctCountries*
FROM *(*SELECT DISTINCT *Country* FROM *Customers);*

WHERE

The SQL WHERE Clause
The WHERE clause is used to filter records.
The WHERE clause is used to extract only those records that fulfill a specified condition.
WHERE Syntax

```
SELECT column1, column2, ...
FROM table_name
WHERE condition;
```

Text Fields vs. Numeric Fields

```
SELECT * FROM Customers
WHERE Country='Mexico';
```

```
SELECT * FROM Customers
WHERE CustomerID=1;
```

Operators in The WHERE Clause
The following operators can be used in the WHERE clause:

Operator	Description	Example
=	Equal	
>	Greater than	
<	Less than	
>=	Greater than or equal	
<=	Less than or equal	
<>	Not equal. Note: In some versions of SQL this operator may be written as !=	
BETWEEN	Between a certain range	
LIKE	Search for a pattern	
IN	To specify multiple possible values for a column	

INSERT

The INSERT INTO statement is used to insert new records in a table.

INSERT INTO Syntax

It is possible to write the INSERT INTO statement in two ways.

The first way specifies both the column names and the values to be inserted:

```
INSERT INTO table_name (column1, column2, column3, ...)
VALUES (value1, value2, value3, ...);
```

```
INSERT INTO table_name
VALUES (value1, value2, value3, ...);
```

INSERT INTO Example

The following SQL statement inserts a new record in the "Customers" table:

Example

```
INSERT INTO Customers (CustomerName, ContactName, Address, City, PostalCode, Country)
VALUES ('Cardinal', 'Tom B. Erichsen', 'Skagen 21', 'Stavanger', '4006', 'Norway');
```

Insert Data Only in Specified Columns

```
INSERT INTO Customers (CustomerName, City, Country)
VALUES ('Cardinal', 'Stavanger', 'Norway');
```

UPDATE

The UPDATE *statement is used to modify the existing records in a table.*

UPDATE *Syntax*

```
UPDATE table_name
SET column1 = value1, column2 = value2, ...
WHERE condition;
```

```
UPDATE Customers
SET ContactName = 'Alfred Schmidt', City= 'Frankfurt'
WHERE CustomerID = 1;
```

UPDATE Multiple Records

It is the WHERE clause that determines how many records that will be updated.

```
UPDATE Customers
SET ContactName='Juan'
WHERE Country='Mexico';
```

Update Warning!

Be careful when updating records. If you omit the WHERE clause, ALL records will be updated!

Example

```
UPDATE Customers
SET ContactName='Juan';
```

DELETE

The DELETE statement is used to delete existing records in a table.
DELETE Syntax
DELETE FROM table_name WHERE condition;

Example
DELETE FROM Customers WHERE CustomerName='Alfreds Futterkiste';

The following SQL statement deletes all rows in the "Customers" table, without deleting the table:
Example
DELETE FROM Customers;

SELECT TOP

The SQL SELECT TOP Clause
The SELECT TOP clause is used to specify the number of records to return.
The SELECT TOP clause is useful on large tables with thousands of records. Returning a large number of records can impact on performance.
Note: Not all database systems support the SELECT TOP clause. MySQL supports the LIMIT clause to select a limited number of records, while Oracle uses ROWNUM.

SQL Server / MS Access Syntax:

```
SELECT TOP number|percent column_name(s)
FROM table_name
WHERE condition;
```

MySQL Syntax:

```
SELECT column_name(s)
FROM table_name
WHERE condition
LIMIT number;
```

Oracle Syntax:

```
SELECT column_name(s)
FROM table_name
WHERE ROWNUM <= number;
```

SQL TOP, LIMIT and ROWNUM Examples

```
SELECT * FROM Customers
LIMIT 3;
SELECT * FROM Customers
WHERE ROWNUM <= 3;
SELECT TOP 50 PERCENT * FROM Customers;
```

CREATE DATABASE TABLE

The CREATE DATABASE statement is used to create a new SQL database.
Syntax

```
CREATE DATABASE databasename;
```

```
CREATE DATABASE testDB;
```

The CREATE TABLE statement is used to create a new table in a database.
Syntax

```
CREATE TABLE table_name (
    column1 datatype,
    column2 datatype,
    column3 datatype,
   ....
);
```

```
CREATE TABLE Persons (
    PersonID int,
    LastName varchar(255),
    FirstName varchar(255),
    Address varchar(255),
    City varchar(255)
);
```

The following SQL creates a new table called "TestTables" (which is a copy of the "Customers" table):
Example

```
CREATE TABLE TestTable AS
SELECT customername, contactname
FROM customers;
```

ALTER TABLE

The ALTER TABLE statement is used to add, delete, or modify columns in an existing table.
The ALTER TABLE statement is also used to add and drop various constraints on an existing table.
ALTER TABLE - ADD Column
To add a column in a table, use the following syntax:

```
ALTER TABLE table_name
ADD column_name datatype;
```

```
ALTER TABLE Customers
ADD Email varchar(255);
```

```
ALTER TABLE table_name
DROP COLUMN column_name;
```

```
ALTER TABLE Customers
DROP COLUMN Email;
```

To change the data type of a column in a table, use the following syntax:

SQL Server / MS Access:

```
ALTER TABLE table_name
ALTER COLUMN column_name datatype;
```

My SQL / Oracle (prior version 10G):

```
ALTER TABLE table_name
MODIFY COLUMN column_name datatype;
```

Oracle 10G and later:

```
ALTER TABLE table_name
MODIFY column_name datatype;
```

```
ALTER TABLE Persons
ADD DateOfBirth date;
```

PRIMARY KEY

The PRIMARY KEY constraint uniquely identifies each record in a table.
Primary keys must contain UNIQUE values, and cannot contain NULL values.
A table can have only ONE primary key; and in the table, this primary key can consist of single or multiple columns (fields).
SQL PRIMARY KEY on CREATE TABLE
The following SQL creates a PRIMARY KEY on the "ID" column when the "Persons" table is created:
MySQL:

```
CREATE TABLE Persons (
    ID int NOT NULL,
    LastName varchar(255) NOT NULL,
    FirstName varchar(255),
    Age int,
    PRIMARY KEY (ID)
);
```

SQL Server / Oracle / MS Access:

```
CREATE TABLE Persons (
    ID int NOT NULL PRIMARY KEY,
    LastName varchar(255) NOT NULL,
    FirstName varchar(255),
    Age int
);
```

To allow naming of a PRIMARY KEY constraint, and for defining a PRIMARY KEY constraint on multiple columns, use the following SQL syntax:
MySQL / SQL Server / Oracle / MS Access:

```
CREATE TABLE Persons (
    ID int NOT NULL,
    LastName varchar(255) NOT NULL,
    FirstName varchar(255),
    Age int,
    CONSTRAINT PK_Person PRIMARY KEY
(ID,LastName)
);
```

CREATE INDEX

The CREATE INDEX statement is used to create indexes in tables.
Indexes are used to retrieve data from the database very fast. The users cannot see the indexes, they are just used to speed up searches/queries.
Note: Updating a table with indexes takes more time than updating a table without (because the indexes also need an update). So, only create indexes on columns that will be frequently searched against.

CREATE INDEX *Syntax*
Creates an index on a table. Duplicate values are allowed:

```
CREATE INDEX index_name
ON table_name (column1, column2, ...);
```

CREATE UNIQUE INDEX *Syntax*
Creates a unique index on a table. Duplicate values are not allowed:

```
CREATE UNIQUE INDEX index_name
ON table_name (column1, column2, ...);
```

CREATE INDEX - cont'd

```
CREATE INDEX idx_lastname
ON Persons (LastName);
```

If you want to create an index on a combination of columns, you can list the column names within the parentheses, separated by commas:

```
CREATE INDEX idx_pname
ON Persons (LastName, FirstName);
```

DROP INDEX Statement

The DROP INDEX statement is used to delete an index in a table.

MS Access:

```
DROP INDEX index_name ON table_name;
```

SQL Server:

```
DROP INDEX table_name.index_name;
```

DB2/Oracle:

```
DROP INDEX index_name;
```

MySQL:

```
ALTER TABLE table_name
DROP INDEX index_name;
```

DROP DATABASE TABLE

The DROP DATABASE *statement is used to drop an existing SQL database.*

DROP DATABASE *Example*
The following SQL statement drops the existing database "testDB":
Example
DROP DATABASE *testDB;*

The DROP TABLE *statement is used to drop an existing table in a database.*

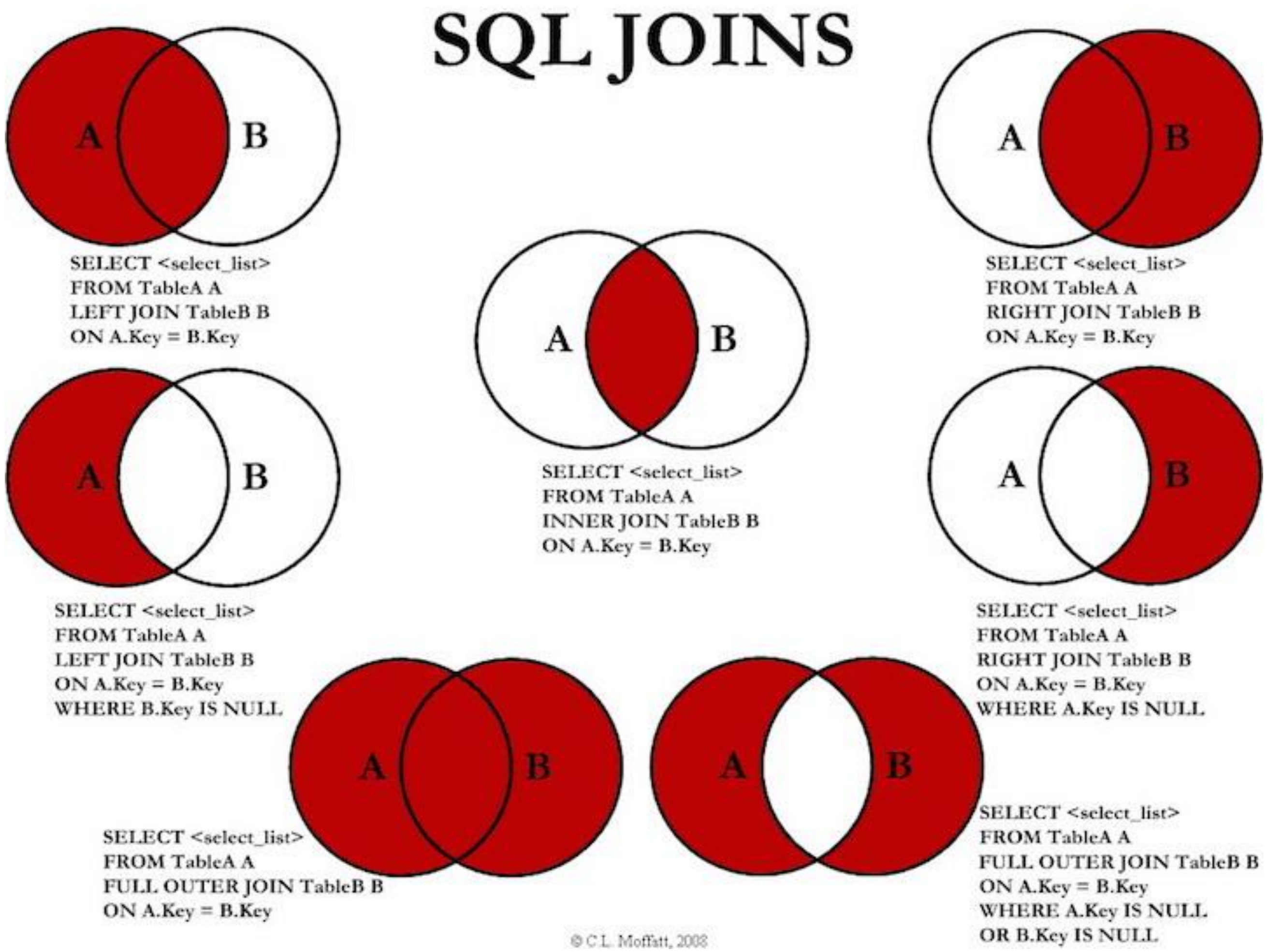
SQL DROP TABLE *Example*
The following SQL statement drops the existing table "Shippers":
Example
DROP TABLE *Shippers;*

Joins

- used (in queries) for
  - **combining columns** from different tables
  - **filtering columns** from one table using criteria in a different table
- joins match a foreign key in one table to a primary key in another table

- Nb. simple joins are generally quite fast, but **compound joins** (involving many tables) can be very slow
- a database join is analogous to a set operation in mathematics

Joins


SQL JOINS
A
B
SELECT <select_list>
FROM TableA A
LEFT JOIN TableB B
ON A.Key = B.Key
SELECT <select_list>
FROM TableA A
RIGHT JOIN TableB B
ON A.Key = B.Key
SELECT <select_list>
FROM TableA A
INNER JOIN TableB B
ON A.Key = B.Key
SELECT <select_list>
FROM TableA A
LEFT JOIN TableB B
ON A.Key = B.Key
WHERE B.Key IS NULL
SELECT <select_list>
FROM TableA A
RIGHT JOIN TableB B
ON A.Key = B.Key
WHERE A.Key IS NULL
SELECT <select_list>
FROM TableA A
FULL OUTER JOIN TableB B
ON A.Key = B.Key
SELECT <select_list>
FROM TableA A
FULL OUTER JOIN TableB B
ON A.Key = B.Key
WHERE A.Key IS NULL
OR B.Key IS NULL
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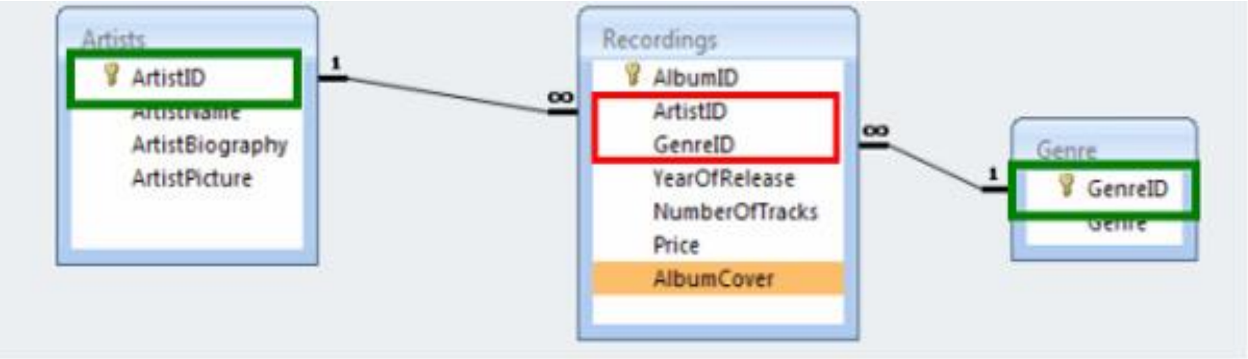
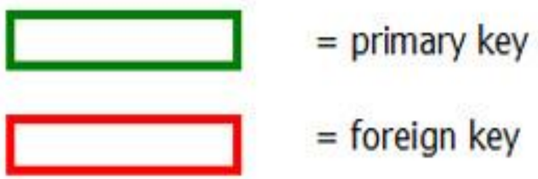
Joins – cont’d

- Compound inner join example





Return artist name and album cover for every album of the ‘rock’ genre:

SELECT Artists.ArtistName,
Recordings.AlbumCover
FROM Artists
INNER JOIN Recordings
ON Artists.ArtistID = Recordings.ArtistID
INNER JOIN Genre
ON Recordings.GenreID = Genre.GenreID
WHERE Genre.Genre = ‘rock’

Joins – cont'd

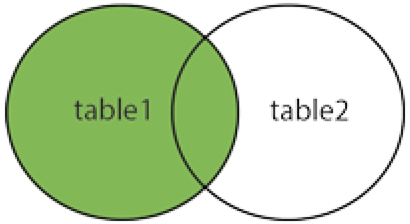
Left Join

- all rows from 1st table, plus matching rows from 2nd table:

SELECT cars.car, trucks.truck FROM cars
LEFT JOIN trucks ON cars.maker = trucks.maker

  - unmatched rows will have NULL in place of truck

Table 1	Table 2
aaa	aaa
bbb	xxx
ccc	ccc
ddd	yyy
eee	eee
fff	fff

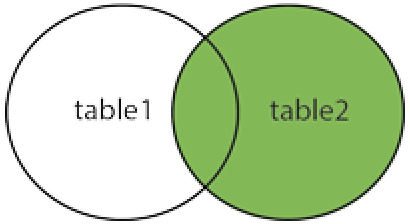


Right Join

- all rows from 2nd table, plus matching rows from 1st table:

SELECT cars.car, trucks.truck FROM cars
RIGHT JOIN trucks ON cars.maker = trucks.maker

  - unmatched rows will have NULL in place of car



Joins – cont'd

Left Join

A

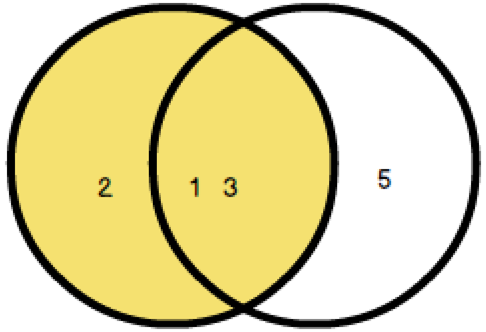
m	f
a1	1
a2	2
a3	3

```
SELECT m, A.f, B.f, n
FROM A
LEFT JOIN B ON B.f = A.f
```

B

n	f
b1	1
b2	3
b3	5

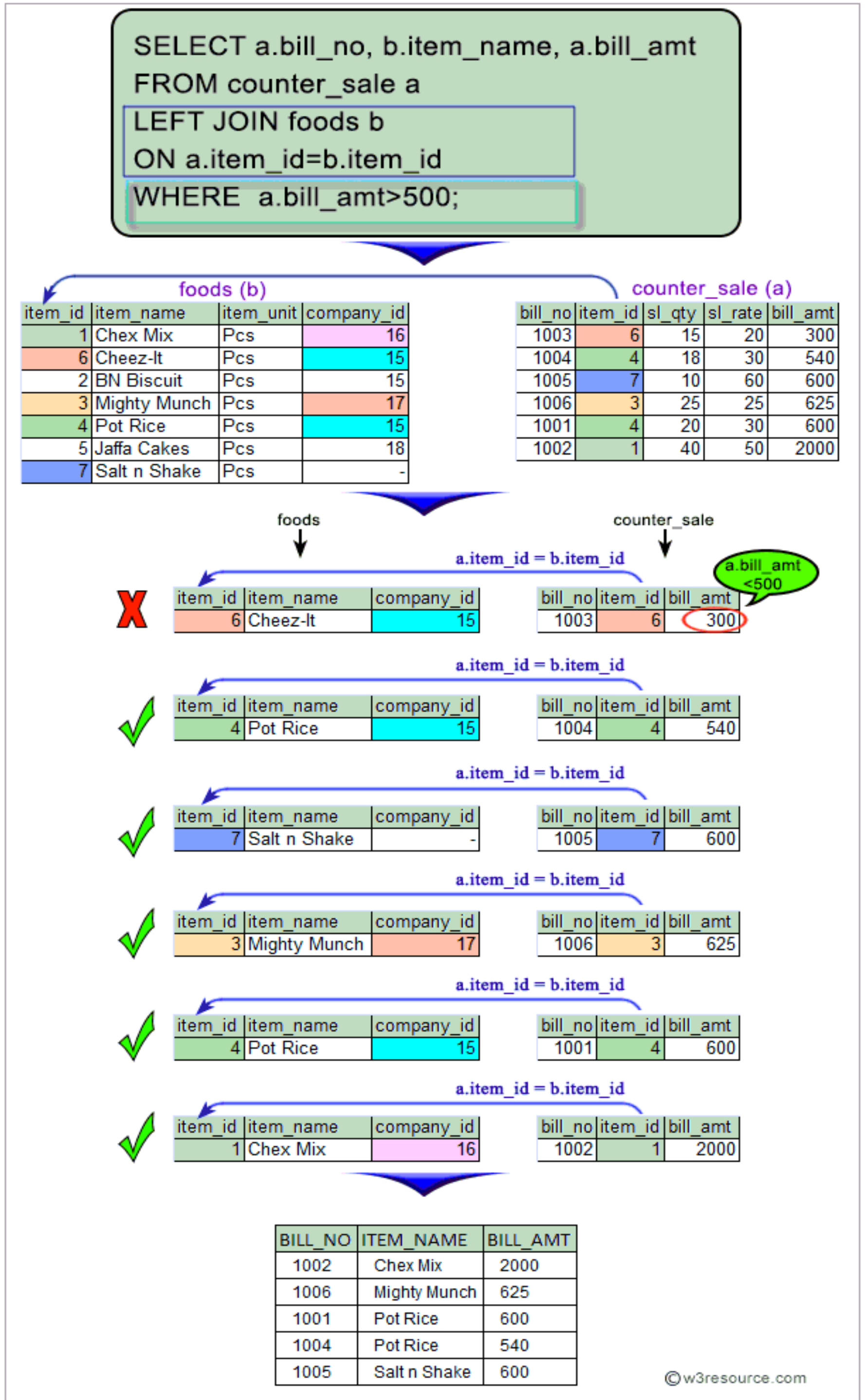
m	A.f	B.f	n
a1	1	1	b1
a2	2	NULL	NULL
a3	3	3	b2



Joins – cont'd

sql left join on multiple columns

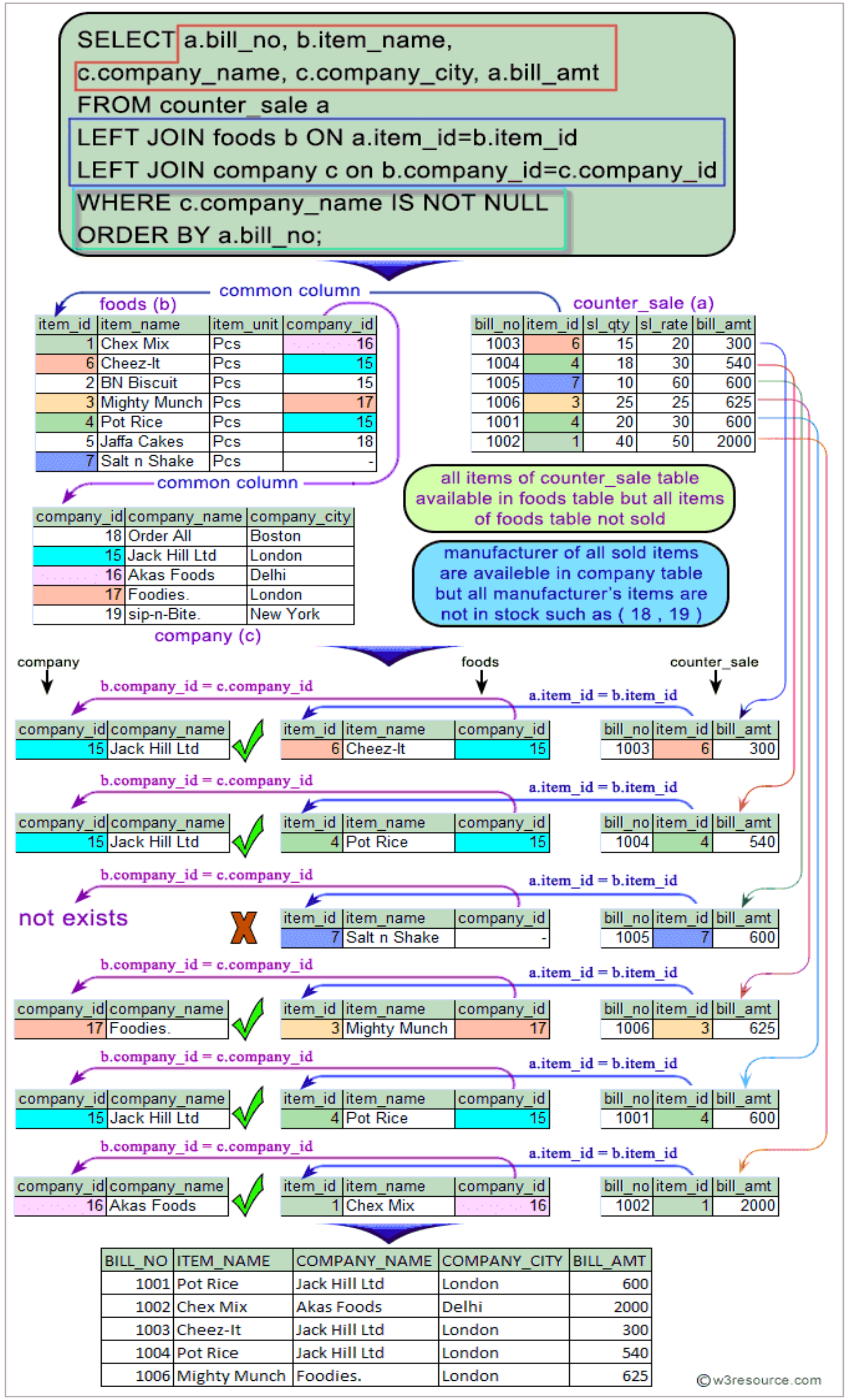
This SQL statement will first join all rows from the counter_sale table and only those rows from the foods table where the joined fields are equal and if the ON clause matches no records in the foods table, the join will still return rows, but the NULL in each column of right table, therefore eliminates those rows which bill amount is less than or equal to 500.



Joins – cont'd

Left Join on multiple table

To filtered out those bill number, item name, company name and city and the bill amount for each bill, which items are available in foods table, and their manufacturer must have enlisted to supply that item, and no NULL value for manufacturer are not allowed



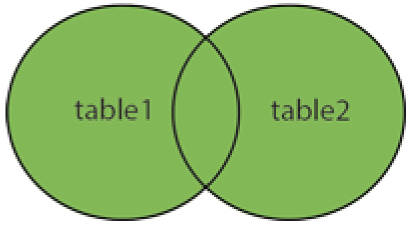
Joins – cont'd

Outer Join

- all rows from 1st table, matched with all rows from 2nd table:

```
SELECT cars.car, trucks.truck FROM cars
OUTER JOIN trucks ON cars.maker = trucks.maker
```

  - returns every possible pairing of car and truck



- uses:
  - creating contingency tables
  - creating dummy data for testing
  - other?

Joins – cont'd

Unfortunately, SQLite does not support the RIGHT JOIN clause and also the FULL OUTER JOIN clause. However, you can easily emulate the FULL OUTER JOIN by using the LEFT JOIN clause.

```
-- create and insert data into the dogs table
CREATE TABLE dogs (
    type      TEXT,
    color TEXT
);
INSERT INTO dogs(type, color)
VALUES('Hunting','Black'), ('Guard','Brown');

-- create and insert data into the cats table
CREATE TABLE cats (
    type      TEXT,
    color TEXT
);
```

```
 INSERT INTO cats(type,color)
VALUES('Indoor','White'),
     ('Outdoor','Black');

SELECT d.type,
         d.color,
         c.type,
         c.color
FROM dogs d
LEFT JOIN cats c USING(color)
UNION ALL
SELECT d.type,
         d.color,
         c.type,
         c.color
FROM cats c
LEFT JOIN dogs d ON d.color=c.color
WHERE d.color IS NULL;
```

Writing code using DB-API - Update Operation

```
import MySQLdb
# Open database connection
db = MySQLdb.connect("localhost","testuser","test123","TESTDB" )
# prepare a cursor object using cursor() method
cursor = db.cursor()
# Drop table if it already exist using execute() method.
cursor.execute("DROP TABLE IF EXISTS EMPLOYEE")

# Create table as per requirement
sql = """CREATE TABLE EMPLOYEE (
         FIRST_NAME  CHAR(20) NOT NULL,
         LAST_NAME  CHAR(20),
         AGE INT,
         SEX CHAR(1),
         INCOME FLOAT )"""

cursor.execute(sql)
# disconnect from server
db.close()
```

Connect to Database and Create Table

If the database does not exist, then it will be created and finally a database object will be returned.

```
#!/usr/bin/python
import sqlite3
conn = sqlite3.connect('test.db')
print "Opened database successfully";

#Create table
conn.execute('''CREATE TABLE COMPANY
       (ID INT PRIMARY KEY     NOT NULL,
       NAME           TEXT    NOT NULL,
       AGE            INT     NOT NULL,
       ADDRESS        CHAR(50),
       SALARY         REAL);''')
print "Table created successfully";
conn.close()
```

Writing code using sqlite3-API - Insert Operation

```
#!/usr/bin/python
import sqlite3
conn = sqlite3.connect('test.db')
print "Opened database successfully";
conn.execute("INSERT INTO COMPANY (ID,NAME,AGE,ADDRESS,SALARY) \
    VALUES (1, 'Paul', 32, 'California', 20000.00 )");
conn.execute("INSERT INTO COMPANY (ID,NAME,AGE,ADDRESS,SALARY) \
    VALUES (2, 'Allen', 25, 'Texas', 15000.00 )");
conn.execute("INSERT INTO COMPANY (ID,NAME,AGE,ADDRESS,SALARY) \
    VALUES (3, 'Teddy', 23, 'Norway', 20000.00 )");
conn.execute("INSERT INTO COMPANY (ID,NAME,AGE,ADDRESS,SALARY) \
    VALUES (4, 'Mark', 25, 'Rich-Mond ', 65000.00 )");
conn.commit()
print "Records created successfully";
conn.close()
```

Writing code using sqlite3-API - Select Operation

```
#!/usr/bin/python
import sqlite3
conn = sqlite3.connect('test.db')
print "Opened database successfully";
cursor = conn.execute("SELECT id, name, address, salary from COMPANY")
for row in cursor:
   print "ID = ", row[0]
   print "NAME = ", row[1]
   print "ADDRESS = ", row[2]
   print "SALARY = ", row[3], "\n"
print "Operation done successfully";
conn.close())
```

Writing code using sqlite3-API - update Operation

```
#!/usr/bin/python
import sqlite3
conn = sqlite3.connect('test.db')
print "Opened database successfully";
conn.execute("UPDATE COMPANY set SALARY = 25000.00 where ID = 1")
conn.commit
print "Total number of rows updated :", conn.total_changes
cursor = conn.execute("SELECT id, name, address, salary from COMPANY")
for row in cursor:
   print "ID = ", row[0]
   print "NAME = ", row[1]
   print "ADDRESS = ", row[2]
   print "SALARY = ", row[3], "\n"
print "Operation done successfully";
conn.close()
```

Writing code using sqlite3-API - DELETE Operation

```
#!/usr/bin/python
import sqlite3
conn = sqlite3.connect('test.db')
print "Opened database successfully";
conn.execute("DELETE from COMPANY where ID = 2;")
conn.commit()
print "Total number of rows deleted :", conn.total_changes
cursor = conn.execute("SELECT id, name, address, salary from COMPANY")
for row in cursor:
   print "ID = ", row[0]
   print "NAME = ", row[1]
   print "ADDRESS = ", row[2]
   print "SALARY = ", row[3], "\n"
print "Operation done successfully";
conn.close()
```

https://www.tutorialspoint.com/sqlite/sqlite_quick_guide.htm
https://gist.github.com/naiquevin/1746005

Connecting to a database using ibm_db API

The ibm_db API provides a variety of useful Python functions for accessing and manipulating data in an IBM data server database, including functions for connecting to a database, repairing and issuing SQL statements, fetching rows from result sets, calling stored procedures, committing and rolling back transactions, handling errors and retrieving metadata.

The ibm_db API uses the IBM Data Server Driver for ODBC, and CLI APIs to connect to IBM, DB2 and Informix.

http://cican17.com/accessing-database-using-python/

SQLite Aggregate Functions -Average

The AVG function is an aggregate function that calculates the average value of all non-NULL values within a group.

```
CREATE TABLE avg_tests (val);1
INSERT INTO avg_tests (val)
VALUES  (1), (2), (10.1), (20.5),
 ('8'), ('B'), (NULL), (x'0010'), (x'0011');
```

```
SELECT rowid,
       val
  FROM avg_tests;
```

```
SELECT  avg(val)
FROM  avg_tests
WHERE  rowid < 5;
```

```
SELECT  avg(val)
FROM  avg_tests;
```

```
SELECT  avg(DISTINCT val)
FROM  avg_tests;
```

SQLite Aggregate Functions - Max/MIN/SUM

The SQLite MAX/MIN/SUM function is an aggregate function that returns the maximum/minimum/sum value of all values in a group.

```
CREATE TABLE avg_tests (val);1
INSERT INTO avg_tests (val)
VALUES  (1), (2), (10.1), (20.5),
 ('8'), ('B'), (NULL), (x'0010'), (x'0011');

SELECT rowid,
       val
  FROM avg_tests;
```

```
SELECT  MAX(val)
FROM  avg_tests;

SELECT  MIN(val)
FROM  avg_tests;

SELECT  SUM(val)
FROM  avg_tests;
```

Lab 2.1.1: SQL

- Purpose:
  - Create account in **Mode Analytics**
  - To discover the basic features of SQL
- Tools and Resources:
  - Mode Analytics (account required)
- Materials:
  - Mode Analytics interactive SQL tutorial https://community.modeanalytics.com/sql/tutorial/introduction-to-sql/

Database Scripting

- shell scripts / commands
  - for quick / convenient execution of routine tasks
    - **populating / updating a database** from a file
    - **backing up or restoring** a database
    - **dumping** a database object to a file
    - **executing queries** to deliver rowsets for subsequent analysis
    - **moving data** between databases, data lakes, etc.
- examples

psql -U postgres -d database_name -c "SELECT c_defaults FROM user_info WHERE c_uid = 'testuser'”

mysql -h "server-name" -u "root" "-pXXXXXXXX" "database-name" < "filename.sql"

Database Administration

- granting **permissions**
  - users, roles
  - tables, views
- performing **backups & recoveries**
- creating & scheduling **jobs**

- Nb. It is not uncommon for a query to join tables from different databases
  - in SQL Server, the query must be created by the *single* owner of *both* databases
  - a database owner should be a virtual user -- not a particular person's login

Discussion

- Why is the RDBMS still in use?
- QUESTIONS?

Advanced SQL

- Aggregation functions
- Grouping
- Window functions

SQL Aggregation functions

- aggregate many rows into a single resultant row
- common aggregation functions:

COUNT	counts all rows meeting criterion
SUM	sums selected field(s) in all rows meeting criterion
AVG	averages …
MIN, MAX	computes minimum/maximum of …

- SQL engine may support user-defined aggregation functions
- example:

```
SELECT MIN(sale_date) AS firstdt, MAX(sale_date) AS lastdt,
SUM(sales) AS netsales FROM sales
```

Aggregating by Groups in SQL

- grouping allows aggregation functions to be applied to subsets based on row-level criteria
- adds GROUP BY clause to select statement
- example:

```
SELECT agent_name, SUM(sales) AS netsales FROM sales GROUP BY agent_name
```

```
SELECT COUNT(CustomerID), Country
FROM Customers
GROUP BY Country
ORDER BY COUNT(CustomerID) DESC;
```

SQL Window Functions

- operates on a *set* of rows and return a value for *each* row
  - like aggregation, but performed in relation to current row
- example: running total

```
SELECT duration, SUM(duration)
OVER (ORDER BY start_time) AS running_total
FROM bikeshare
```

  - OVER clause designates window
  - ORDER BY sets sequence of rowset (oldest to newest values of start_time)
  - each row shows current duration and sum of all previous values of duration

Lab 2.1.2: Advanced SQL

- Purpose:
  - To discover the more powerful features of SQL

- Tools and Resources:
  - Mode Analytics (account required)
  - Mode Analytics interactive SQL tutorial

    https://community.modeanalytics.com/sql/tutorial/introduction-to-sql/

SQL in Python

- Python/SQL integration paradigms
- Python with embedded SQL db (SQLite)
- Python with external SQL db (pyodbc)

Python / SQL Integration Paradigms

- **Embedded**
  - an SQL RDBMS is emulated by a library designed to work with Python
  - databases are not normally accessible outside of Python
  - ideal for a self-contained Python app with its own db

- **External**
  - a stand-alone SQL RDBMS resides on a database server that other applications can connect to
  - the db is made accessible to Python via an ODBC driver specific to the RDBMS in use
    - SQL Server, MySQL, DB2, etc.
  - used when the Python app is just a client of a more general-purpose db

Python with Embedded SQL Database

Example: SQLite

```
import sqlite3
connection = sqlite3.connect("company.db")

sql_command = """
CREATE TABLE employee (
staff_number INTEGER PRIMARY KEY,
fname VARCHAR(20),
lname VARCHAR(30),
date_joined DATE);"""
```

Python with External SQL Database

Example: pyodbc

```
import pyodbc
cnxn = pyodbc.connect("DSN=MSSQL-PYTHON")
cursor = cnxn.cursor()
cursor.tables()
rows = cursor.fetchall()
for row in rows:
    print row.table_name
```

Python with pyodbc

- Python uses a cursor to iterate through a returned rowset

```
            import pyodbc
import pandas.io.sql as psql
import pandas as pd

cxnstr = "Server=myServerAddress;Database=myDB;User Id=myUsername;Password=myPass;"
cxn = pyodbc.connect(cxnstr)
cursor = cnxn.cursor()
cursor.execute("""SELECT ID, FirstName, LastName FROM mytable""")
rows = cursor.fetchone()
objects_list = []
  for row in rows:
      d = collections.OrderedDict()
      d['UserID']= row.ID
      d['FirstName']= row.FirstName
      d['LastName']= row.LastName
cxn.close()
```

HOMEWORK

1. Install
   - MongoDB Community Server https://www.mongodb.com/download-center#community
   - Neo4j Community Server https://neo4j.com/download-center/#releases

2. Install Python packages:
   - pymongo (conda)
   - neo4j-driver (pip)

Lab 2.1.3: SQL in Python

- Purpose:
  - To investigate SQL implementation in Python

- Tools and Resources:
  - Sqlit: Install on your labtop
  https://www.sqlite.org/download.html
  - Jupyter Notebooks
  - Python package sqlite3

- Materials:
  - 'Lab 2.1.3 – Databases.ipynb'

- Data:
  - 'housing-data.csv'

Scalable SQL

- massively parallel processing relational database systems (**MPP** RDBMS)
  - (expensive) architecture supports scalability and high performance

- NoSQL databases *with SQL*

Where Does Big Data Come From?

It’s all happening online – could record every:

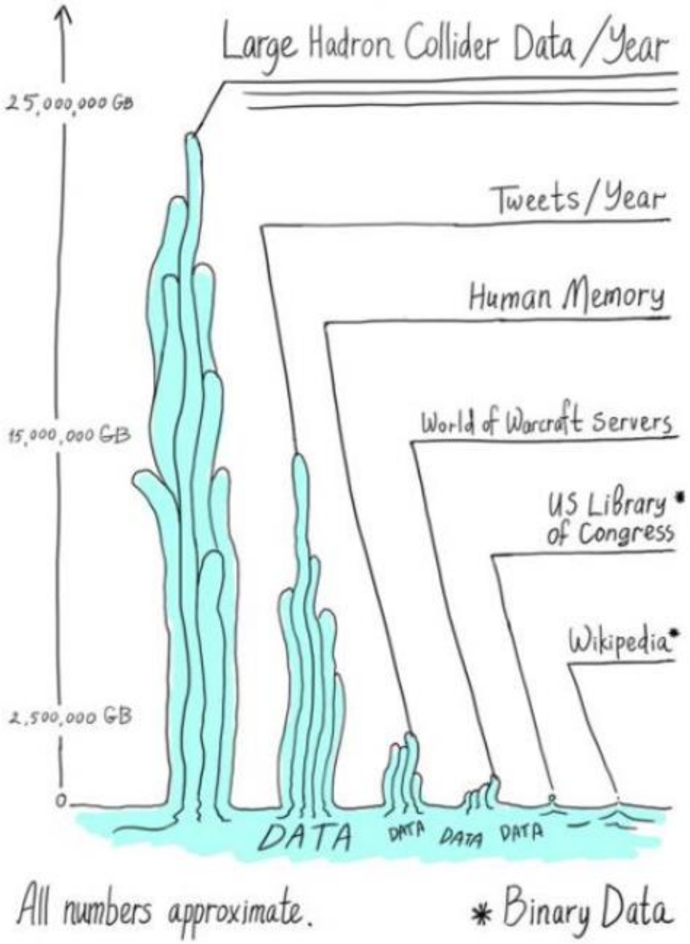
» Click
» Ad impression
» Billing event
» Fast Forward, pause,…
» Server request
» Transaction
» Network message
» Fault
» …

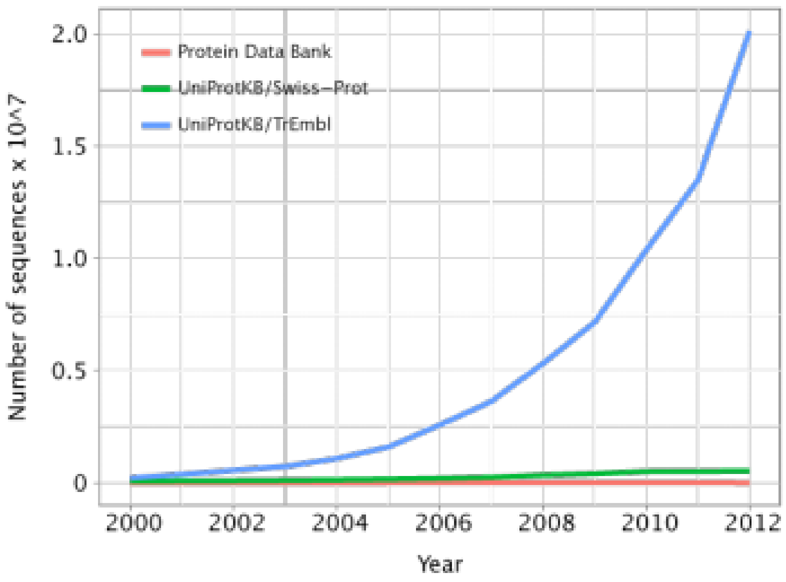
Where Does Big Data Come From?

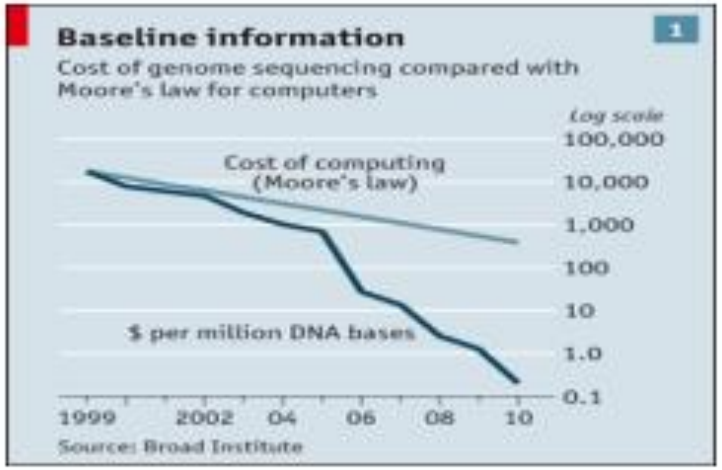
User Generated Content (Web & Mobile)
» Facebook
» Instagram
» Yelp
» TripAdvisor
» Twitter
» YouTube
» …

Where Does Big Data Come From?

Health and Scientific Computing



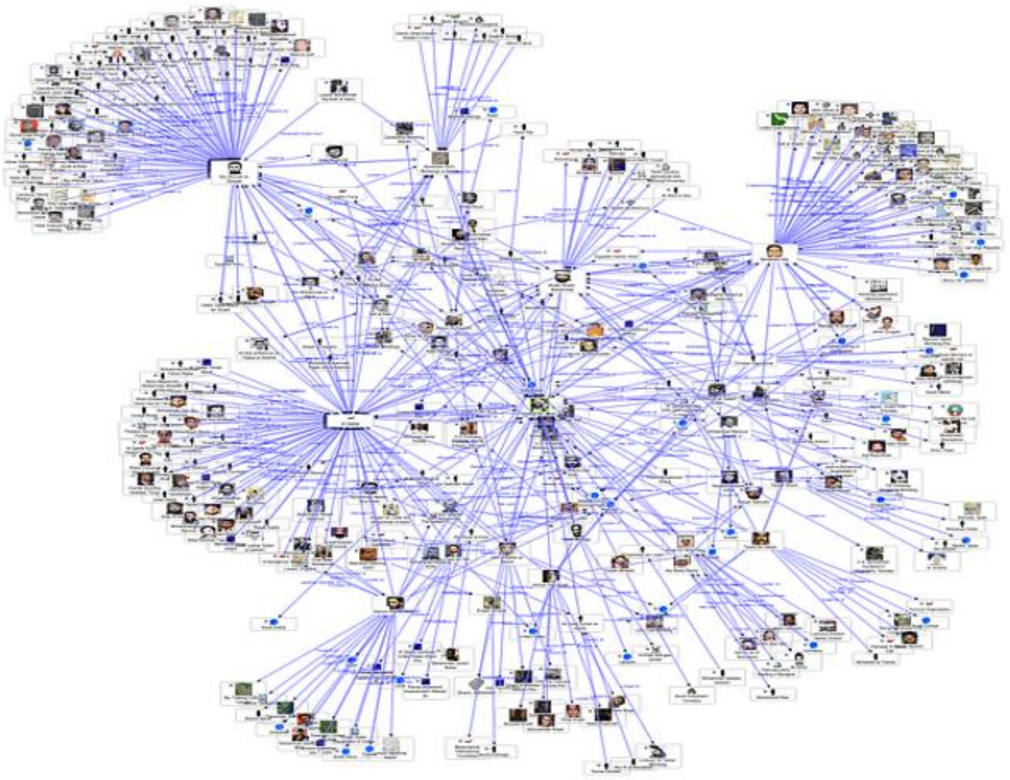




Where Does Big Data Come From?

Graph Data
Lots of interesting data has a graph structure:
- Social networks
- Telecommunication Networks
- Computer Networks
- Road networks
- Collaborations/Relationships
- …

Some of these graphs can get quite large
 (e.g., Facebook user graph)



Where Does Big Data Come From?

Log Files – Apache Web Server Log

```
uplherc.upl.com - - [01/Aug/1995:00:00:07 -0400] "GET / HTTP/1.0" 304 0
uplherc.upl.com - - [01/Aug/1995:00:00:08 -0400] "GET /images/ksclogo-medium.gif HT
1.0" 304 0
uplherc.upl.com - - [01/Aug/1995:00:00:08 -0400] "GET /images/MOSAIC-logosmall.gif
HTTP/1.0" 304 0
uplherc.upl.com - - [01/Aug/1995:00:00:08 -0400] "GET /images/USA-logosmall.gif HT
1.0" 304 0
ix-esc-ca2-07.ix.netcom.com - - [01/Aug/1995:00:00:09 -0400] "GET /images/launch-
logo.gif HTTP/1.0" 200 1713
uplherc.upl.com - - [01/Aug/1995:00:00:10 -0400] "GET /images/WORLD-logosmall.gif H
1.0" 304 0
slppp6.intermind.net - - [01/Aug/1995:00:00:10 -0400] "GET /history/skylab/skylab.h
HTTP/1.0" 200 1687
piweba4y.prodigy.com - - [01/Aug/1995:00:00:10 -0400] "GET /images/launchmedium.gif
HTTP/1.0" 200 11853
tampico.usc.edu - - [14/Aug/1995:22:57:13 -0400] "GET /welcome.html HTTP/1.0" 200
```

Where Does Big Data Come From?

Internet of Things: RFID tags

California FasTrak Electronic Toll Collection transponder
Used to pay tolls
Collected data also
used for traffic reporting
» http://www.511.org/

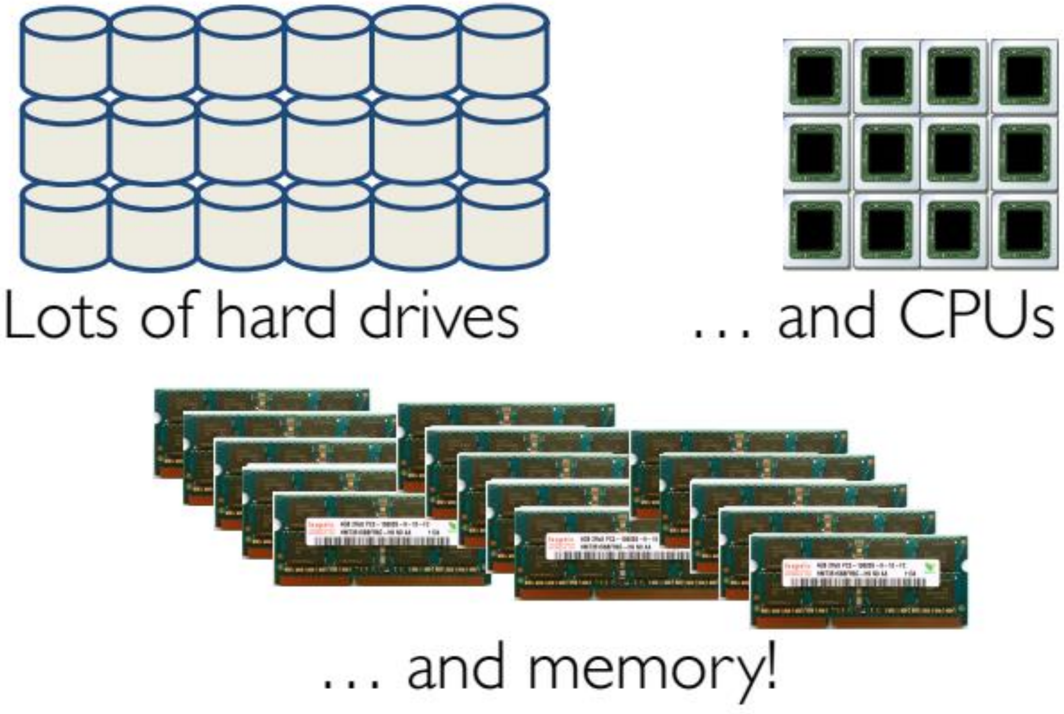
The Big Data Problem

Data growing faster than computation speeds
Growing data sources
» Web, mobile, scientific, …
Storage getting cheaper
» Size doubling every 18 months
But, stalling CPU speeds and storage bottlenecks

Big Data Examples
Facebook's daily logs: 60 TB
1,000 genomes project: 200 TB
Google web index: 10+ PB
Cost of 1 TB of disk: ~$35
Time to read 1 TB from disk: 3 hours (100 MB/s)

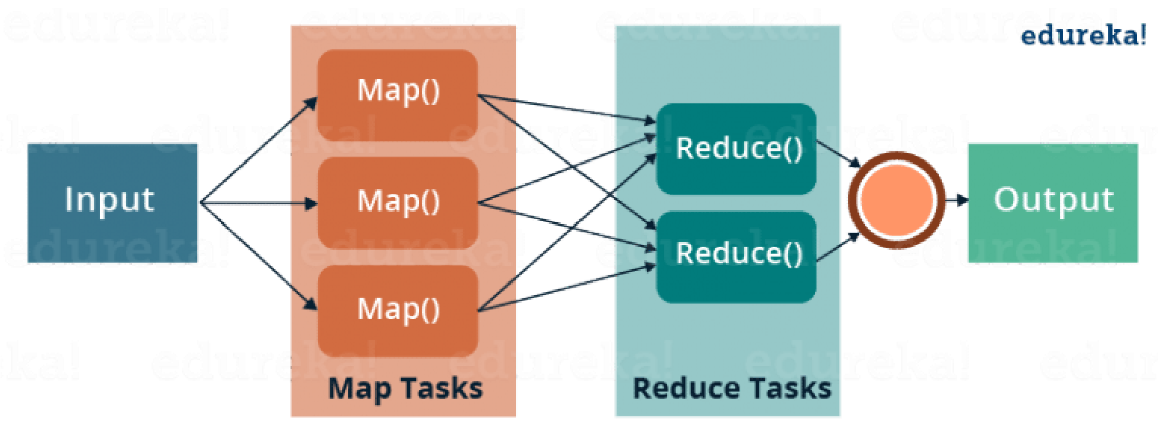
The Big Data Problem

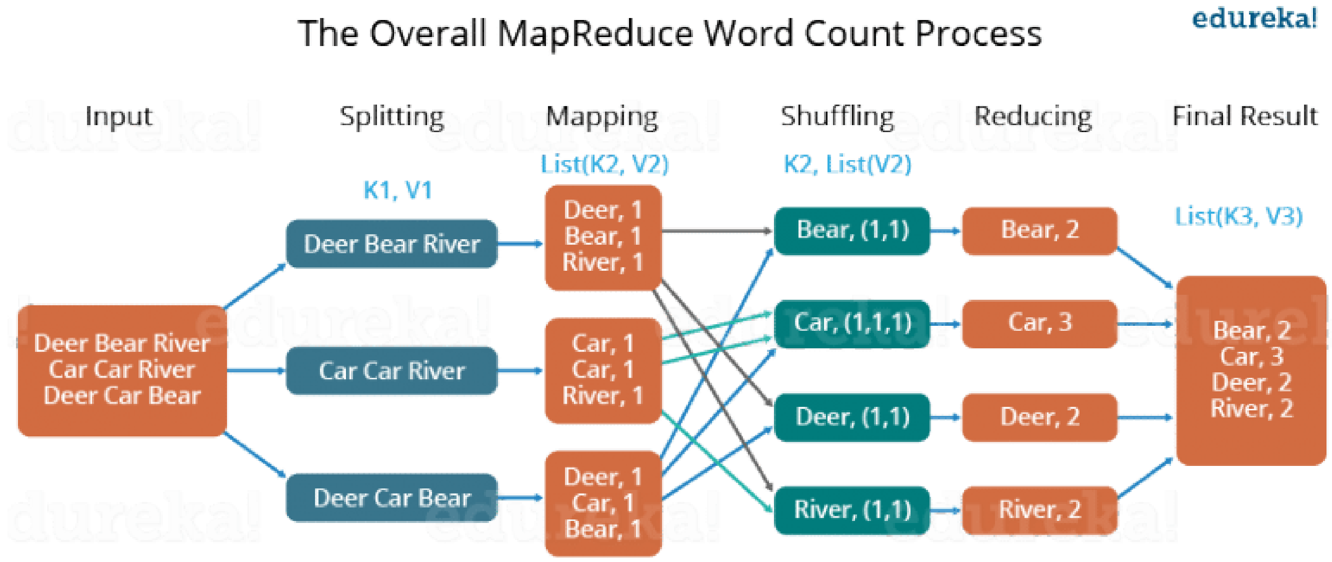
One machine can not process or even store all the data!
Solution is to distribute data over cluster of machines



MapReduce

MapReduce is a programming framework that allows us to perform distributed and parallel processing on large data sets in a distributed environment.





Motivation

Most current cluster programming models are based on *acyclic data flow* from stable storage to stable storage

Benefits of data flow: runtime can decide where to run tasks and can automatically recover from failures

Acyclic data flow is inefficient for applications that repeatedly reuse a *working set* of data:
Iterative algorithms (machine learning, graphs)
Interactive data mining tools (R, Excel, Python)
With current frameworks, apps reload data from stable storage on each query

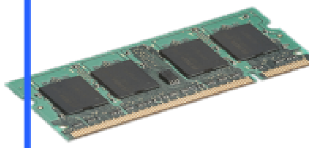
Spark DataFrames

Big Data

Word	Index	Count
I	0	1
am	2	1
Sam	5	1
I	9	1
am	11	1
Sam	14	1

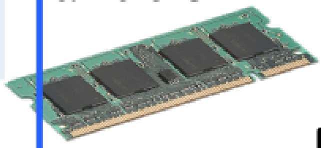
I	0	1
am	2	1

Partition 1



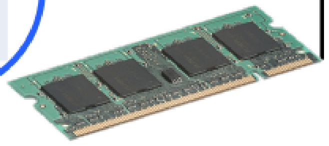
Sam	5	1
I	9	1

Partition 2



am	11	1
Sam	14	1

Partition 3



DataFrame

Spark - Fast, Interactive, Language-Integrated Cluster Computing

Solution: Resilient Distributed Datasets (RDDs)

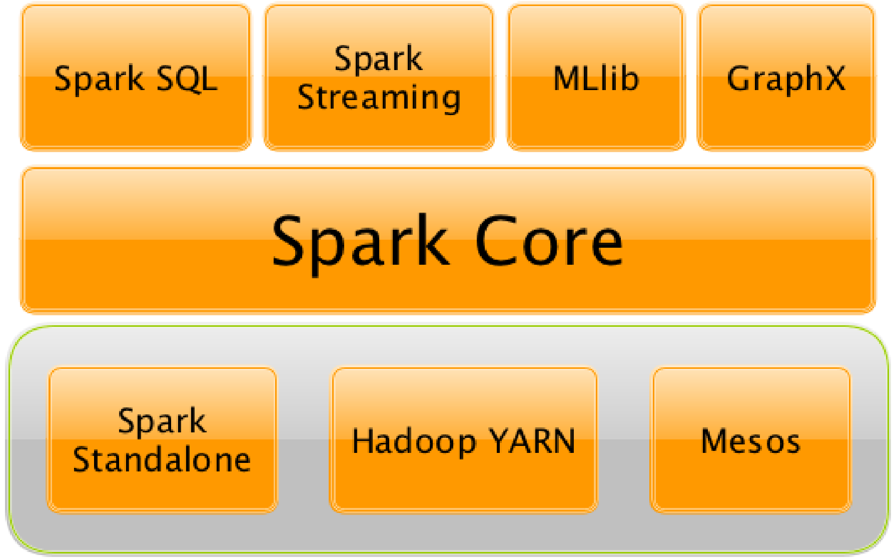
Spark is often called cluster computing engine or simply execution engine. You could also describe Spark as a distributed, data processing engine for batch and streaming modes featuring SQL queries, graph processing, and machine learning.

Allow apps to keep working sets in memory for efficient reuse

Retain the attractive properties of MapReduce

•Fault tolerance, data locality, scalability

Support a wide range of applications

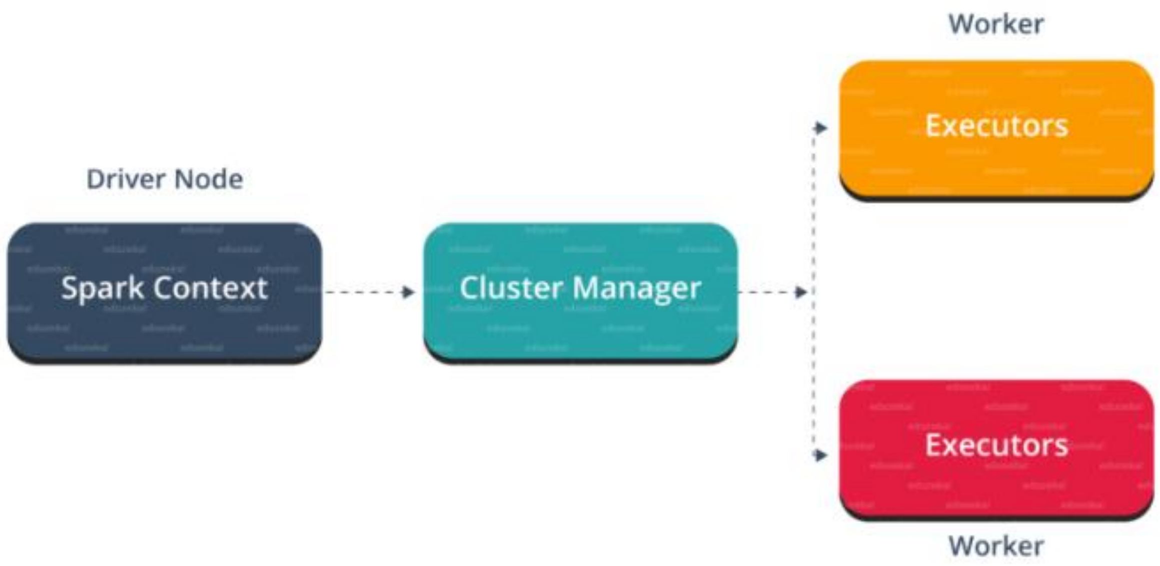


Spark Architecture Overview

Spark Architecture Overview
Apache Spark has a well-defined layered architecture where all the spark components and layers are loosely coupled. This architecture is further integrated with various extensions and libraries. Apache Spark Architecture is based on two main abstractions:

•Resilient Distributed Dataset (RDI

•Directed Acyclic Graph (DAG)



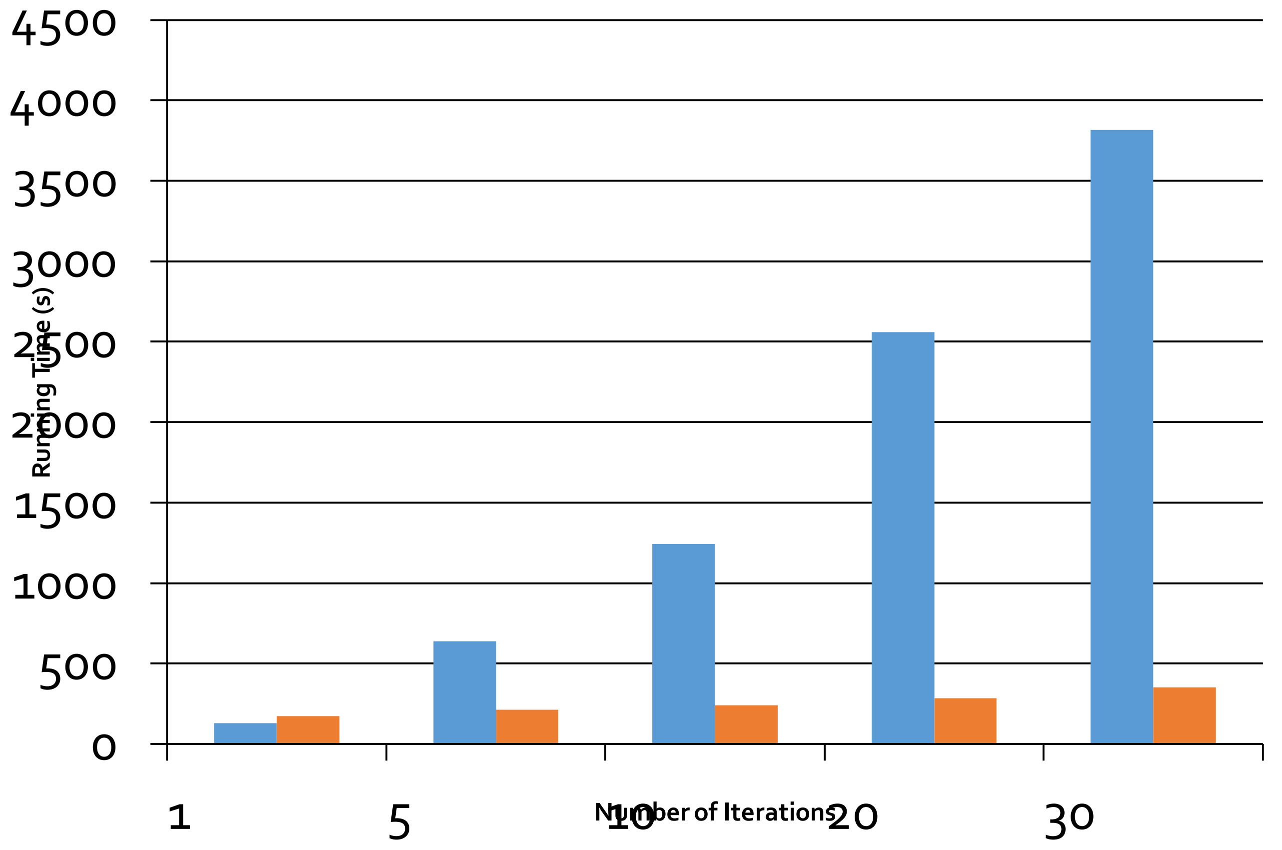
Spark - Fast, Interactive, Language-Integrated Cluster Computing

In contrast to Hadoop's two-stage disk-based MapReduce computation engine, Spark's multi-stage (mostly) in-memory computing engine allows for running most computations in memory, and hence most of the time provides better performance for certain applications, e.g. iterative algorithms or interactive data mining (read Spark officially sets a new record in large-scale sorting).

Spark aims at speed, ease of use, extensibility and interactive analytics.

Spark is a distributed platform for executing complex multi-stage applications, like machine learning algorithms, and interactive ad hoc queries. Spark provides an efficient abstraction for in-memory cluster computing called Resilient Distributed Dataset.

Logistic Regression Performance



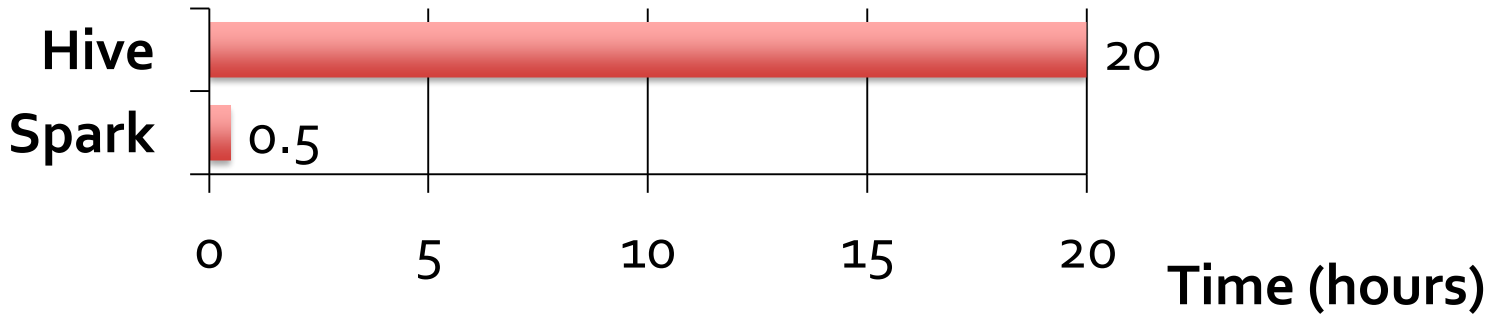
127 s / iteration

first iteration 174 s
further iterations 6 s

Spark Applications

- In-memory data mining on Hive data (Conviva)
- Predictive analytics (Quantifind)
- City traffic prediction (Mobile Millennium)
- Twitter spam classification (Monarch)
- Collaborative filtering via matrix factorization

Conviva GeoReport



Aggregations on many keys w/ same WHERE clause

40 × gain comes from:

- » Not re-reading unused columns or filtered records
- » Avoiding repeated decompression
- » In-memory storage of deserialized objects

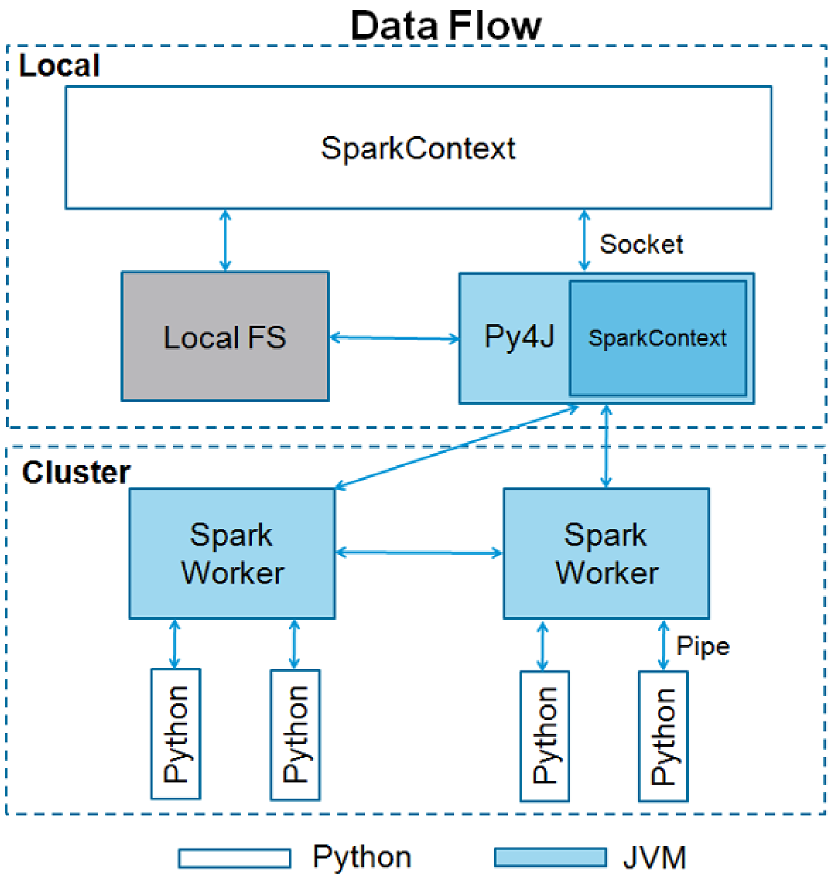
Python Spark (pySpark)

We are using the Python programming interface to Spark (pySpark)

pySpark provides an easy-to-use programming abstraction and parallel runtime:

» “Here’s an operation, run it on all of the data”

DataFrames are the key concep



Spark and SQL Contexts

A Spark program first creates a SparkContext object

» SparkContext tells Spark how and where to access a cluster

» pySpark shell, Databricks CE automatically create SparkContext

» iPython and programs must create a new SparkContext

The program next creates a sqlContext object

Use sqlContext to create DataFrames

SparkContext Example - Python Program

```
from pyspark import SparkContext
logFile = "file:///home/hadoop/spark-2.1.0-bin-hadoop2.7/README.md"
sc = SparkContext("local", "first app")
logData = sc.textFile(logFile).cache()
numAs = logData.filter(lambda s: 'a' in s).count()
numBs = logData.filter(lambda s: 'b' in s).count()
print "Lines with a: %i, lines with b: %i" % (numAs, numBs)
```

SparkContext Example - Python Program

Basically, this program just counts the number of lines in ‘a’ and ‘b’ in a text file. However, we need to replace $YOUR_SPARK_HOME with the Spark’s installation location.

```
from pyspark import SparkContext

logFile = "$YOUR_SPARK_HOME/README.md"  # Should be some file on your system

sc = SparkContext("local", "Simple App1")

logData = sc.textFile(logFile).cache()

numAs = logData.filter(lambda s: 'a' in s).count()

numBs = logData.filter(lambda s: 'b' in s).count()

print "Lines with a: %i, lines with b: %i" % (numAs, numBs)
```

Continue PySpark on github

https://github.com/andfanilo/pyspark-tutorial

https://github.com/PacktPublishing/Learning-PySpark

NoSQL Databases

- Scaling Up
- What (and why) are NoSQL databases
- Characteristics of NoSQL databases
- NoSQL database types

Scaling Up

- Issues with scaling up when the dataset is just too big
- RDBMS were not designed to be distributed
- Began to look at multi-node database solutions
- Known as ‘scaling out’ or ‘horizontal scaling’
- Different approaches include:
  - Master-slave
  - Sharding

Scaling RDBMS - Sharding

- Partition or sharding
  - Scales well for both reads and writes
  - Not transparent, application needs to be partition-aware
  - Can no longer have relationships/joins across partitions
  - Loss of referential integrity across shards

Other ways to scale RDBMS

- Multi-Master replication
- INSERT only, not UPDATES/DELETES
- No JOINs, thereby reducing query time
  - This involves de-normalizing data
- In-memory databases

What is NoSQL?

- Stands for **N**ot **O**nly **SQL**
- Class of non-relational data storage systems
- Usually do not require a fixed table schema nor do they use the concept of joins
- All NoSQL offerings relax one or more of the ACID properties (will talk about the CAP theorem)

Why NoSQL?

- For data storage, an RDBMS cannot be the be-all/end-all
- Just as there are different programming languages, need to have other data storage tools in the toolbox
- A NoSQL solution is more acceptable to a client now than even a year ago
  - Think about proposing a Ruby/Rails or Groovy/Grails solution now versus a couple of years ago

How did we get here?

- Explosion of social media sites (Facebook, Twitter) with large data needs
- Rise of cloud-based solutions such as Amazon S3 (simple storage solution)
- Just as moving to dynamically-typed languages (Ruby/Groovy), a shift to dynamically-typed data with frequent schema changes
- Open-source community

Dynamo and BigTable

- Three major papers were the seeds of the NoSQL movement

  - BigTable (Google)
  - Dynamo (Amazon)
    - Gossip protocol (discovery and error detection)
    - Distributed key-value data store
    - Eventual consistency
  - CAP Theorem (discuss in a sec ..)

The Perfect Storm

- Large datasets, acceptance of alternatives, and dynamically-typed data has come together in a perfect storm
- Not a backlash/rebellion against RDBMS
- SQL is a rich query language that cannot be rivaled by the current list of NoSQL offerings

CAP Theorem

- Three properties of a system: consistency, availability and partitions
- You can have at most two of these three properties for any shared-data system
- To scale out, you have to partition. That leaves either consistency or availability to choose from
- In almost all cases, you would choose availability over consistency

What kinds of NoSQL

- NoSQL solutions fall into two major areas:
  - Key/Value or ‘the big hash table’.
    - Amazon S3 (Dynamo)
    - Voldemort
    - Scalaris
  - Schema-less which comes in multiple flavors, column-based, document-based or graph-based.
    - Cassandra (column-based)
    - CouchDB (document-based)
    - Neo4J (graph-based)
    - HBase (column-based)

Key/Value

Pros:

- very fast
- very scalable
- simple model
- able to distribute horizontally

Cons:

- many data structures (objects) can't be easily modeled as key value pairs

Schema-Less

Pros:

- Schema-less data model is richer than key/value pairs
- eventual consistency
- many are distributed
- still provide excellent performance and scalability

Cons:

- typically no ACID transactions or joins

Characteristics of NoSQL Databases

- Cheap, easy to implement (open source)
- Data are replicated to multiple nodes (therefore identical and fault-tolerant) and can be partitioned
    - Down nodes easily replaced
    - No single point of failure
- Easy to distribute
- Don't require a schema
- Can scale up and down
- Relax the data consistency requirement (

Characteristics of NoSQL Databases – cont'd

Disadvantages

- many don't support true ACID transactions
  - application code is obliged to try to manage concurrency issues
- easy to modify schemas
  - application developers need to collaborate closely to ensure schema development is under control
- much slower than RDBMS
- lack powerful management & development features of RDBMS

Use Cases

- simple data requirements
- application-specific data
- start-ups

What are we giving up?

- joins
- group by
- order by
- ACID transactions
- SQL as a sometimes frustrating but still powerful query language
- easy integration with other applications that support SQL

Cassandra

- Originally developed at Facebook
- Follows the BigTable data model: column-oriented
- Uses the Dynamo Eventual Consistency model
- Written in Java
- Open-sourced and exists within the Apache family
- Uses Apache Thrift as it’s API

Thrift

- Created at Facebook along with Cassandra
- Is a cross-language, service-generation framework
- Binary Protocol (like Google Protocol Buffers)
- Compiles to: C++, Java, PHP, Ruby, Erlang, Perl, ...

Searching

- Relational
  - SELECT `column` FROM `database`,`table` WHERE `id` = key;
  - SELECT product_name FROM rockets WHERE id = 123;
- Cassandra (standard)
  - keyspace.getSlice(key, “column_family”, "column")
  - keyspace.getSlice(123, **new** ColumnParent(“rockets”), *getSlicePredicate*());

Typical NoSQL API

- Basic API access:
  - get(key) -- Extract the value given a key
  - put(key, value) -- Create or update the value given its key
  - delete(key) -- Remove the key and its associated value
  - execute(key, operation, parameters) -- Invoke an operation to the value (given its key) which is a special data structure (e.g. List, Set, Map .... etc).

NoSQL Databases Types

- wide column store
  - Hadoop / **HBase**, MapR, BigTable, Hortonworks, Cloudera, Cassandra, Informix
- document store
  - MongoDB, CouchDB, Azure DocumentDB
- key value / tuple store
  - DynamoDB, Azure Table Storage, Oracle NoSQL
- graph databases
  - Neo4j
- multi-model databases
  - ArangoDB, OrientDB
- object databases
  - Versant, Objectivity VelocityDB

NoSQL Databases – cont'd

- Document databases
  - MongoDB

Document Databases

- semi-structured data
- records do not all need to have the same fields

XML:

a record is a block of XML tags and values

```
<contact>
  <firstname>Bob</firstname>
  <address>5 Oak St.</lastname>
  <hobby>saling</hobby>
</contact>
```

JSON:

a record is a list of key:value pairs

```
{
    "FirstName": "Bob",
    "Address": "5 Oak St.",
    "Hobby": "sailing"
}
```

MongoDB

- an **open-source** document database
  - no charge for *Community Server* version
- high performance
  - **embedded data models** reduce I/O activity
  - indexes
    - can include keys from embedded documents, arrays
- high availability
  - replication facility
    - automatic fail-over
    - data redundancy
- automatic scalability (horizontal)

MongoDB

- CRUD √
  - create, read, update, delete
- ACID ?
  - traditionally:
    - document databases are only ACID-compliant only at document level
    - no *transactions* for containing multiple I/O operations
    - application code is obliged to emulate transactions, if required
    - latency results in an **eventual consistency** model
  - MongoDB 4.0
    - introduced transactions

MongoDB: High-Level Objects

***Document*:**
- a set of field:value pairs
  - values can be hierarchical
- analogous to RDB row

examples:

{ name: “sue”, age: 26, status: “A”, groups: [“news”, “sports”] }

{ name: “fred”, status: “A”, groups: [“sports”, “hobbies”, “cars”] }

{ name: { first: “fred”, last: “bloggs” }, status: “A”, groups: [“sports”, “hobbies”, “cars”] }

***Collection*:**
- a logical group of documents
- analogous to RDB table

MongoDB with Python

example:

```
import pymongo
connection =
pymongo.MongoClient("mongodb://localhost")
db = connection.school
students = db.students
cursor = students.find()

# find minimum homework score...
for doc in cursor:
    scores = doc["scores"]
    minhs = 101
    for entry in scores:
        if entry["type"] == "homework":
            if entry["score"] < minhs:
                minhs = entry["score"]
```

- create mongod client
- connect to database ‘school’
- create alias for table ‘students’
- fetch all rows into cursor

- loop through docs in cursor
- get value (doc) associated with key ‘scores’
- initialise min to impossibly large value (> 100%)
- loop through ‘scores’ docs, looking for ‘homework’ keys
- test each corresponding score to find new minimum

Lab 2.1.4: Python with MongoDB (Optional homework)

- Purpose:
  - To develop skills in NoSQL database programming with MongoDB
- Materials:
  - ‘Lab 2.1.4.ipynb’

NoSQL Databases – cont’d

- Graph Databases
  - Neo4j

Graph Databases

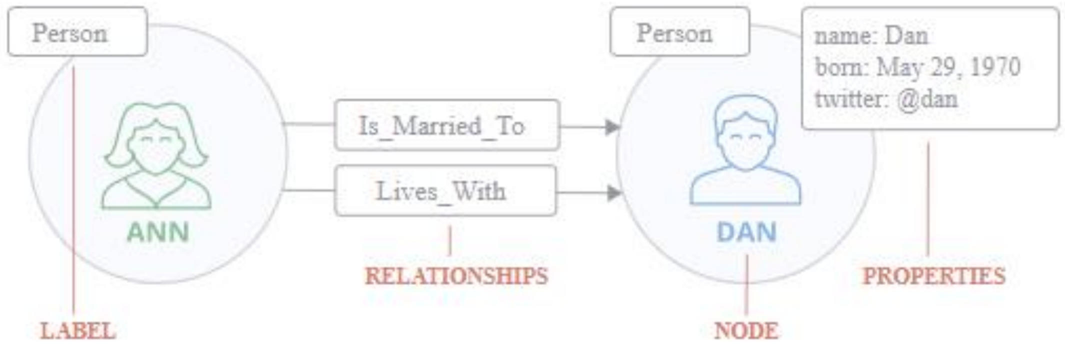
- model members and relationships as a network
- high-level objects:
  - nodes
    - entities (e.g. people, accounts, organisations)
  - edges
    - connections between nodes
  - properties
    - node: differentiates types of nodes
      - roles, classifications, etc.
    - edge: describes the relationship
      - 2-way, 1-way, directionless
      - friend, follower, commenter, etc.

Neo4j

- open source
  - no charge for *Community Server* edition
- ACID-compliant, transactional database with native graph storage & processing
- online backup
- high availability
- most popular graph database

Neo4j: Basics

The Labeled Property Graph Model



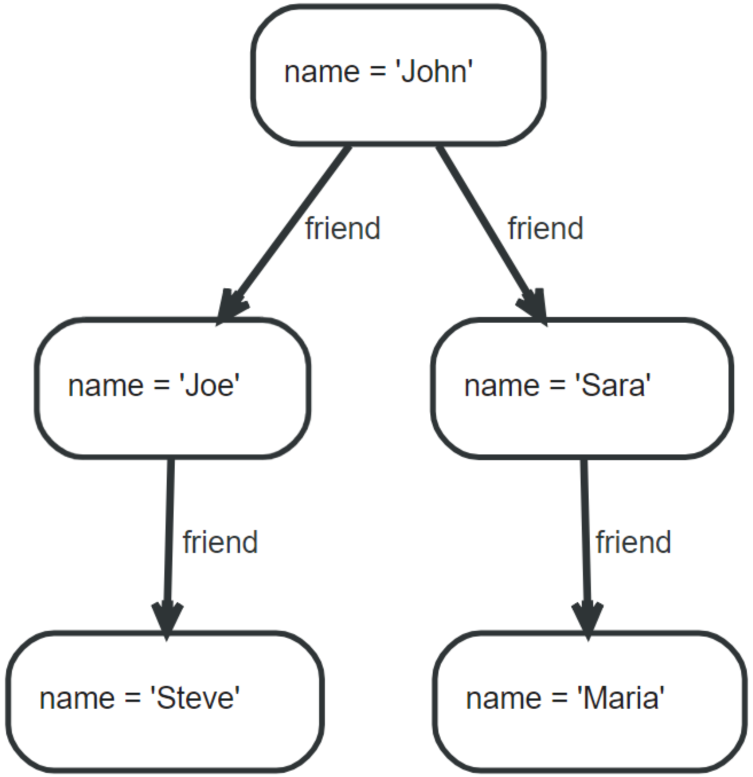
Nodes

- Nodes are the main data elements
- Nodes are connected to other nodes via **relationships**
- Nodes can have one or more **properties** (i.e., attributes stored as key/value pairs)
- Nodes have one or more **labels** that describes its role in the graph

Relationships

- Relationships connect two nodes
- Relationships are directional
- **Nodes** can have multiple, even recursive relationships
- Relationships can have one or more **properties** (i.e., attributes stored as key/value pairs)

Cypher Query Language



- example: find friends of friends of John

```
    MATCH (john {name: 'John'})-[:friend]->
()-[:friend]->(fof)
    RETURN john.name, fof.name
```

output:

```
+----------------------+
| john.name | fof.name |
+----------------------+
| "John"    | "Maria"  |
| "John"    | "Steve"  |
+----------------------+
```

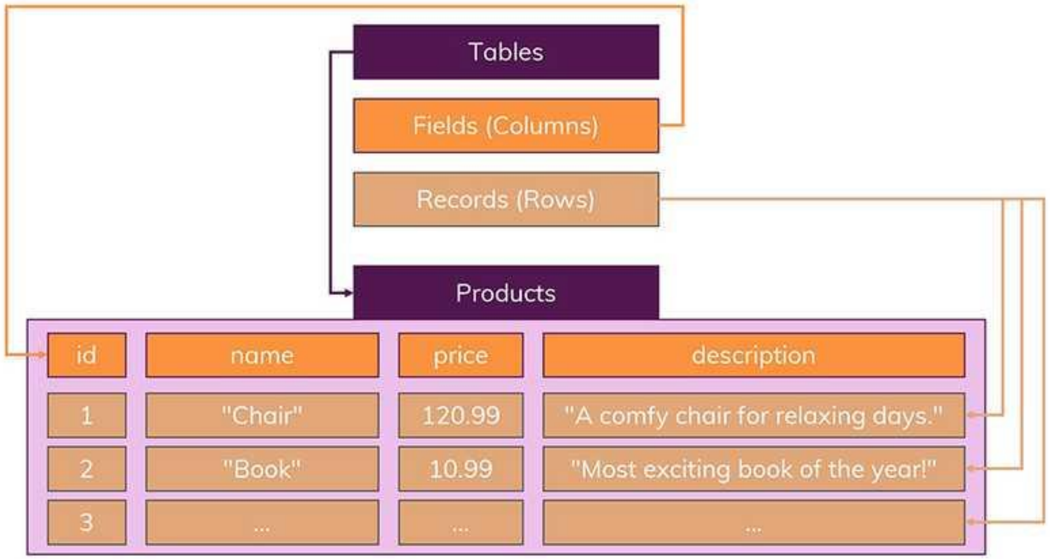
Lab 2.1.5: Neo4j and Python (Optional homework)

- Purpose:
  - To develop familiarity with graph database programming (Neo4j) using:
    - the Neo4j GUI
    - a Python library for Neo4j
- Resources:
  - Neo4j built-in tutorials
  - Cypher cheatsheet
    - https://neo4j.com/docs/cypher-refcard/3.2/
- Materials:
  - ‘Lab 2.1.5.ipynb’

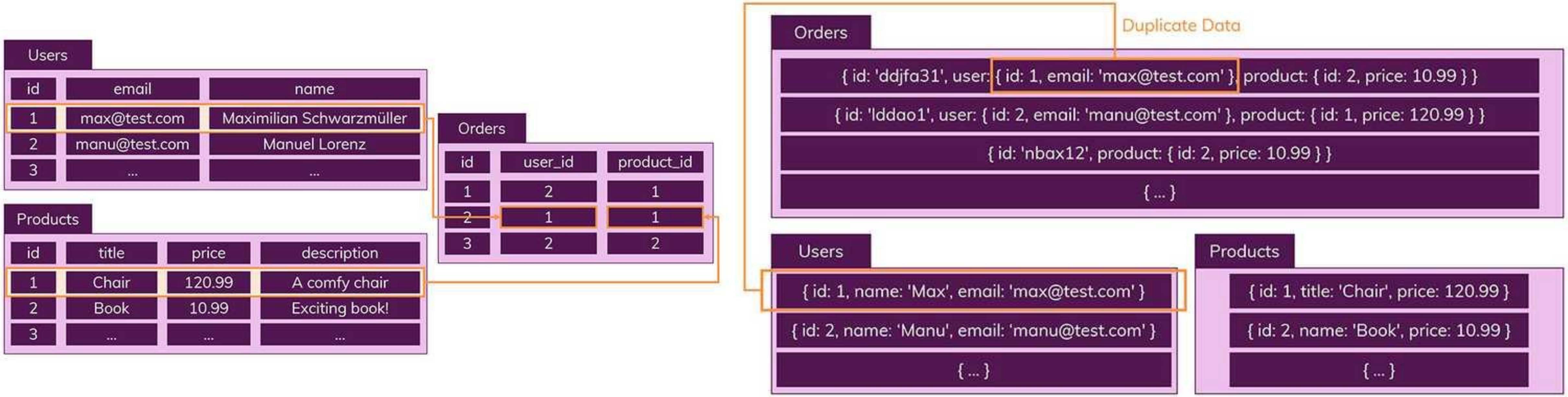
Discussion: SQL vs NoSQL

SQL	NoSQL
Traditional rows and columns governed data model	No predefined data structure database at mercy of developers
Strict structure (incl. primary keys) schema changes difficult, risky	Ideal for unstructured data schema can change with application requirements
Entire column for each feature	Cheaper hardware
Industry standard	Supports design flexibility & growth popular among startups
ACID	Application code must manage transactions

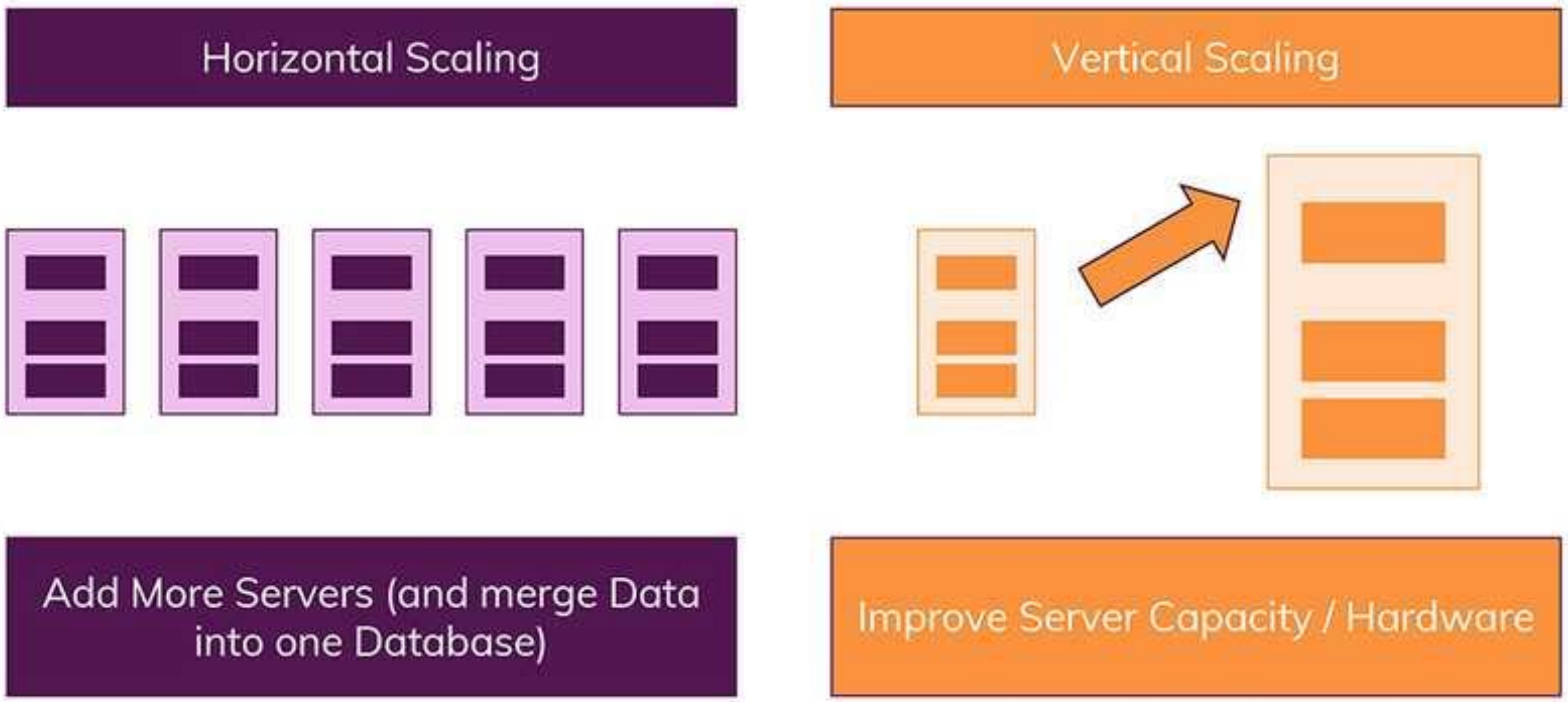
Discussion: SQL vs NoSQL



Discussion: SQL vs NoSQL



Discussion: SQL vs NoSQL



Discussion: NoSQL with SQL ?!

- Why has SQL infiltrated the NoSQL paradigm?

Questions?

Appendices

Relational Databases – Normalisation

Codd's 1st-normal form

- the domain of each attribute contains only atomic (indivisible) values
- the value of each attribute contains only a single value from that domain

Customer

Customer ID	First Name	Surname	Telephone Number
123	Pooja	Singh	555-861-2025, 192-122-1111
456	San	Zhang	(555) 403-1659 Ext. 53; 182-929-2929
789	John	Doe	555-808-9633

Customer

Customer ID	First Name	Surname	Telephone Number
123	Pooja	Singh	555-861-2025
123	Pooja	Singh	192-122-1111
456	San	Zhang	182-929-2929
456	San	Zhang	(555) 403-1659 Ext. 53
789	John	Doe	555-808-9633

Relational Databases – – Normalisation - cont'd

Codd's 2nd-normal form

- in 1st-normal form
- no non-prime attribute is dependent on any proper subset of any candidate key of the relation
  (an attribute that is not a part of any candidate key of the relation)

Electric Toothbrush Models

Manufacturer	Model	Model Full Name	Manufacturer Country
Forte	X-Prime	Forte X-Prime	Italy
Forte	Ultraclean	Forte Ultraclean	Italy
Dent-o-Fresh	EZbrush	Dent-o-Fresh EZbrush	USA
Kobayashi	ST-60	Kobayashi ST-60	Japan
Hoch	Toothmaster	Hoch Toothmaster	Germany
Hoch	X-Prime	Hoch X-Prime	Germany

Electric Toothbrush Manufacturers

Manufacturer	Manufacturer Country
Forte	Italy
Dent-o-Fresh	USA
Kobayashi	Japan
Hoch	Germany

Electric Toothbrush Models

Manufacturer	Model	Model Full Name
Forte	X-Prime	Forte X-Prime
Forte	Ultraclean	Forte Ultraclean
Dent-o-Fresh	EZbrush	Dent-o-Fresh EZbrush
Kobayashi	ST-60	Kobayashi ST-60
Hoch	Toothmaster	Hoch Toothmaster
Hoch	X-Prime	Hoch X-Prime

Relational Databases – – Normalisation - cont'd

Codd's 3rd-normal form

- in 2nd-normal form
- every non-prime attribute (of a table) is non-transitively dependent on every key (of a table)

Tournament Winners

Tournament	Year	Winner	Winner Date of Birth
Indiana Invitational	1998	Al Fredrickson	21 July 1975
Cleveland Open	1999	Bob Albertson	28 September 1968
Des Moines Masters	1999	Al Fredrickson	21 July 1975
Indiana Invitational	1999	Chip Masterson	14 March 1977

Tournament Winners

Tournament	Year	Winner
Indiana Invitational	1998	Al Fredrickson
Cleveland Open	1999	Bob Albertson
Des Moines Masters	1999	Al Fredrickson
Indiana Invitational	1999	Chip Masterson

Winner Dates of Birth

Winner	Date of Birth
Chip Masterson	14 March 1977
Al Fredrickson	21 July 1975
Bob Albertson	28 September 1968

Which RDBMS Object to Use When

- queries
  - **ad hoc** queries
  - **stored** or **generated** in application code
- views
  - stored (**reusable**) queries
  - can incorporate **joins** with other views
  - **preferable** to queries in application code
- stored procedures
  - **more powerful than views** (can query and/or modify data)
  - preferred for delivering data to applications (**security, control, maintainability**)
- reports
  - **formatted output** containers based on tables, views
  - text & graphics
  - usually provided via a separate application (designed for but existing outside the RDBMS)
  - may have built-in subscription service

End of presentation