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

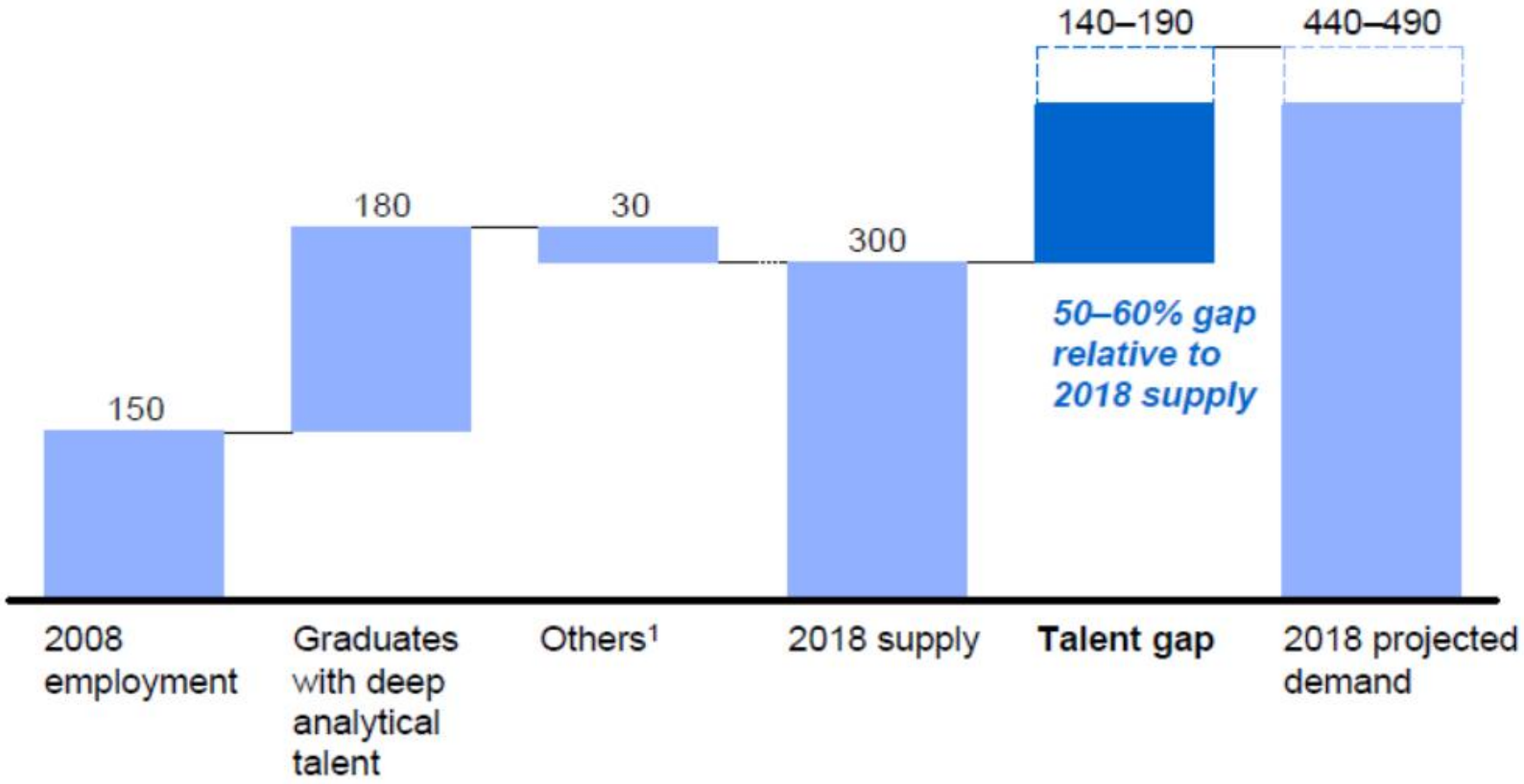
- How is a database used?
  - data **insertion** & **retrieval** are (typically) performed using a **query language**
    - a compact programming syntax
    - basic operators for data transformation

- 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

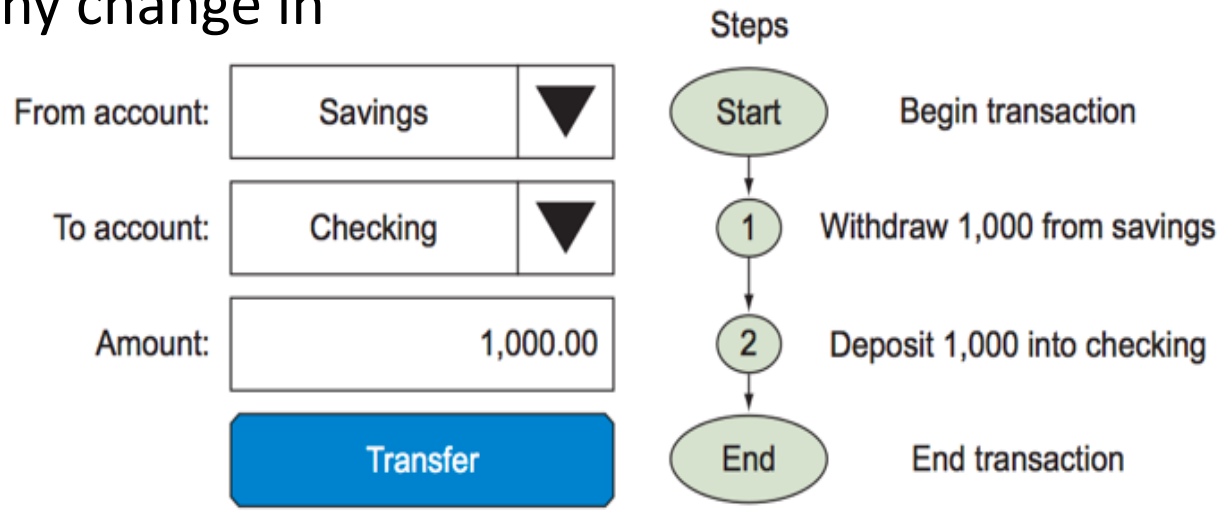
Database Elements

- 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**



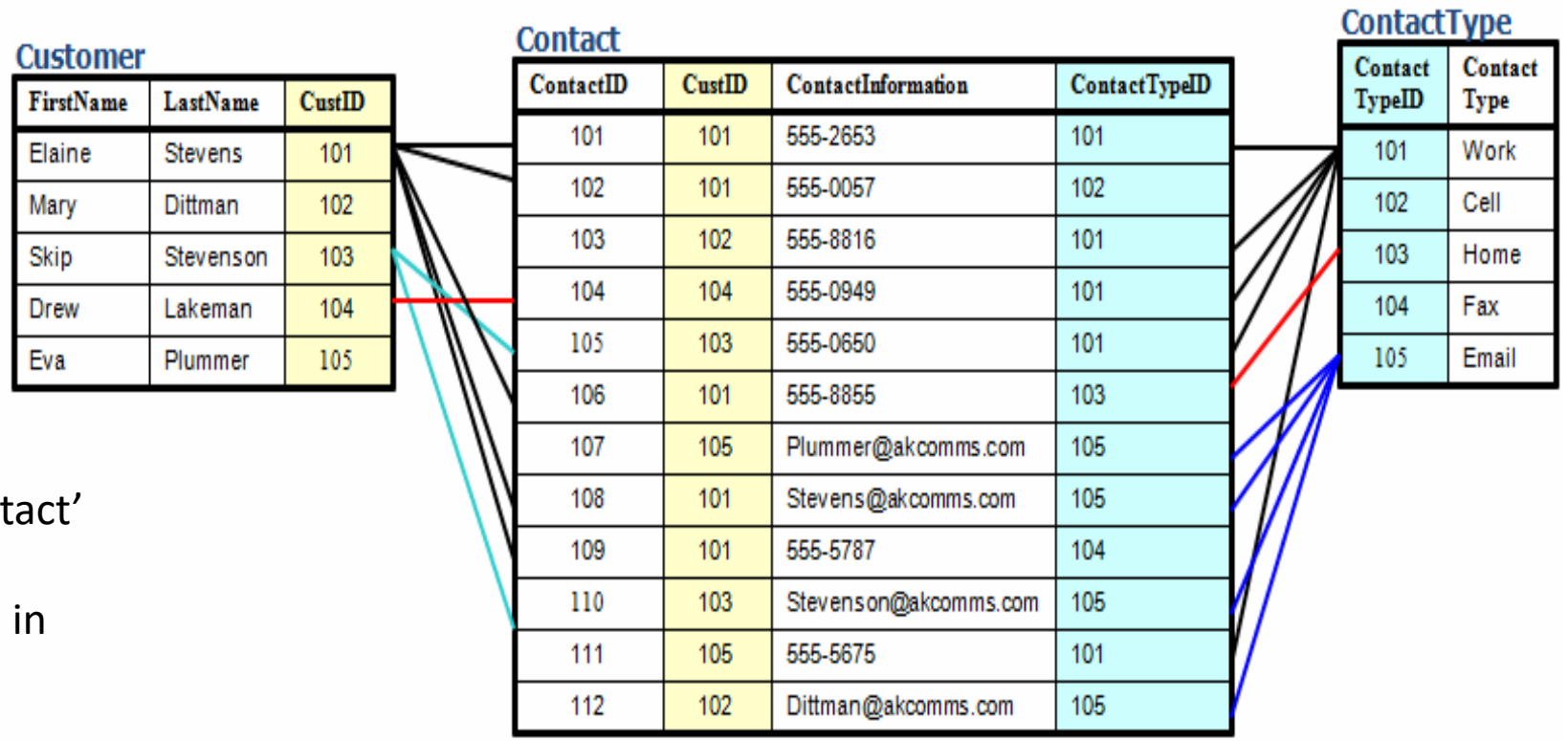
Database Principles: ACID

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

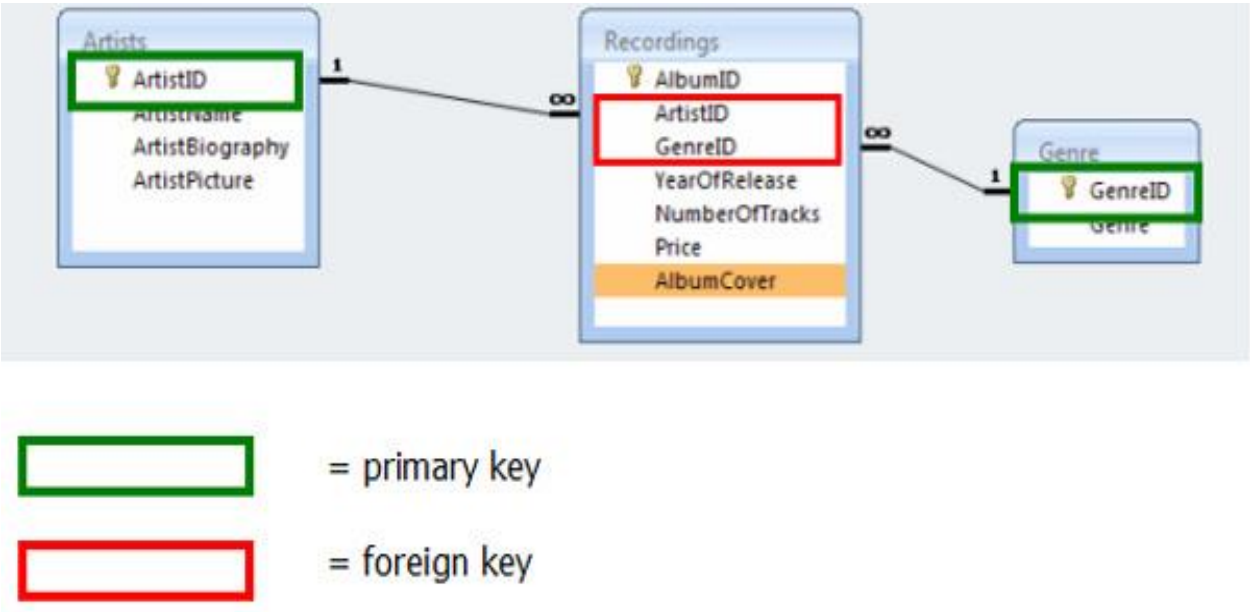
ContactType

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.

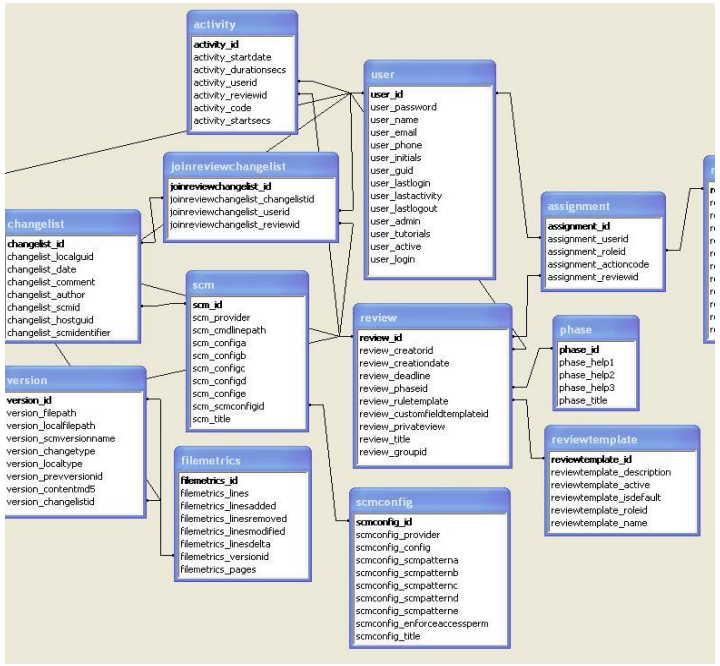
In principle you could have an RDBMS that uses some other language for access, and in principle you could use SQL to interact with some other kind of database system, though in practice the two are closely coupled.

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



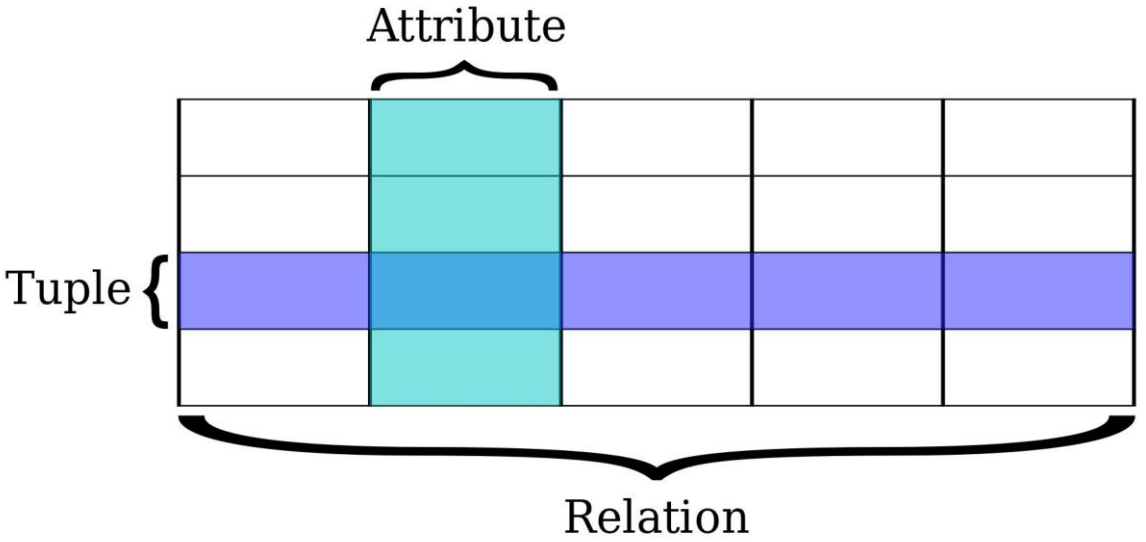
Relation Variables

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/***

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.

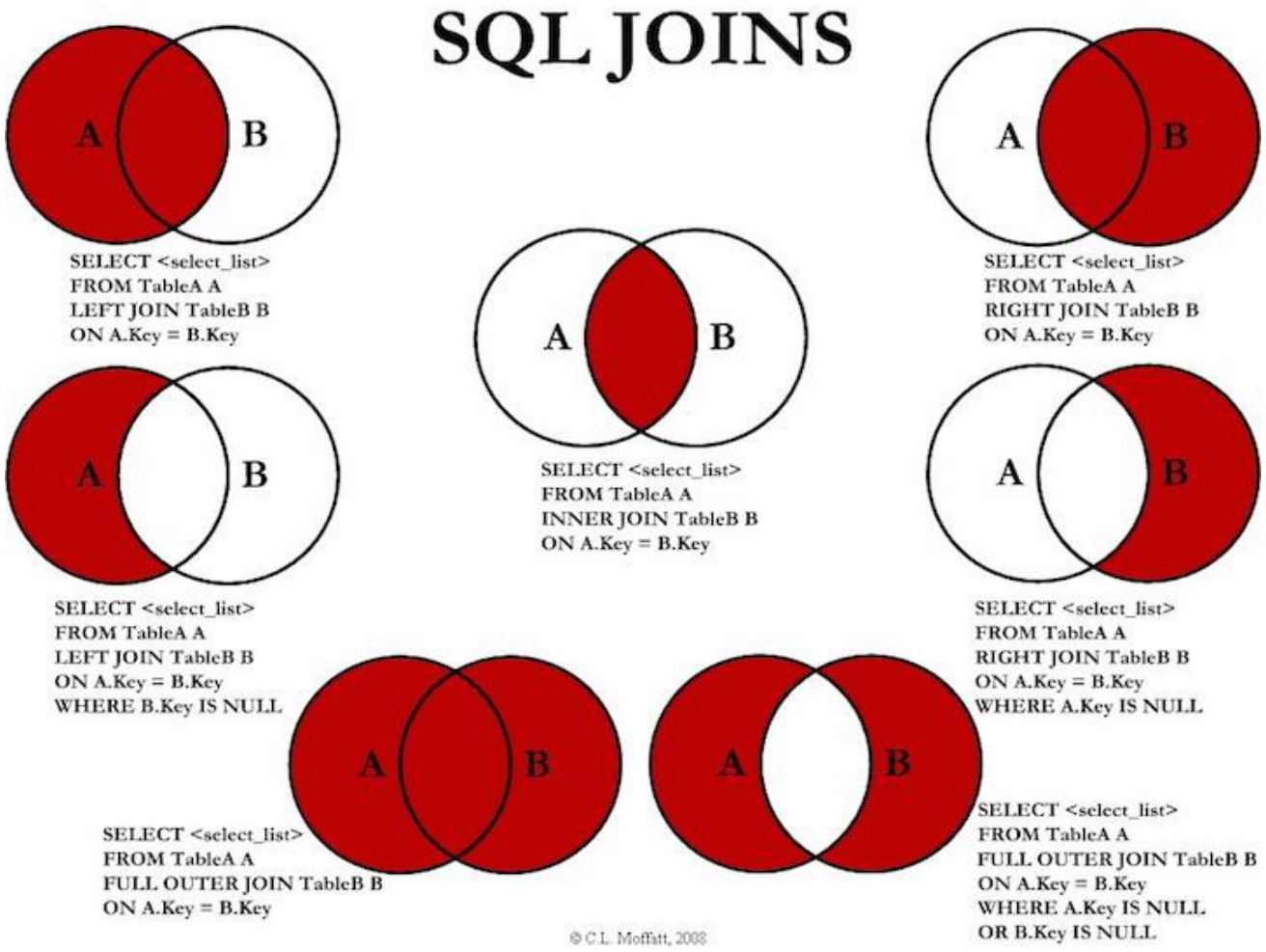
SQL DROP TABLE Example
The following SQL statement drops the existing table "Shippers":
Example
```
DROP TABLE Shippers;
```

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

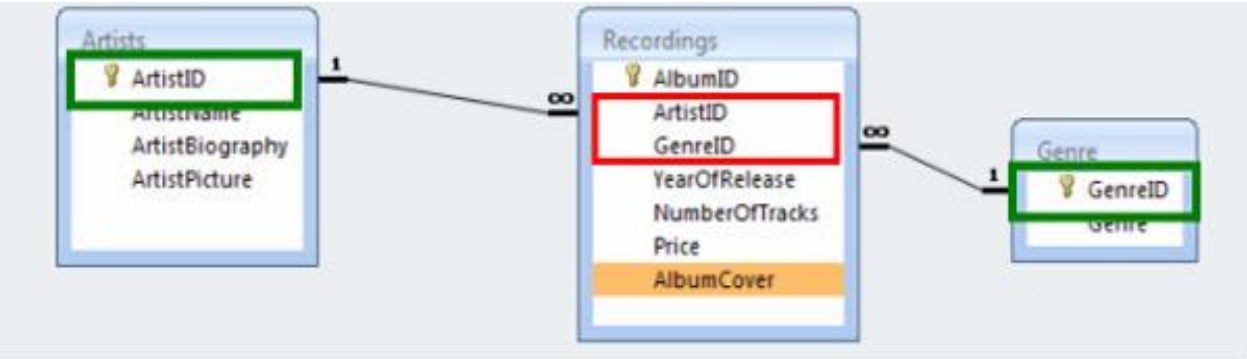
- Nb. simple joins are generally quite fast, but **compound joins** (involving many tables) can be very slow
- a database join is analogous to a set operation in mathematics

Joins



Joins – cont'd

- Compound inner join example



= primary key

= foreign key

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

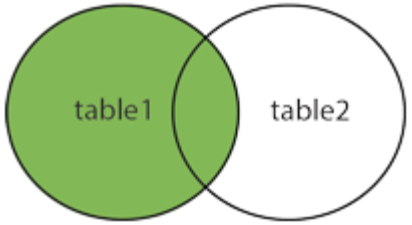
Left Join

- 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

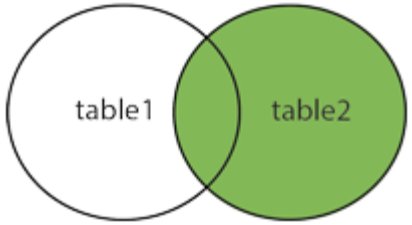


Right Join

- 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



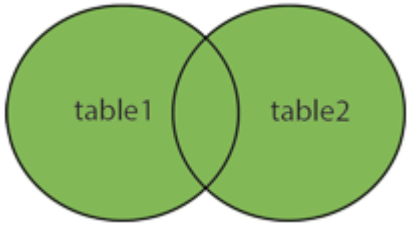
Joins – cont'd

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?

How to access databases using Python

```
#!/usr/bin/python

import MySQLdb

# Open database connection
db = MySQLdb.connect("localhost","testuser","test123","TESTDB" )

# prepare a cursor object using cursor() method
cursor = db.cursor()

# execute SQL query using execute() method.
cursor.execute("SELECT VERSION()")

# Fetch a single row using fetchone() method.
data = cursor.fetchone()
print "Database version : %s " % data

# disconnect from server
db.close()
```

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()
```

Reading and Modifying the table

- INSERT Operation
- READ Operation
- Update Operation
- DELETE Operation

https://www.tutorialspoint.com/python/python_database_access.htm

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/

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
```

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*

NoSQL Databases

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

What and Why are NoSQL Databases

What

- non-tabular
- non-relational

Why

- scalable
- flexible
- simple

- storage and retrieval of data that is modelled by means other than tabular relations
- not a new idea (1960+)
- supports **distributed** storage and processing
- term ‘NoSQL’ popularised by Facebook, Amazon, Google, etc.

Characteristics of NoSQL Databases

Advantages

- avoid administration & expense of RDBMS
- small footprint
- easy to modify schemas

Use Cases

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

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

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

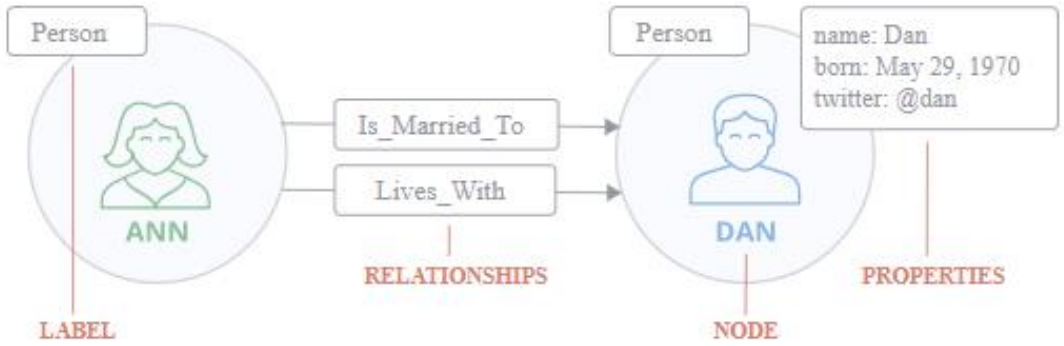
- model members and relationships as a network
- high-level objects:
  - nodes
    - entities (e.g. people, accounts, organisations)
  - edges
    - connections between nodes
  - properties
    - node: differentiates types of nodes
      - roles, classifications, etc.
    - edge: describes the relationship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



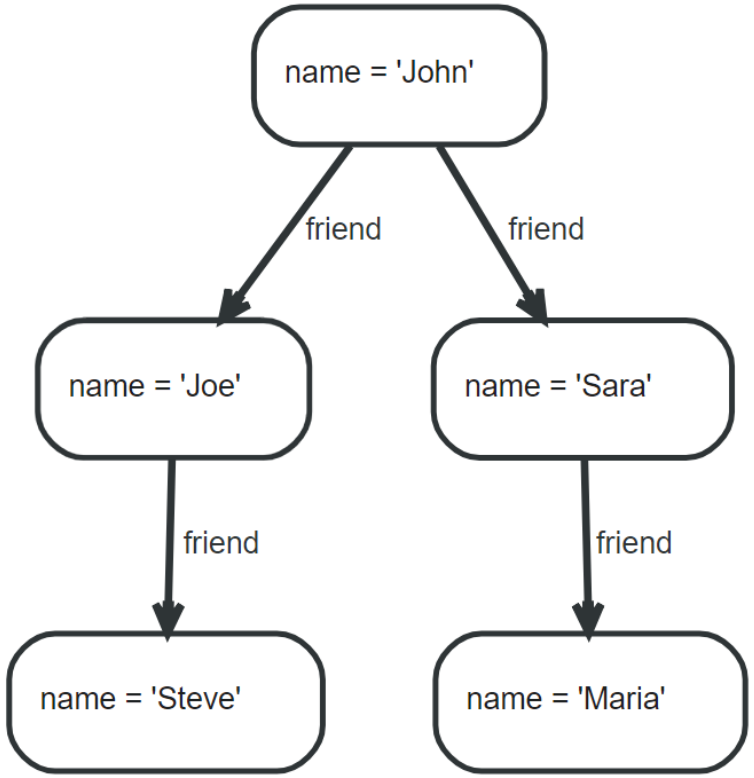
Nodes

- 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: NoSQL with SQL ?!

- Why has SQL infiltrated the NoSQL paradigm?

Questions?

Appendices

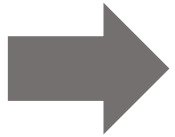
Relational Databases – Normalisation

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

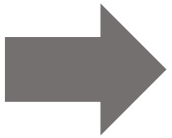
Relational Databases – – Normalisation - cont'd

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

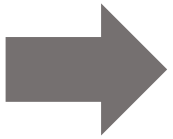
Relational Databases – – Normalisation - cont'd

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