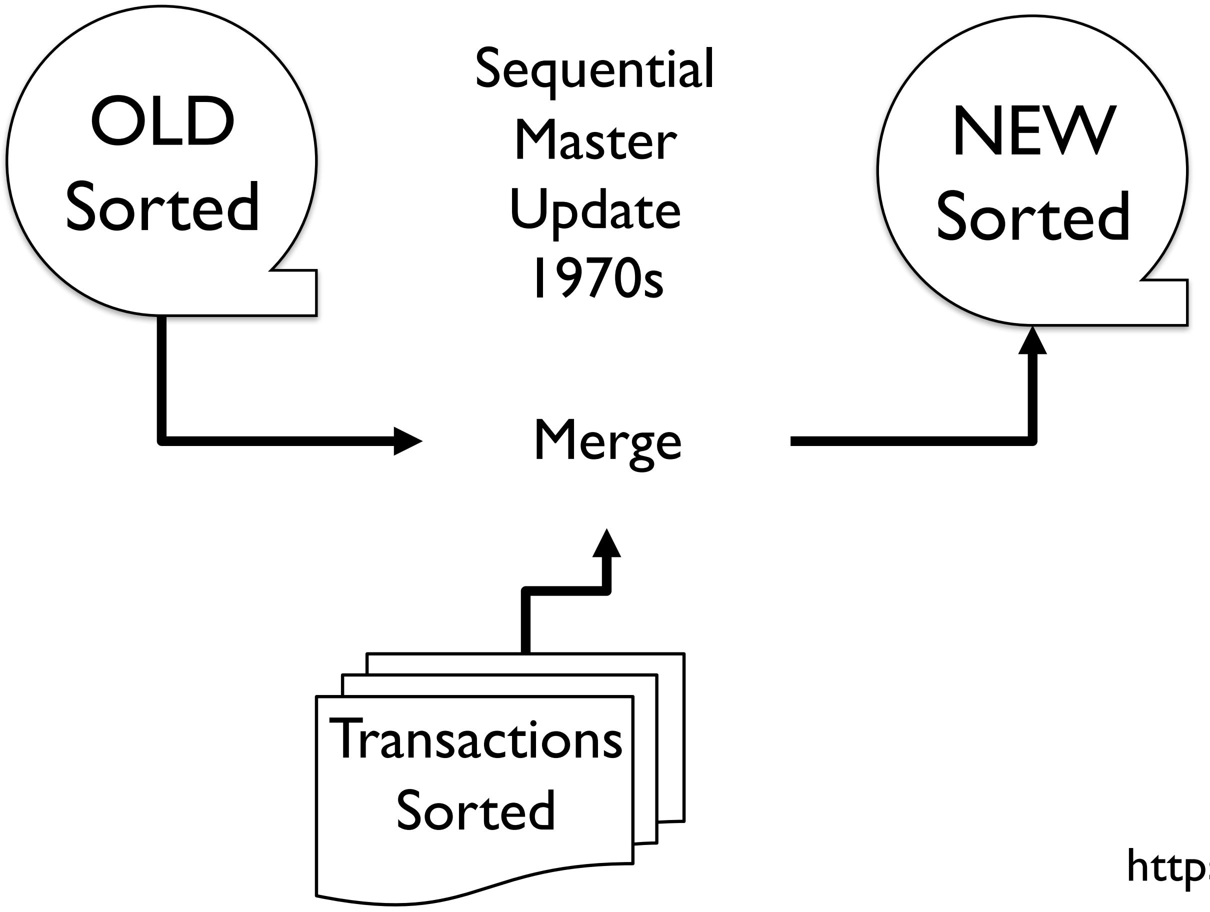
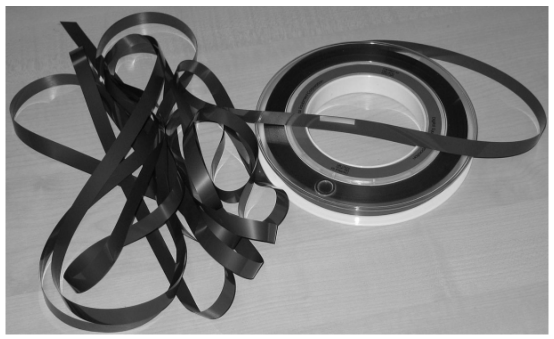
Relational Databases and PostgreSQL

Charles Severance
www.pg4e.com

Sequential Master Update 1970s





https://en.wikipedia.org/wiki/IBM_729

Random Access

- When you can randomly access data...
- How can you lay out data to be most efficient?
- Sorting might not be the best idea

https://en.wikipedia.org/wiki/Hard_disk_drive_platter

Relational Databases

Relational databases model data by storing rows and columns in tables. The power of the relational database lies in its ability to efficiently retrieve data from those tables - in particular, where the query involves multiple tables and the relationships between those tables.

http://en.wikipedia.org/wiki/Relational_database

<u>S</u>tructured <u>Q</u>uery <u>L</u>anguage

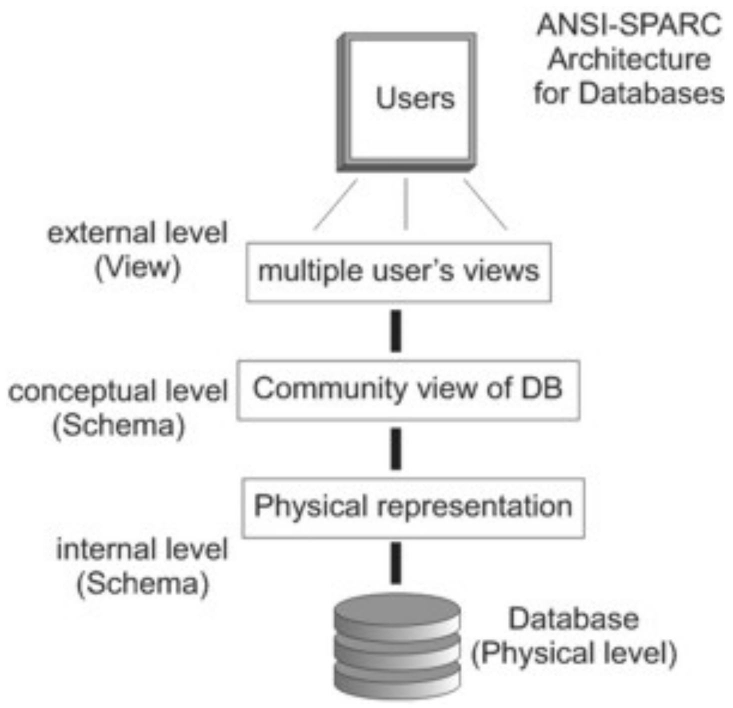
- Structured Query Language (SQL) came out of a government / industry partnership
- National Institute of Standards and Technology (NIST)

https://youtu.be/rLUm3vst87g

SQL

Structured Query Language is the language we use to issue commands to the database

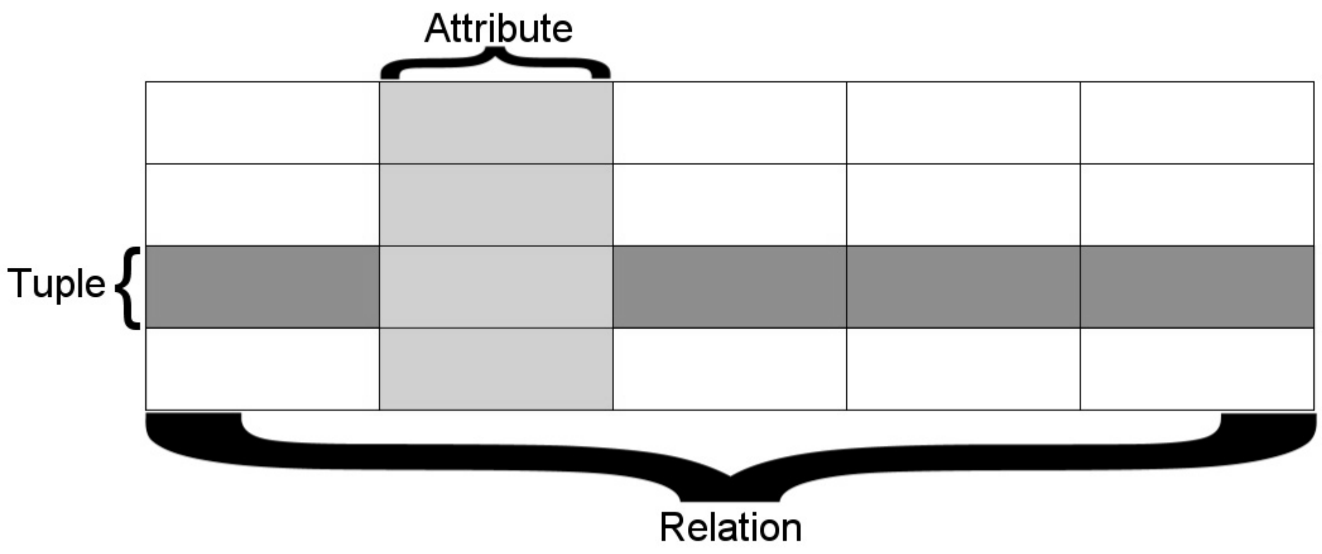
- Create/Insert data
- Read/Select some data
- Update data
- Delete data



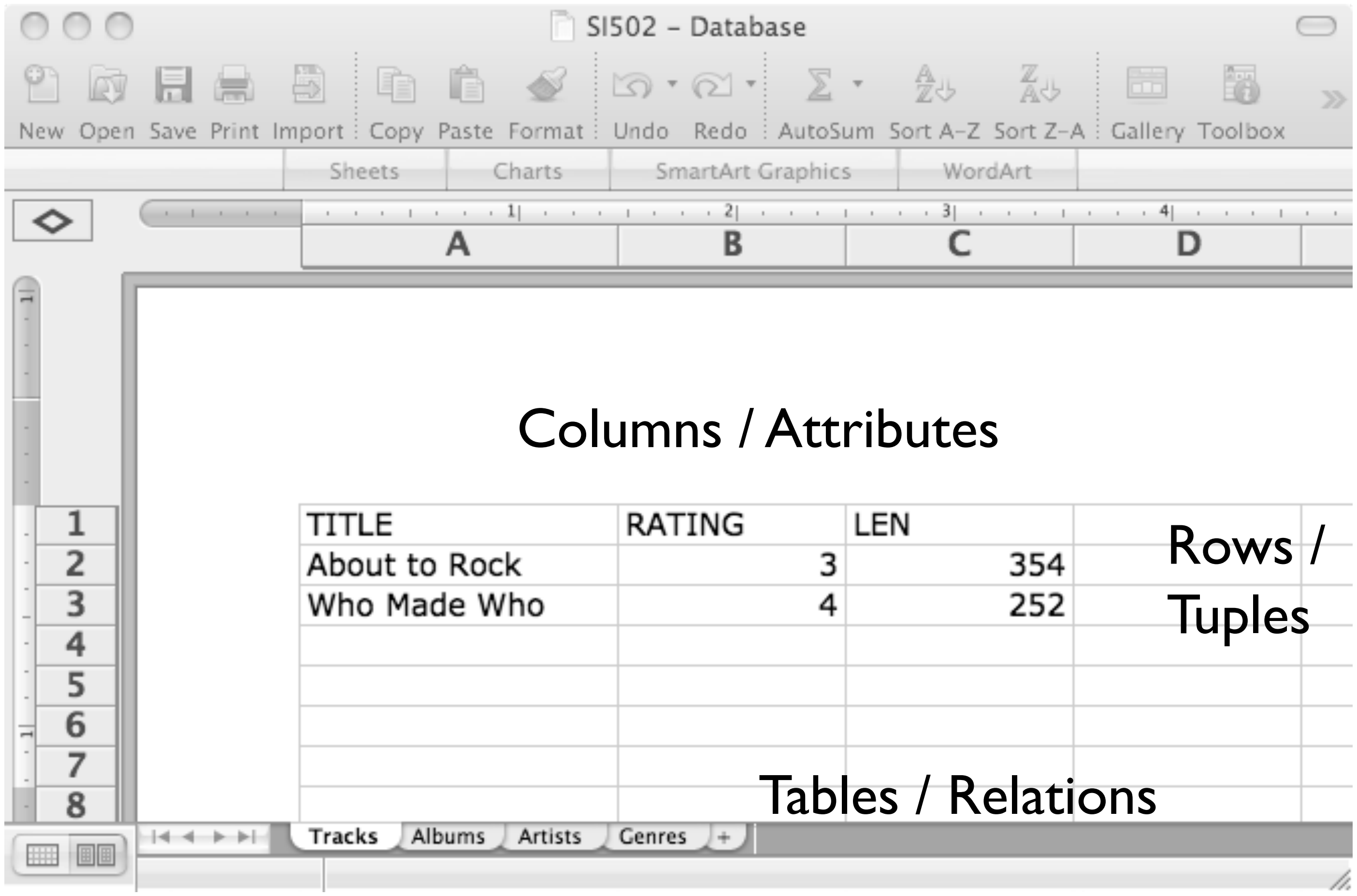
http://en.wikipedia.org/wiki/SQL
https://en.wikipedia.org/wiki/ANSI-SPARC_Architecture

Terminology

- Database - contains one or more tables
- Relation (or table) - contains tuples and attributes
- Tuple (or row) - a set of fields which generally represent an “object” like a person or a music track
- Attribute (also column or field) - one of possibly many elements of data corresponding to the object represented by the row



A relation is defined as a set of tuples that have the same attributes. A tuple usually represents an object and information about that object. Objects are typically physical objects or concepts. A relation is usually described as a table, which is organized into rows and columns. All the data referenced by an attribute are in the same domain and conform to the same constraints. (wikipedia)



Columns / Attributes

TITLE	RATING	LEN
About to Rock	3	354
Who Made Who	4	252

Rows / Tuples

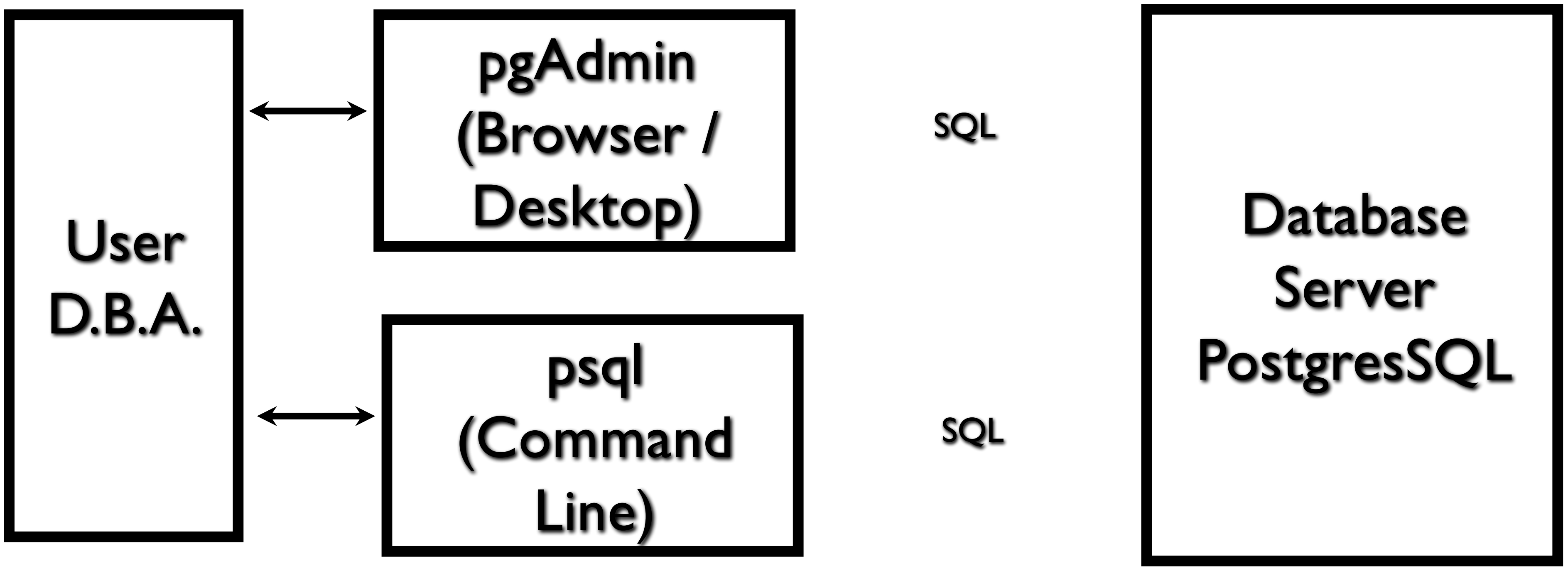
Tables / Relations

Common Database Systems

- Major Database Management Systems in wide use
  - PostgreSQL – 100% Open source, feature rich
  - Oracle - Large, commercial, enterprise-scale, very tweakable
  - MySQL - Fast and scalable - commercial open source
  - SqlServer - Very nice - from Microsoft (also Access)
- Smaller projects: SQLite, HSQL, …

SQL Architecture

Using SQL

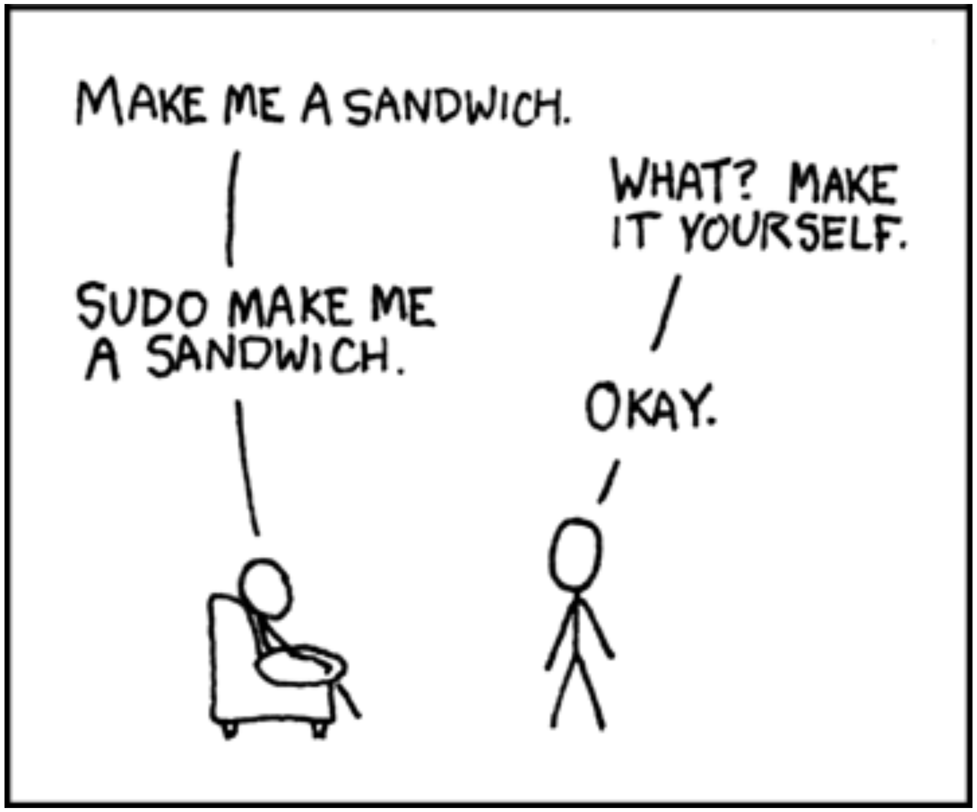

User
D.B.A.
pgAdmin
(Browser /
Desktop)
psql
(Command
Line)
SQL
SQL
Database
Server
PostgresSQL

Starting PostgreSQL Command Line

```
$ psql –U postgres
Password for user postgres: <password here>
psql (9.3.5, server 11.2)
Type "help" for help.

postgres=#
```

Super User Prompt



https://xkcd.com/149/

Your First PostgreSQL Command

```
postgres-# \l
                                  List of databases
   Name    |  Owner   | Encoding | Collate | Ctype |   Access privileges
-----------+----------+----------+---------+-------+-----------------------
 postgres  | postgres | UTF8     | C       | C     |
 template0 | postgres | UTF8     | C       | C     | =c/postgres          +
           |          |          |         |       | postgres=CTc/postgres
 template1 | postgres | UTF8     | C       | C     | =c/postgres          +
           |          |          |         |       | postgres=CTc/postgres
(3 rows)

postgres-#
```

Creating a User and Database

```
postgres=# CREATE USER  WITH PASSWORD 'secret';
CREATE ROLE
postgres=# CREATE DATABASE people WITH OWNER '';
CREATE DATABASE
postgres=# \q
```

https://www.postgresql.org/docs/11/sql-createuser.html
https://www.postgresql.org/docs/11/sql-createdatabase.html

Connecting to a Database

```
$ psql people
Password for user : <password here>
psql (9.3.5, server 11.2)

people=> \dt
No relations found.
people=>
```

Not a Super User Prompt

https://www.postgresql.org/docs/11/app-psql.html

Creating a Table

```
CREATE TABLE users(
  name VARCHAR(128),
  email VARCHAR(128)
);
```

```
people=> CREATE TABLE users(
people(>   name VARCHAR(128),
people(>   email VARCHAR(128)
people(> );
CREATE TABLE
people=> \dt
       List of relations
 Schema | Name  | Type  | Owner
--------+-------+-------+-------
 public | users | table |
(1 row)

people=> \d+ users
                                 Table "public.users"
 Column |          Type          | Modifiers | Storage  | Stats target | Description
--------+------------------------+-----------+----------+--------------+------------
 name   | character varying(128) |           | extended |              |
 email  | character varying(128) |           | extended |              |
Has OIDs: no

people=>
```

SQL: Insert

The INSERT statement inserts a row into a table

```
INSERT INTO users (name, email) VALUES ('Chuck', 'csev@umich.edu') ;
INSERT INTO users (name, email) VALUES ('Somesh', 'somesh@umich.edu') ;
INSERT INTO users (name, email) VALUES ('Caitlin', 'cait@umich.edu') ;
INSERT INTO users (name, email) VALUES ('Ted', 'ted@umich.edu') ;
INSERT INTO users (name, email) VALUES ('Sally', 'sally@umich.edu') ;
```

SQL: Delete

Deletes a row in a table based on selection criteria

```
DELETE FROM users WHERE email='ted@umich.edu';
```

SQL: Update

Allows the updating of a field with a WHERE clause

```
UPDATE users SET name='Charles' WHERE email='csev@umich.edu';
```

Retrieving Records: Select

Retrieves a group of records - you can either retrieve all the records or a subset of the records with a WHERE clause

```
SELECT * FROM users;

SELECT * FROM users WHERE email='csev@umich.edu';
```

Sorting with ORDER BY

You can add an ORDER BY clause to SELECT statements to get the results sorted in ascending or descending order

```
SELECT * FROM users ORDER BY email;
```

The LIKE Clause

We can do wildcard matching in a WHERE clause
using the LIKE operator

```
SELECT * FROM users WHERE name LIKE '%e%';
```

The LIMIT/OFFSET Clauses

- We can request the first "n" rows, or the first "n" rows after skipping some rows.
- The WHERE and ORDER BY clauses happen *before* the LIMIT / OFFSET are applied.
- The OFFSET starts from row 0

```
  SELECT * FROM users ORDER BY email DESC LIMIT 2;
SELECT * FROM users ORDER BY email OFFSET 1 LIMIT 2;
```

Counting Rows with SELECT

You can request to receive the count of the rows that would be retrieved instead of the rows

```
SELECT COUNT(*) FROM users;
SELECT COUNT(*) FROM users WHERE email='csev@umich.edu';
```

SQL Summary

```
INSERT INTO users (name, email) VALUES ('Ted', 'ted@umich.edu');

DELETE FROM users WHERE email='ted@umich.edu';

UPDATE users SET name='Charles' WHERE email='csev@umich.edu';

SELECT * FROM users WHERE email='csev@umich.edu';

SELECT * FROM users ORDER BY email;

SELECT * FROM users WHERE name LIKE '%e%';

SELECT * FROM users ORDER BY email OFFSET 1 LIMIT 2;

SELECT COUNT(*) FROM users WHERE email='csev@umich.edu'
```

This is not too exciting (so far)

- Tables pretty much look like big, fast programmable spreadsheets with rows, columns, and commands.
- The power comes when we have more than one table and we can exploit the relationships between the tables.

Data Types in PostgreSQL

Looking at Data Types

- Text fields (small and large)
- Binary fields (small and large)
- Numeric fields
- AUTO_INCREMENT fields

String Fields

- Understand character sets and are indexable for searching
- CHAR(n) allocates the entire space (faster for small strings where length is known)
- VARCHAR(n) allocates a variable amount of space depending on the data length (less space)

Text Fields

- Have a character set - paragraphs or HTML pages
  - TEXT varying length
- Generally not used with indexing or sorting - and only then limited to a prefix

Binary Types (rarely used)

- Character = 8 - 32 bits of information depending on character set
- Byte = 8 bits of information
  - BYTEA(n) up to 255 bytes
- Small Images - data
- Not indexed or sorted

Integer Numbers

Integer numbers are very efficient, take little storage, and are easy to process because CPUs can often compare them with a single instruction.

- SMALLINT (-32768, +32768)
- INTEGER (2 Billion)
- BIGINT - (10**18 ish)

https://www.postgresql.org/docs/9.1/datatype-numeric.html

Floating Point Numbers

Floating point numbers can represent a wide range of values, but accuracy is limited.

- REAL (32-bit) 10**38 with seven digits of accuracy
- DOUBLE PRECISION (64-bit) 10**308 with 14 digits of accuracy
- NUMERIC(accuracy, decimal) – Specified digits of accuracy and digits after the decimal point

https://www.postgresql.org/docs/11/datatype-numeric.html

Dates

- TIMESTAMP - 'YYYY-MM-DD HH:MM:SS'
  (4713 BC, 294276 AD)
- DATE - 'YYYY-MM-DD'
- TIME - 'HH:MM:SS'
- Built-in PostgreSQL function NOW()

https://www.postgresql.org/docs/11/datatype-datetime.html

I'M GLAD WE'RE SWITCHING TO 64-BIT, BECAUSE I WASN'T LOOKING FORWARD TO CONVINCING PEOPLE TO CARE ABOUT THE UNIX 2038 PROBLEM.
WHAT'S THAT?
REMEMBER Y2K? THIS COULD BE EVEN *WORSE!*

https://xkcd.com/607/

Database Keys and Indexes

AUTO_INCREMENT

Often as we make multiple tables and need to JOIN them together we need an integer primary key for each row so we can efficiently add a reference to a row in some other table as a foreign key.

```
DROP TABLE users;

CREATE TABLE users (
  id SERIAL,
  name VARCHAR(128),
  email VARCHAR(128) UNIQUE,
  PRIMARY KEY(id)
);
```

PostgreSQL Functions

Many operations in PostgreSQL need to use the built-in functions (like NOW() for dates).

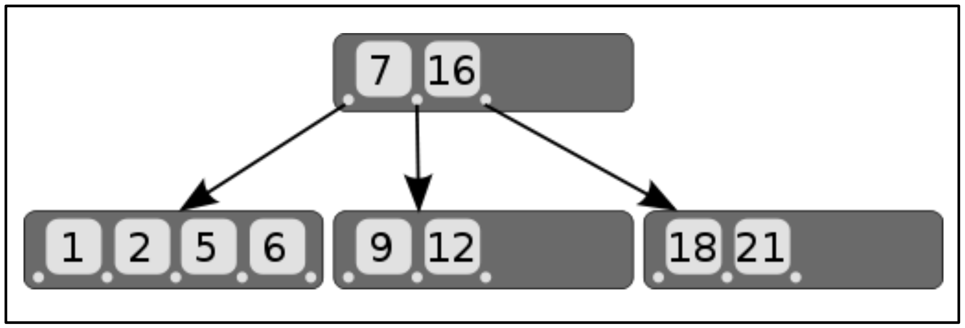
https://www.postgresql.org/docs/11/functions.html

Indexes

- As a table gets large (they always do), scanning all the data to find a single row becomes very costly
- When drchuck@gmail.com logs into Twitter, they must find my password amongst 500 million users
- There are techniques to greatly shorten the scan as long as you create data structures and maintain those structures - like shortcuts
- Hashes or Trees are the most common

B-Trees

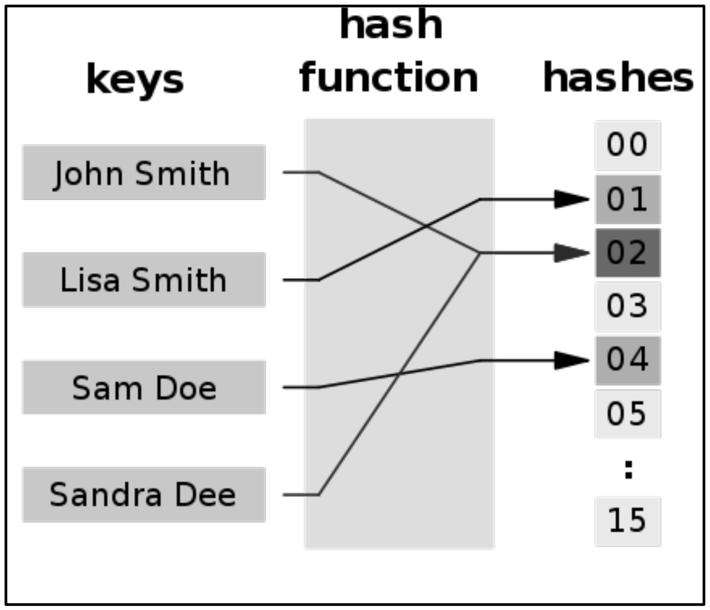
A B-tree is a tree data structure that keeps data sorted and allows searches, sequential access, insertions, and deletions in logarithmic amortized time. The B-tree is optimized for systems that read and write large blocks of data. It is commonly used in databases and file systems.



http://en.wikipedia.org/wiki/B-tree

Hashes

A hash function is any algorithm or subroutine that maps large data sets to smaller data sets, called keys. For example, a single integer can serve as an index to an array (cf. associative array). The values returned by a hash function are called hash values, hash codes, hash sums, checksums, or simply hashes. Hash functions are mostly used to accelerate table lookup or data comparison tasks such as finding items in a database...



http://en.wikipedia.org/wiki/Hash_function

Summary

- SQL allows us to describe the shape of data to be stored and give many hints to the database engine as to how we will be accessing or using the data.
- SQL is a language that provides us operations to Create, Read, Update, and Delete (CRUD) our data in a database.

Acknowledgements / Contributions

Initial Development: Charles Severance, University of Michigan School of Information

Insert new Contributors and Translators here including names and dates

Continue new Contributors and Translators here