CS143: Relational Model

Book Chapters

(5th) Chapters 1.3-7, 2.1, 3.1-2, 4.1
(6th) Chapters 1.3-6, 2.1-4, 3.1-2, 4.5
(7th) Chapters 2.1-4, 3.1-2

Things to Learn

- Data model
- Relational model
- Database construction steps

DataBase Management System (DBMS)

- Q: What is DBMS?
  - A system that manages data and provides six properties
  - *Massive*
  - *Convenient*
  - *Efficient*
  - *Safe*
  - *Persistent*
  - *Multi-user*
- High-level architecture of DBMS:

Data Model

- The way we model/conceptualize/visualize/represent data
- Need some representation to manage data in a computer
- Many different ways to model data
  - **Example (Airline flight):** Graph model
    - Node: city
    - Edge: flight between cities
    - Label on edge: flight time, etc.
    - Example standard: RDF (Resource Description Framework)
  - **Example (Company hierarchy):** Tree model
    - CEO → Presidents → Vice presidents → Department heads ...
    - Example standard: XML (eXtensible Markup Language), JSON (JavaScript Object Notation)
  - Models to learn in the class: Relational and E/R model

Example to Use in the Class

- School information
  - Student(sid, name, age, GPA, address, ...)
  - Class(dept, cnum, sec, title, instructor, ...)
  - Enroll(sid, dept, cnum, sec)
  - ...

Relational Model

- **Example:** Student(sid, name, address, age, GPA)
  Student

sid	name	addr	age	GPA
301	John	183 Westwood	19	2.1
303	Elaine	301 Wilshire	17	3.9
401	James	183 Westwood	17	3.5
208	Esther	421 Wilshire	20	3.1

- All data is represented as *relations* (= *tables*)
- Each relation has a set of *attributes* (= *columns*)
- Each relation contains of a set of *tuples* (= *rows*)
- Each attribute has a *domain* (= *type*)
  - Only atomic types
- Similar to Excel spreadsheet

History of Relational Model

- By far, the most significant invention in the history of DBMS
  - E.F. Codd, 1970
  - Completely revolutionized the field
  - Before it, network and hierarchical model: difficult to use and pose queries
  - Turing Award, 1981
- *Extremely* simple and strong mathematical foundation
- Supported by most DBMS systems
- An argument for simplicity

Concepts and Terminology

Schema

The structure of relations in database: relation name, attribute name, domain (optional).

- **Example:**
  - Student(sid, name, address, GPA, age)
  - Course(dept: char(2), cnum: int, sec: int, unit: int, title: char(100))
    char(2): string of length 2

Instance (= Data)

Actual contents (tuples) of relation (explain using the table example)

- Schema ≈ Type, Instance ≈ Value
- Schema ≈ Class, Instance ≈ Instance

Keys

- A set of attributes that are known to be unique in the relation
  - Student(<u>sid</u>, name, address, GPA, age)
  - Course(<u>dept</u>, <u>cnum</u>, <u>sec</u>, unit, instructor, title)
- Multiple keys possible
  - Course(<u>dept</u>, <u>cnum</u>, <u>sec</u>, unit, instructor, title)
  - Course(<u>dept</u>, <u>cnum</u>, sec, unit, <u>instructor</u>, title)
  - Course(<u>dept</u>, cnum, <u>sec</u>, unit, instructor, <u>title</u>)
- **Q:** When do we need keys? How can they be used?

Name Scope

- Names of relation: Unique across relations
- Names of attributes: Unique in a table, same name in different tables OK

Set semantics

- No duplicate tuples (different in SQL. More discussion later)
  - Q: Can a relation with no duplicates have no keys?
- Tuple order does not matter
  - Authors of a paper: Need explicit ordering
- Orders of attributes do not matter

Null value

- Common interpretation
  - Do not know
  - Do not want to say
  - Not applicable
  - Example: Student(id, dept, name, GPA) – before first quarter?
- Complications from Null
  - Example: Student(id, dept, name, age, GPA)
  - Q_1: Find students whose age ≥ 20. Susan's age is Null. Susan in the result?
  - Q_2: Find students whose age < 20. Susan in the result?
  - Q_3: Find students whose age ≥ 20 or age < 20 and. Susan in the result?
    - But $Q_3 = Q_1 \cup Q_2$? Something is wrong.
- Relational algebra, SQL: 3-valued logic
  - Every condition is evaluated as True, False or Unknown
  - Various (arbitrary) rules to deal with anomalous situation
  - More discussion later
- Unfortunately, Nulls are very common in DB.
- Common sources of error in data analysis: "Pay attention to Nulls!"

Steps in Database Construction

Flow chart diagram

1. *Domain Analysis*: Understand application-domain semantics being captured
   - E/R diagram
   - discussed later
2. *Database design*: Design tables to capture the information
   - Relational design theory (functional dependency, normal form, etc)
   - discussed later if time and interest permit
3. *Table creation*: using Database Definition Language
   - DDL: A language to define relations and their characteristics:
     - Schema, integrity constraints, indexes, ...
4. *Load*: typically bulk-load. insert tuple possible
5. *Query and update*: using Data Manipulation Language
   - DML: A language to query and update relations

SQL and DDL, Load, DML

What is SQL?

- Structured Query Language
- The standard language for interacting with all commercial RDBMS
- The history of SQL standard
  - SQL89: first standard
  - SQL92: the main and most widely-supported standard. several hundred pages
  - SQL1999, SQL2003, SQL2006, SQL2008, SQL2011, SQL2016
  - We will mainly use the standard SQL92 in class. Individual product uses slight variations of the standard. Some class query may not run on them.
- SQL has many components
  - DDL: Schema definition, constraints, indexes, ...
  - DML: data retrieval, modification, ...
  - Transactions, Authorization, ...
- We learn schema definition part today.

Basic SQL Types

- Basic SQL types (commonly used subset)
  - String
    - Char(n) – padded fixed length
      - Padding character is system dependent (space for Oracle, auto-removed for MySQL)
    - Varchar(n) – variable length
  - Number
    - Integer – 32bit
    - Decimal(5,2) – 999.99
    - Real, Double – 32bit, 64bit
  - Datetime
    - Date – '2002-01-15'
    - Time – '13:50:00'
    - Timestamp – '2002-01-15 13:50:00' (On MySQL, Datetime is preferred)
- Schema definition (table creation)
  - Course(dept, cnum, sec, unit, instructor, title)
    - ```
      CREATE TABLE Course (
                  dept CHAR(2) NOT NULL,
                  cnum INTEGER NOT NULL,
                  sec INTEGER NOT NULL,
                  unit INTEGER,
                  instructor VARCHAR(30),
                  title VARCHAR(30),
                  PRIMARY KEY(dept, cnum, sec) )
      ```
    - No Null in primary key
  - Course(dept, cnum, sec, unit, instructor, title)
    Course(dept, cnum, sec, unit, instructor, title)
    Course(dept, cnum, sec, unit, instructor, title)
    - ```
      CREATE TABLE Course (
                  dept CHAR(2) NOT NULL DEFAULT 'CS',
                  cnum INTEGER NOT NULL,
                  sec INTEGER NOT NULL,
                  unit INTEGER,
                  instructor VARCHAR(30),
                  title VARCHAR(30) DEFAULT,
                  PRIMARY KEY(dept, cnum, sec),
                  UNIQUE(dept, cnum, instructor),
                  UNIQUE(dept, sec, title) )
      ```
    - One primary key per table

        * Unique for other keys
        * Primary key, unique are enforced through index (more discussion later)
        * SQL92: No Null in primary key. Null OK for unique
            · MySQL: automatically add not null for primary key attributes
        * DEFAULT for default values

- SQL for dropping a table
    - `DROP TABLE Course`

Loading data

- Vendor specific
- MySQL
    - `LOAD DATA LOCAL INFILE <datafile> INTO TABLE Course`
- Microsoft SQL Server
    - `BULK INSERT Course FROM <datafile>`

Things to remember

- Data model
- Schema
- Instance
- Relational model
    - relation, attribute, tuple, domain
    - key
    - null value
    - set semantics
- Database construction steps
    1. Domain analysis: E/R model, UML
    2. Database design: Database design theory
    3. Table creation: DDL
    4. Load
    5. Query and update: DML