

**Lecture 1: Database and DBMS**

*Instructor: Alex Dekhtyar*

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## **Introduction**

Definition of a database and DBMS in Professor Notes.

## Lecture 2: Relational Data Model

*Instructor: Alex Dekhtyar**Ishaan Sathaye*

## Relational Data Model

**Definition 1** *Relational data model is an approach to organizing collections of data*

- Relation
  - Relational Table  $\rightarrow$  **Name + Schema**
    - \* Schema: List of attribute name + attribute type pairs
- Relational Database  $\rightarrow$  **Collection of Relations tables**
- **Table Instance**: set of records with instantiated values of the attributes
  - Finite
  - Records, rows, tuples

One unit of data is called a **datum**.

Object, entity, event: description of one object, entity, event

- **Records** consist of attributes or fields (rows in the table).
- **Attributes** is a named container for a value of a specific type.

## Database Table Constraint

**Definition 2** *Limitations of table instances*

- **Candidate Key**: set or lists of attributes that uniquely define a record in a table, **minimal such set of attributes**, made up of multiple attributes sometimes.
  - **Every attribute is necessary.**

## Examples

### CSC 365 Example

Course Object:

- Prefix: CSC  $\rightarrow$  **String**
- Course #: 365  $\rightarrow$  **Integer**
- Name: Introduction to Database Systems  $\rightarrow$  **String**
- Description: Basic Principles, ...  $\rightarrow$  **String**
- Units: 4  $\rightarrow$  **Integer**

Department Object:

- Name: Computer Science and Software Engineering
- Abbreviation: CSSE
- Building: 14
- Room: 245
- College: CENG

Stringing these objects together based on relationship would make a **network model**.

## Schema Example

```
Course(Prefix String, Course# Integer, Name String, Description
String, Units Integer)
```

Prefix	Course#	Name	Description	Units
CSC	365	Introduction to Database Systems	Basic Principles, ...	4
CSC	357	Systems Programming	...	4

```
Department(Name, College, Building, Room): Department would also have a table as well.
```

CSC 365-07: Introduction to Database Systems

Spring 2023

## Lecture 3: RDM Cont.

*Instructor: Alex Dekhtyar*

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## Relational Data Model

What makes a record unique?

- **Superkey**: any set of attributes that uniquely defines a record in a table
- **Primary Key**: candidate key chosen by you

## Lecture 4: SQL DDL and DML

*Instructor: Alex Dekhtyar**Ishaan Sathaye*

## MySQL Access

1. Server Address = host: **mysql.labthreesixfive.com**
2. Port: 3306
3. username
4. password

### MySQL Database

- Namespace
- Collection of Tables
- Set of Permissions

## Case Sensitivity

### Case Sensitive

- Table Names
- Database Names

### Not Case Sensitive

- Attribute Names
- SQL Keywords

## Types

- **Numeric Types**
  - **Integer Types**
    - \* TINYINT
    - \* SMALLINT
    - \* MEDIUMINT

- \* **INT**
- \* **BIGINT**
- **Floating Point Types**
  - \* **FLOAT**
  - \* **DOUBLE(P, D)**
  - \* **DECIMAL**
- **String Types**
  - **Character Types**
    - \* **CHAR(N)** → **Fixed Length**
    - \* **VARCHAR(N)** → **Variable Length**
    - \* **TINYTEXT**
    - \* **TEXT** → for storing large amounts of text
    - \* **MEDIUMTEXT**
    - \* **LONGTEXT**
- **Date and Time Types**
  - **Date Types**
    - \* **DATE**
    - \* **DATETIME**
    - \* **TIMESTAMP**
    - \* **TIME**
    - \* **YEAR**

## Data Definition Language (DDL)

Commands from DDL act upon the schema

- **CREATE TABLE**
- **DROP TABLE**
- **ALTER TABLE**

### Define a Relational Table

Aspects needed to define a table:

- **Table Name**
- **Attributes: Name + Type**
- **Constraints**

```
CREATE TABLE <table_name> (
    <attribute_name> <sql_type> [<single_line_constraints>],
    ...,
    <attribute_name> <sql_type> [<single_line_constraints>] [,
    <constraints>[,
    <constraints>]
]);
```

## Data Manipulation Language (DML)

Commands from DML act upon the instance.

- INSERT
- DELETE
- UPDATE

### Inserting Data

```
INSERT INTO <table_name>(<attribute_name>, ...)
VALUES (<value>, ...);
```

Supply values in order of attribute declarations in CREATE TABLE statement. Can omit the attribute names if values supplied are in the same order. If need to omit a value then omit that attribute name as well.

## More on Constraints

- **[NOT] NULL** - attribute cannot be null
- **UNIQUE**
- **PRIMARY KEY**
- **FOREIGN KEY**
- **DEFAULT** <exp> - default value for attribute
- **AUTO\_INCREMENT** - means that the attribute is an integer and is automatically incremented

## Lab 2

MySQL Server

- LabThreeSixFive.com

- mysql command line client
- IDE (DatGrip)
- mysql connectivity from Python

Lab 2 uses Create Table, Drop Table, and Insert.

## Code from Lab

```
show tables
```

```
CREATE TABLE Departments (
    DeptId INT PRIMARY KEY,
    Abbr VARCHAR(20) UNIQUE, -- UNIQUE makes candidate key
    Name VARCHAR(128) UNIQUE,
    College CHAR(10),
    Building INT,
    Room CHAR(6),
    -- set multiple candidate keys at the bottom
    UNIQUE(Building, Room),
    -- foreign key always a separate line statement:
    -- FOREIGN KEY(College) REFERENCES colleges(abbr)
);

describe colleges;
SELECT * FROM colleges;

show CREATE TABLE colleges;

show CREATE TABLE Departments;

INSERT INTO Departments
VALUES(1, 'CSSE', 'Computer Science and Software Engineering', 'CENG', 14, '245');

INSERT INTO Departments(DeptId, Abbr, Name, College, Building, Room)
VALUES(1, 'CSSE', 'Computer Science and Software Engineering', 'CENG', 14, '245');
```



## Lecture 5: DDL and DML Continued

*Instructor: Alex Dekhtyar**Ishaan Sathaye*

## DML

### Updating Data

```
UPDATE <table_name>
  SET <attribute_name> = <value>
  WHERE <condition>;
```

#### Example

```
UPDATE colleges
  SET abbr = 'COSAM'
  WHERE abbr = 'COASM'
```

WHERE clause is a filter that determines which rows are updated.

### Deleting Data

```
DELETE FROM <table_name> -- just this is a valid command to delete all rows
  WHERE <condition>;
```

## DDL

### Altering Tables

```
ALTER TABLE <table_name>
  <Command> <parameters>;
```

#### Commands

- ADD - add a column/attribute/key
- DROP
- MODIFY
- RENAME

**Parameters**

- COLUMN
- CONSTRAINT
- FOREIGN KEY
- PRIMARY KEY
- UNIQUE

Adding an attribute, dropping/adding a constraint, renaming a table, disable/enabling keys, and modifying attributes examples are in this professor notes: [4-SQLDDLML.pdf](#)

**CSC 365-07: Introduction to Database Systems**

**Spring 2023**

## Lecture 6: DML/DDL Cont., WHERE Clause., and MySQL Conn.

*Instructor: Alex Dekhtyar*

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### Announcements

#### Running Scripts for Lab 2

Can run from command line using mysql command or using mysql client. For running using mysql command need to specify the database if not using default database.

```
source script.sql
```

### DML/DDL

**Data Manipulation works on instance and Data Definition works on schema.**

#### Altering a Table

Modifying the schema. ALTER examples in class.

For CREATE TABLE, you can name constraints:

```
CREATE TABLE Example (
    Id int PRIMARY KEY,
    X INT,
    Y INT,
    CONSTRAINT Point UNIQUE (X, Y)
);
```

#### Updating and Deleting from Table: WHERE Clause

Ex. Deleting in Table

```
DELETE FROM test02
WHERE b > c
```

This deletes rows where b is greater than c.

Ex. Deleting with Scope

```
DELETE FROM test02
```

```
FOR EACH ROW in test01
DO
    DELETE FROM test02 -- delete(row, condition)
    WHERE b > c
```

### SQL Boolean Expressions

- 0, 1
- Builtin: IN(...)  $\rightarrow$  returns bool
- $\langle Expression \rangle < op1 \rangle \langle op2 \rangle //$  can also use IN or LIKE
- $\langle Expression \rangle$  AND  $\langle Expression \rangle$
- $\langle Expression \rangle$  OR  $\langle Expression \rangle$
- NOT  $\langle Expression \rangle$

## MySQL Connectivity

Breifly went over the Python examples on Course webpage that connect to MySQL server.

## Lecture 7: Python Connectivity and Relational Algebra

*Instructor: Alex Dekhtyar**Ishaan Sathaye*

## Python MySQL Connectivity

Relational Database is sitting on a server. It is listening for connections, and our program is a client that connects to the server via the port. Essentially, there is a pipe and a exchange of messages that is happening. Generates a connection object that stores info about how to properly access the database.

### Package

```
import mysql.connector
```

### Connection

5 Things Needed: Host, Port, Username, Password, Database (sometimes not necessarily)

These get passed to `mysql.connector.connect()` function. This returns a connection object. `is_connected()` returns a cursor object.

Cursor object that is returned from the connection object. Cursor object is used to execute queries.

## Relational Algebra

Relational  $\longrightarrow$  Database Model  $\longrightarrow$  Relational Model. Algebra: set of elements & operations on elements

Relational Algebra is operations on relational tables.

Boolean Algebra introduces operations on truth values

- T, F
- $\sim, \wedge, \vee, \rightarrow, \leftrightarrow$

### Notation

Upper case letters like R, S, T,  $R_1$ ,  $S_7$ , ... are relational table names. Letters from first half of alphabet like A, B, C, ... are attributes names.  $R(A_1, \dots, A_n)$  are to represent schema.  $t, s, r \in R$  are tuples.  $a_1, a_2, \dots$  are values. Ex.  $t = (a_1, \dots, a_n)$  and it could be referred to as  $t.A_1 = a_1$ .

## Operations

### Binary

### Unary

- Selection  $\sigma$  - filter rows
- Projection  $\pi$  - filter columns

### Selection Operation

- $\sigma_{\langle \text{selectioncondition} \rangle}(R)$  - returns rows that satisfy condition
- Selection Condition denoted by  $C$
- Ex.  $C = A_2 = 'Riley' \wedge A_3 = 'Hicks'$
- **Formal Notation:**  $\sigma_C(R) = \{t \in R | t \text{ satisfies } C\}$

### Projection Operation

- $\pi_{\langle \text{attributelist} \rangle}(R)$  - returns columns that are in attribute list
- $F$  is the projection list which is a list of attributes
- Ex.  $F = (B_1, \dots, B_m)$  where  $B_i \in A_1, \dots, A_n$
- **Formal Notation:**  $\pi_F(R) = \{t' | \exists t \in R, s.t. \forall B \in F, t'.B = t.B\}$
- **Projection squeezes out duplicates**

## Lecture 8: Relational Algebra

*Instructor: Alex Dekhtyar**Ishaan Sathaye*

## Relational Algebra

R, S, T are relational tables and these are sets. Set Operations include Union, Intersection, Difference, Symmetric Difference...

Example:

Table 1: R

A	B	C
1	2	a
2	4	b
3	1	d
4	4	d
4	5	a

Table 2: S

B	D	E
2	a	1
3	a	2
7	b	3
5	b	1
1	c	2

## Selection Review

Duplicate Elimination:  $\sigma_{A=4 \vee B=4}(R)$

A	B	C
2	4	b
4	4	d
4	5	a

## Projection Review

- Subset and Columns:  $\pi_{B,D}(R)$ . The schema here is  $R(B, D)$ .
- Can make composition of operations:  $\pi_{B,E}(\sigma_{D=b}(R))$  because an result of an operation is a relational table. Result:

B	E
7	3
5	1

- Can also reorder columns:  $\pi_{EBD}(R)$
- Duplicate Columns:  $\pi_{ABA}(R)$ . Issue with this is that there are 2 columns with the same name. Disambiguate by renaming:  $\pi_{A_1BA_2}(R)$
- Can also introduce new columns:  $\pi_{A,B,2 \cdot A}(R)$

## Cartesian Product

- $R \times S$  is the cartesian product of R and S. Result is a table with all possible combinations of rows from R and S.

- Notation:  $R \times S = \{(t, t') | t \in R, t' \in S\}$

Ex.  $\sigma_{A < 3}(R) \times \sigma_{B < 3}(S)$

A	B	C	B	D	E
1	2	a	2	a	1
1	2	a	3	a	2
1	2	a	5	b	1
2	4	b	2	a	1
2	4	b	3	a	2
2	4	b	5	b	1

## Join

Table 3: R

Id	Customer	C
1	2	a
2	4	b
3	1	d
4	4	d
4	5	a

Table 4: S

Id	Name	E
2	a	1
3	a	2
7	b	3
5	b	1
1	c	2

- Who purchased Receipt 3  $\longrightarrow$  Find a person with Id 1:  $\pi_{Name}(\pi_{R.Cust=S.Id}(\sigma_{Id=3}(R)) \times S)$

- Notation:  $R \bowtie_C S = \sigma_{R.xoperationS.Y}(R \times S)$



## Lecture 9: Joins

*Instructor: Alex Dekhtyar**Ishaan Sathaye*

## Announcements

- Double-sided cheat sheet allowed for Midterm.
- Homework assigned on Thursday as prep for Midterm.

## Example

Table 5: T

Id	Name	Course	Grade
1	Joe	CSC 365	A
2	Mary	CSC 365	A
3	Lisa	CSC 101	B
4	Luis	STAT 301	C
5	Steve	STAT 301	A
1	Joe	CSC 357	B
2	Mary	CSC 357	C

Table 6: C

CourseId	Instructor
CSC 357	Nico
CSC 365	Migler
STAT 301	Bodwin
CSC 101	Rivera
STAT 302	Frame

Transcript Table T has primary key ( $Id, Course$ ) and foreign key ( $Course$ ) referencing Course Table C.

- **Find all Joe's instructors.**

$$\begin{aligned}
 & \sigma_{Name=Joe}(T) \\
 & \pi_{Course}(\sigma_{Name=Joe}(T)) \\
 & C \times \pi_{Course}(\sigma_{Name=Joe}(T)) \\
 & \sigma_{C.CourseNo=T.Course}(C \times \pi_{Course}(\sigma_{Name=Joe}(T))) \\
 & \pi_{Instructor}(\sigma_{C.CourseNo=T.Course}(C \times \pi_{Course}(\sigma_{Name=Joe}(T))))
 \end{aligned}$$

Cartesian Product in line 3 makes table with Course No., Instructor, and Course combination for Joe. So it would be every combination with Course and CourseNo.:

C.CourseNo	C.Instructor	T.Course
CSC 357	Nico	CSC 365
CSC 365	Migler	CSC 365
...	...	...
CSC 357	Nico	CSC 357
CSC 365	Migler	CSC 357
...	...	...

In Line 4, we are selecting the rows where the CourseNo. in C is equal to the Courses in T.

- **For each course grade, report the instructor who assigned it.**

$$\pi_{T.Course, T.Grade, C.Instructor}(\sigma_{T.Course=C.CourseId}(T \times C))$$

First, we are taking the Cartesian product which gives us 35 rows. Then we are making the table smaller by only selecting the rows that are equal in Courses.

## $\Theta$ –Join

$$R \bowtie_{\Theta} S = \sigma_{\Theta}(R \times S)$$

$\Theta$  - selection condition where each comparison uses attributes from R and S

## Equi-Join

$$R \bowtie_{\Theta} S$$

$$\Theta = (R.A = S.B) \wedge (R.C = S.D) \wedge (R.E = S.F)$$

## Natural Join

$$\begin{array}{l} R(A_1, \dots, A_k, B_1, \dots, B_k) \\ S(B_1, \dots, B_k, C_1, \dots, C_k) \end{array}$$

$$R \bowtie S = \pi_{R.*, S.C_1, \dots, S.C_k}(R \bowtie_{Condition} S)$$

$$Condition \text{ is where } R.B_1 = S.B_1 \wedge \dots \wedge R.B_k = S.B_k.$$

Natural join looks at all **common attributes** of two relations and joins on them, removing one set of common attributes from the final relation.

## Semi-Join

Special case of natural join where only attributes of one relation are kept. Essentially, it is a projection on all elements of 1 relation.

Left Semi Join:

$$R \bowtie_{\Theta} S = \pi_{R.*}(R \bowtie_{\Theta} S)$$

Right Semi Join:

$$R \bowtie_{\Theta} S = \pi_{S.*}(R \bowtie_{\Theta} S)$$

Example:

$$(\sigma_{Name=Joe}(R) \bowtie C)$$

## Lecture 10: RA Operations

Instructor: Alex Dekhtyar

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## Examples

Table 7: Patients (P)

Id	Name	DoB
1	Mary	1/1/2000
2	Jack	3/7/1982
3	Amy	4/12/1976
4	Tom	12/17/1995

Table 8: Prescriptions (R)

PId	MId	Date	Refills
1	1	3/30/23	2
1	3	12/20/22	12
2	4	3/15/23	0
3	5	3/15/23	7
3	2	1/1/23	3

Table 9: Medications (M)

Id	Name	Dosage
1	Ibuprofen	200
2	Ibuprofen	500
3	Metformin	100
4	Aspirin	10
5	Romapril	20

- Find Ibuprofen dosages for each patient (Name, Dosage).

$$\begin{aligned}
 & R \bowtie_{R.MId=M.Id \ \sigma_{Name=Ibuprofen}}(M) \\
 & P \bowtie_{P.Id=R.Id} (R \bowtie_{R.MId=M.Id \ \sigma_{Name=Ibuprofen}}(M)) \\
 & \pi_{P.Name, Dosage}(P \bowtie_{P.Id=R.Id} (R \bowtie_{R.MId=M.Id \ \sigma_{Name=Ibuprofen}}(M)))
 \end{aligned}$$

First line we add the columns of M to R but only the Ibuprofen rows. At the same only adding these columns to the rows in R which have the MIds match:

PId	MId	Date	Refills	Id	Name	Dosage
1	1	3/30/23	2	1	Ibuprofen	200
3	2	1/1/23	3	2	Ibuprofen	500

Finally, in the second line we join this new schema with P only referring to the Ids:

Id	Name	DoB	PId	MId	Date	Refills	Id	Name	Dosage
1	Mary	1/1/2000	1	1	3/30/23	2	1	Ibuprofen	200
3	Amy	4/12/1976	3	2	1/1/23	3	2	Ibuprofen	500

Then we just use projection to get the needed columns:

Name	Dosage
Mary	200
Amy	500

- Find all patients who are older than Jack.

$$\sigma_{DoB < 3/7/82}(P)$$

This above equation is **wrong** because you are searching through all rows of P.

$$P \bowtie_{DoB < DoB} (\sigma_{Name=Jack}(P))$$

This above is called a **self-join** because you are joining a table with itself. But you need to disambiguate so you need to use the renaming operator  $\rho$ .

$$\begin{aligned} & P \bowtie_{P.DoB < J.DoB} \rho_J(\sigma_{Name=Jack}(P)) \\ & \pi_{P.*}(P \bowtie_{P.DoB < J.DoB} \rho_J(\sigma_{Name=Jack}(P))) \end{aligned}$$

right another way using left semi join.

## Renaming Operator $\rho$

$$\begin{aligned} & \rho_x(R) \\ & \rho_{(A_1 \rightarrow B_1, \dots)}(R) \\ & \rho_{x(A_1 \rightarrow B_1, \dots)}(R) \end{aligned}$$

First line renames the table name to x. Second line renames the attributes to the new names. This is useful for self-joins. Can also combine first 2 lines as in the third line.

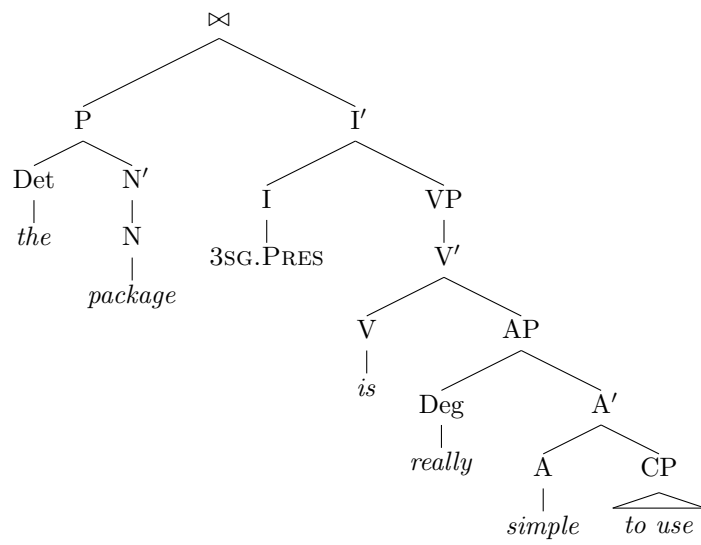
Once M and R are renamed then they are forgotten for the duration of the operation.

## Expression Trees

Example: Ibuprofen Relational Tree

Begin writing relational tree from the bottom up. Start with the inner most operation and work your way up. For the above example the selection would be the inner most operation and the outer join would be the topmost operation.

There can be multiple ways to represent the relational tree, but some trees work better as they generate less data.



## Lecture 11: Relational Algebra Continued and SQL Select Statement

*Instructor: Alex Dekhtyar**Ishaan Sathaye***Sort:  $\tau$** 

$\tau_F$  where F is a list of attributes. Sorts the relation by the attributes.  $F = A, B, C$  which is a project list. Can also put operations on the attributes.  $F = Desc(A \text{ MOD } B), B, Desc(C)$ .

**Example**

A	B	C
1	2	3
4	5	6
7	8	9

$$\pi_B(\tau_{Desc(A)}(R))$$

This above sorts the table by A in descending order and then projects the B column. The result is:

B
8
5
2

**Set Operations**

- Only apply these when R, S have the same schema.
- These are bag operations.

**Union:  $\cup$** 

All elements that are in either set.

Definition:

$$R \cup S = \{t | t \in R \vee t \in S\}$$

**Set Difference:  $-$** 

All elements that are in R but not in S.

Definition:

$$R - S = \{t | t \in R \wedge t \notin S\}$$

**Intersection:  $\cap$** 

All elements that are in both sets.

Definition:

$$R \cap S = \{t | t \in R \wedge t \in S\}$$

**Example**

Table 10: R

A	B
1	2
4	5
7	8

Table 11: S

A	B
1	2
7	8
5	11
6	3

Table 12:  $R \cup S$ 

A	B
1	2
4	5
7	8
5	11
6	3

Table 13:  $R - S$ 

A	B
4	5

Table 14:  $R \cap S$ 

A	B
1	2
7	8

**Duplicate Elimination:  $\delta$** 

Removes duplicate tuples from a relation. Definition:  $\delta(R)$ . This is a set representation of bag R.

**This operation allows us to go between bag and set representations.** Example:  $R \cap S$  would allow duplicates, but  $\delta(R - S)$  would not.

**SQL Select Statement**

*Technical Debt:* Grouping and Outer Joins



```

SELECT <select-list>
FROM <table1>, <table2>, ...
WHERE <condition>
ORDER BY <sort-list>

```

- FROM gets evaluated first. Here cartesian products and renaming operations are done.
- WHERE gets evaluated second. Responsible for the conversion between cartesian product to joins.
- ORDER BY gets evaluated next. Responsible for sorting.
- SELECT gets evaluated last. Responsible for projection and some renaming to be done.

### Patterns:

$\sigma_C(R)$  translates to the following SQL statement:

```

SELECT *
FROM R
WHERE C

```

$\pi_F(R)$  translates to the following SQL statement:

```

SELECT DISTINCT F --removes duplicates
FROM R

```

$\tau_F(R)$  translates to the following SQL statement:

```

SELECT DISTINCT F
FROM R
ORDER BY F

```

$R \times S$  translates to the following SQL statement:

```

SELECT * -- start because there is no projection
FROM R, S

```