Data Modeling

🔨 *Engineering = building the thing right*
🎯 *Leadership = building the right thing*

Outline

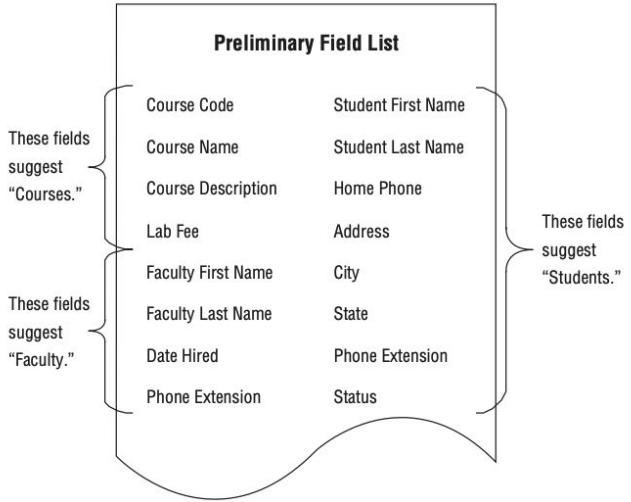
1. Database Design
    - Logical Design
        i. Design Process
        ii. Schema
        iii. Table Format
    - Physical Design
        i. Data Types
2. Case Studies

1. Database Design

1.1. Design Process

2.2. Design Process

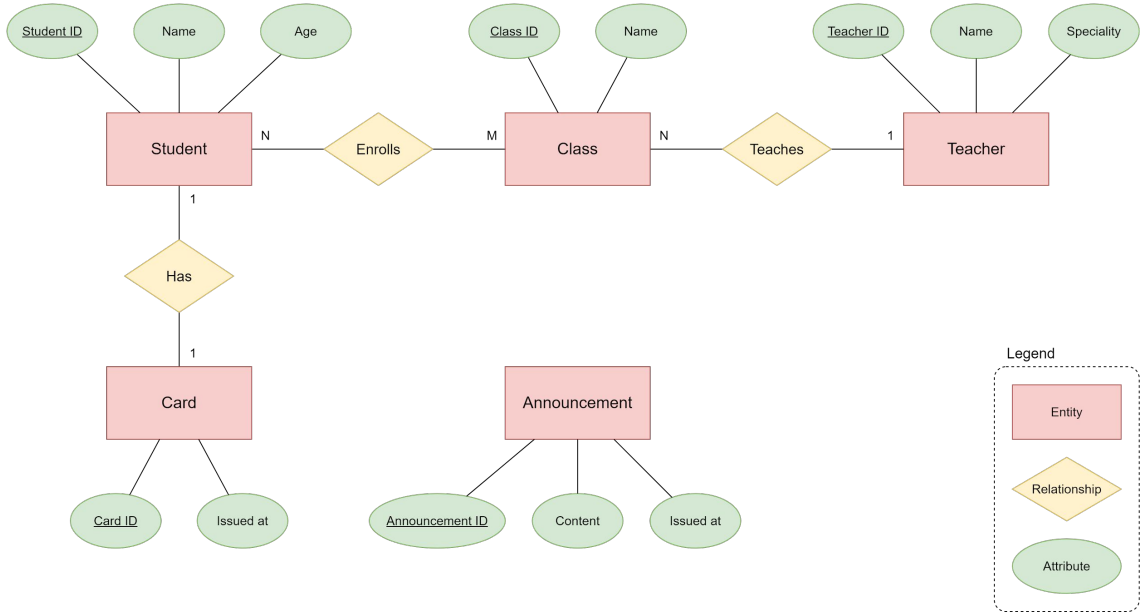
- Analysis
  - **Clear requirements, data access patterns**
  - Current DB
  - Preliminary Field List
- Data modeling
  - Define tables
  - Assign fields to each table
  - Refine the Table Structure
  - Keys, Relationships
- Data integrity
  - Review
  - Normalization / Denormalization



1.2. Schema

1.2.1. Entity-Relationship Diagram (ERD)

- Entity: object has **identity and life cycle (status)**
- Entity-Relationship Diagram (ERD) is a visual diagram to illustrate the **relationships between different entities** or tables



1.2.2. Types of Tables

- Entity Table
- Relation Table (N - M)
- Support Table (for entity)
- Config Table (example: countries, provine, config, …)

Example

1.2.3. Normalization

- Normalization is the **process of organizing data to reduce redundancy and improve data integrity**.
- Normalization **breaking down large tables into smaller, related tables** and establishing relationships between them
- Pros:
  - **Reduce redundancy**
  - **Data integrity**
- Cons:
  - Increase complexity to schema
  - Join to get needed data
  - Some cases can not take effect of indexes

Student ID	Name	Age	Class ID	Name
1	Ly	24	2	Math
2	Trang	25	3	Physic
3	Linh	18	1	English
4	Hoa	20	1	English
5	Trang	25	2	Math

Student

Student ID	Name	Age
1	Ly	24
2	Trang	25
3	Linh	18
4	Hoa	20
5	Trang	25

Enroll

Student ID	Class ID
1	2
2	3
3	1
4	1
5	2

Class

Class ID	Name
1	English
2	Math
3	Physic

1.2.4. Denormalization

- Denormalization is the inverse process of normalization.
- Denormalization **combine tables or adding redundant data.**
- Pros:
  - **Improved query performance**
  - Leverage Index
- Cons:
  - Increased Storage
  - **Data Consistency**

Student

Student ID	Name	Age
1	Ly	24
2	Trang	25
3	Trinh	18

Enroll

Student ID	Class ID
1	2
2	3
3	1
1	1
3	2

Student

Student ID	Name	Age	Classes
1	Ly	24	2
2	Trang	25	1
3	Trinh	18	2

1.2.5. Problem 4: Foreign Key

Problem: With foreign keys (constraints)

- During insert and update operations, DB needs to check the existence of the referenced key.
- Complexity of schema
- App must catch and inspect DB exception to know reason
- Backup process is complex

Solution: (my opinion)

- **Remove constraint foreign key**
- **Implement the constraints in app layer**

Note: Foreign Key != Reference Column

1.3.5. Where is reference column placed?

- Context:
  - Use case: Order
    - Create a order
    - Create a payment transaction
  - Use case: Donate
    - Create a donate transaction
  - Transaction and order has relation (1 - 1)
- Question: Where is the reference column placed?
- Answer:
  - Place reference column (order_id) in transaction table
  - **Entity sinh ra sau sẽ lưu reference tới entity gốc (sinh ra trước).**
    → improve scalability

1.3. Table Format

1.3.1. Problem 1

Problem: In old version of MySQL, adding another fields/columns requires a **full table lock**
→ Downtime

1.3.1. JSON datatype

- **data: json → scalability**

```sql
CREATE TABLE user (
    user_id BIGINT NOT NULL
        AUTO_INCREMENT PRIMARY KEY ,
    name VARCHAR(100),
    age SMALLINT NOT NULL ,
    biography TEXT NULL ,
    status TINYINT NOT NULL ,
    data JSON NULL,
    created_at TIMESTAMP(3),
    created_by VARCHAR(100),
    updated_at TIMESTAMP(3),
    updated_by VARCHAR(100)
);
```

1.3.2. Problem 2

Problem: Need to index a field in JSON.

In older versions of MySQL, DB do not support index on JSON (function)

→ We need columns to index.

1.3.2. Redundant Columns

- Create **redundant columns when creating tables**
- Adding new data into the unused column
- **Cons: Document** the meaning of columns

```sql
CREATE TABLE user (
    user_id BIGINT NOT NULL
        AUTO_INCREMENT PRIMARY KEY ,
    name VARCHAR(100),
    age SMALLINT NOT NULL ,
    biography TEXT NULL ,

    c1 VARCHARV(200),
    c2 VARCHARV(200),
    c3 VARCHARV(100),
    c4 VARCHARV(100),
    c5 INT,
    c6 INT,
);
```

1.3.3. Problem 3

Problem: **Before MySQL 5.6 (InnoDB), adding an index requires a full table lock**

Solution:

- Before 5.6:
  - pt-Online-Schema-Change from Percona Toolkit
  - Gradually copy data from the original table to a new table.
  - Rename the new table to replace the old table
  - Minimize lock/downtime.
- After 5.6: Online DDL operations
  - ALTER TABLE my_table ADD INDEX my_table__idx (my_column), **ALGORITHM=INPLACE, LOCK=NONE;**
  - Create an index on a huge MySQL production table without table locking - Stack Overflow
  - At the end of the index creation process, there might be a small lock

1.3.4. Table Template

- What types of data?
- Business data
  - Id
  - Status
  - Name, …
- Technical data
  - Version
  - Created_at
  - …

1.3.4. Table Template: Common Columns

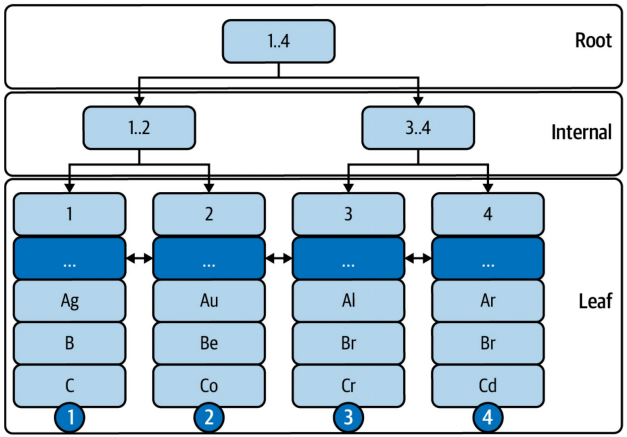
- (Business)
  - Id
  - Other columns
    - Grouping columns
  - **status**
- **data: json → scalability**
- (Technical)
  - version
  - created_at
  - created_by
  - updated_at
  - updated_by

```sql
CREATE TABLE user (
    user_id BIGINT NOT NULL
        AUTO_INCREMENT PRIMARY KEY ,
    name VARCHAR(100),
    age SMALLINT NOT NULL ,
    biography TEXT NULL ,
    status TINYINT NOT NULL ,
    data JSON NULL,
    created_at TIMESTAMP(3),
    created_by VARCHAR(100),
    updated_at TIMESTAMP(3),
    updated_by VARCHAR(100)
);
```

1.1. Data Types

1.1.1. Data Type / String

- VARCHAR:
  - Uses **only as much space as it needs**.
    Uses 1 or 2 extra bytes to record the value's length
  - Best: Short (< 255), frequently retrieved, infrequently update
  - Use cases: user name, subject, …
- TEXT, BLOB
  - InnoDB may use a separate "external" storage area for TEXT, BLOB
  - MySQL can **not index the full length** of these data types and can't use the indexes for sorting.
  - Best fits: Long, frequently update, …
  - Use case: logs, message, comments, …



1.1.2. Data Type / Number

- Integer:
  - SMALLINT, INT, BIGINT
  - Use small if possible
  - Correct Misunderstanding: For storage and computational purposes, INT(1) is identical to INT(9)
- Real number:
  - FLOAT, DOUBLE consume less bytes than DECIMAL
  - To store money:
    - Do not use FLOAT, DOUBLE.
    - The IEEE 754 standard uses **the closest value in base-2** to store
    - **Use DECIMAL and fractional number**
      → **accuracy**

1.1.3. Data Type / Date

- Timestamp:
  - Pros: consume less space
  - Cons: limitation of value range
  - Use cases: to record a (more or less) fixed point in time. Example: created_at
- Datetime:
  - Pros: readable, no limitation of value range
  - Cons: consume more space, depend time zone
  - Use cases: time can be set and changed arbitrarily. Example: appointment time
- Practices:
  - **Use a fractional seconds**
  - Save time zone in addition
  - **JVM time zone = OS time zone = DB time zone = time zone 0**

1.1.4. Choosing Data Types

- **Smaller** is usually better.
- **Simple** is good.
- **Avoid NULL** if possible. It’s harder for MySQL to optimize queries that refer to nullable columns, because they make indexes, index statistics, and value comparisons more complicated.

2. Case Studies

2.1. Multiple Languages

- Context: View a post in multi languages
- Requirements:
  - Simple schema, don't break schema when adding a new language
  - Easy to query

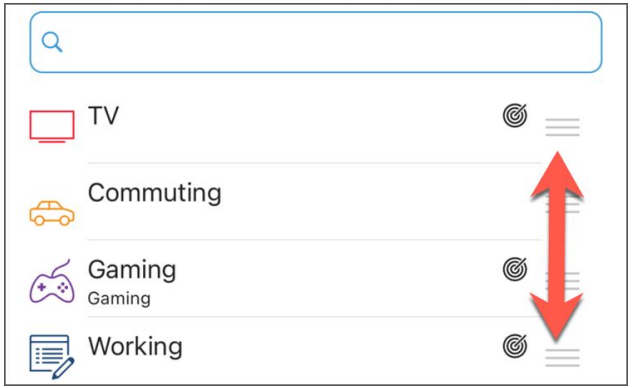
- Solution:
  - There are a several solutions
  - Towards an Evaluation Framework for Multilingual Supported Data Modeling Patterns
  - Suggestion: add a “translation” json column in the same table

id	original_title	title_translation

1	Engineer	{
		"vi": "Kỹ Sư",
		"en": "Engineer",
		"cn": "工程师"
		}

2.2. Ordering

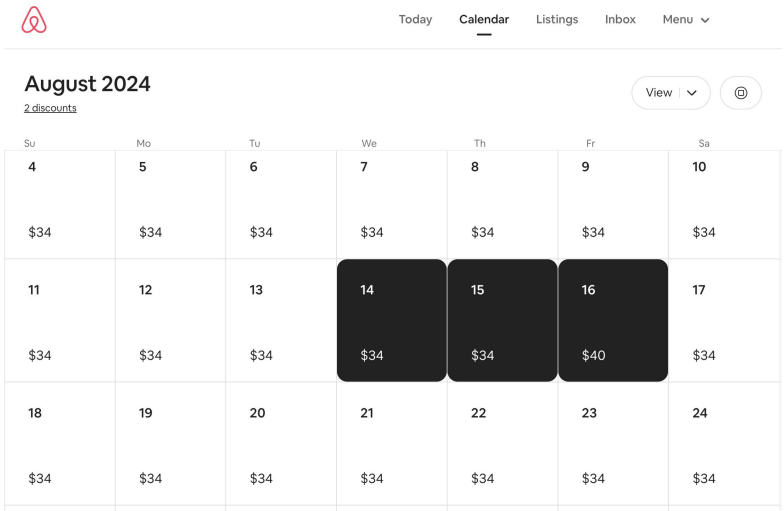
- Context: Reorder tasks in to-do list
- Requirements:
  - Easy to order
  - Less operations to update the order
- Solution:
  - Order column with the **gaps between values**
  - New order value = **(upper + lower) / 2**
- Problem:
  - No value between upper and lower values
  - Upper: 1001 and lower 1000
- Solution: use float



ID	Name	Order
1	TV	1000
4	Working	1500
2	Commuting	2000
3	Gaming	3000

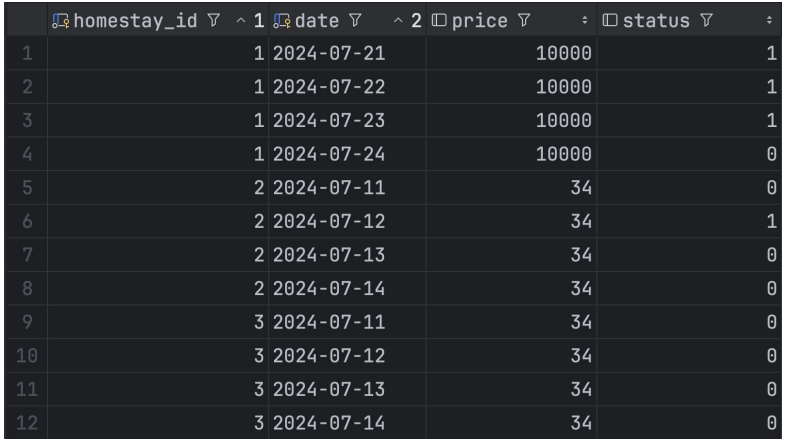
2.3. Homestay Booking

- Requirements:
  - Check status of a date.
  - Able to change price of a day.
- Solution:
  - Table homestay_availability
    - Homestay_id
    - Date
    - Price
    - Status
  - After creating a homestay, **generating 365 rows (1 year) in advance**.



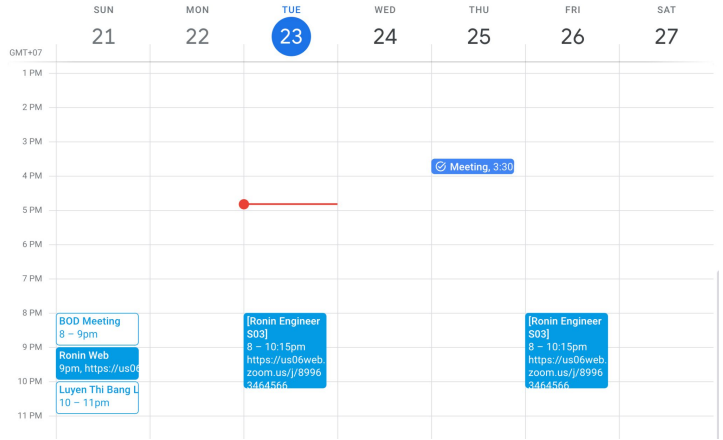
2.3. Homestay Booking

- Requirements:
  - Check status of a date.
  - Able to change price of a day.
- Solution:
  - Table homestay_availability
    - Homestay_id
    - Date
    - Price
    - Status
  - After creating a homestay,
    generating 365 rows (1 year) in advance.



	homestay_id 1	date 2	price	status
1	1	2024-07-21	10000	1
2	1	2024-07-22	10000	1
3	1	2024-07-23	10000	1
4	1	2024-07-24	10000	0
5	2	2024-07-11	34	0
6	2	2024-07-12	34	1
7	2	2024-07-13	34	0
8	2	2024-07-14	34	0
9	3	2024-07-11	34	0
10	3	2024-07-12	34	0
11	3	2024-07-13	34	0
12	3	2024-07-14	34	0

2.4. Calendar



- Requirements:
  - Create time based events
    - Start time, and time
    - Can be repeated daily, weekly, …
  - Query events in a specific week.

- Solution:
  - **Create time slots in advance**

```
CREATE TABLE time_slots (
  id INTEGER NOT NULL PRIMARY KEY AUTO_INCREMENT,
  time_event_id INTEGER NOT NULL,
  begin_local_time DATETIME NOT NULL,
  end_local_time DATETIME NOT NULL,
  timezone_id INTEGER NOT NULL
);
```

2.5. Tagging / Labeling

- Context: a post can have multiple tags
- Requirements:
  - (1) Get all tags of a post
  - (2) Get all posts by a tag
  - (1) > (2)
- Solution:
  - (1) Create a new table to present many-to-many relationships
  - (2) Suggestion: (Postgres)
    - Column tags: **array**
    - **Create inverted index**

id	title	tags
34	Ronin Engineer	[technical, software, it, …]

2.6. Report

- Context: Count total clicks in last day
- Requirements:
  - Response time
  - Accuracy
- Solution:
  - Approximate:
    - **Statistics**
    - Hyperloglog
  - Cron job to sum clicks
  - Material view (sum clicks async)
  - Stream processing (real-time)

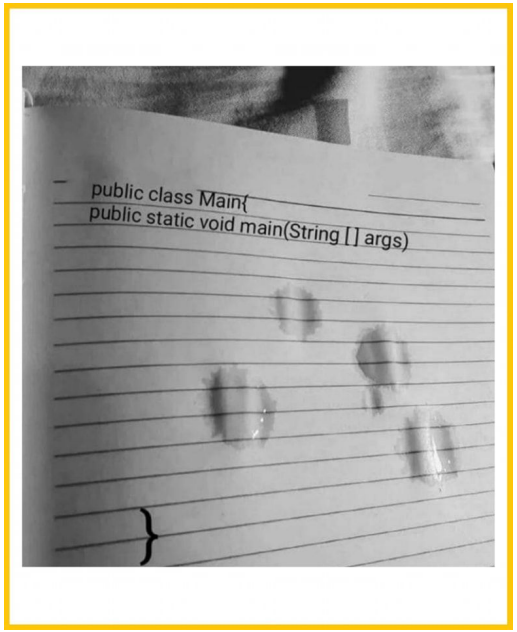
Recap

- Leverage JSON if possible.
- Not Normalization or Denormalization.

  Normalization and Denormalization.
- Query a specific datetime easily, consider to generate time slot in advance.

Homework

- Design schema for
  - Booking flights
- Use the suggested table template



References

- https://stackoverflow.com/questions/42513839/mysql-view-performance-temptable-or-merge
- https://stackoverflow.com/questions/2023481/mysql-large-varchar-vs-text
- https://stackoverflow.com/questions/4244685/create-an-index-on-a-huge-mysql-production-table-without-table-locking
- https://dba.stackexchange.com/questions/261752/adding-indexes-to-very-large-tables-in-mysql

Thank you 🙏

2. View

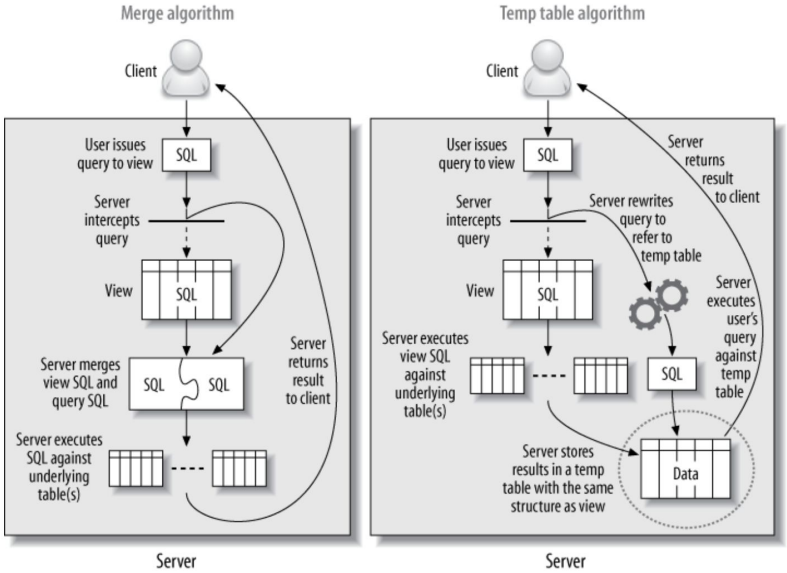
1.1. Introduction

- A view is a virtual table that **doesn’t store any data** itself.
- Instead, the **data in the base table**.
- Syntax:
  CREATE VIEW simple_bookings AS
  SELECT book_ref, date(book_date), total_amount
  FROM bookings;
- **Normally, view is not updatable**.
- There is a type of updatable views, but this is not recommended.

1.2. How View Works?

Processing Algorithm:

1. **MERGE** (by default):
    1.1. Merge user's SQL + view's SQL = Final SQL
    1.2. Execute the final SQL on base table (index).
2. **TEMPTABLE**:
    2.1. Execute view's SQL on base table
    2.2. Create temporary table
    2.3. Execute user's SQL on the temporary table (**no index in some case**).



1.3. Limitation

- Views might trick developers into thinking they’re simple, when in fact they’re very **complicated under the hood.**
- In some case, no index in used
- **MySQL does not support the materialized views**. A materialized view generally stores its results in an invisible table behind the scenes, with periodic updates to refresh the invisible table from the source data

1.4. Practices

- Use Cases:
  - Simplify complex query (**join, function,**…)
  - **Add extra security layers**
    - HR can only view user profile
    - Accountant can view user balance
  - Enable backward compatibility
- Best Practices:
  - Use merge view for read
  - Check execution plan of SQL on views