Star and snowflake schema

DATABASE DESIGN

SQL

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Star schema

Dimensional modeling: star schema

Fact tables

- Holds records of a metric
- Changes regularly
- Connects to dimensions via foreign keys

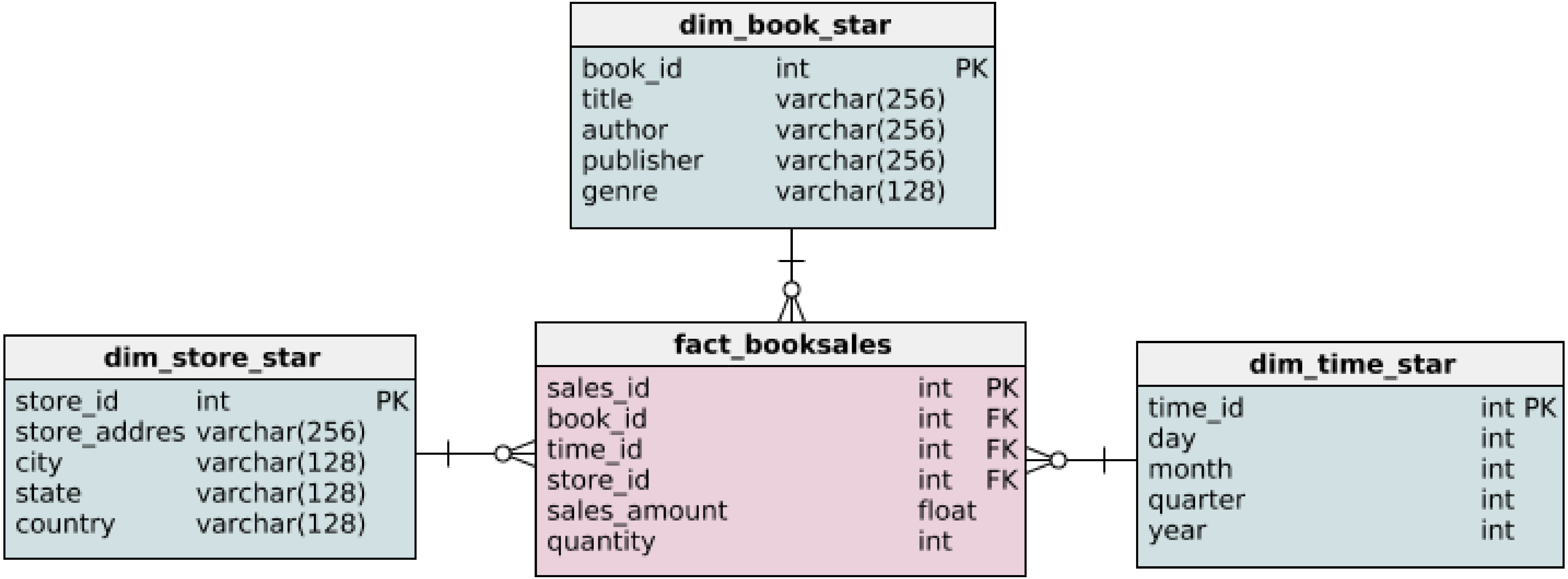
Dimension tables

- Holds descriptions of attributes
- Does not change as often

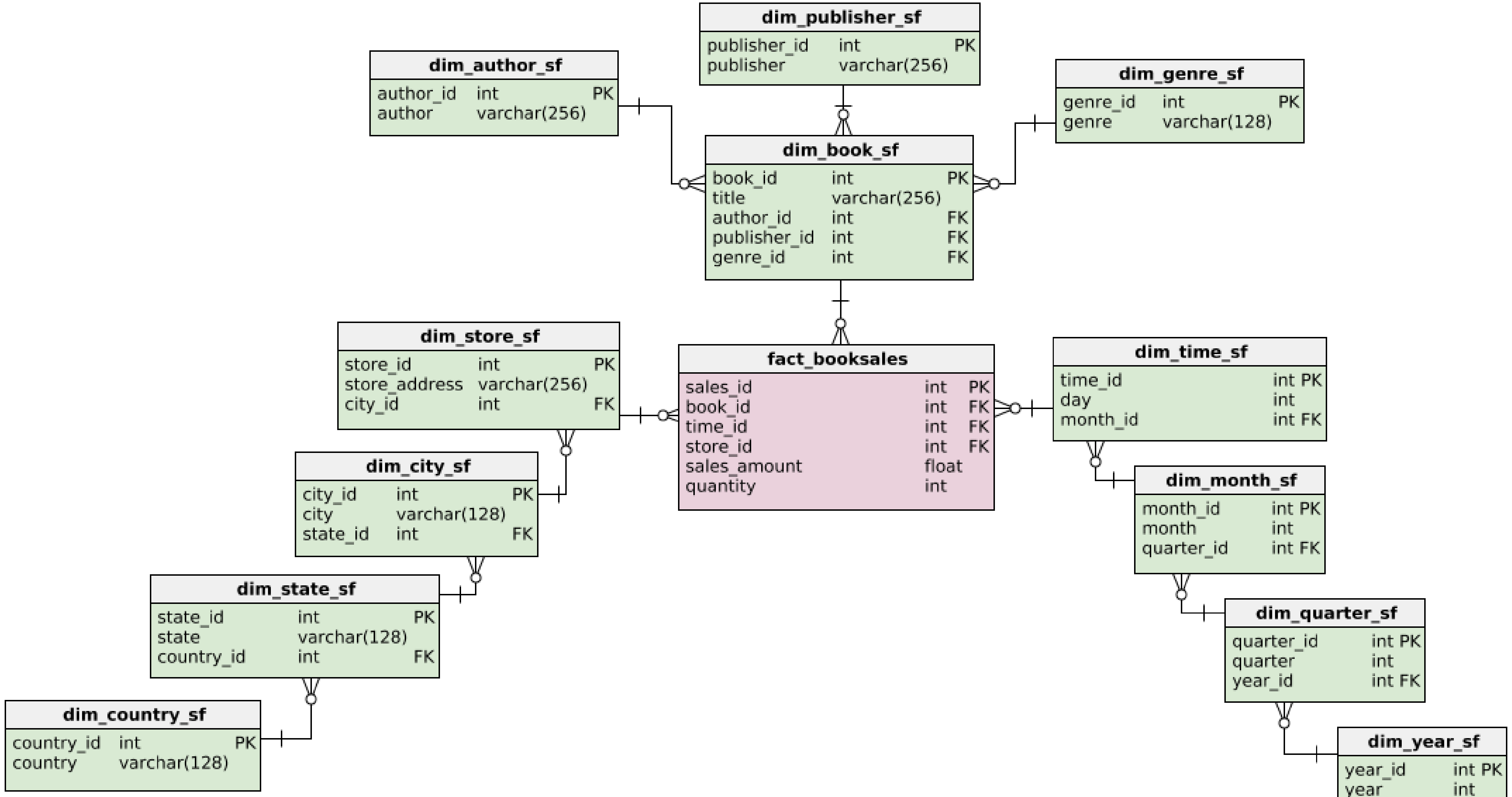
Example:

- Supply books to stores in USA and Canada
- Keep track of book sales

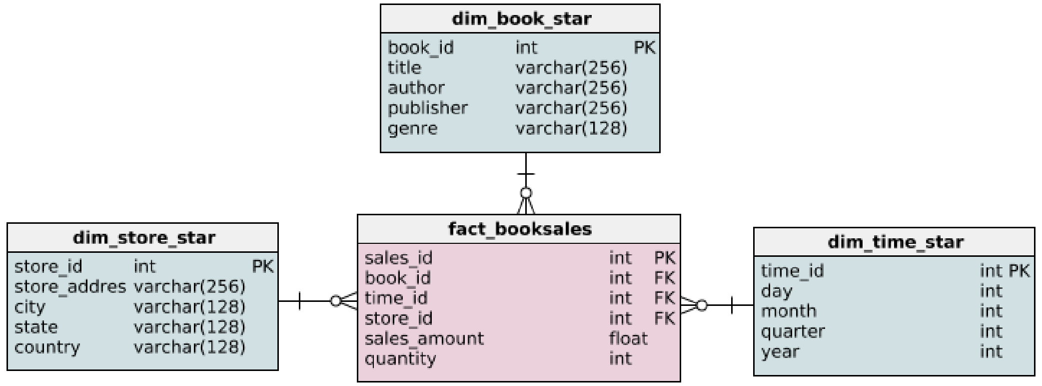
Star schema example

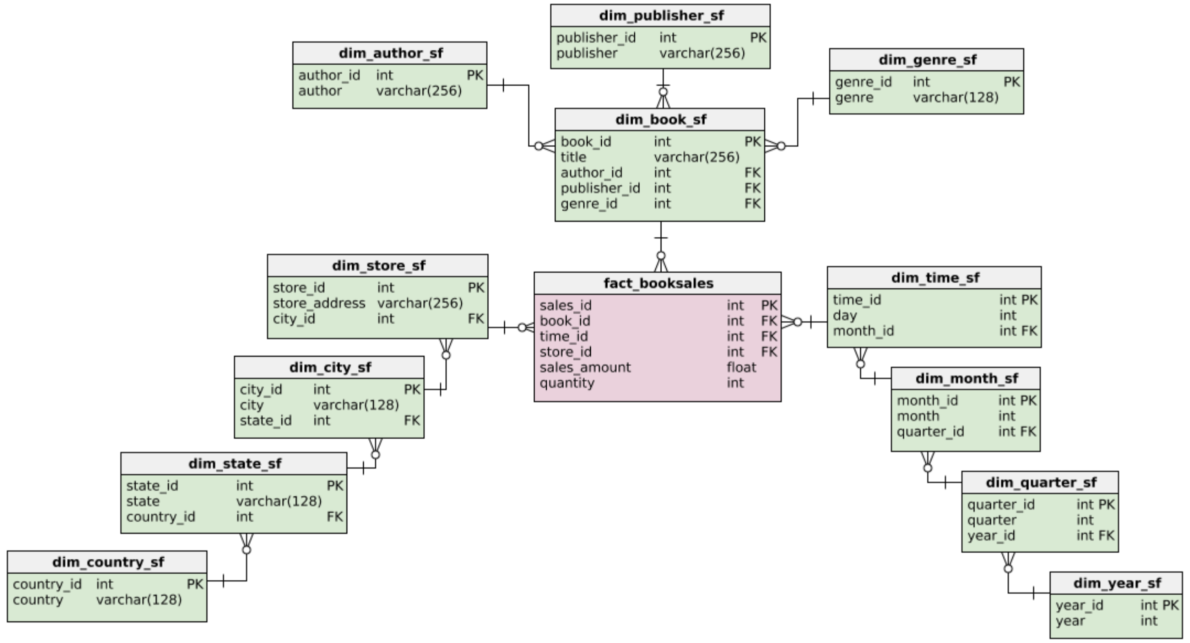


Snowflake schema (an extension)



Same fact table, different dimensions





Star schemas: one dimension

Snowflake schemas: more than one dimension

Because dimension tables are ***normalized***

What is normalization?

- Database design technique
- Divides tables into smaller tables and connects them via relationships
- **Goal:** reduce redundancy and increase data integrity

What is normalization?

- Database design technique
- Divides tables into smaller tables and connects them via relationships
- **Goal:** reduce redundancy and increase data integrity

Identify repeating groups of data and create new tables for them

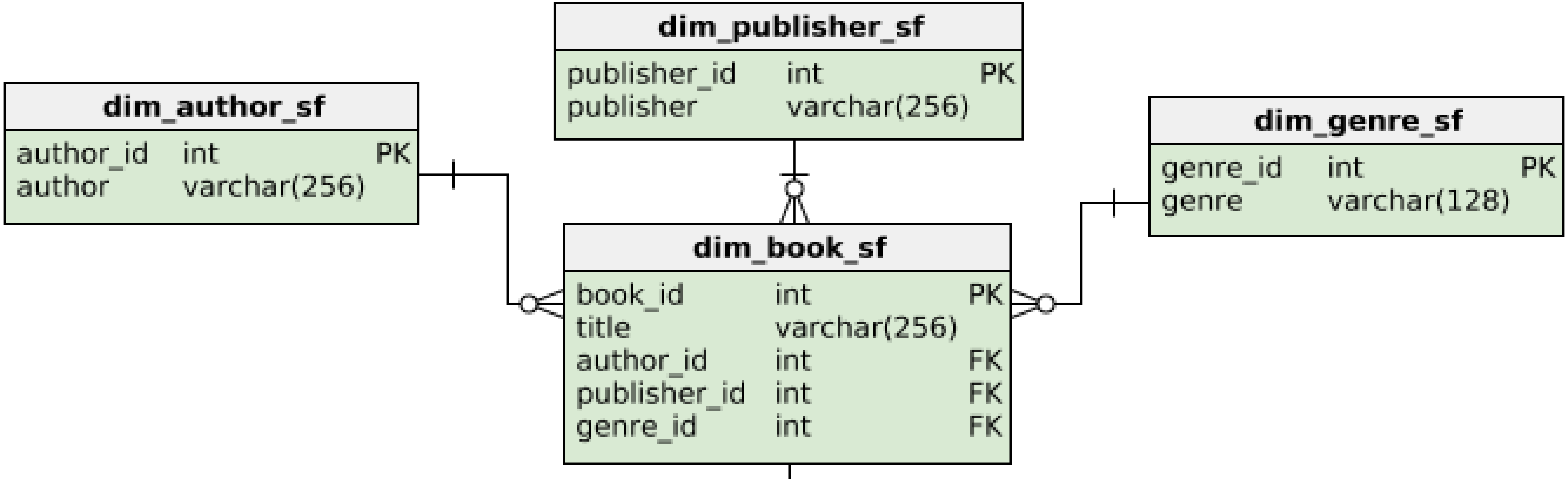
Book dimension of the star schema

dim_book_star		
book_id	int	PK
title	varchar(256)	
author	varchar(256)	
publisher	varchar(256)	
genre	varchar(128)	

Most likely to have repeating values:

- Author
- Publisher
- Genre

Book dimension of the snowflake schema

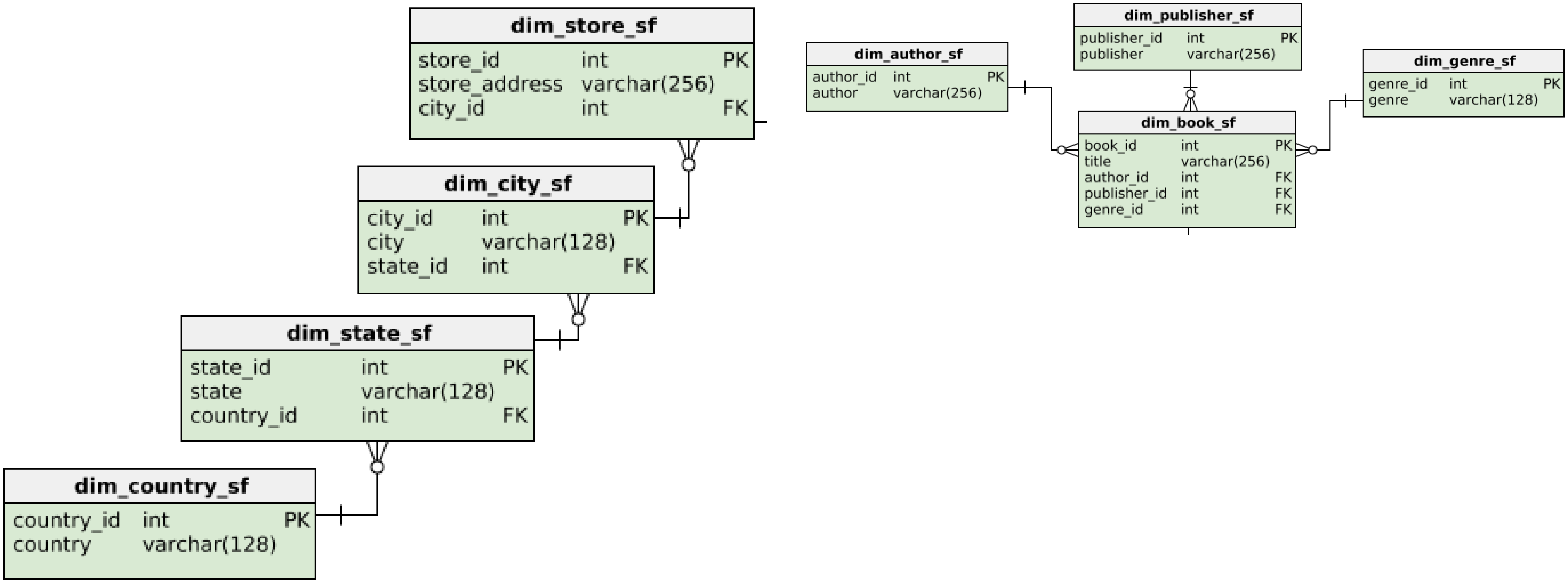


Store dimension of the star schema

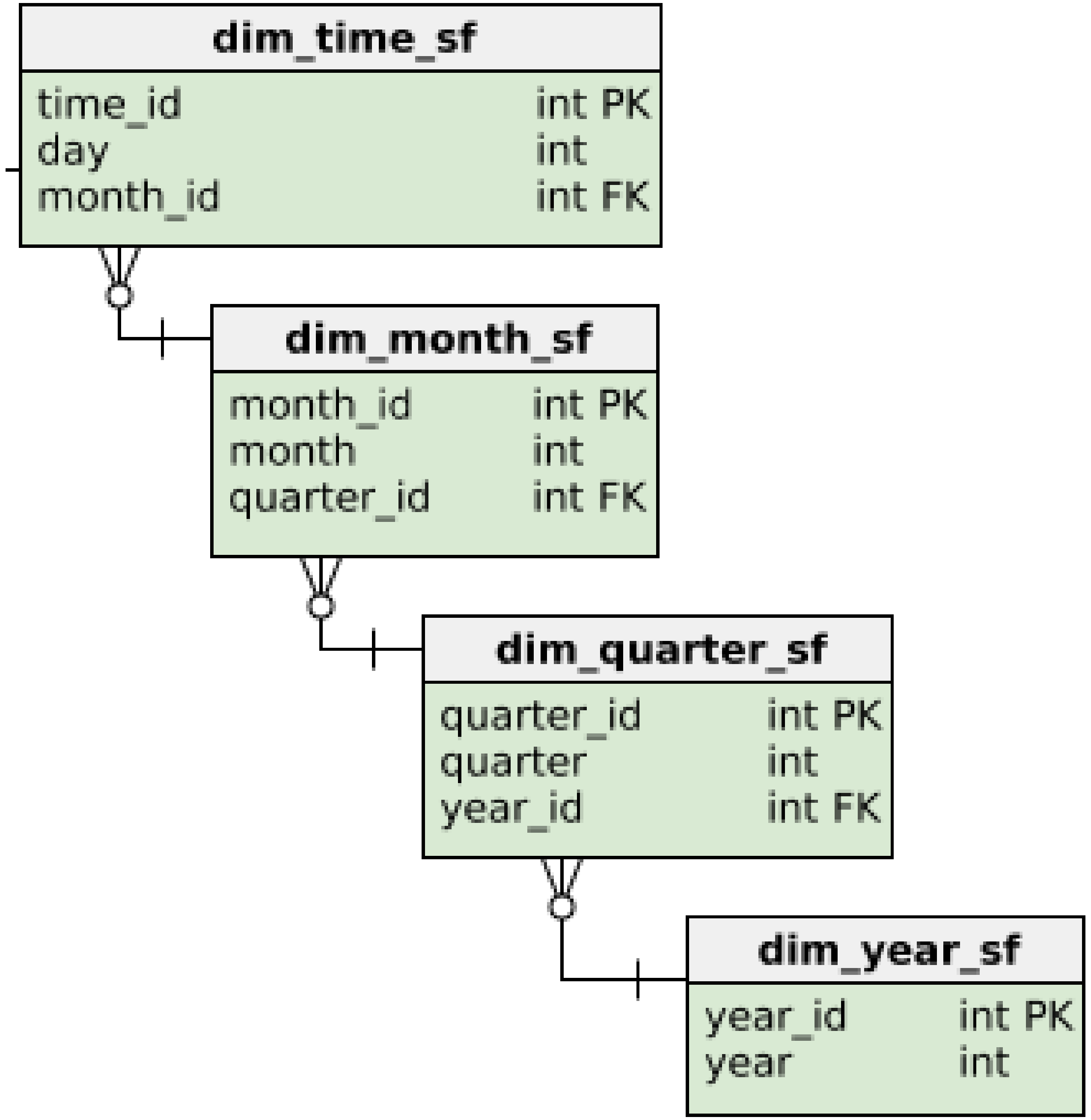
dim_store_star		
store_id	int	PK
store_addres	varchar(256)	
city	varchar(128)	
state	varchar(128)	
country	varchar(128)	

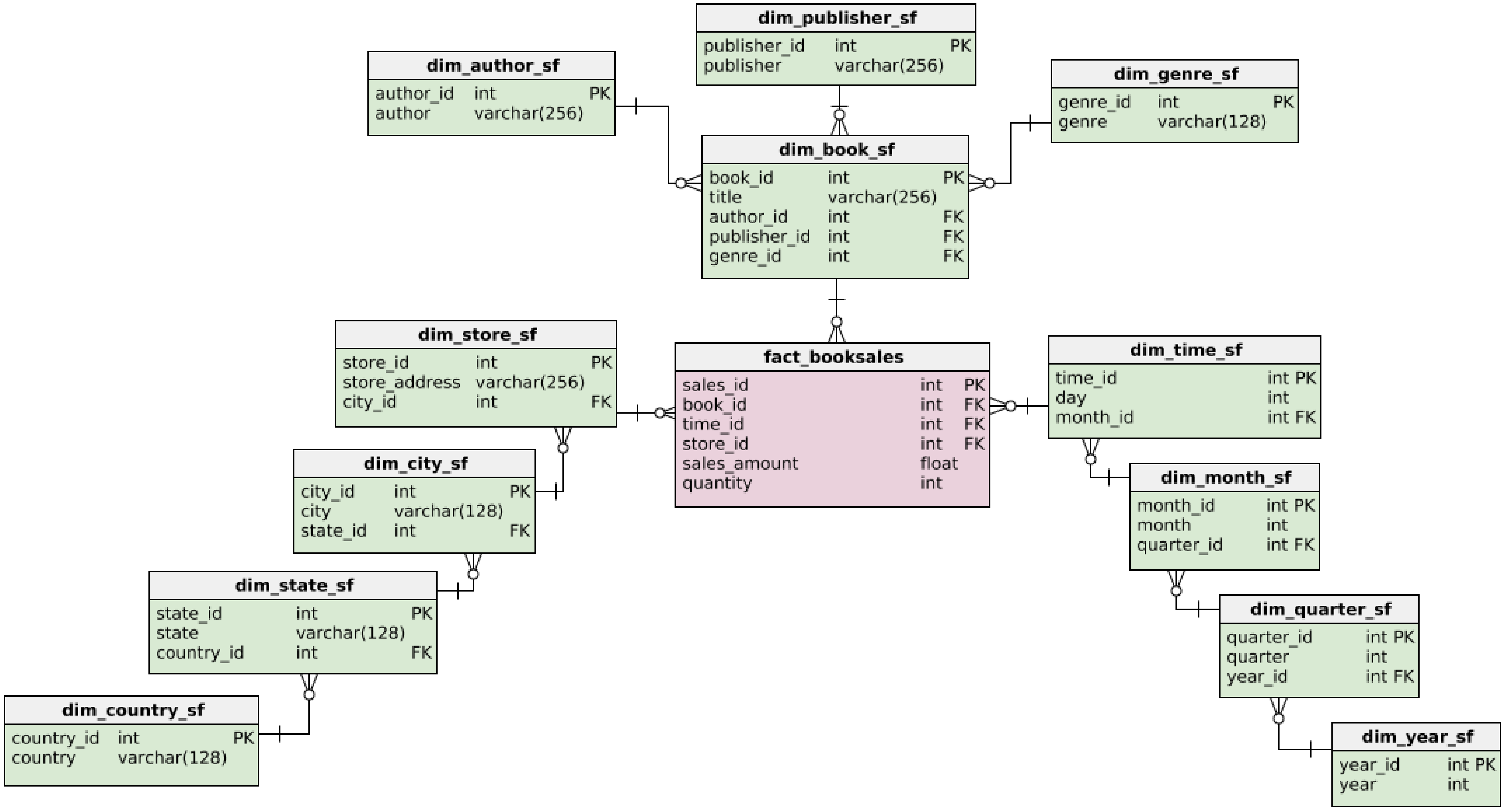
- City
- State
- Country

Store dimension of the snowflake schema




dim_time_star
time_id int PK
day int
month int
quarter int
year int


dim_time_sf
time_id int PK
day int
month_id int FK
dim_month_sf
month_id int PK
month int
quarter_id int FK
dim_quarter_sf
quarter_id int PK
quarter int
year_id int FK
dim_year_sf
year_id int PK
year int


dim_author_sf
author_id int PK
author varchar(256)
dim_publisher_sf
publisher_id int PK
publisher varchar(256)
dim_genre_sf
genre_id int PK
genre varchar(128)
dim_book_sf
book_id int PK
title varchar(256)
author_id int FK
publisher_id int FK
genre_id int FK
dim_store_sf
store_id int PK
store_address varchar(256)
city_id int FK
fact_booksales
sales_id int PK
book_id int FK
time_id int FK
store_id int FK
sales_amount float
quantity int
dim_time_sf
time_id int PK
day int
month_id int FK
dim_city_sf
city_id int PK
city varchar(128)
state_id int FK
dim_month_sf
month_id int PK
month int
quarter_id int FK
dim_state_sf
state_id int PK
state varchar(128)
country_id int FK
dim_quarter_sf
quarter_id int PK
quarter int
year_id int FK
dim_country_sf
country_id int PK
country varchar(128)
dim_year_sf
year_id int PK
year int

Let's practice!

DATABASE DESIGN

Normalized and denormalized databases

DATABASE DESIGN

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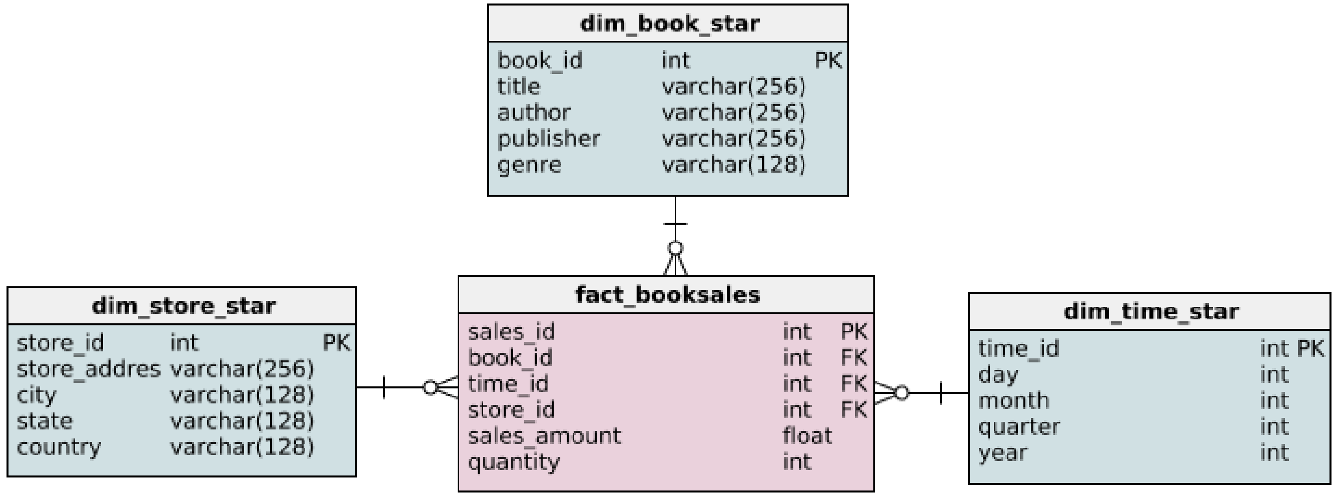
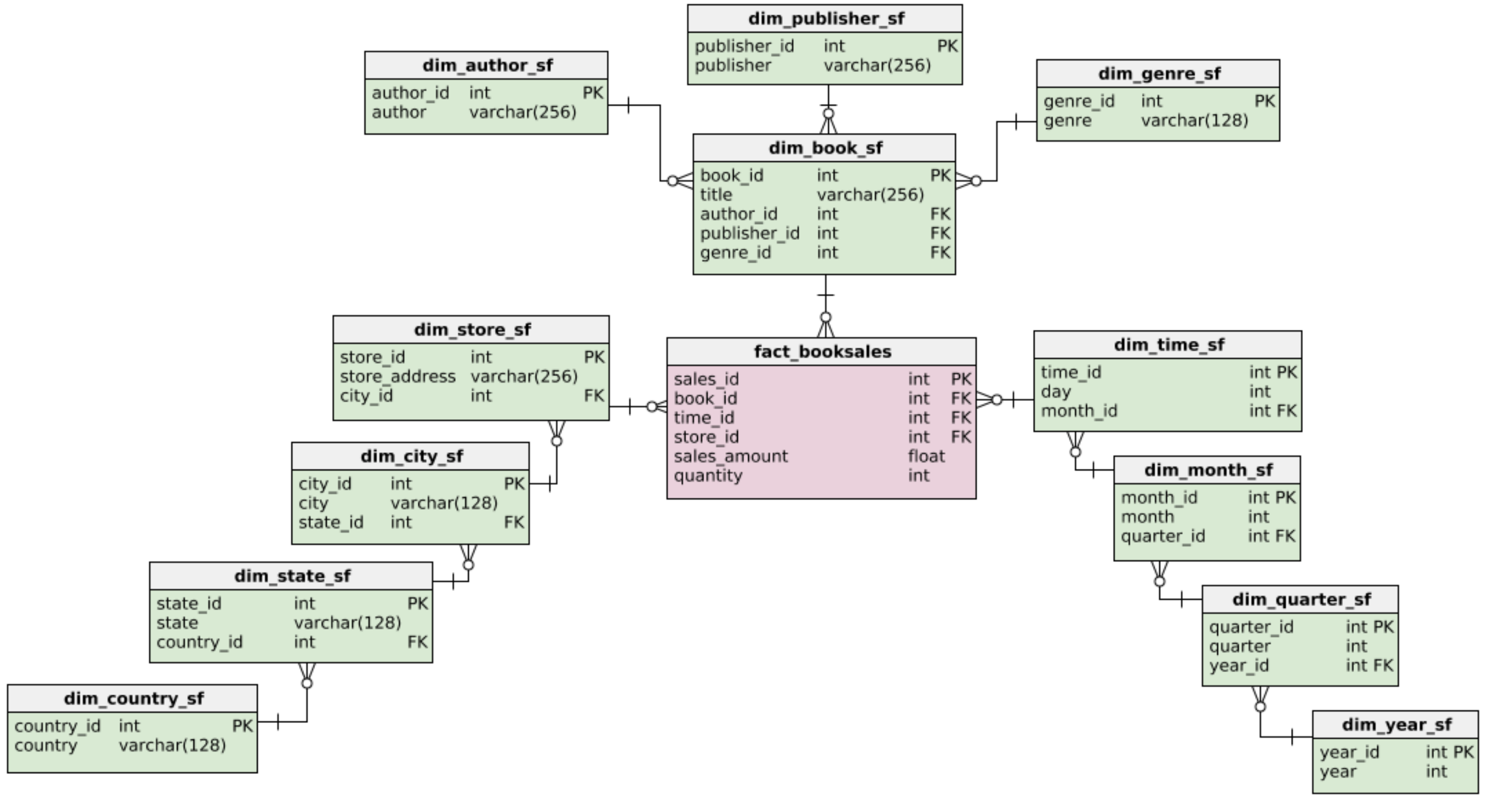
Back to our book store example

Denormalized: star schema



Normalized: snowflake schema



Denormalized Query

Goal: get quantity of all Octavia E. Butler books sold in Vancouver in Q4 of 2018

```sql
SELECT SUM(quantity) FROM fact_booksales
  -- Join to get city
  INNER JOIN dim_store_star on fact_booksales.store_id = dim_store_star.store_id
  -- Join to get author
  INNER JOIN dim_book_star on fact_booksales.book_id = dim_book_star.book_id
  -- Join to get year and quarter
  INNER JOIN dim_time_star on fact_booksales.time_id = dim_time_star.time_id
WHERE
  dim_store_star.city = 'Vancouver' AND dim_book_star.author = 'Octavia E. Butler' AND
  dim_time_star.year = 2018 AND dim_time_star.quarter = 4;
```

```
7600
```

Total of 3 joins

Normalized query

```
SELECT
  SUM(fact_booksales.quantity)
FROM
  fact_booksales
  -- Join to get city
  INNER JOIN dim_store_sf ON fact_booksales.store_id = dim_store_sf.store_id
  INNER JOIN dim_city ON dim_store_sf.city_id = dim_city_sf.city_id
  -- Join to get author
  INNER JOIN dim_book_sf ON fact_booksales.book_id = dim_book_sf.book_id
  INNER JOIN dim_author_sf ON dim_book_sf.author_id = dim_author_sf.author_id
  -- Join to get year and quarter
  INNER JOIN dim_time_sf ON fact_booksales.time_id = dim_time_sf.time_id
  INNER JOIN dim_month_sf ON dim_time_sf.month_id = dim_month_sf.month_id
  INNER JOIN dim_quarter_sf ON dim_month_sf.quarter_id =  dim_quarter_sf.quarter_id
  INNER JOIN dim_year_sf ON dim_quarter_sf.year_id = dim_year_sf.year_id
```

Normalized query (continued)

```
WHERE
  dim_city_sf.city = `Vancouver`
  AND
  dim_author_sf.author = `Octavia E. Butler`
  AND
  dim_year_sf.year = 2018 AND dim_quarter_sf.quarter = 4;
```

```
sum
7600
```

Total of 8 joins

So, why would we want to normalize a databases?

Normalization saves space

dim_store_star

id	store_address	city	state	country
1	67 First St	**Brooklyn**	**New York**	**USA**
2	12 Jefferson Rd	San Francisco	**California**	**USA**
3	90 Coolidge St	Los Angeles	**California**	**USA**
4	85 Main Ave	**Brooklyn**	**New York**	**USA**
5	123 Bedford St	**Brooklyn**	**New York**	**USA**

Denormalized databases enable **data redundancy**

Normalization saves space

dim_store_sf

id	store_address	city_id
1	67 First St	2
2	12 Jefferson Rd	3
3	90 Coolidge St	4
4	85 Main Ave	2
5	123 Bedford St	2

dim_city_sf

city_id	city_name	state_id
2	Brooklyn	43
3	San Francisco	36
4	Los Angeles	36

dim_state_sf

state_id	state	country_id
43	New York	121
36	California	121

Normalization eliminates **data redundancy**

Normalization ensures better data integrity

1. Enforces data consistency

Must respect naming conventions because of referential integrity, e.g., 'California', not 'CA' or 'california'

2. Safer updating, removing, and inserting

Less data redundancy = less records to alter

3. Easier to redesign by extending

Smaller tables are easier to extend than larger tables

Database normalization

Advantages

- Normalization eliminates data redundancy: save on storage
- Better data integrity: accurate and consistent data

Disadvantages

- Complex queries require more CPU

Remember OLTP and OLAP?

OLTP

e.g., Operational databases

Typically highly normalized

- Write-intensive
- Prioritize quicker and safer insertion of data

OLAP

e.g., Data warehouses

Typically less normalized

- Read-intensive
- Prioritize quicker queries for analytics

Let's practice!

DATABASE DESIGN

Normal forms

DATABASE DESIGN

SQL

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Normalization

Identify repeating groups of data and create new tables for them

A more formal definition:

> The goals of normalization are to:
>
> - Be able to characterize the level of redundancy in a relational schema
> - Provide mechanisms for transforming schemas in order to remove redundancy

[1] Database Design, 2nd Edition by Adrienne Watt

Normal forms (NF)

Ordered from least to most normalized:

- First normal form (1NF)
- Second normal form (2NF)
- Third normal form (3NF)
- Elementary key normal form (EKNF)
- Boyce-Codd normal form (BCNF)
- Fourth normal form (4NF)
- Essential tuple normal form (ETNF)
- Fifth normal form (5NF)
- Domain-key Normal Form (DKNF)
- Sixth normal form (6NF)

[1] https://en.wikipedia.org/wiki/Database_normalization

1NF rules

- Each record must be unique - no duplicate rows
- Each cell must hold one value

Initial data

```
| Student_id | Student_Email   | Courses_Completed                                     |
|------------|-----------------|-------------------------------------------------------|
| 235        | jim@gmail.com   | Introduction to Python, Intermediate Python           |
| 455        | kelly@yahoo.com | Cleaning Data in R                                    |
| 767        | amy@hotmail.com | Machine Learning Toolbox, Deep Learning in Python     |
```

In 1NF form

```
| Student_id | Student_Email   |
|------------|-----------------|
| 235        | jim@gmail.com   |
| 455        | kelly@yahoo.com |
| 767        | amy@hotmail.com |
```

```
| Student_id | Completed                  |
|------------|----------------------------|
| 235        | Introduction to Python     |
| 235        | Intermediate Python        |
| 455        | Cleaning Data in R         |
| 767        | Machine Learning Toolbox   |
| 767        | Deep Learning in Python    |
```

2NF

- Must satisfy 1NF **AND**
  - If primary key is one column
    - then automatically satisfies 2NF
  - If there is a composite primary key
    - then each non-key column must be dependent on all the keys

Initial data

```
| Student_id (PK) | Course_id (PK) | Instructor_id | Instructor    | Progress |
|-----------------|----------------|---------------|---------------|----------|
| 235             | 2001           | 560           | Nick Carchedi | .55      |
| 455             | 2345           | 658           | Ginger Grant  | .10      |
| 767             | 6584           | 999           | Chester Ismay | 1.00     |
```

In 2NF form

Student_id (PK)	Course_id (PK)	Percent_Completed
235	2001	.55
455	2345	.10
767	6584	1.00

Course_id (PK)	Instructor_id	Instructor
2001	560	Nick Carchedi
2345	658	Ginger Grant
6584	999	Chester Ismay

3NF

- Satisfies 2NF
- No **transitive dependencies:** non-key columns can't depend on other non-key columns

Initial Data

```
| Course_id (PK) | Instructor_id | Instructor    | Tech   |
|----------------|---------------|---------------|--------|
| 2001           | 560           | Nick Carchedi | Python |
| 2345           | 658           | Ginger Grant  | SQL    |
| 6584           | 999           | Chester Ismay | R      |
```

In 3NF

Course_id (PK)	Instructor	Tech
2001	Nick Carchedi	Python
2345	Ginger Grant	SQL
6584	Chester Ismay	R

Instructor_id	Instructor
560	Nick Carchedi
658	Ginger Grant
999	Chester Ismay

Data anomalies

What is risked if we don't normalize enough?

1. Update anomaly

2. Insertion anomaly

3. Deletion anomaly

Update anomaly

Data inconsistency caused by data redundancy when updating

Student_ID	Student_Email	Enrolled_in	Taught_by
230	lisa@gmail.com	Cleaning Data in R	Maggie Matsui
367	bob@hotmail.com	Data Visualization in R	Ronald Pearson
520	ken@yahoo.com	Introduction to Python	Hugo Bowne-Anderson
520	ken@yahoo.com	Arima Models in R	David Stoffer

To update student `520` 's email:

- Need to update more than one record, otherwise, there will be inconsistency
- User updating needs to know about redundancy

Insertion anomaly

Unable to add a record due to missing attributes

Student_ID	Student_Email	Enrolled_in	Taught_by
230	lisa@gmail.com	Cleaning Data in R	Maggie Matsui
367	bob@hotmail.com	Data Visualization in R	Ronald Pearson
520	ken@yahoo.com	Introduction to Python	Hugo Bowne-Anderson
520	ken@yahoo.com	Arima Models in R	David Stoffer

Unable to insert a student who has signed up but not enrolled in any courses

Deletion anomaly

Deletion of record(s) causes unintentional loss of data

```
| Student_ID | Student_Email   | Enrolled_in             | Taught_by            |
|------------|-----------------|-------------------------|----------------------|
| 230        | lisa@gmail.com  | Cleaning Data in R      | Maggie Matsui        |
| 367        | bob@hotmail.com | Data Visualization in R | Ronald Pearson       |
| 520        | ken@yahoo.com   | Introduction to Python  | Hugo Bowne-Anderson  |
| 520        | ken@yahoo.com   | Arima Models in R       | David Stoffer        |
```

If we delete Student `230`, what happens to the data on `Cleaning Data in R`?

Data anomalies

What is risked if we don't normalize enough?

1. **Update anomaly**

2. **Insertion anomaly**

3. **Deletion anomaly**

The more normalized the database, the less prone it will be to data anomalies

Don't forget the downsides of normalization from the last video

Let's practice!

DATABASE DESIGN