NUS | Computing

National University of Singapore

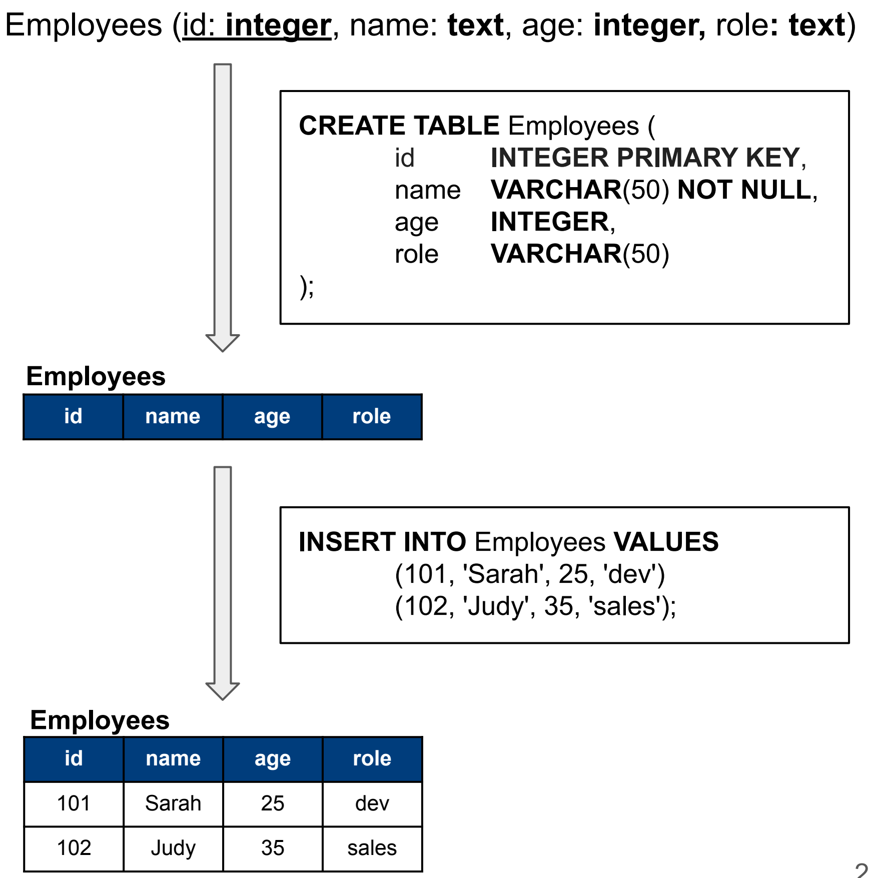
CS2102: Database Systems

Lecture 3 — Entity Relationship Model (ER Model)

Quick Recap: SQL for Creating Databases

- Data Definition Language (DDL)
  - Create, modify and drop tables
    to implement a given DB schema
  - Specify integrity constraints
    (e.g., **NOT NULL**, **PRIMARY KEY**, **FOREIGN KEY**, **CHECK**)

- Data Manipulation Language (DML)
  - Insert, update and delete data from tables



Employees (id: **integer**, name: **text**, age: **integer,** role**: text**)

```
CREATE TABLE Employees (
        id      INTEGER PRIMARY KEY,
        name    VARCHAR(50) NOT NULL,
        age     INTEGER,
        role    VARCHAR(50)
);
```

Employees

id	name	age	role

```
INSERT INTO Employees VALUES
        (101, 'Sarah', 25, 'dev')
        (102, 'Judy', 35, 'sales');
```

Employees

id	name	age	role
101	Sarah	25	dev
102	Judy	35	sales

We Sneakily Skipped a Step

- Open questions:
  - Where does the database schema come from?
  - What tables with which attributes do we need?
  - What data integrity constraints are required?
  - Table names, attribute names, data types, …?

➜ **Database Design Process**

Quick Quiz: Which table is "better"?

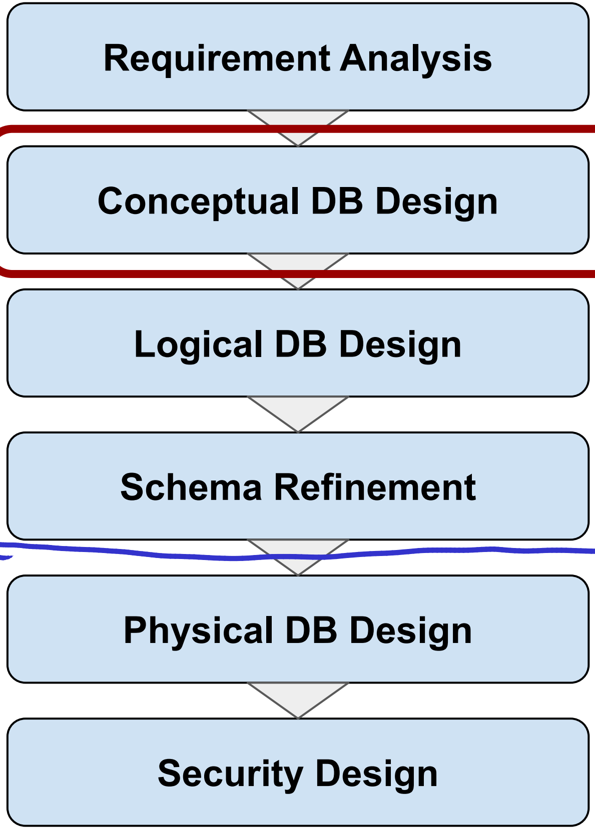
```
CREATE TABLE Employees (
        id      INTEGER PRIMARY KEY,
        name    VARCHAR(50) NOT NULL,
        age     INTEGER,
        role    VARCHAR(50)
);
```

or

✓

```
CREATE TABLE Employees (
        id      INTEGER PRIMARY KEY,
        name    VARCHAR(50) NOT NULL,
        dob     DATE,
        role    VARCHAR(100)
);
```

Database Design Process — 6 Common Steps



Requirement Analysis

- Identification and collection of user needs
- e.g., data / application / performance requirements

L3

Conceptual DB Design

- Capturing requirements using a conceptual model
- RDBMS: **Entity Relationship Model (ER Model)**

Logical DB Design

- Mapping conceptual model to logical schema of DBMS
- RDBMS: Entity Relationship Model → Relational Schema

2nd

Schema Refinement

- Checking schema / tables for redundancies and anomalies

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Physical DB Design

- Implementing database based on final data schema
- Consideration of performance requirements

Security Design

- Identification of users and user groups and their permissions to access which parts of the data

Overview

- **Entity Relationship Model**
  - **Overview + ER diagrams**
  - Entity sets and attributes
  - Relationship sets
  - Cardinality & participation constraints
  - Dependency constraints: weak entity sets
  - Aggregation
- Relational Mapping
  - From ER diagram to database tables
- Summary

Requirement Analysis: Online Airline Reservation System (OARS)

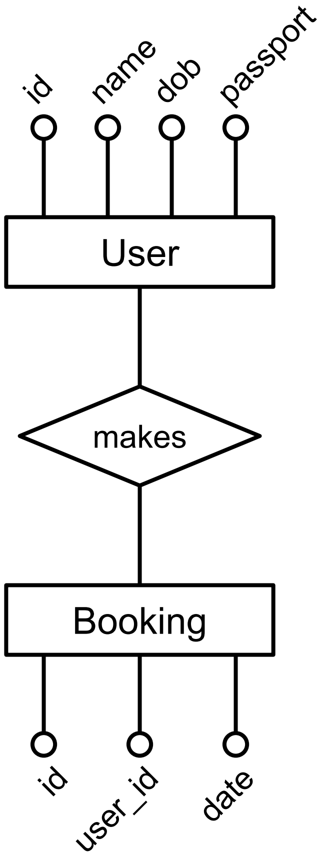
Users need to be able to make bookings from an origin to a destination airport which may comprise multiple connecting flights. Each flight has a flight number, the origin and destination airport, the distance in kilometers, the departure and arrival time, and the days of the week the flight is in operation.

A flight instance is the actual scheduled flight on a given day together with the assigned aircraft type. For example, flight SQ231 flies daily from Singapore to Sydney, typically with a Boeing 777-300ER (code: B77W).

For a valid booking, we need the user's name, sex, address, phone number(s), and the passport number. Users are only able to pay via credit card. When making a booking, the user can select the class, the seat number, as well as meal preferences (if available).

Entity Relationship Model

- ER Model
  - Most common model for conceptual database design
  - Developed by Peter Chen (1976)
  - Visualized using **ER diagrams**
    (Important: many revised version – no one single set of notations!)
- Core concepts
  - All data is described in terms of **entities** and their **relationships**
  - Information about entities & relationships are described using **attributes**
  - Certain data constraints can be described using additional annotations



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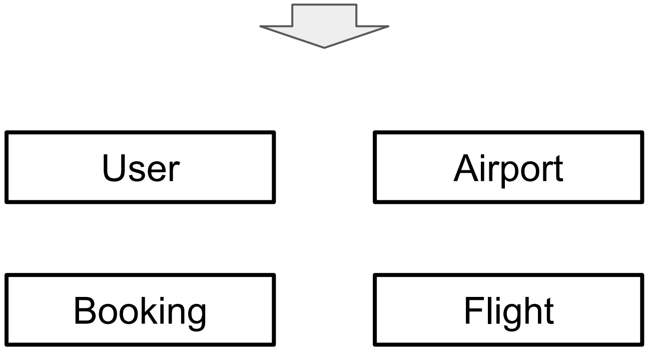
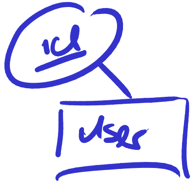
Entities and Entity Sets

- **Entity**
  - Real-world things or objects that are distinguishable from other objects (e.g., an individual user, airport, flight, or booking)
- **Entity Set**
  - Collection of entities of the same type
  - Represented by rectangles in ER diagrams
  - Names are typically nouns

Users *need to be able to make* ***bookings*** *from an origin to a destination* ***airport*** *which may comprise multiple connecting* ***flights****. Each flight has a flight number, [...]*



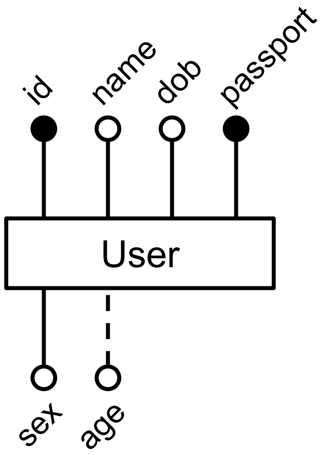
Attributes



- **Attribute**:
  - specific information describing an entity
  - represented by a small circle in ER diagrams

- 2 main subtypes of attributes
  - **Key attribute(s)**: uniquely identifies each entity
    - Indicated by a filled circle in ER diagram
    - Different attributes may uniquely identify an entity
    - Multiple attributes may form a composite key
  - **Derived attribute**: derived from other attributes
    - Indicated by a dashed line in ER diagram
    - Example: derive "age" from "dob"

> *For a valid booking, we need the **user's name**, **sex**, **address**, **phone number(s)**, and the **passport number**. Users are only able to pay via* credit card. *[...]*



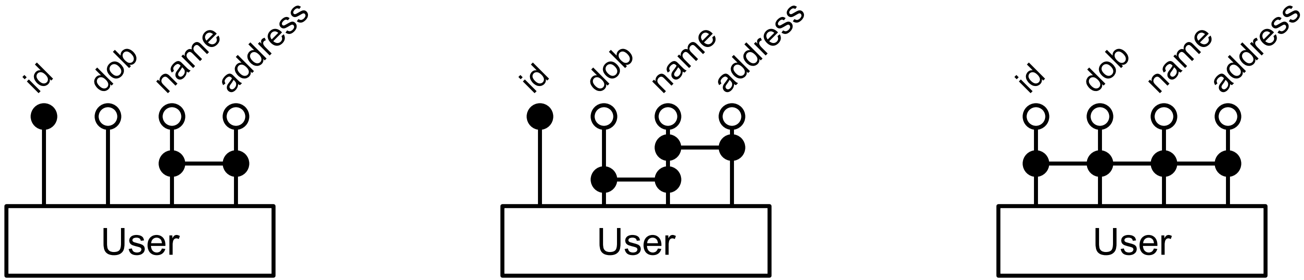
What about address and phone numbers?

Key Attributes

- **Composite** key attributes:
  - 2 or more attributes together uniquely identify each entity
  - An entity may have multiple composite key attributes
  - Representation in ER diagram: additional connecting line

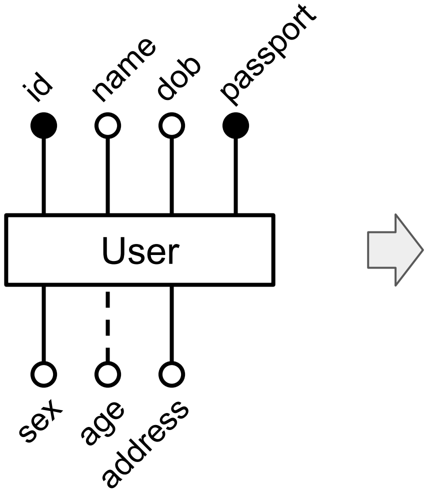
- Examples (for illustration purposes; not necessarily realistic!)

- At least all attributes uniquely identify an entity
- We typical prefer a minimum set of attributes



"Composite" Attributes

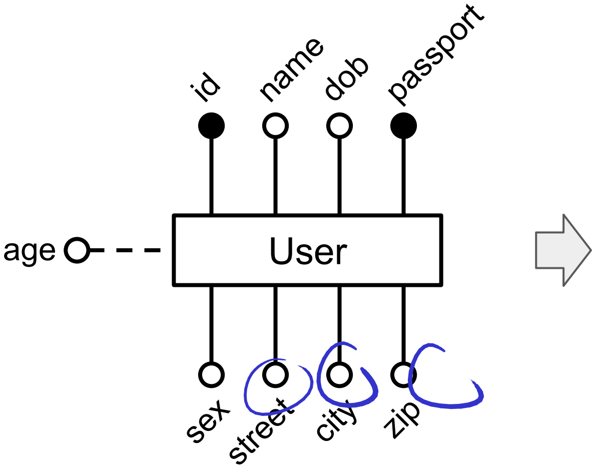
- Common: requirement analysis often vague / ambiguous / unclear
  - Not always obvious how certain attributes should be modeled
  - Example "address": single string attribute vs. multiple attributes



id	name	dob	age	sex	passport	address
101	Alice	15-02-2000	26	f	KEJR4A90	15 Computing Drive, Singapore 117418

"Composite" Attributes

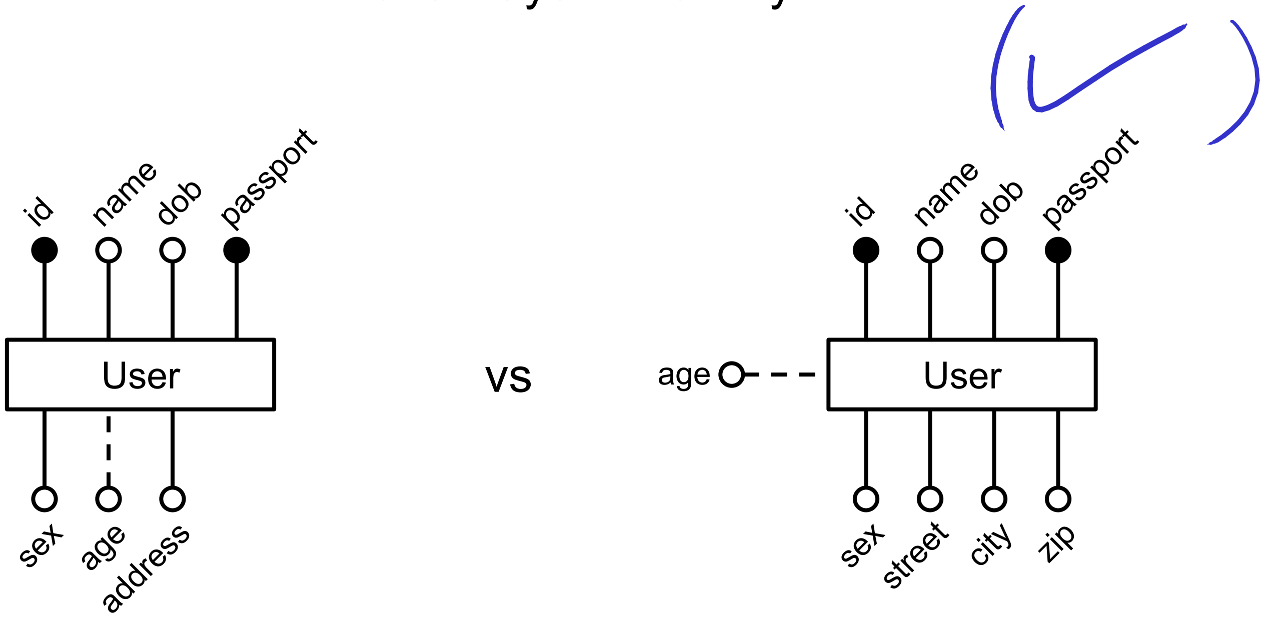
- Common: requirement analysis often vague / ambiguous / unclear
  - Not always obvious how certain attributes should be modeled
  - Example "address": single string attribute vs. multiple attributes



id	name	dob	age	sex	passport	street	city	zip
101	Alice	15-02-2000	26	f	KEJR4A90	15 Computing Drive	Singapore	117418

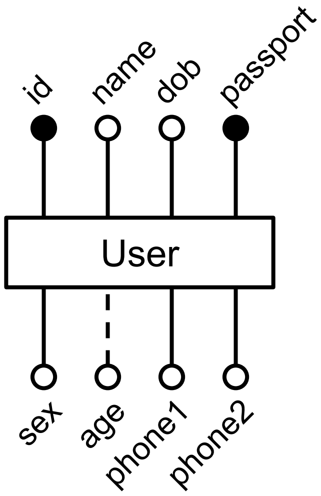
Quick Quiz

Which solution is typically the **preferred** one?
But always? And why?



Multivalued Attributes

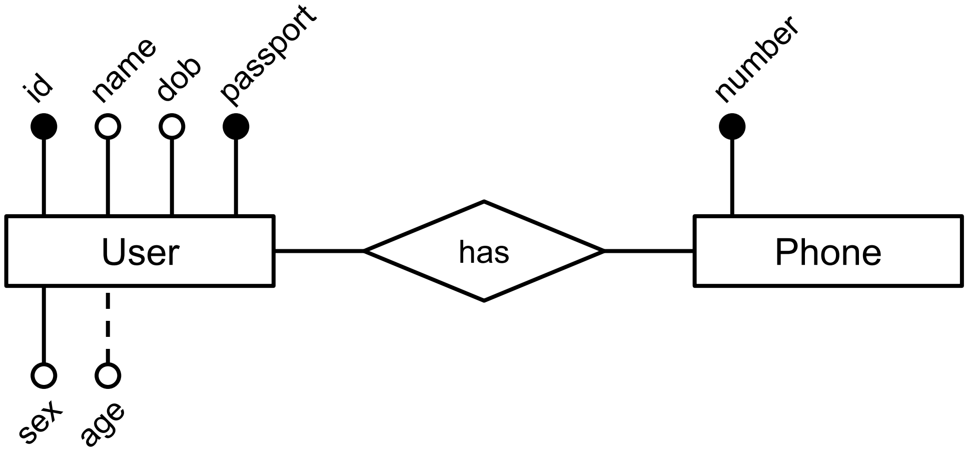
- Common: an attribute may refer to a set/list of values
  - Examples: phone numbers, hobbies, tags/keywords
  - However: all attributes must be single-valued
  - Example "phone numbers": fixed number of single-valued attributes vs. dedicated entity set



id	name	dob	age	sex	passport	phone1	phone2
101	Alice	15-02-2000	26	f	KEJR4A90	+65-1234-5678	+65-8765-4321

Multivalued Attributes

- Common: an attribute may refer to a set/list of values
  - Examples: phone numbers, hobbies, tags/keywords
  - However: all attributes must be single-valued
  - Example "phone numbers": fixed number of single-valued attributes vs. <u>dedicated entity set</u>



Quick Quiz

Which solution is typically the **preferred** one?

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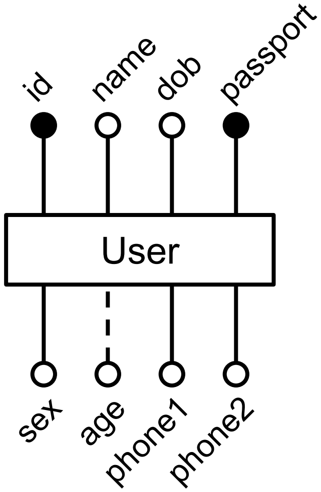
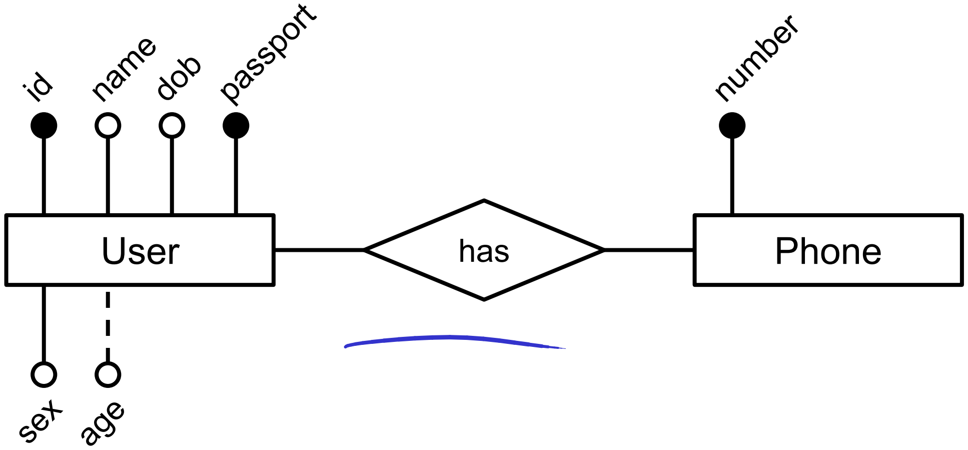


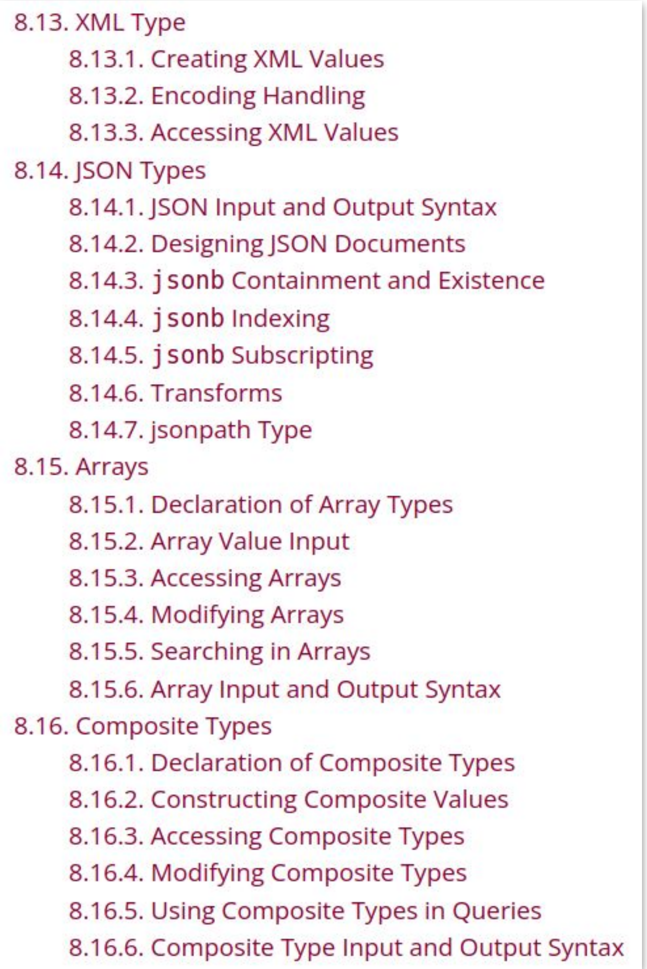
vs



Side Note

- PostgreSQL (and most modern RDBMS)
  - Not limited to basic single-valued data types
  - Support for complex / composite data types
  - Support for user-defined composite types

Quick Quiz: What are potential downsides of this more complex data types?



- 8.13. XML Type
  - 8.13.1. Creating XML Values
  - 8.13.2. Encoding Handling
  - 8.13.3. Accessing XML Values
- 8.14. JSON Types
  - 8.14.1. JSON Input and Output Syntax
  - 8.14.2. Designing JSON Documents
  - 8.14.3. jsonb Containment and Existence
  - 8.14.4. jsonb Indexing
  - 8.14.5. jsonb Subscripting
  - 8.14.6. Transforms
  - 8.14.7. jsonpath Type
- 8.15. Arrays
  - 8.15.1. Declaration of Array Types
  - 8.15.2. Array Value Input
  - 8.15.3. Accessing Arrays
  - 8.15.4. Modifying Arrays
  - 8.15.5. Searching in Arrays
  - 8.15.6. Array Input and Output Syntax
- 8.16. Composite Types
  - 8.16.1. Declaration of Composite Types
  - 8.16.2. Constructing Composite Values
  - 8.16.3. Accessing Composite Types
  - 8.16.4. Modifying Composite Types
  - 8.16.5. Using Composite Types in Queries
  - 8.16.6. Composite Type Input and Output Syntax

Source: PostgreSQL docs

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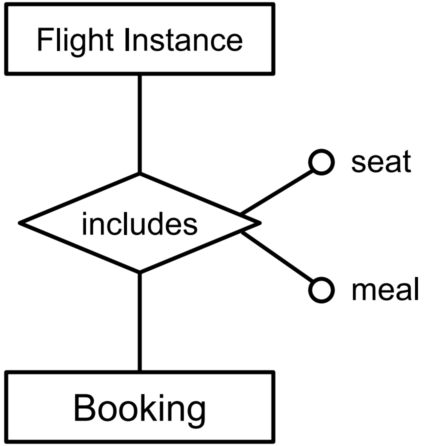
Relationships and Relationship Sets

- **Relationship**
  - Association among two or more entities

- **Relationship Set**
  - Collection of relationships of the same type
  - Represented by diamonds in ER diagrams
  - Can have their own attributes that further describe the relationship
  - Names are typically verbs

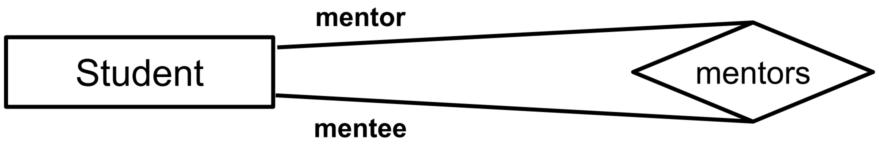


- Additional annotations to further specify relationships
  - Roles, degree, cardinalities, participation, dependencies

Relationship Roles

- **Role**
  - Descriptor of an entity set's participation in a relationship
  - Most of the time implicitly given by the name of the entity sets
  - Explicit role labels only common in case of ambiguities
    (typically in case the same entity sets participate in the same relationship more than once)

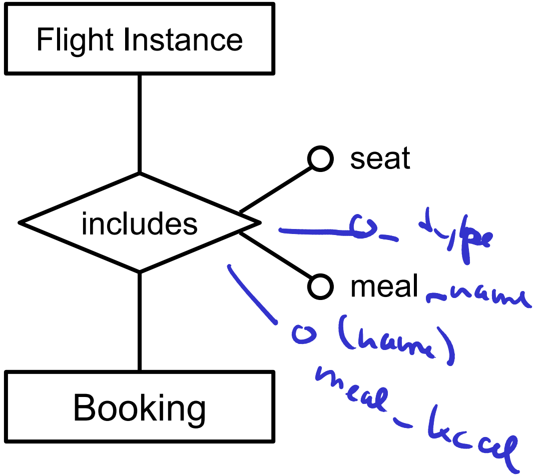
- Example: Students can mentor other students



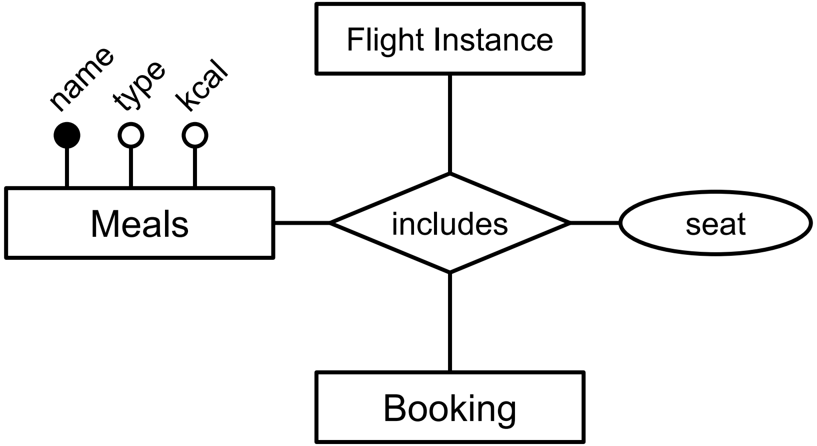
Degree of Relationship Sets

- **Degree**
  - In principle, no limitation on how many entity roles participate in a relationship
  - An *n*-ary relationship set involves *n* entity roles ➜ *n* = degree of relationship set

n = 2 ➜ binary relationship set

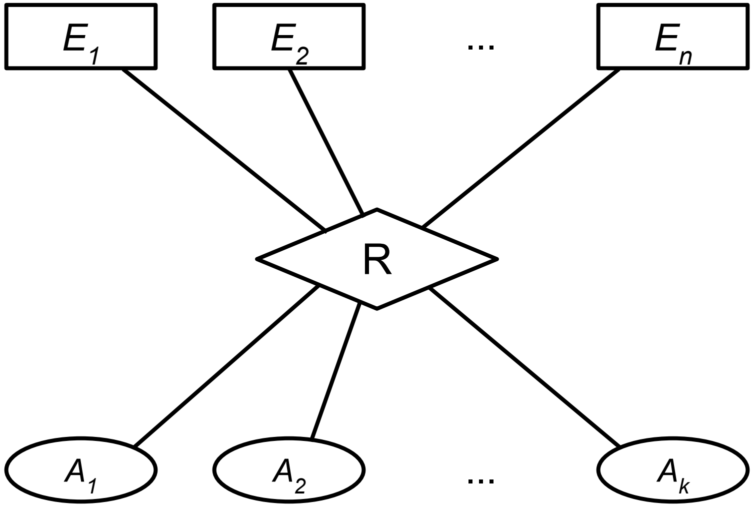


n = 3 ➜ ternary relationship set



Degree of Relationship Sets

- General n-ary relationship set R
  - *n* participating entity sets $E_1, E_2, \ldots, E_n$
  - *k* relationship attributes $A_1, A_2, \ldots, A_k$



"In typical modeling, binary relationships are the most common and relationships with n>3 are very rare" - Peter Chen (2009)

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Cardinality & Participation Constraints

- Cardinalities of Relationship Sets
  - Describe how often an entity can participate in a relationship <u>at most</u>
  - 3 basic cardinality constraints
    - **Many-to-many** (e.g., a flight can be performed by different aircrafts; an aircraft can perform different flights)
    - **Many-to-one** (e.g., a user can make many bookings, but each booking is done by one user)
    - **One-to-one** (e.g., a user is associated with one set of credit card details, and vice versa)

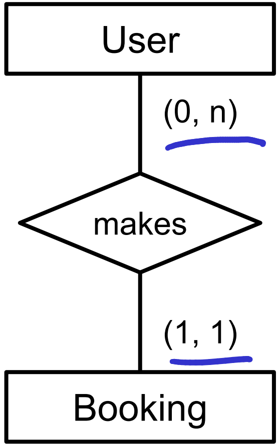
upper bound

- Participation constraints
  - Describe how often an entity has to participate in a relationship <u>at least</u>
  - Is the participation of an entity in a relationship even mandatory?

lower bound

Cardinality & Participation Constraints

- Representation in ER diagram
    - (min,max) label at connections between entity and relationship sets

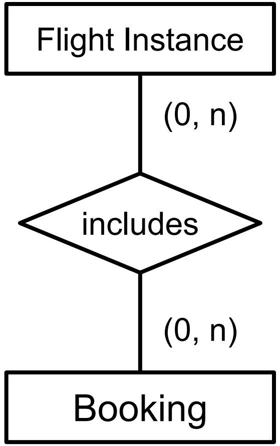


Interpretation

- Each user can make multiple bookings
  (but not every user must have made a booking)
- Each booking was done by exactly one user
  (implies that each booking is associated with a user)

Cardinality: Many-to-Many (no mandatory participation)

- Many-to-many relationship between bookings and flight instances
  - Each booking can include 0 or more flight instances
    (note that a booking with 0 flights might not meaningful; we will improve on that)
  - Each flight instance can be part of 0 or more bookings



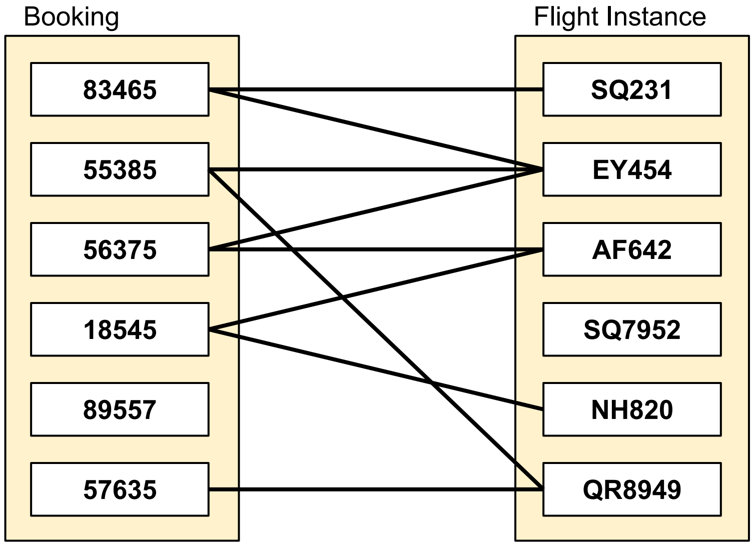
Flight Instance

(0, n)

includes

(0, n)

Booking



Booking

83465

55385

56375

18545

89557

57635

Flight Instance

SQ231

EY454

AF642

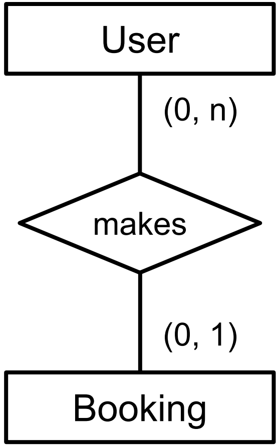
SQ7952

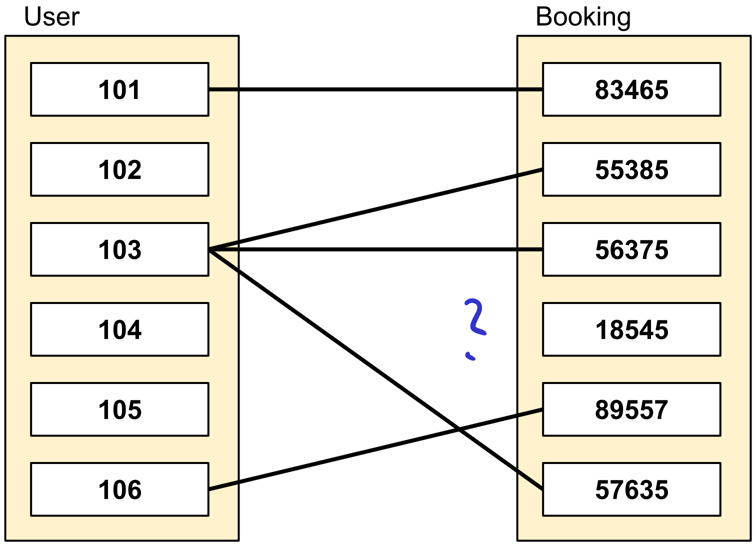
NH820

QR8949

Cardinality: Many-to-One (no mandatory participation)

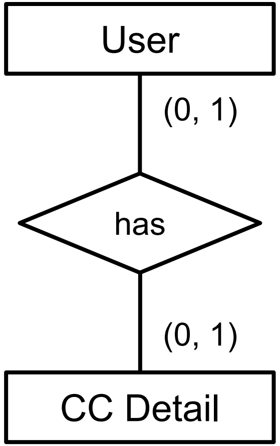
- Many-to-one relationship between users and bookings
  - Each user can make 0 or more bookings
  - Each booking is done by one 1 user <u>at most</u>
    (again, not perfect yet, and we will improve on that)





Cardinality: One-to-One (no mandatory participation)

- One-to-one relationship between users and credit card details
  - Each user can provide only 1 set of credit card details at most
  - Each set of credit card details is associated with 1 user at most



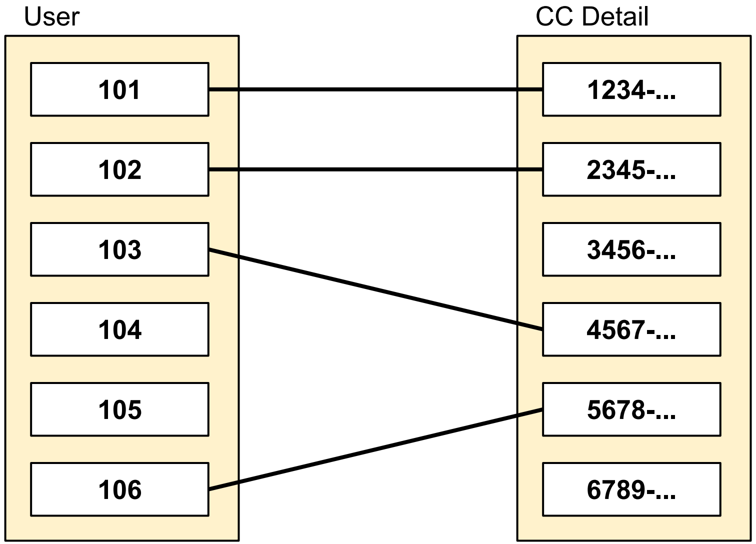
User

(0, 1)

has

(0, 1)

CC Detail



User

101

102

103

104

105

106

CC Detail

1234-...

2345-...

3456-...

4567-...

5678-...

6789-...

Participation Constraints

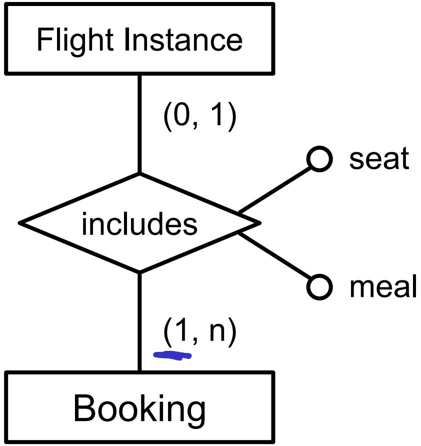
- Limitation of (basic) cardinality constraints from previous examples
  - A booking can include 0 flights
  - A booking can be done by 0 users
  - A set of credit card details does not need to be associated with a user

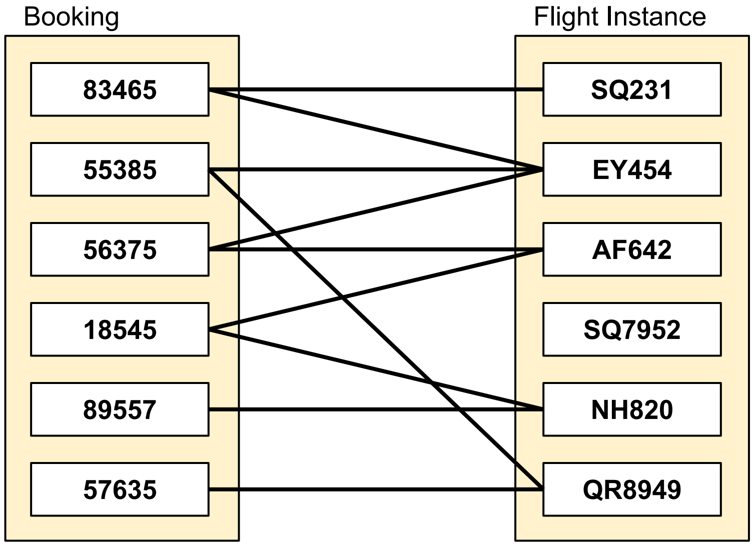
an entity does not have to participate in a relation

➜ Let's include **participation constraints**

Cardinality & Participation Constraints

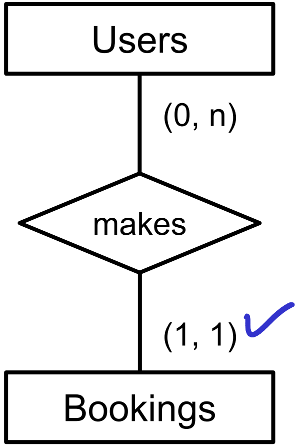
- Many-to-many relationship between bookings and flight instances
  - Each booking includes 1 or more flight instances
  - Each flight instance can be part of 0 or more bookings

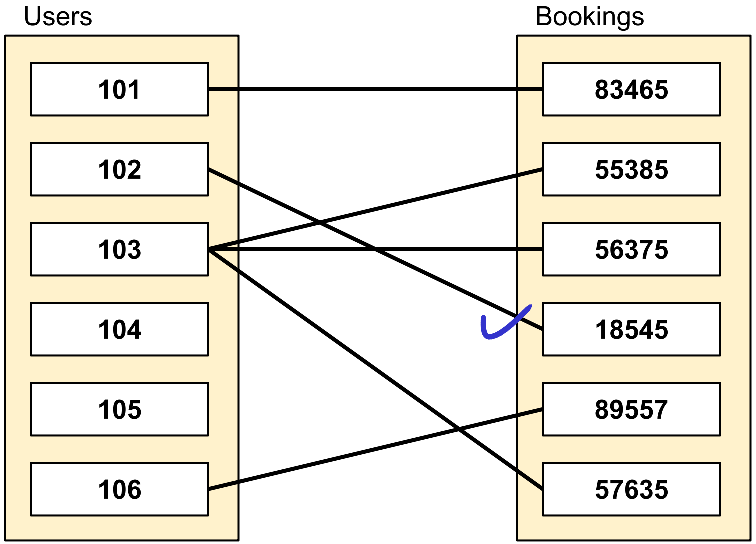




Cardinality & Participation Constraints

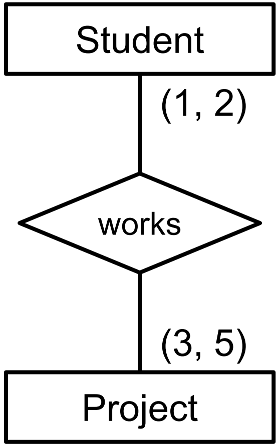
- Many-to-one relationship between users and bookings
  - Each user can make 0 or more bookings
  - Each booking is done by exactly 1 user





Cardinality & Participation Constraints

- Flexibility of (min,max) notation
  - Minimum not limited to 0 or 1; maximum no limited to n
  - Arbitrary specific values to capture real-world constraint



Interpretation

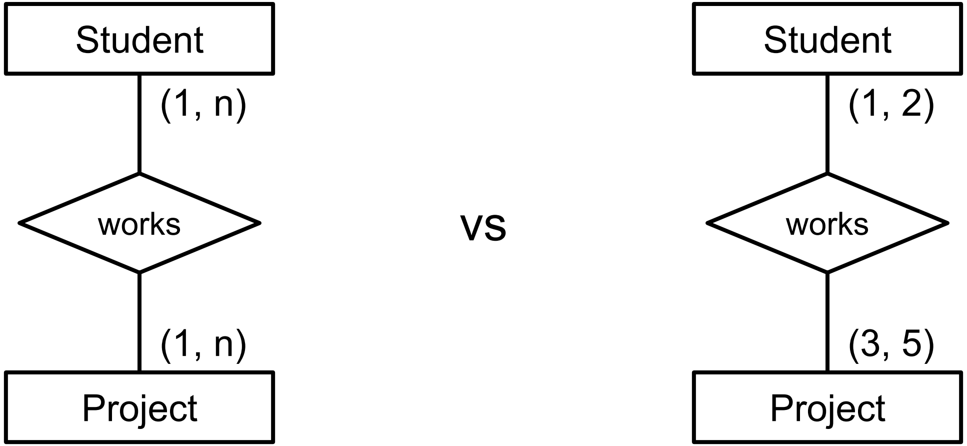
- Each student must work on at least 1 project
- Each student may not work on more than 2 projects
- Each project consists of at least 3 students
- Each project may not consist of more than 5 students

Quick Quiz

Why do values other than 0/1/n add significant complexity?

(just think about it for a minute here; we will cover it later)

triggers



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    - Aggregation
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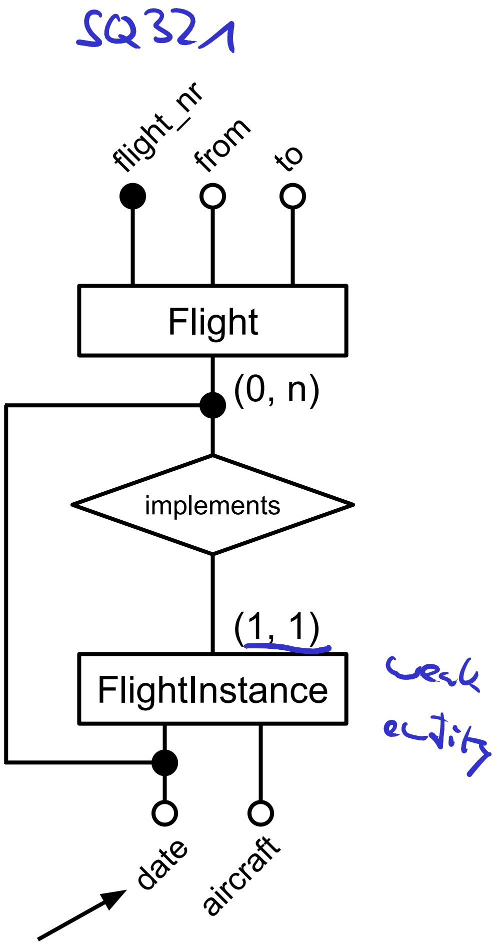
Dependency Constraints

- **Weak entity sets**
  - Entity set that does not have its own key
  - A weak entity can only be uniquely identified by considering the primary key of the **owner entity**
  - A weak entity's existence depends on the existence of its owner entity
  - Weak entity set and identifying relation set are represented via double-lined rectangles / diamonds

- Requirements
  - Many-to-one relationship (identifying relationship) from weak entity set to owner entity set
    (one-to-one possible but less common)
  - Weak entity set must have (1, 1) attached to identifying relationship

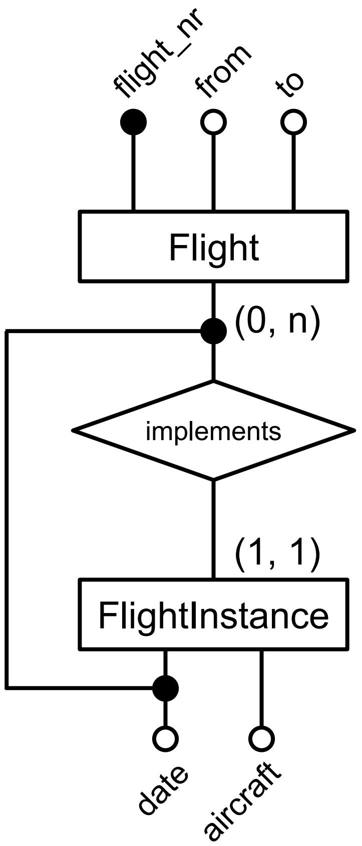
Dependency Constraints

- Example
  - A flight instance is the actual scheduled flight (with a unique flight number) on a given day
    - Each flights instance is identified by the "flight_nr and the "date"
    - "date" is a **partial key**
  - A flight instance cannot "exist" without the flight



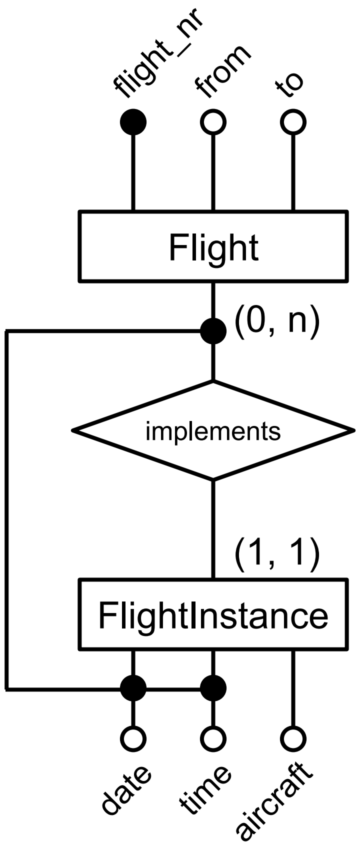
partial key

Dependency Constraints



Only 1 flight (instance)
per day maximum

More than 1 flight
(instance) per day



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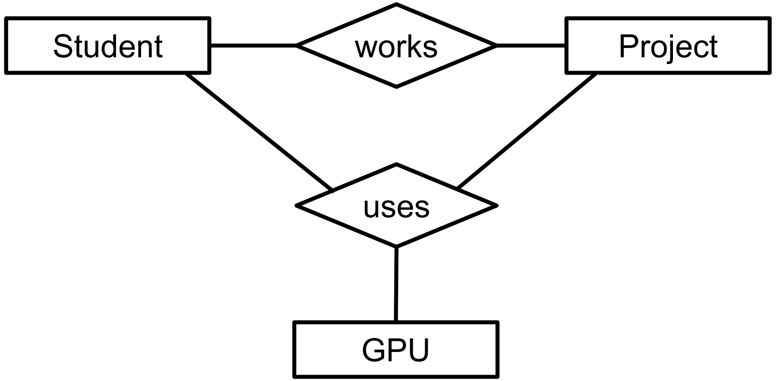
  - **Aggregation**
- Relational Mapping
  - From ER diagram to database tables
- Summary

Extended Concepts — Aggregation

- Concepts of ER diagrams so far
  - Only relationships between entity sets
  - No relationships between entity sets and relationship sets

- Motivating example



Limitations:

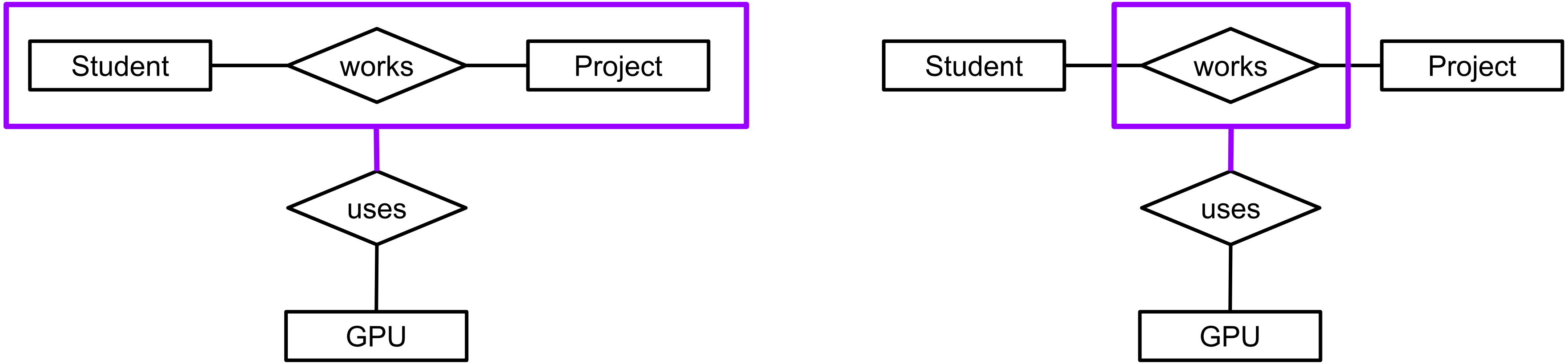
- Relationship between "works" and "uses" not explicitly captured
- "works" and "uses" are kind of redundant relationships

➜ **Aggregation**

Extended Concepts — Aggregation

- Aggregation — basic idea
  - Abstraction that treats relationships as higher-level entities
  - Example: treat Students-works-Projects as an entity set

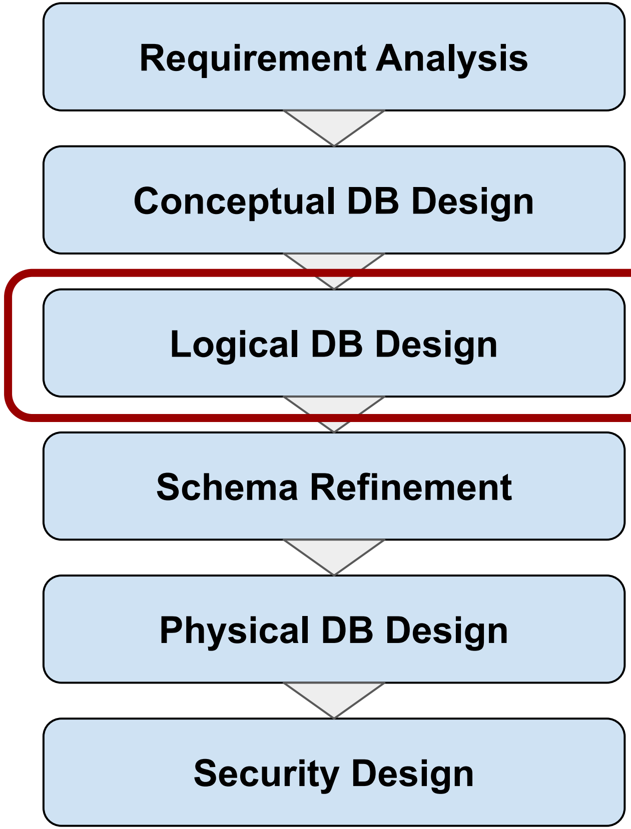
- Notation in ER diagram (2 equivalent alternatives)



Overview

- Entity Relationship Model
  - Overview + ER diagrams
  - Entity sets and attributes
  - Relationship sets
  - Cardinality & participation constraints
  - Dependency constraints: weak entity sets
  - Aggregation
- **Relational Mapping**
  - **From ER diagram to database tables**
- Summary

Database Design Process — 6 Common Steps



Requirement Analysis

- Identification and collection of user needs
- e.g., data /application / performance requirements

Conceptual DB Design

- Capturing requirements using a conceptual model
- RDBMS: **Entity Relationship Model (ER Model)**

Logical DB Design

- Mapping conceptual model to logical schema of DBMS
- RDBMS: Entity Relationship Model → Relational Schema

Schema Refinement

- Checking schema / tables for redundancies and anomalies

Physical DB Design

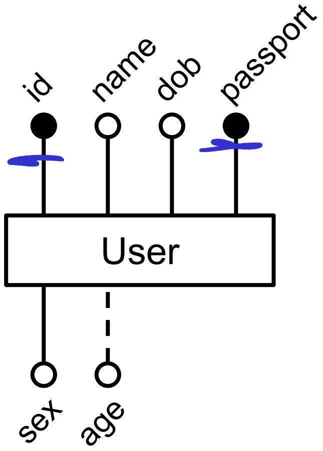
- Implementing database based on final data schema
- Consideration of performance requirements

Security Design

- Identification users and user groups and their permissions to access which parts of the data

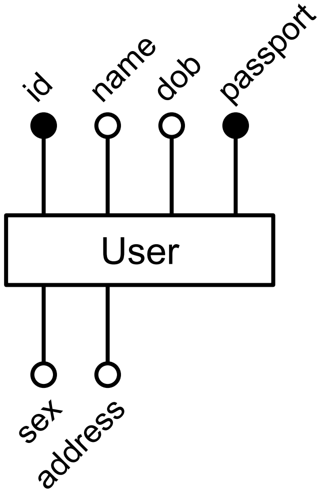
Entity Sets

- Straightforward mapping from entity sets to tables (except for composite & multivalued attributes)
  - Name of entity set ➜ name of table
  - Attributes of entity set ➜ attributes of table
  - Key attributes of entity set ➜ primary key of table

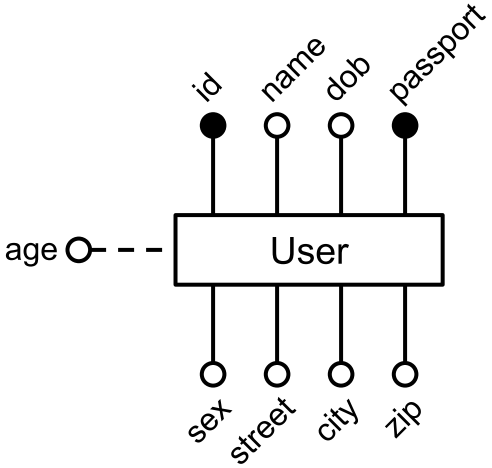


```
CREATE TABLE Users (
        id              INTEGER,
        name            VARCHAR(100),
        dob             DATE,
        sex             CHAR(1)
        age             INTEGER,
        passport        VARCHAR(20),
        PRIMARY KEY (id),
        UNIQUE (passport)
);
```

Note: PostgreSQL supports Generated Column but there are come caveats when used in practice that are beyond our scope.



VS

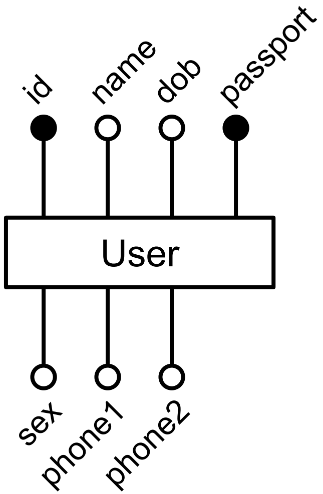


```
CREATE TABLE Users (
        id              INTEGER,
        name            VARCHAR(100),
        dob             DATE,
        sex             CHAR(1)
        passport        VARCHAR(20),
        address         VARCHAR(200),
        PRIMARY KEY (id),
        UNIQUE (passport)
);
```

```
CREATE TABLE Users (
        id              INTEGER,
        name            VARCHAR(100),
        dob             DATE,
        sex             CHAR(1)
        passport        VARCHAR(20),
        street          VARCHAR(100),
        city            VARCHAR(100),
        zip             VARCHAR(10),
        PRIMARY KEY (id),
        UNIQUE (passport)
);
```

Multivalued Attributes

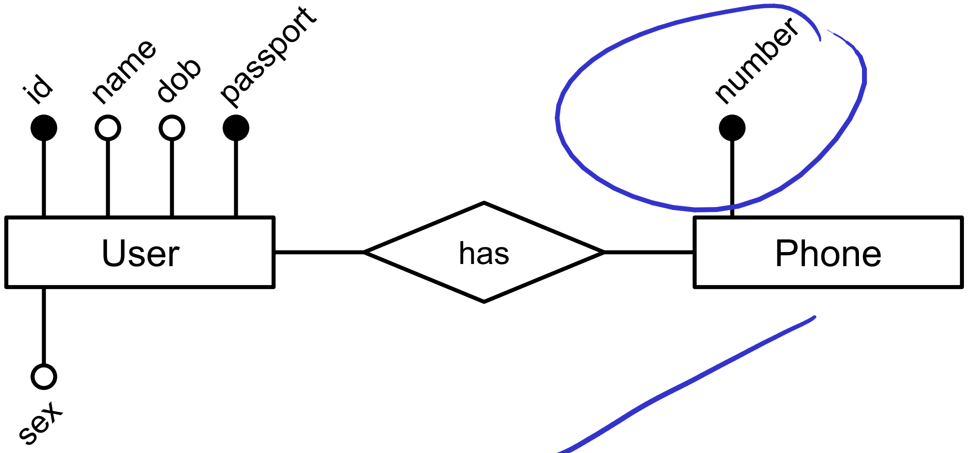
- Fixed number of single-valued attributes



```
CREATE TABLE Users (
        id              INTEGER,
        name            VARCHAR(100),
        dob             DATE,
        sex             CHAR(1)
        passport        VARCHAR(20),
        phone1          VARCHAR(20),
        phone2          VARCHAR(200),
        PRIMARY KEY (id),
        UNIQUE (passport)
);
```

Multivalued Attributes

- Separate entity set for phone numbers

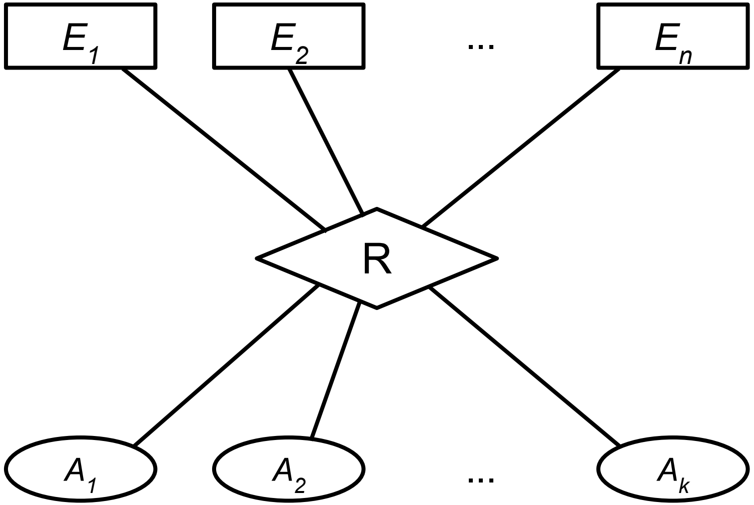


```
CREATE TABLE Users (
          id              INTEGER,
          name            VARCHAR(100),
          dob             DATE,
          sex             CHAR(1)
          passport        VARCHAR(20),
          PRIMARY KEY (id),
          UNIQUE (passport)
);
```

```
CREATE TABLE Phones (
          number          VARCHAR(20),
          user_id         INTEGER,
          PRIMARY KEY (number),
          FOREIGN KEY (user_id) REFERENCES Users (id)
);
```

Relationship Sets

- General n-ary relationship set R
  - *n* participating entity sets E_1, E_2, …, E_n
  - *k* relationship attributes A_1, A_2, …, A_k
  - Let $Key(E_i)$ be the attributes of the selected key of entity set E_i



➜ Attributes of relationship set *R*

- $Key(E_1)$, $Key(E_2)$, …, $Key(E_n)$ — key attributes of all participating entity sets E_i
- A_1, A_2, …, A_k — all relationship attributes of *R*

Cardinality: Many-to-Many (no mandatory participation)

Quick Quiz: Where does "flight_nr" come from?

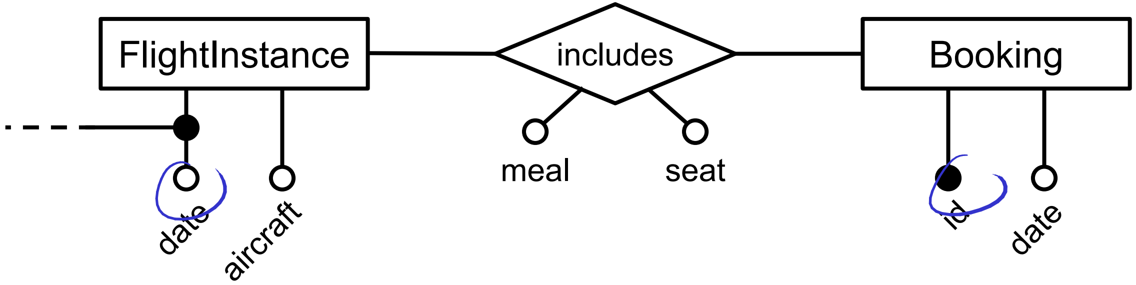
CREATE TABLE FLIGH (

fnr

date

:

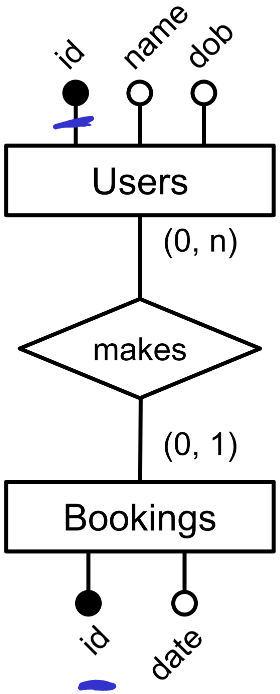
);



```
CREATE TABLE Includes (
        flight_nr       VARCHAR(10),
        flight_date     DATE,
        booking_id      INTEGER,
        seat            VARCHAR(10),
        meal            VARCHAR(50),
        PRIMARY KEY (flight_nr, flight_date, booking_id),
        FOREIGN KEY (flight_nr, flight_date) REFERENCES FlightInstances (flight_nr, date),
        FOREIGN KEY (booking_id) REFERENCES Bookings (id),
);
```

Cardinality: Many-to-One (no mandatory participation)

- **Approach 1**: Represent "makes" with a separate table
  - Similar to Many-to-Many but with different primary key!

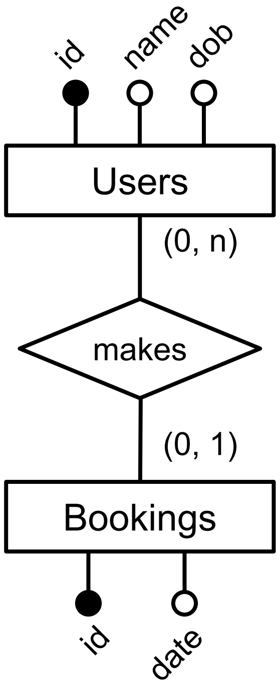


```
CREATE TABLE Makes (
        user_id         INTEGER,
        booking_id      INTEGER,
        PRIMARY KEY (booking_id),
        FOREIGN KEY (user_id) REFERENCES Users (id),
        FOREIGN KEY (booking_id) REFERENCES Bookings (id)
);
```

Cardinality: Many-to-One (no mandatory participation)

Quick Quiz: What is typically the preferred approach? 1 or 2?

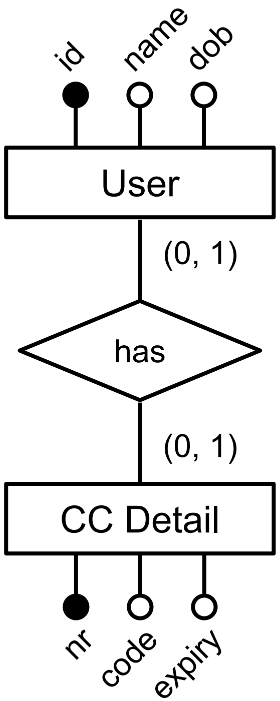
- **Approach 2:** Combine "makes" and "Bookings" into one table
  - Possible because given a booking, we can uniquely identify the user who made it



```
CREATE TABLE Bookings (
        id              INTEGER,
        date            DATE,
        user_id         INTEGER,
        PRIMARY KEY (id),
        FOREIGN KEY (user_id) REFERENCES Users (id)
);
```

Cardinality: One-to-One (no mandatory participation)

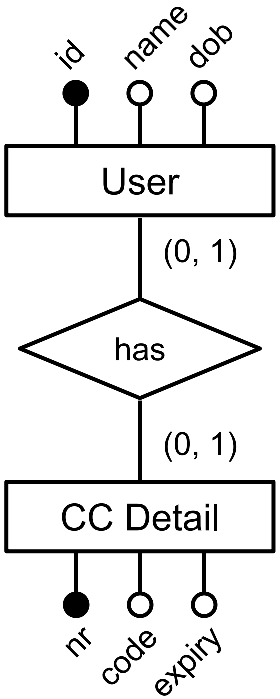
- **Approach 1**: Represent "has" with a separate table
  - Similar to Many-to-One but primary key can be chosen



```
CREATE TABLE Has (
          user_id          INTEGER,
          cc_nr            CHAR(16) UNIQUE,
          PRIMARY KEY (user_id),
          FOREIGN KEY (user_id) REFERENCES Users (id),
          FOREIGN KEY (cc_nr) REFERENCES CCDetails (id)
);
```

Cardinality: One-to-One (no mandatory participation)

- **Approach 2**: Combine "has" and "Users" or "has" and "CC Details"



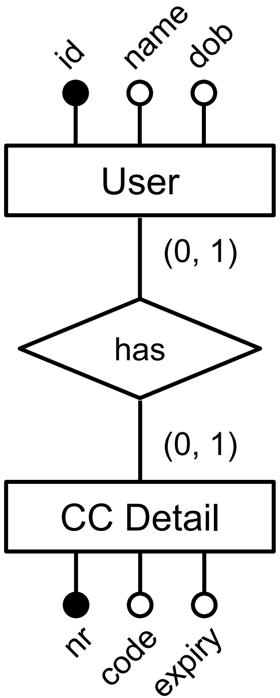
```
CREATE TABLE Users (
        id              INTEGER,
        name            VARCHAR(100),
        dob             DATE,
        cc_nr           CHAR(16) UNIQUE,
        PRIMARY KEY (id),
        FOREIGN KEY (cc_nr) REFERENCES CCDetails (nr)
);
```

```
CREATE TABLE CCdetails (
        nr              CHAR(16),
        code            CHAR(3),
        expiry          DATE,
        user_id         INTEGER UNIQUE,
        PRIMARY KEY (nr),
        FOREIGN KEY (user_id) REFERENCES Users (id)
);
```

Cardinality Constraints: One-to-One

Quick Quiz: What could be a downside of this approach? (Hint: security)

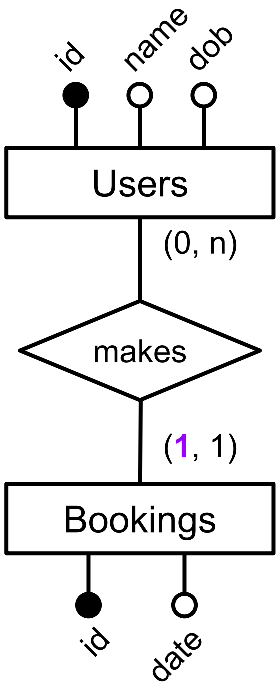
- **Approach 3**: Combine "has", "Users", and "CC Details"



```
CREATE TABLE Users (
          id              INTEGER,
          name            VARCHAR(100),
          dob             DATE,
          cc_nr           CHAR(16) UNIQUE,
          cc_code         CHAR(3),
          cc_expiry       DATE,
          PRIMARY KEY (id)
);
```

Cardinality & Participation Constraints

- **Approach 1** (separate table): fails to capture mandatory participation!



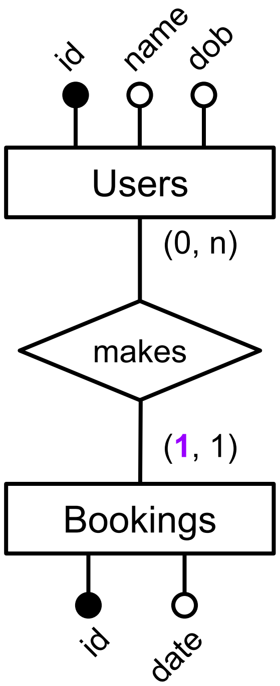
≠

```
CREATE TABLE Makes (
        user_id        INTEGER NOT NULL,
        booking_id     INTEGER,
        PRIMARY KEY (booking_id),
        FOREIGN KEY (user_id) REFERENCES Users (id),
        FOREIGN KEY (booking_id) REFERENCES Bookings (id)
);
```

- Schema does not enforce mandatory participation of "Bookings" w.r.t. "Makes"
- e.g.: "Makes" can be empty while both "Users" and "Bookings" are non-empty

Cardinality & Participation Constraints

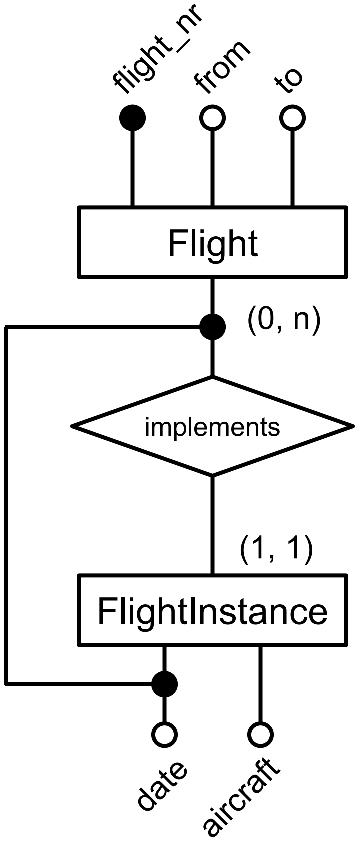
- **Approach 2**: Combine "makes" and "Bookings" into one table
  - Enforces total participation via NOT NULL constraint



≙

```
CREATE TABLE Bookings (
        id          INTEGER,
        date        DATE,
        user_id     INTEGER NOT NULL,
        PRIMARY KEY (id),
        FOREIGN KEY (user_id) REFERENCES Users (id)
);
```

Weak Entity Sets



```
CREATE TABLE Flights (
        flight_nr       VARCHAR(10),
        from            VARCHAR(10),
        to              VARCHAR(10),
        PRIMARY KEY (flight_nr)
);
```

```
CREATE TABLE FlightInstances (
        flight_nr       VARCHAR(10),
        date            DATE,
        aircraft        VARCHAR(10),
        PRIMARY KEY (flight_nr, date),
        FOREIGN KEY (flight_nr) REFERENCES Flights (flight_nr)
                ON DELETE CASCADE
                ON UPDATE CASCADE
);
```

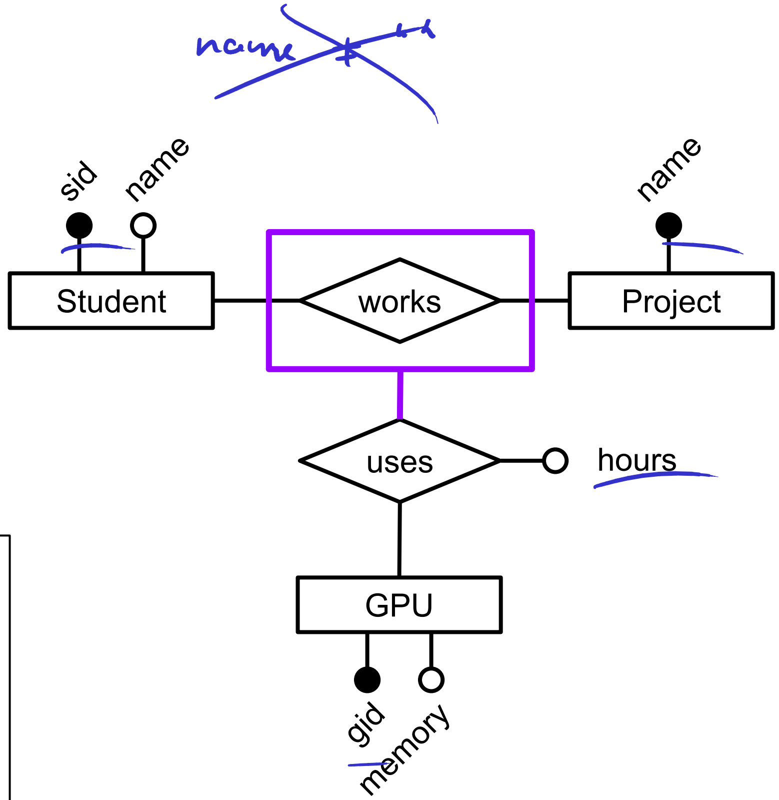
Aggregation — Relational Mapping

Schema definition of "uses"

- Primary key of aggregation relationship ➜ (sid, pname)
- Primary key of associated entity set "GPUs" ➜ gid
- Descriptive attributes of "uses" ➜ hours

```
CREATE TABLE Uses (
        gid             INTEGER,
        sid             CHAR(20),
        pname           VARCHAR(50),
        hours           NUMERIC,
        PRIMARY KEY (gid, sid, pname),
        FOREIGN KEY (gid) REFERENCES GPUs (gid),
        FOREIGN KEY (sid, pname) REFERENCES works (sid, pname)
);
```

} comes from aggr.



ER Design & Relational Mapping — Basic Guidelines

- Guidelines for ER design
  - An ER diagram should capture as many of the constraints as possible
  - An ER diagram must not impose any constraints that are not required

- Guidelines for relational mapping
  (i.e., from ER diagram to relational database schema)
  - The relational schema should enforce as many if the constraints as possible using column and/or table constraints
  - The relational schema should not impose and constraints that are not required

Overview

- Entity Relationship Model
  - Overview + ER diagrams
  - Entity sets and attributes
  - Relationship sets
  - Cardinality & participation constraints
  - Dependency constraints: weak entity sets
  - Aggregation
- Relational Mapping
  - From ER diagram to database tables
- **Summary**

Summary

- Entity-Relationship (ER) model
  - Basic concepts: entity sets, relationship sets, attributes
  - Cardinality constraints and participation constraints
  - Extended concepts: (ISA hierarchies) aggregation ✓

Visualized using **ER diagrams**

- Relational Mapping
  - Mapping ER diagram to database schema
  - Not all constraints of ER diagram may be captured

- Outlook for next lecture
  - SQL for querying a database ~~(recommendation: study RA)~~

Quick Quiz Solutions

Quick Quiz (Slide 3)

- Solution
  - Storing the "dob" instead of "age" is arguably the preferred approach
  - The value of "age" changes each year (not really a big deal)
  - "dob" provides more detailed information compared the "age"

Quick Quiz (Slide 14)

- Solution
  - Modeling "address" and "phone" as a single-values string might be OK-ish if we never use these attributes to select rows
  - If we only need to get the address or all phone numbers for a given user then this solution might be good enough
  - However, queries using "address" or "phone" to filter rows will become unnecessarily complicated or even impossible
  - A query such as "Return all users with addresses with the ZIP code 123456" is possible since SQL supports string pattern matching and even regular expression. The performance would degrade, though.
  - More intricate queries might still be formulated but the complexity of the SQL query would quickly blow up

Quick Quiz (Slide 17)

- Solution
  - Using a fixed number of single-valued attributes avoids "splitting" the data across multiple tables (and avoids joining them as part of queries – costly operation)
  - Two disadvantages when a fixed number of single-valued attributes
    - Unable to store then 2 phone numbers
    - Requires storing NULL values if user does not have exactly 2 phone numbers
  - A separate table only stores the information needed and is more flexible, but will relies on join operations to bring the information together

Quick Quiz (Slide 18)

- Solution
  - Complex data types are generally more difficult to query
  - For example: How to check the value for an optional field in a JSON document? Maybe be possible but often requires more complex and non-standard syntax

Quick Quiz (Slide 34)

- Solution
  - 0/1/n constraints can typically captures using basic integrity constraints (as shown later)
  - Any more specific upper and lower bounds require more integrity checks, particularly since these constraints involve more than 1 table
  - General solution: **triggers**
  - Also not uncommon: don't use DBMS to enforce constraints

Quick Quiz (Slide 49)

- Solution
  - "Flight Instances" is weak entity set with "Flights" being the owner entity set
  - Thus, "Flight Instances" is identified by the key of "Flights" (i.e., "fnr") and its own partial key "date"

Quick Quiz (Slide 51)

- Solution
  - Approach 2 is generally the preferred approach as it leads to a smaller number of table
  - Less tables also means that queries might need less join operations
    (which are typically the more expensive operations)
  - Good rule of thumb but not a "law"

Quick Quiz (Slide 54)

- Solution
  - Access privileges can (mostly) only be set on the table level
  - Separating the basic user data and the credit card details allows assign different access privilege to different users
  - Also, separate table avoid NULL values if some users do not have a credit card