Logical database design

- The learning objectives for this week are:
  - Knowing what is the objective *logical database design*
  - Knowing how to *derive relations* from simple ER diagrams
  - Knowing how to determine *natural primary keys* and *foreign keys*

Logical database design

- The typical main phases in a database design process are:
    i. Conceptual database design
    ii. Logical database design
    iii. Physical database design
- Each phase from top to bottom adds more detail to the design
- We have familiarized ourselves with the *concetual database design* by defining entity types and their relationship based on the requirements
- The *logical database design* is the process of refining and translating the conceptual schema into a logical database schema based on a specific data model, e.g. the relational model

Logical database design

- Entity types, attributes, and relationship types can be directly transformed into relations with some simple rules
- Typically, the logical database design process includes the following types of activities:
    i. Deriving relations for the logical data model
    ii. Validating relations using normalisation
    iii. Validating relations against user transaction
    iv. Double-checking integrity constraints
    v. Reviewing logical data model with user

Deriving relations for the logical data model

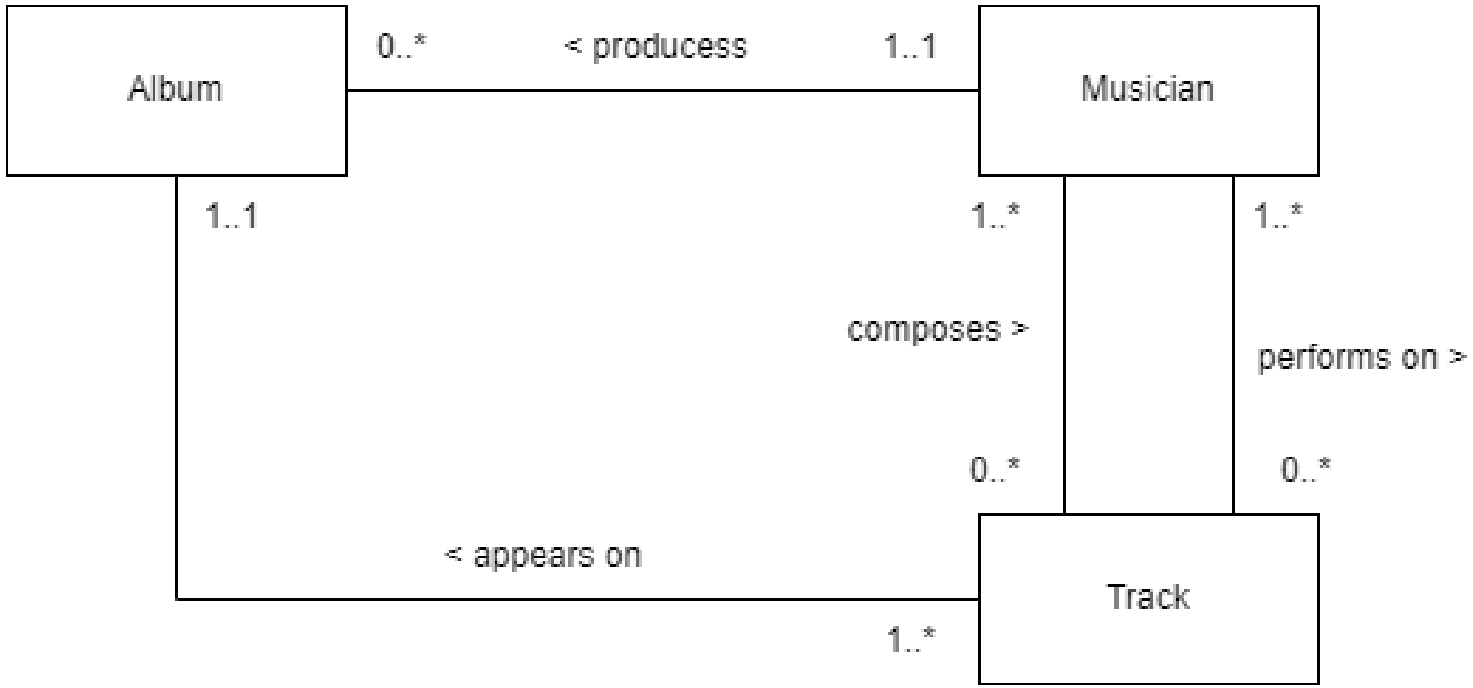
- The process starts by *deriving relations for the logical data model*, which includes:
    i. Creating the relations
    ii. Refining the attributes
    iii. Determing primary and foreign keys
    iv. Determing other types of integrity constraints

Creating relations

- We create the relations in the following manner:
  - For *each entity type*, create a relation that includes all simple attributes of the entity
  - For *M:N (many-to-many) relationship types*, create a "*bridge relation*" to represent the relationship
  - For *multi-valued attributes*, create a new relation to represent the multi-valued attribute. For example, a person may have several phone numbers, but multi-valued attributes are not allow in relations

Example of creating relations

- Let's consider creating relations for the following conceptual model:



Example of creating relations

- In the example there's two many-to-many relationships:
  - A musician performs on multiple tracks and tracks have multiple performers
  - A musician composes multiple tracks and tracks are composed by multiple musicians
- In this case we create two bridge relations: *Track_Performer* and *Track_Composer*
- The are no multi-valued attributes, which leaves with the following relations: *Album*, *Musician*, *Track*, *Track_Performer*, and *Track_Composer*

Refining the attributes

- Once we have created the relations we need to refine the attributes in the following manner:
  - Divide a non-atomic attribute into smaller (atomic) attributes. For example person's address can be divided into, city, postal code and street address
  - Refine attribute domains: data types and lengths, requiredness, validation rules etc.
  - Define which attributes can have NULL values. Allow NULL in an attribute only based on *strong arguments*

Determing primary keys

- There should be *exactly one primary key in each relation*
- The primary key can be either a *simple key* (single column) or a *composite key* (several columns)
- By definition, the primary key should always satisfy the properties of *requiredness*, *uniqueness* and *minimality*
- The primary key *should remain stable*. That is, primary key values should not need to be updated later
- The primary key should be *reasonably short*
- The primary key should have *no privacy issues*. For example social security number has privacy issues

Determing primary key for a weak entity type

- A *weak entity type* is an entity type that is dependent on the existence of another entity type
- For example *CourseGrade* is existence-dependent on *Student* and *CourseOffering*
- When a relation derived from a weak entity type, the natural primary key is partially or fully derived from the weak entity type's owner entity type
- For example, the natural primary key of the *CourseGrade* relation is a composite key that *includes columns from two foreign keys*, one referencing *Student* and other referencing *CourseOffering*
- The primary key of the weak entity's relation cannot be made until after the foreign keys have been determined for the relation

Surrogate keys

- If there is initially no suitable candidate key for a relation, then we cannot determine a natural primary key
- We have to take care of the situation by including an extra attribute in the relation to act as the primary key
- This kind of primary key is a *surrogate key*
- Surrogate keys are commonly generated values, such as incrementing or random numbers

Alternate keys

- Candidate keys that are not selected to be primary the key are called *alternate keys*
- We should consider the use of the *unique constraint* on alternate keys to make sure that their values remain unique:

```
Student (studentnumber, ssn, familyname, givenname)
  UNIQUE (ssn)
```

- Especially, when we are using a surrogate primary key, a unique constraint on at least one natural alternate key improves data quality

Determing foreign keys

- In a relational database, *relationships* are represented by the *primary key/foreign key mechanism*
- Before deciding where to place the foreign key we have to identify the *parent entity type* and the *child entity type* involved in the relationship

Determing foreign keys

- For example, in the ER diagram above *Company* is the *parent* entity type and *Department* is the *child* entity type
- When we translate this diagram to relation schemas we must do the following:
  - We create the two relations: *Company* and *Department*
  - We determine primary keys for both relations
  - We represent the relationship by placing a copy of the parent relation's (Company) primary key into the child relation (Department), to act as the foreign key

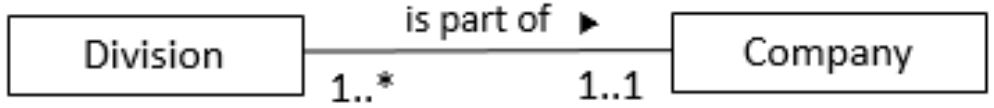
Determing foreign keys

- The result could be for example the following relation schema:

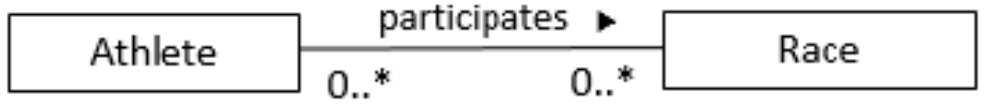
```
Company (company_id, name)

Department (department_id, company_id, name)
  FK (company_id), REFERENCES Company(company_id)
```

Determing foreign keys

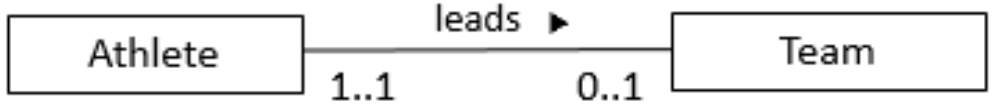
- To know in which relation to place the foreign key we need to *identify the relationship type*
- Most often the structure falls in one of these categories:
  - N:1 (many-to-one) binary relationship



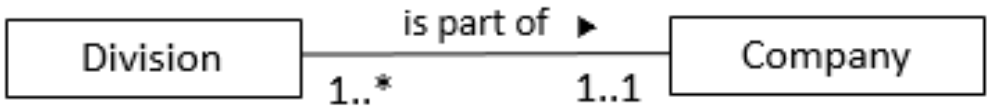
  - M:N (many-to-many) binary relationship



  - 1:1 (one-to-one) binary relationship



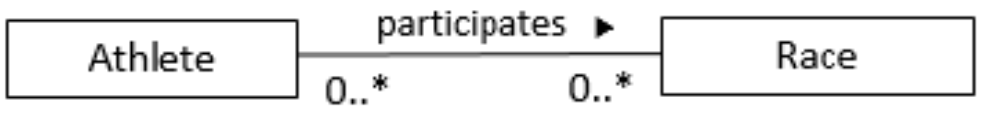
N:1 (many-to-one) binary relationship



- Place a copy of the parent relation's ("..1" side) primary key into the child relation ("..*" side), to act as a foreign key
- If the child relation is derived from a weak entity type, then the primary key of the child relation is typically a composite key
- In the example above, we would get the following relation schema:

```
Company (company_id, name)

Division (division_id, company_id, name)
  FK (company_id), REFERENCES Company(company_id)
```

M:N (many-to-many) binary relationship



- Create a bridge relation to represent the relationship
- Place a copy of the primary key from each of the parent relations into the bridge relation to act as foreign keys
- Typically, the bridge relation's primary key is a composite key that includes the both foreign keys
- In the example above, we would get the following relation schema:

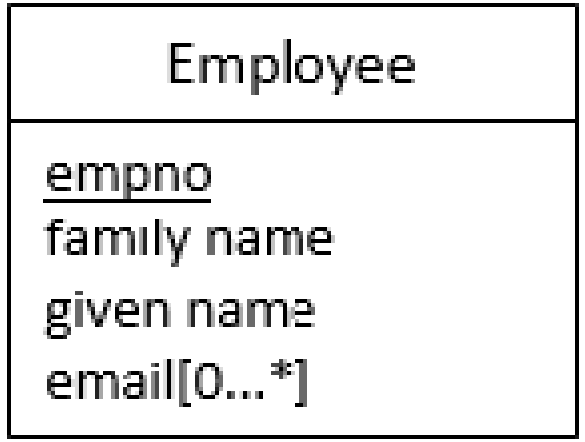
```
Athlete (athlete_id, first_name, family_name)
Race (race_id, name, date)
Race_Participation(athlete_id, race_id)
  FK (athlete_id), REFERENCES Athlete(athlete_id),
  FK (race_id), REFERENCES Race(race_id)
```

1:1 (one-to-one) binary relationship

- In case of *mandatory participation ("1..1") on one side only*, place a copy of the primary key from the relation on the "1..1" side into the relation on the "0..1" side to act as the foreign key
- In case of *mandatory participation on both sides* we can usually *combine the two relations* into one relation
- In case *optional participation ("0..1") on both sides* the foreign key can be placed in either relation
- In the example above, we would get the following relation schema:

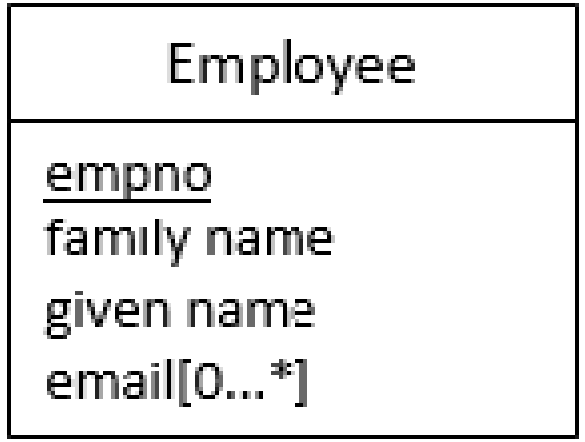
```
Athlete (athlete_id, first_name, family_name)
Team (team_id, athlete_id, name)
  FK (athlete_id), REFERENCES Athlete(athlete_id)
```

Multi-value attributes



- A relation can't have attributes with *multiple values*, such as the *email* attribute of the *Employee* entity type above
- In such case, we must create a *new relation* to represent the multi-valued attribute
- We move the attribute from the original relation and place it to the new relation
- We Place a copy of the parent relation's primary key into the child relation, to act as the foreign key

Multi-value attributes



- In the example above, we would get the following relation schema:

```
Employee (empno, first_name, family_name)
Email (email, empno)
  FK (empno), REFERENCES Employee(empno)
```

Summary

- The objective of logical database design is to translate the conceptual schema into a logical database schema based on a specific data model
- When we derive relations from entity types, we create a relation for each entity type
- Many-to-many relationship requires an additional bridge relation
- There should be exactly one primary key in each relation
- The foreign key placement depends on the relationship type (many-to-one, many-to-many or one-to-one)