Databases

Jörg Endrullis

VU University Amsterdam

2015

Database Design

- **formal model** of the relevant aspects of the real word
  - mini world
  - universe of disclosure

Database Design

- **formal model** of the relevant aspects of the real word
  - mini world
  - universe of disclosure
- the real world serves as **measure of correctness**
  - possible database states should correspond to the states of the real world

Database Design

Database Design

- **formal model** of the relevant aspects of the real word
  - mini world
  - universe of disclosure
- the real world serves as **measure of correctness**
  - possible database states should correspond to the states of the real world

Database design is challenging:

- **Expertise**: requires expertise in the application domain
- **Flexibility**: real world often permits exceptional cases
- **Size**: database schema may become huge

Database Design

Due to the complexity, the design is a multi-step process. . .

Three Phases of Database Design

Database Design

Due to the complexity, the design is a multi-step process. . .

Three Phases of Database Design

- **Conceptual Database Design**
  - what information do we store
  - how are the information elements related to each other
  - what are the constraints?
  - e.g. E/R model or UML model

Database Design

Due to the complexity, the design is a multi-step process. . .

Three Phases of Database Design

- **Conceptual Database Design**
  - what information do we store
  - how are the information elements related to each other
  - what are the constraints?
  - e.g. E/R model or UML model
- **Logical Database Design**
  - transformation of the conceptual schema into the schema supported by the database
  - e.g. relational model

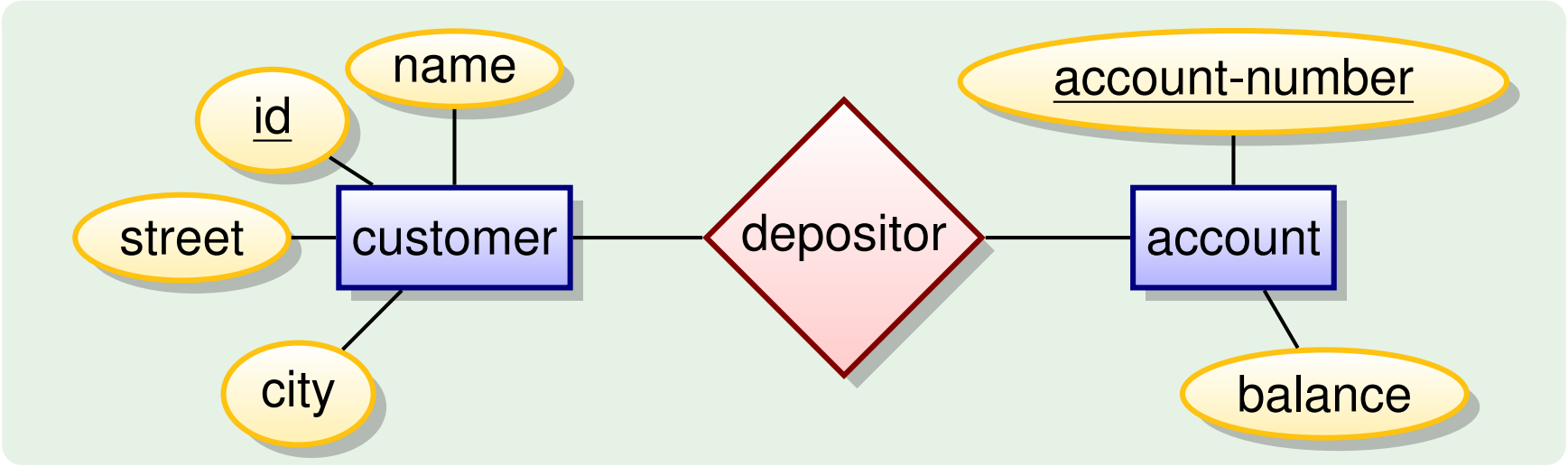
Database Design

Due to the complexity, the design is a multi-step process. . .

Three Phases of Database Design

- **Conceptual Database Design**
  - what information do we store
  - how are the information elements related to each other
  - what are the constraints?
  - e.g. E/R model or UML model
- **Logical Database Design**
  - transformation of the conceptual schema into the schema supported by the database
  - e.g. relational model
- **Physical Database Design**
  - design indexes, table distribution, buffer sizes,. . .
  - to maximise performance of the final system

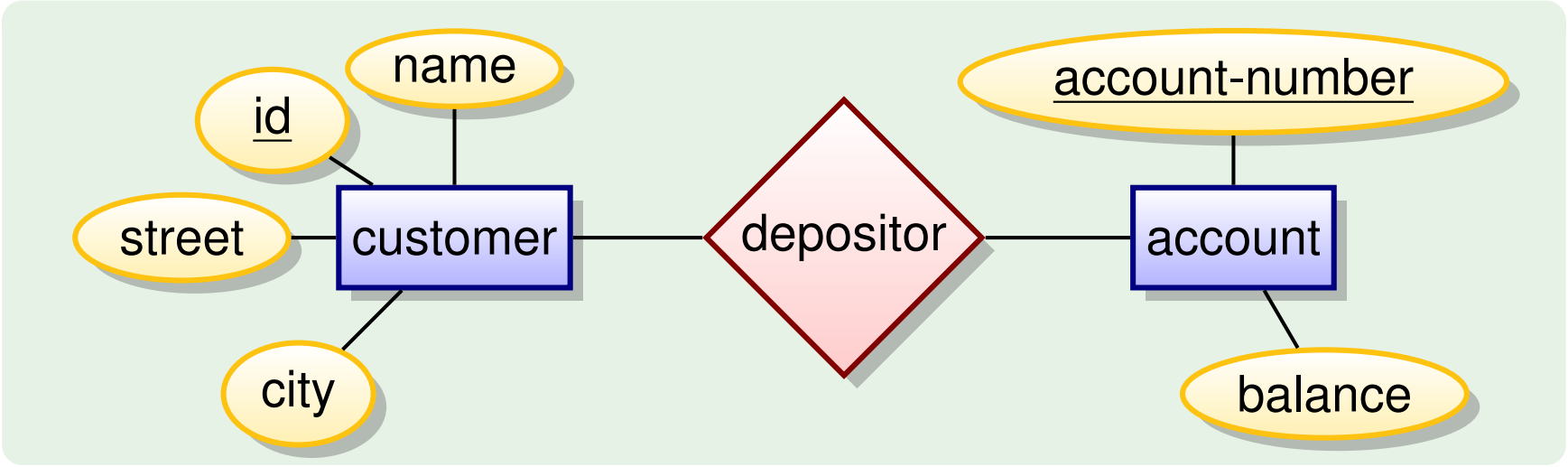
Entity-Relationship Model



The three main ingredients of entity-relationship diagrams are:

- **Entity sets**
- **Attributes**
- **Relationships**

Entity-Relationship Model



- **Rectangles** represent entity sets
- **Ellipses** represent attributes
  - **Double ellipses** represent multi-valued attributes
  - **Dashed ellipses** denote derived attributes
- **Diamonds** represent relationship sets
- **Lines** link attributes and relationship sets to entity sets
- **Underline** indicates primary key attributes

Entity Sets

- **entity** is an abstract object
  - e.g.: specific person, company, event

Entity Sets

- **entity** is an abstract object
  - e.g.: specific person, company, event
- entities have **attributes**
  - e.g.: people have names and addresses

Entity Sets

- **entity** is an abstract object
  - e.g.: specific person, company, event
- entities have **attributes**
  - e.g.: people have names and addresses
- **entity set** is a collection of similar entities
  - similar = sharing the same properties (attributes)
  - e.g.: set of all persons, companies, trees, holidays

Entity Sets

- **entity** is an abstract object
  - e.g.: specific person, company, event
- entities have **attributes**
  - e.g.: people have names and addresses
- **entity set** is a collection of similar entities
  - similar = sharing the same properties (attributes)
  - e.g.: set of all persons, companies, trees, holidays

Comparison with object-oriented programming:

- entity $\approx$ object
- entity set $\approx$ class

Entity Sets

- **entity** is an abstract object
  - e.g.: specific person, company, event
- entities have **attributes**
  - e.g.: people have names and addresses
- **entity set** is a collection of similar entities
  - similar = sharing the same properties (attributes)
  - e.g.: set of all persons, companies, trees, holidays

Comparison with object-oriented programming:

- entity $\approx$ object
- entity set $\approx$ class

Important difference: the **E/R model is static**

- models structure of the data, not the operations
- no methods/functions associated to entity sets

Attributes

An entity set is represented by a set of **attributes**, that is, descriptive properties possessed by all entities of the entity set.

```
CUSTOMER = (ID, NAME, STREET, CITY)
LOAN = (LOAN-NUMBER, AMOUNT)
```

Attributes

An entity set is represented by a set of **attributes**, that is, descriptive properties possessed by all entities of the entity set.

```
CUSTOMER = (ID, NAME, STREET, CITY)
LOAN = (LOAN-NUMBER, AMOUNT)
```

- **domain** = set of permitted values for each attribute

Attributes

An entity set is represented by a set of **attributes**, that is, descriptive properties possessed by all entities of the entity set.

```
CUSTOMER = (ID, NAME, STREET, CITY)
LOAN = (LOAN-NUMBER, AMOUNT)
```

- **domain** = set of permitted values for each attribute

Attribute types

Attributes

An entity set is represented by a set of **attributes**, that is, descriptive properties possessed by all entities of the entity set.

```
CUSTOMER = (ID, NAME, STREET, CITY)
LOAN = (LOAN-NUMBER, AMOUNT)
```

- **domain** = set of permitted values for each attribute

Attribute types

- **simple** and **composite** attributes
  - e.g. street is composed of street name and number

Attributes

An entity set is represented by a set of **attributes**, that is, descriptive properties possessed by all entities of the entity set.

```
CUSTOMER = (ID, NAME, STREET, CITY)
LOAN = (LOAN-NUMBER, AMOUNT)
```

- **domain** = set of permitted values for each attribute

Attribute types

- **simple** and **composite** attributes
  - e.g. street is composed of street name and number
- **single-valued** and **multi-valued** attributes
  - e.g. single-valued: age of a person
  - e.g. multi-valued: person can have multiple phone numbers

Attributes

An entity set is represented by a set of **attributes**, that is, descriptive properties possessed by all entities of the entity set.

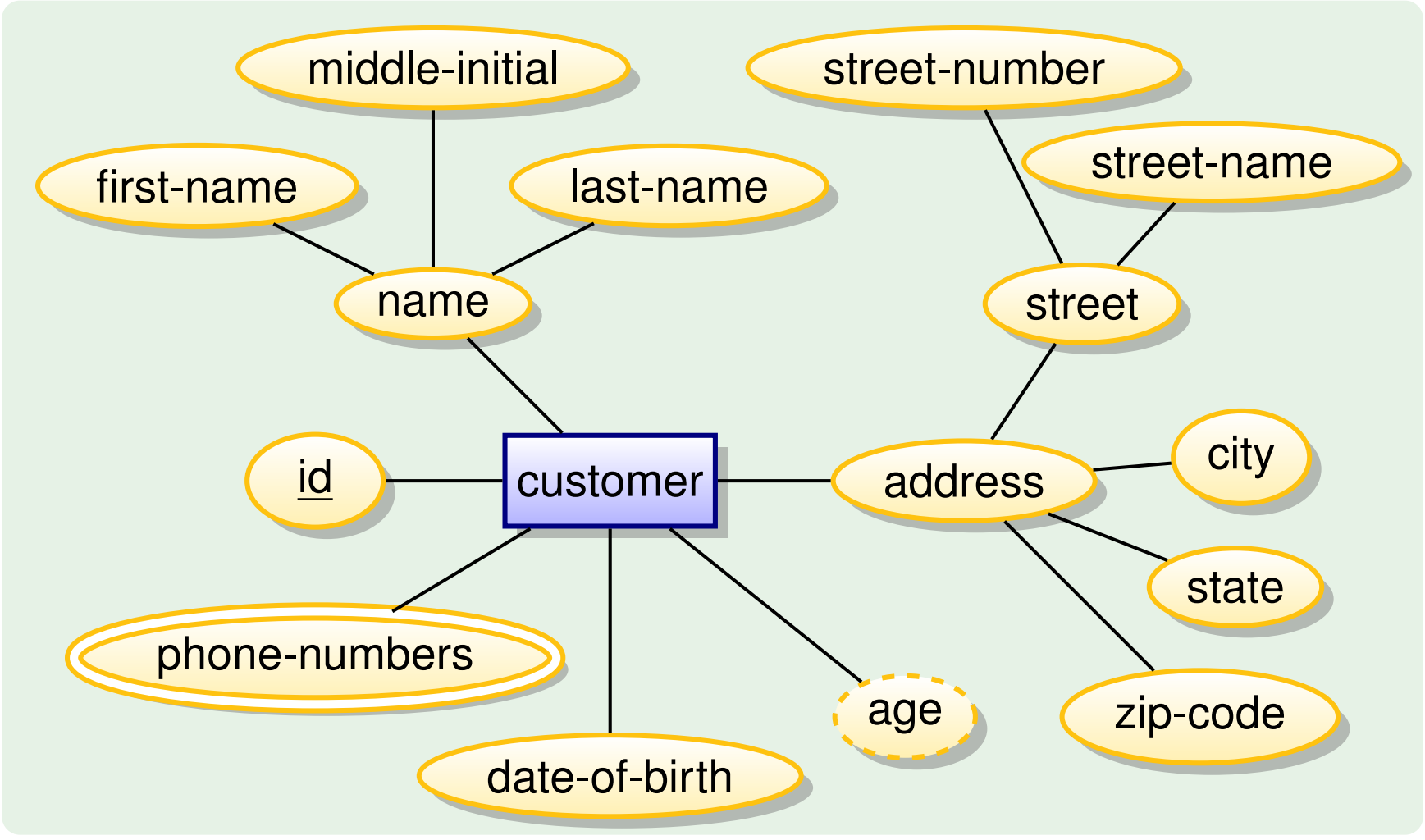
```
CUSTOMER = (ID, NAME, STREET, CITY)
LOAN = (LOAN-NUMBER, AMOUNT)
```

- **domain** = set of permitted values for each attribute

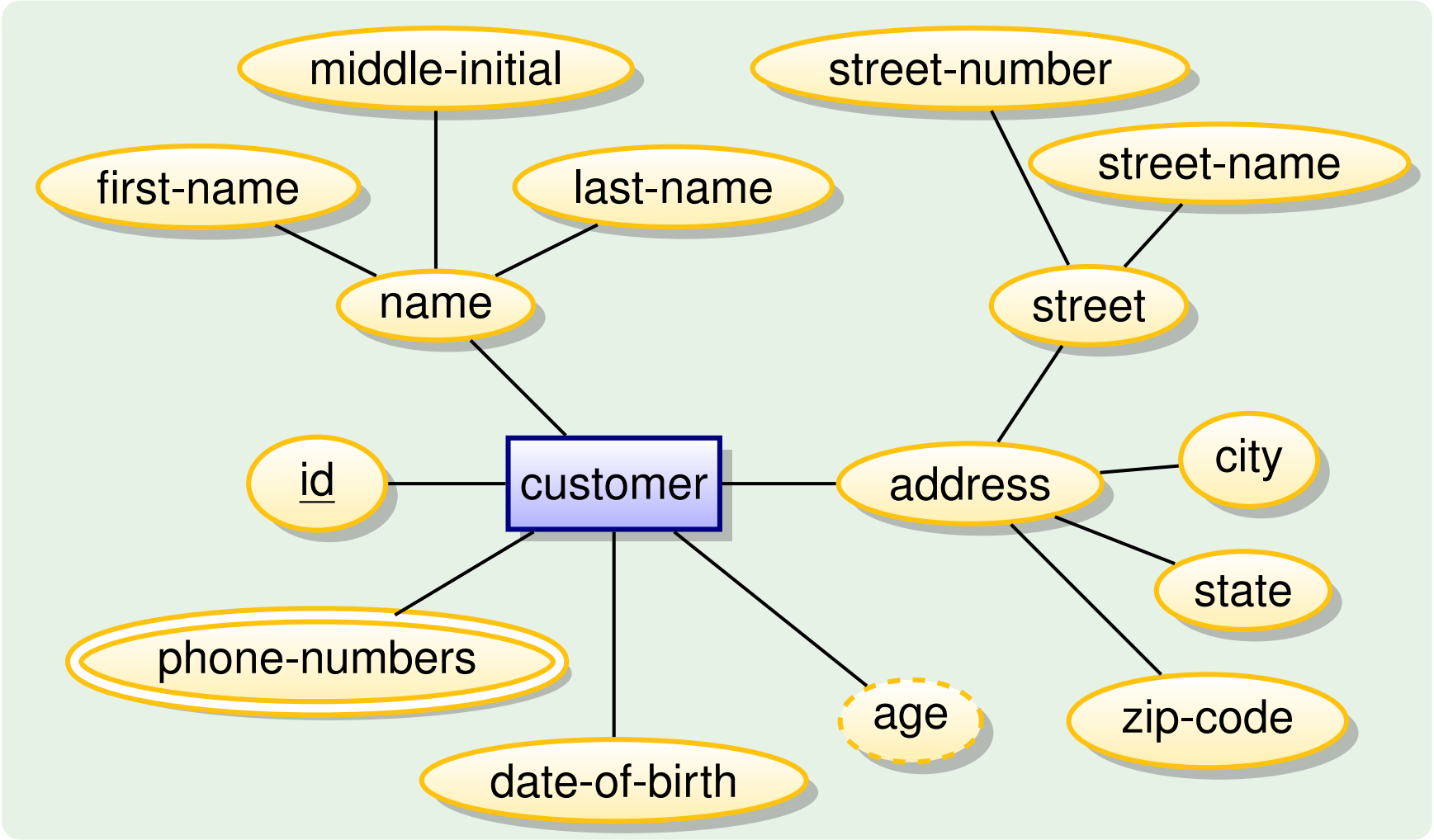
Attribute types

- **simple** and **composite** attributes
  - e.g. street is composed of street name and number
- **single-valued** and **multi-valued** attributes
  - e.g. single-valued: age of a person
  - e.g. multi-valued: person can have multiple phone numbers
- **derived attributes**
  - can be computed from other attributes
  - e.g. age, given the date of birth

Attributes

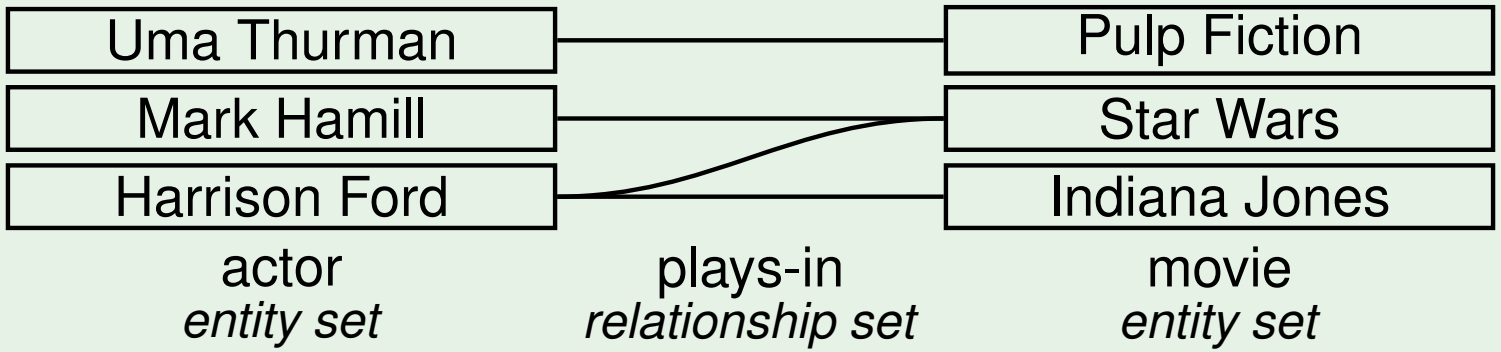

middle-initial
street-number
first-name
last-name
street-name
name
street
id
customer
address
city
state
phone-numbers
age
zip-code
date-of-birth

Attributes

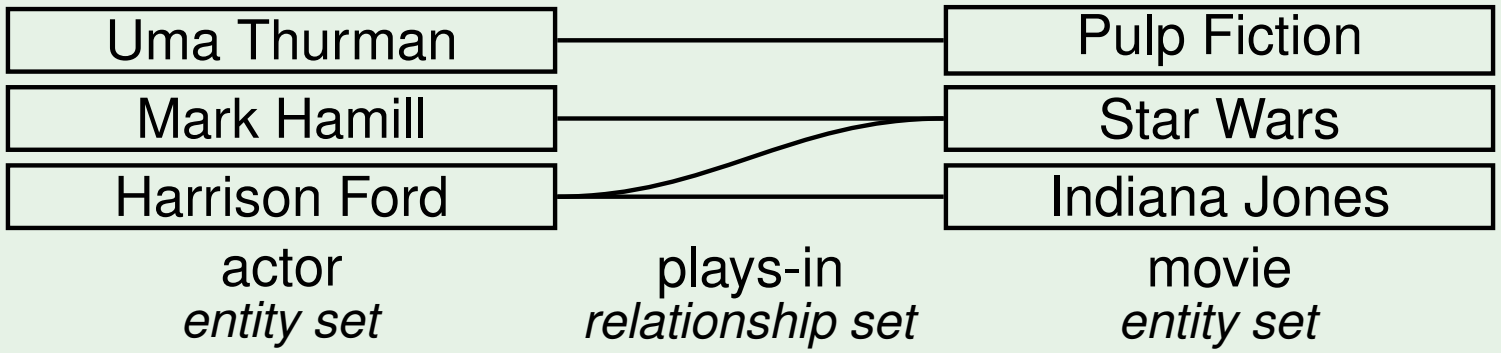


- *name*, *address* and *street* are composite attributes
- *phone numbers* is a multi-valued attribute
- *age* is a derived attribute (derived from *date-of-birth*)

Relationship Sets



Relationship Sets

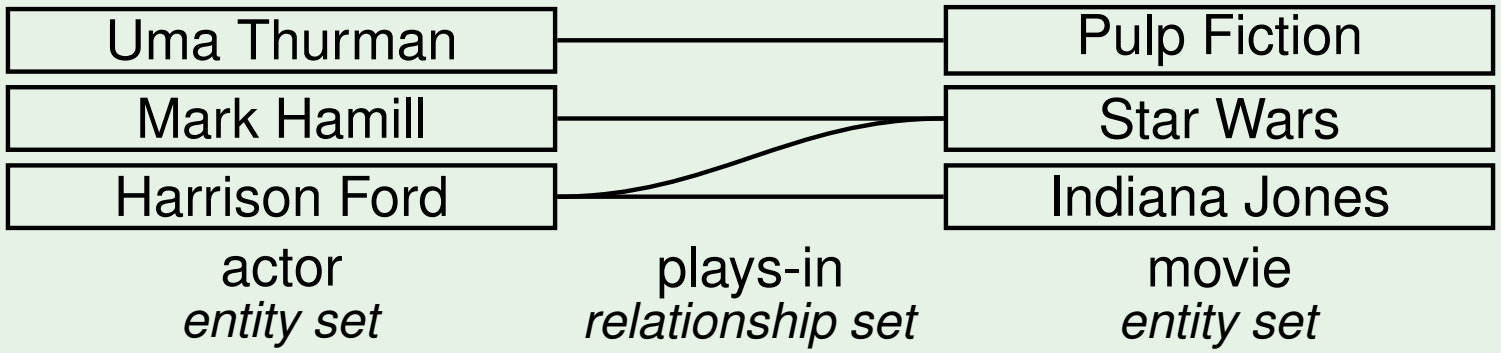


A **relationship** is an association among several entities.

That is, a **relationship** is a tuple $(e_1, e_2, \ldots, e_n)$ of entities.

- (Mark Hamill, Star Wars) is a relationship
- (Harrison Ford, Indiana Jones) is a relationship

Relationship Sets



A **relationship set** is set of relationships of the same kind.

That is, a **relationship set** is a set of tuples $(e_1, e_2, \ldots, e_n)$ where $e_1 \in E_1, \ldots, e_n \in E_n$ are from entity sets $E_1, \ldots, E_n$.

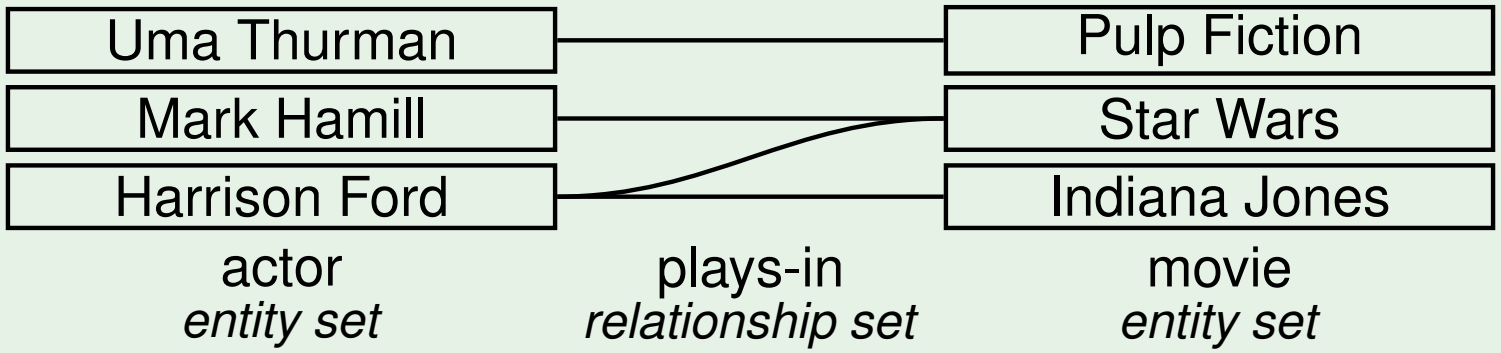
Example of a relationship set

$\{$ (Uma Thurman, Pulp Fiction), (Mark Hamill, Star Wars), (Harrison Ford, Star Wars), (Harrison Ford, Indiana Jones) $\}$

The elements of a relationship set are relationships:

- (Mark Hamill, Star Wars) $\in$ shows is a relationship

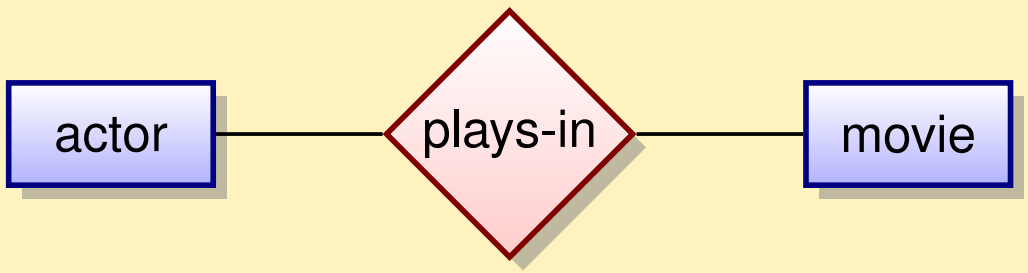
Relationship Sets



A **relationship set** is set of relationships of the same kind.

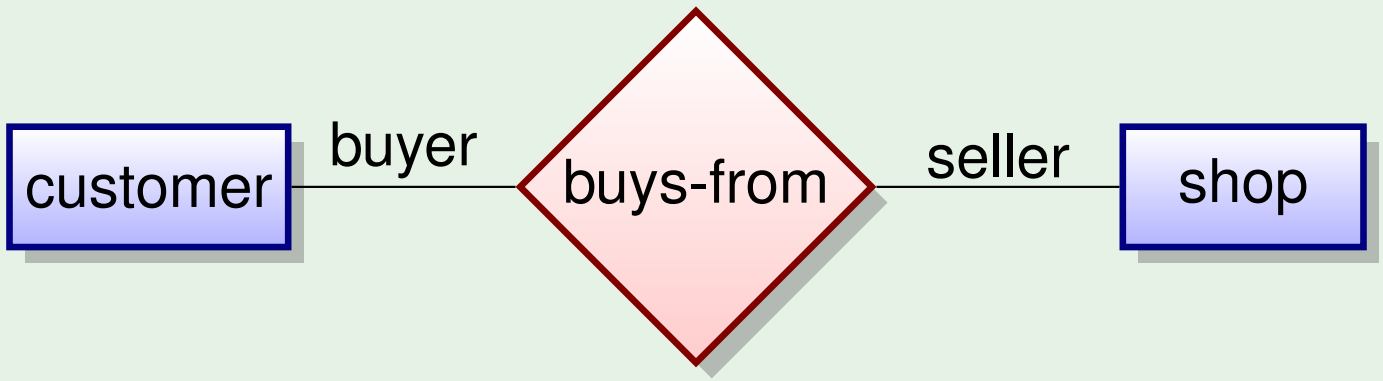
That is, a **relationship set** is a set of tuples $(e_1, e_2, \ldots, e_n)$ where $e_1 \in E_1, \ldots, e_n \in E_n$ are from entity sets $E_1, \ldots, E_n$.

A relationship set *plays-in* between entity sets *actor* and *movie* is indicated as follows in E/R models:



Relationship Sets and Role Names

The relationship set connections can be annotated with **role indicators**.



- role indicators improve readability

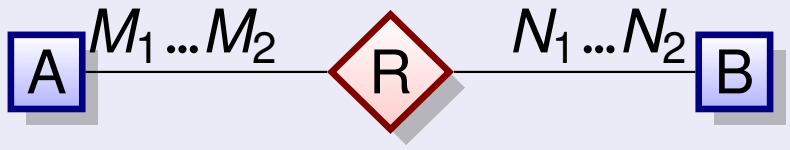
Cardinality Limits

Cardinality limits express the number of entities to which another entity can be associated via a relationship set.

Cardinality Limits

Cardinality limits express the number of entities to which another entity can be associated via a relationship set.

There are many notations. The most intuitive notation is:

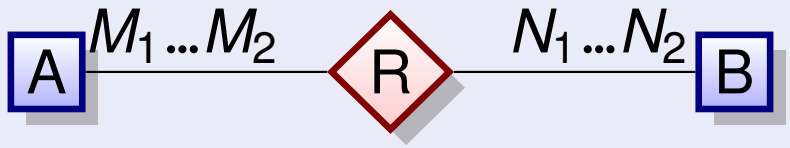


- Every entity a from A is connected to at least N_1, and at most N_2 entities in B.
- Every entity b from B is connected to at least M_1, and at most M_2 entities in A.

Cardinality Limits

Cardinality limits express the number of entities to which another entity can be associated via a relationship set.

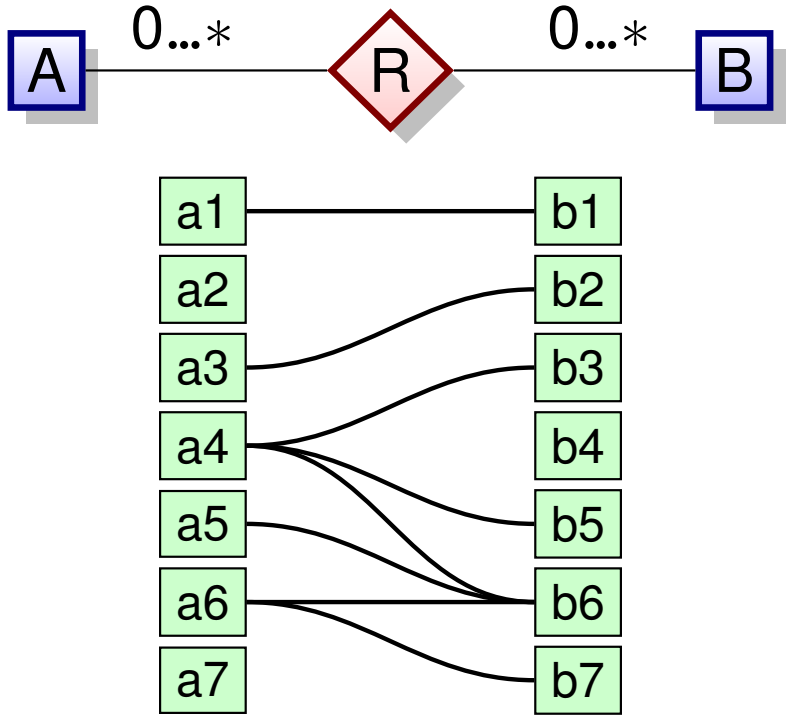
There are many notations. The most intuitive notation is:



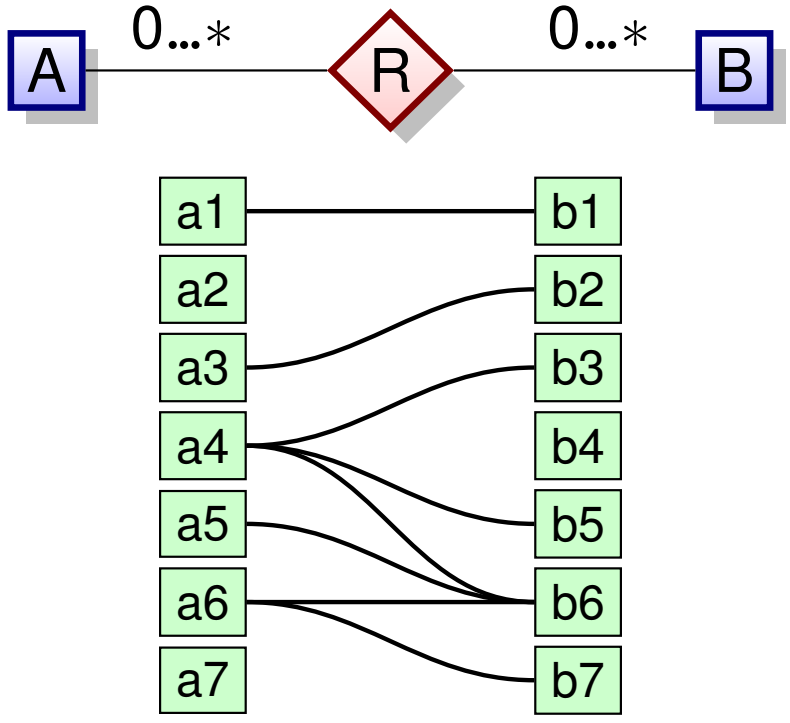
- Every entity a from A is connected to at least N_1, and at most N_2 entities in B.
- Every entity b from B is connected to at least M_1, and at most M_2 entities in A.

- 0…1 = zero or one
- 1…1 = precisely one
- 0…$*$ = any number
- 1…$*$ = at least one

Cardinality Limits: Many-to-Many



Cardinality Limits: Many-to-Many

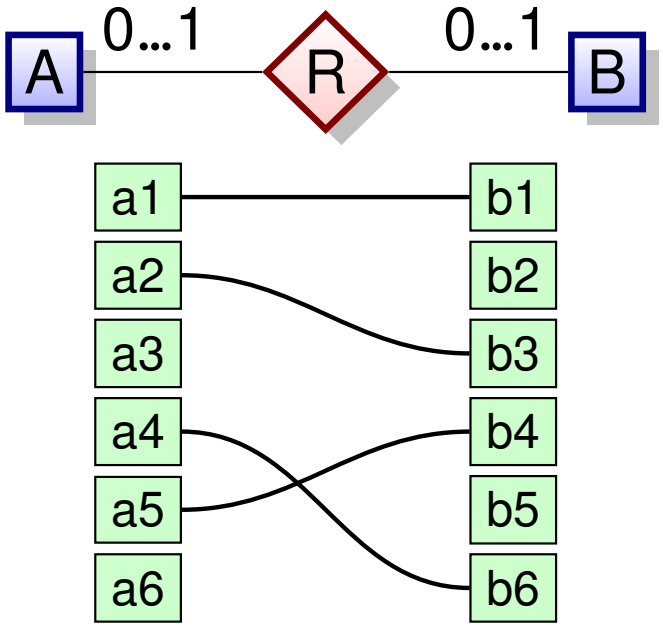


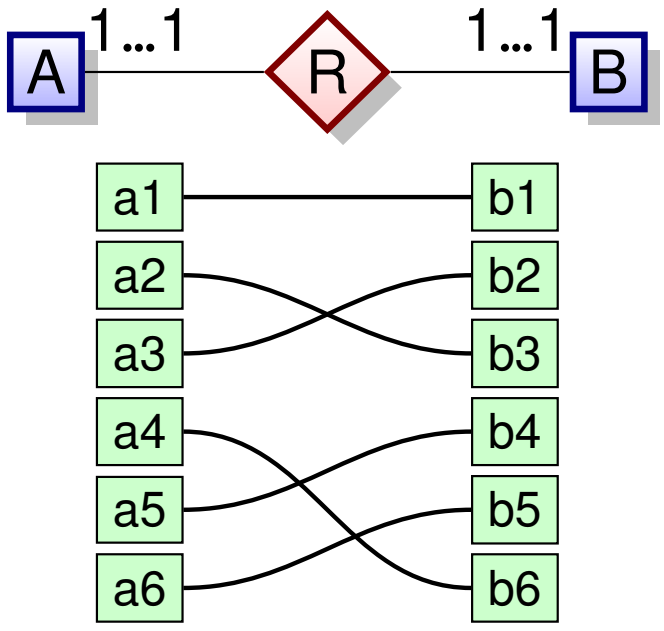
This describes a **many-to-many** relationship set:

- the entities may be connected arbitrarily
- every *a* in *A* can be linked to an arbitrary number of *B*'s
- every *b* in *B* can be linked to an arbitrary number of *A*'s

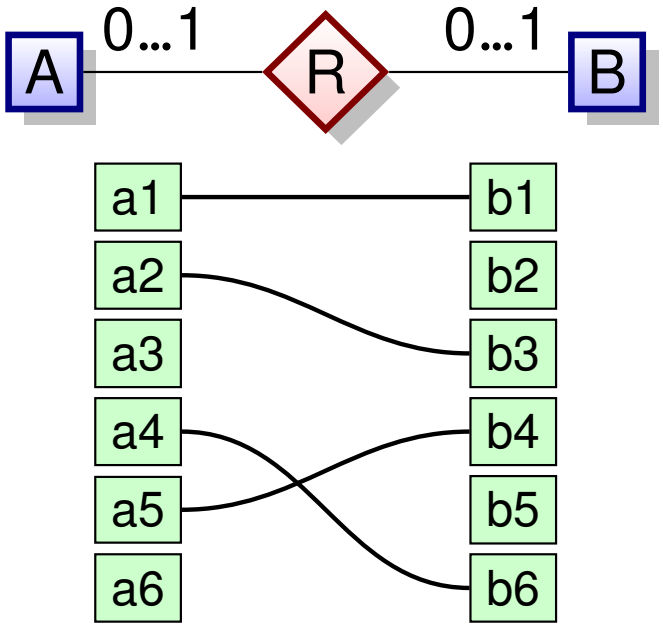
If the cardinalities are not given, the **default is many-to-many**.

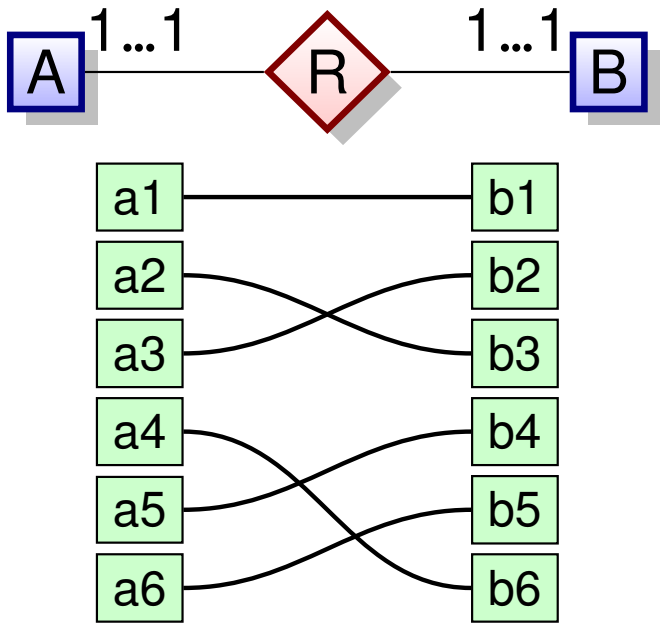
Cardinality Limits: One-to-One





Cardinality Limits: One-to-One





Both are called **one-to-one** relationship set.

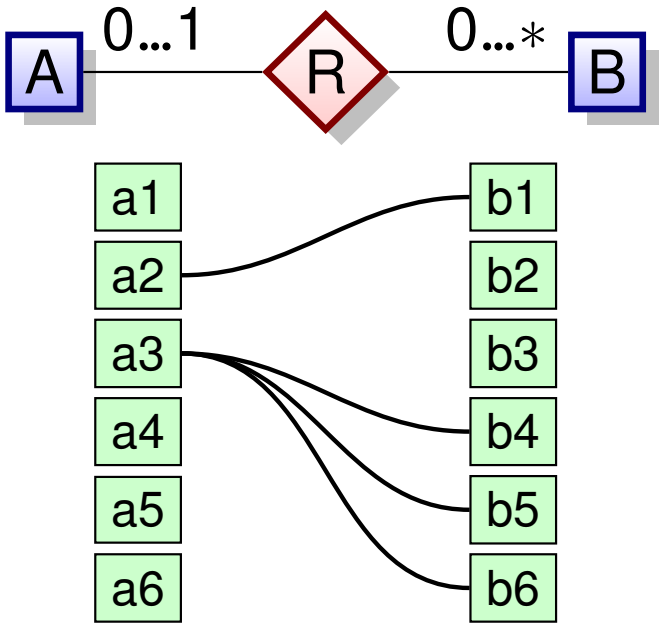
For the diagram on the left we have:

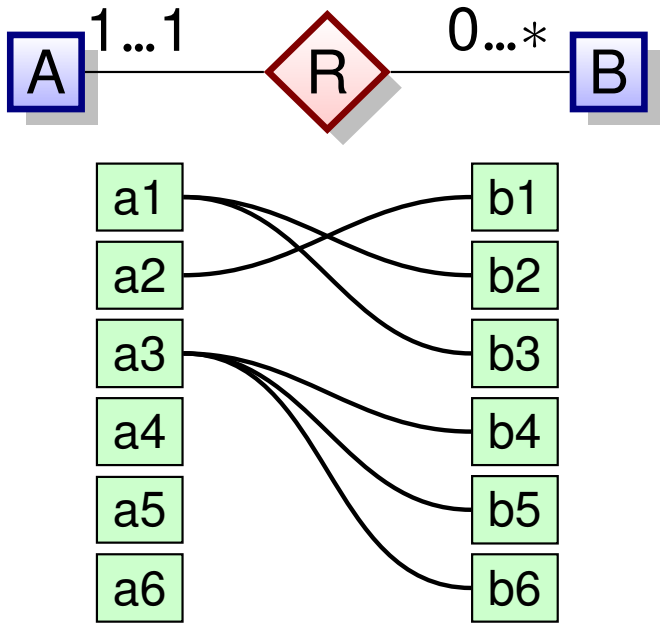
- every *a* in *A* is connected to at most one (= 0 or 1) *b* in *B*
- every *b* in *B* is connected to at most one (= 0 or 1) *a* in *A*

For the diagram on the right we have:

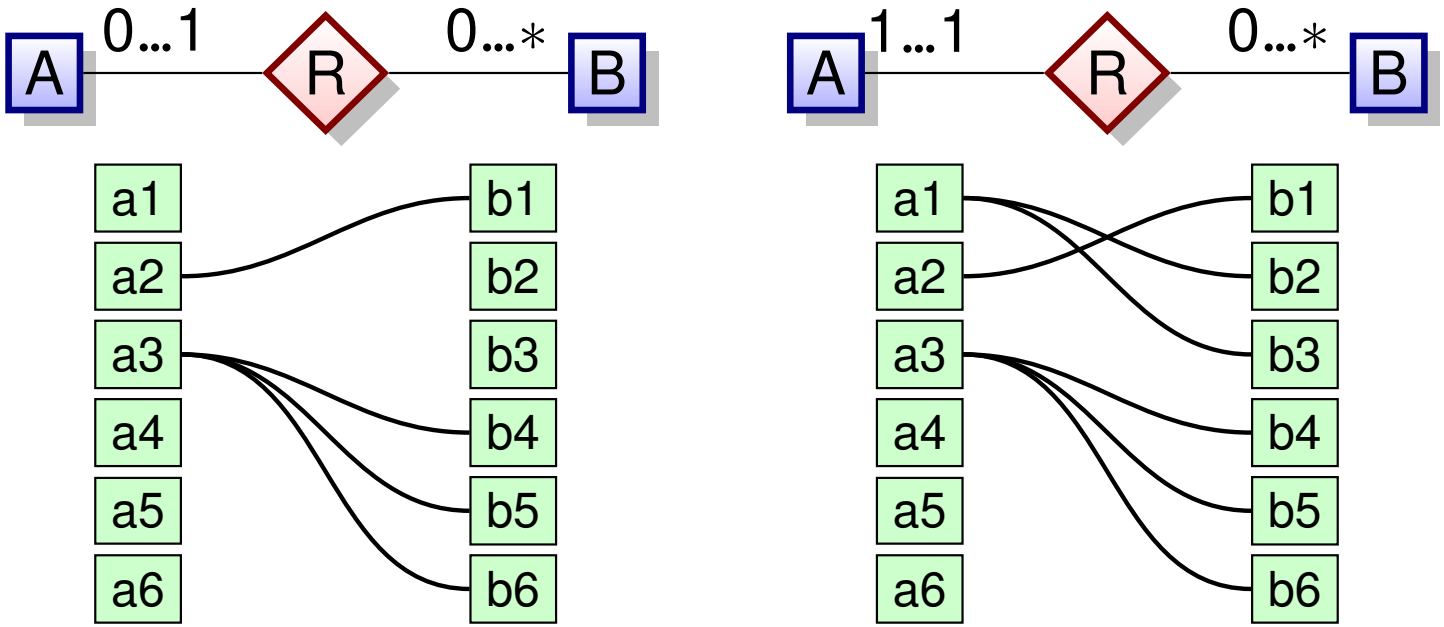
- every *a* in *A* is connected to precisely one *b* in *B*
- every *b* in *B* is connected to precisely one *a* in *A*

Cardinality Limits: One-to-Many





Cardinality Limits: One-to-Many



Both are called **one-to-many** relationship set.

In both diagrams:

- every *a* can have an arbitrary number of links to *b* in *B*

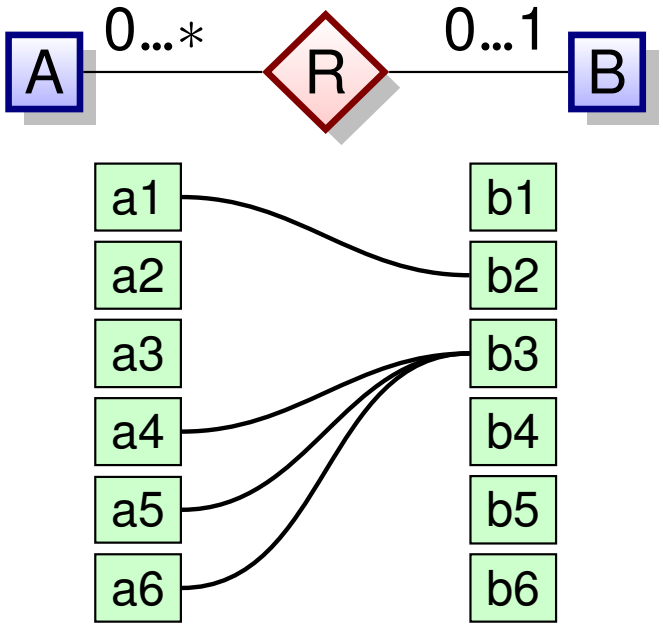
For the diagram on the left we have:

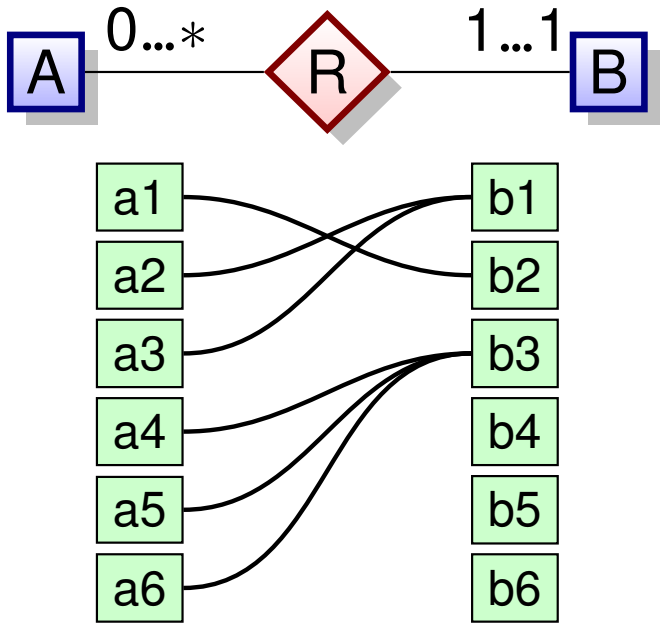
- every *b* in *B* is connected to at most one *a* in *A*

For the diagram on the right we have:

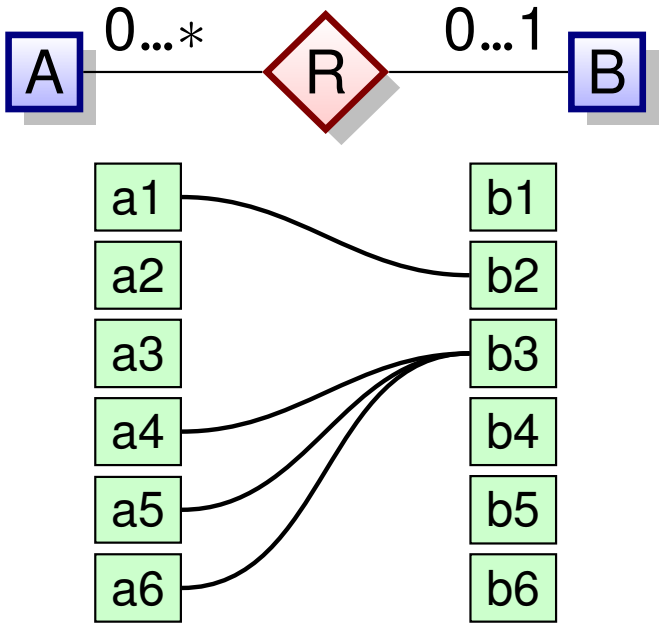
- every *b* in *B* is connected to precisely one *a* in *A*

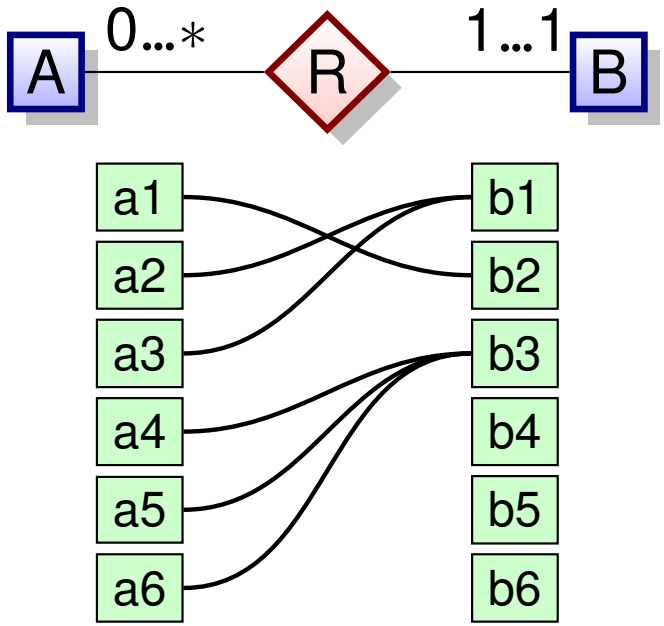
Cardinality Limits: Many-to-One





Cardinality Limits: Many-to-One





Both are called **many-to-one** relationship set.

In both diagrams:

- every *b* can have an arbitrary number of links to *a* in *A*

For the diagram on the left we have:

- every *a* in *A* is connected to at most one *b* in *B*

For the diagram on the right we have:

- every *a* in *A* is connected to precisely one *b* in *B*

Cardinality Limits

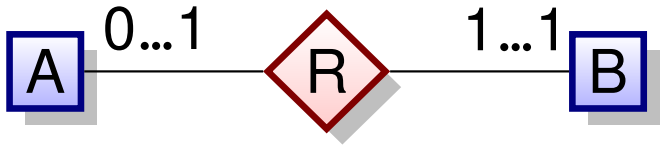
Express the following:

- Every a in A is connected to precisely one b in B, and every b in B is connected to at most one a in A.

Cardinality Limits

Express the following:

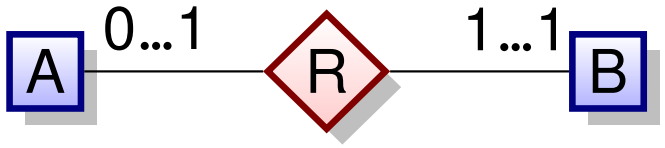
- Every *a* in *A* is connected to precisely one *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.



Cardinality Limits

Express the following:

- Every *a* in *A* is connected to precisely one *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.

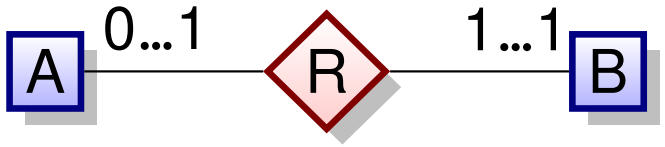


- Every *a* in *A* is connected to one or more *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.

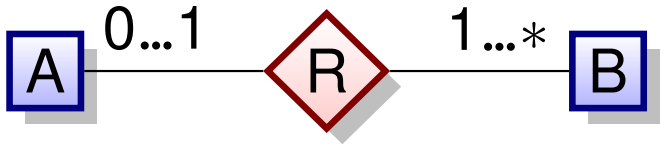
Cardinality Limits

Express the following:

- Every *a* in *A* is connected to precisely one *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.



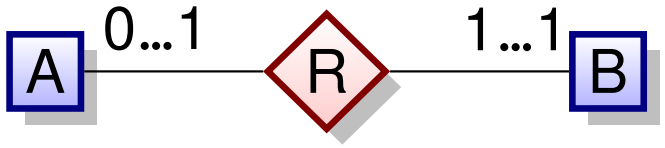
- Every *a* in *A* is connected to one or more *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.



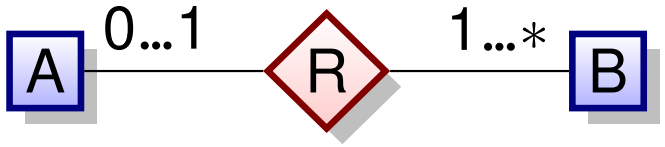
Cardinality Limits

Express the following:

- Every *a* in *A* is connected to precisely one *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.



- Every *a* in *A* is connected to one or more *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.

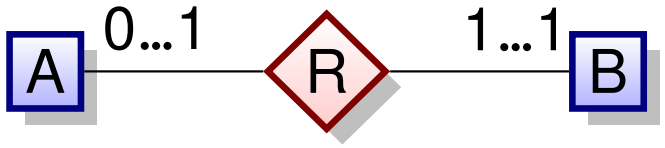


- Every *a* in *A* is connected to one or more *b* in *B*, and every *b* in *B* is connected to precisely one *a* in *A*.

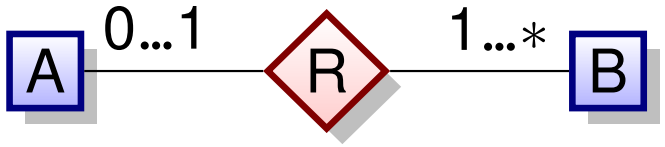
Cardinality Limits

Express the following:

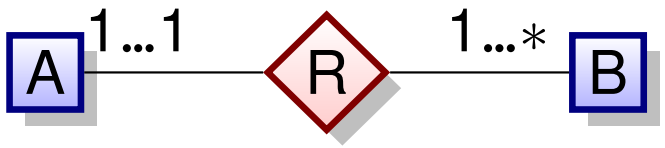
- Every *a* in *A* is connected to precisely one *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.



- Every *a* in *A* is connected to one or more *b* in *B*, and every *b* in *B* is connected to at most one *a* in *A*.



- Every *a* in *A* is connected to one or more *b* in *B*, and every *b* in *B* is connected to precisely one *a* in *A*.



Cardinality Limits: Alternative Notations

There are many different notations for E/R models.

Cardinality Limits: Alternative Notations

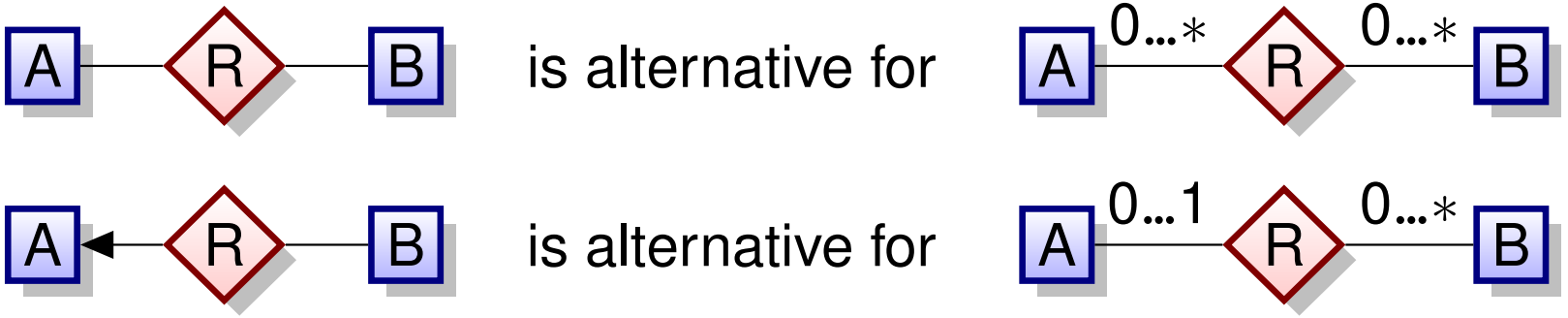
There are many different notations for E/R models.

For example:

Cardinality Limits: Alternative Notations

There are many different notations for E/R models.

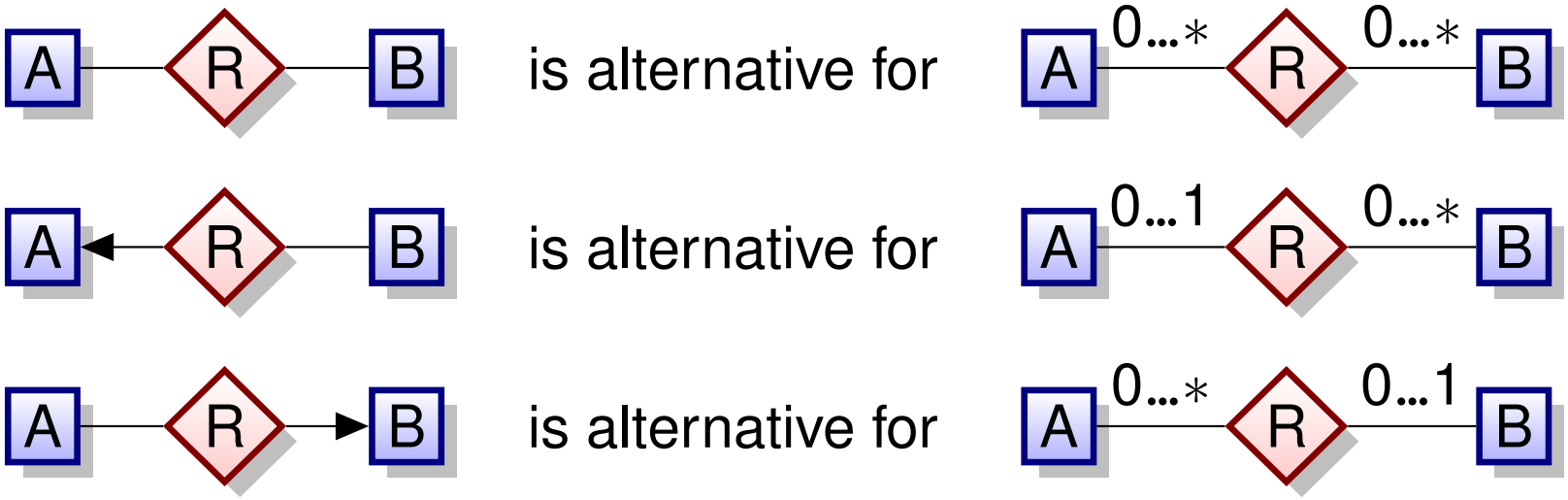
For example:



Cardinality Limits: Alternative Notations

There are many different notations for E/R models.

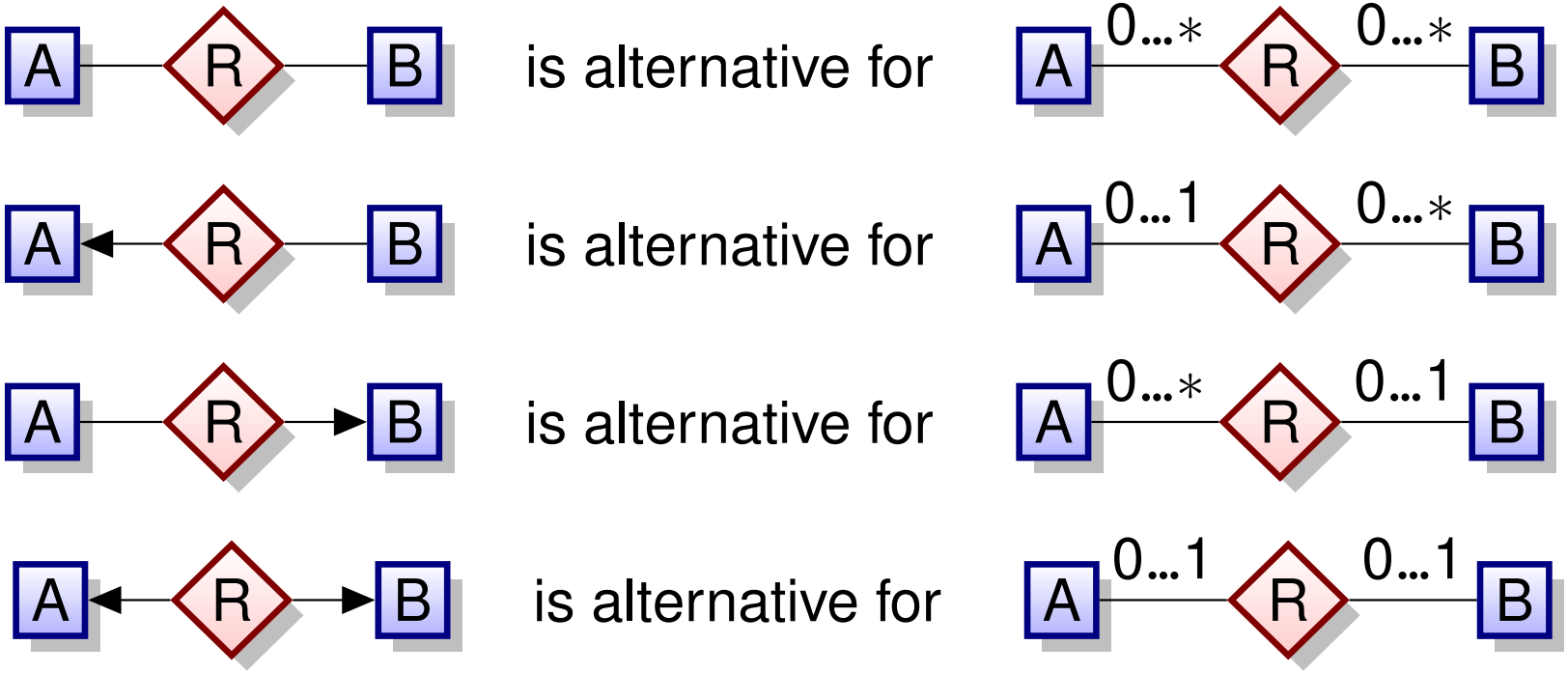
For example:



Cardinality Limits: Alternative Notations

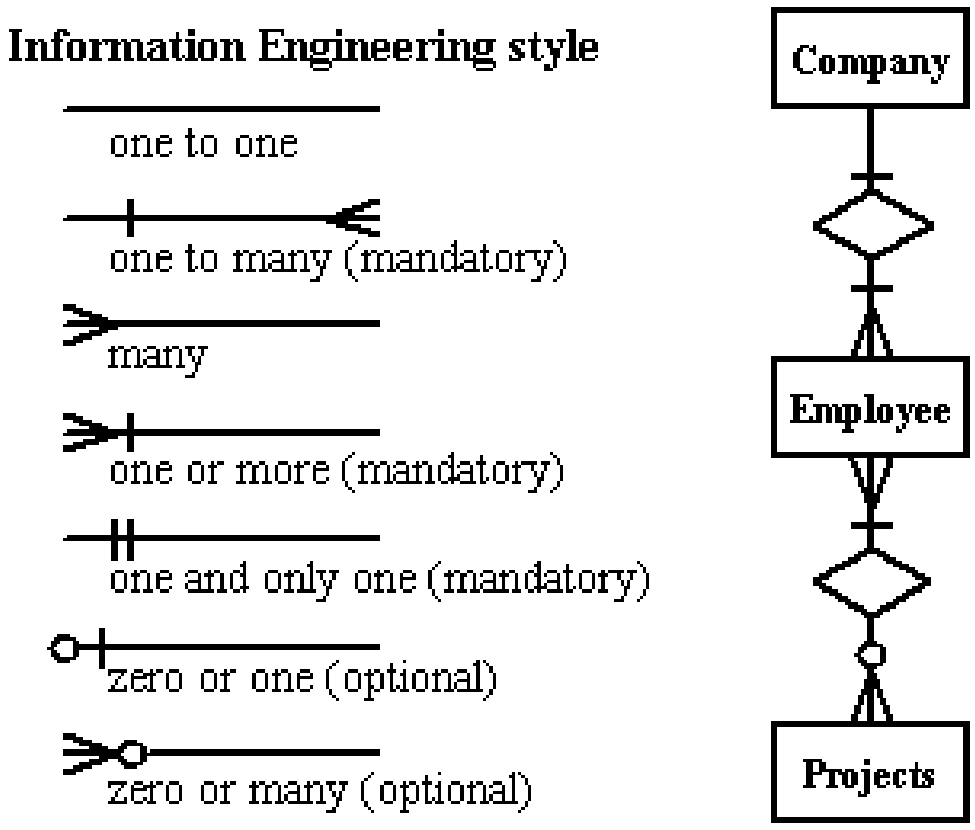
There are many different notations for E/R models.

For example:



Alternative Notations

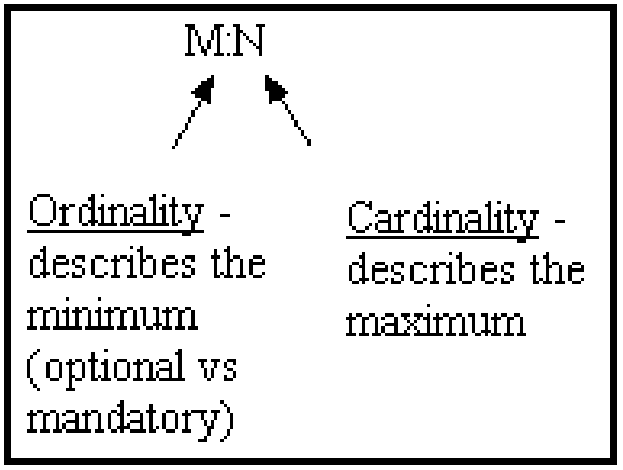
- Information engineering style



Alternative Notations

- Chen style

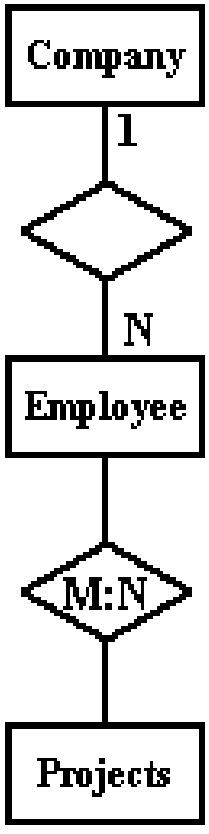
Chen style



1:N (n=0,1,2,3...)
one to zero or more

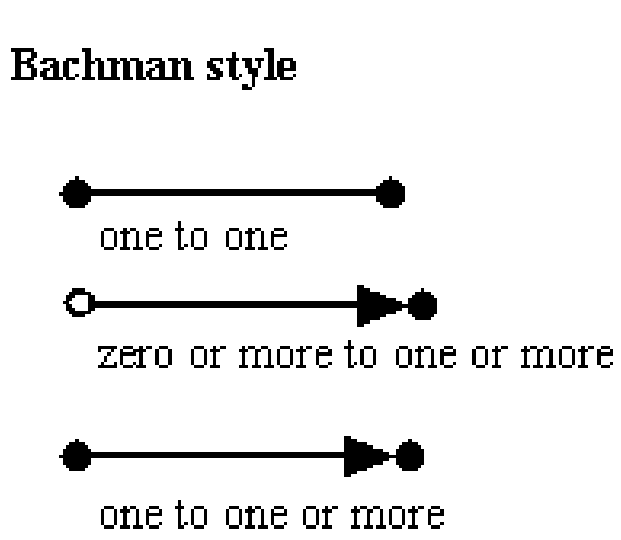
M:N (m and n=0,1,2,3...)
zero or more to zero or more
(many to many)

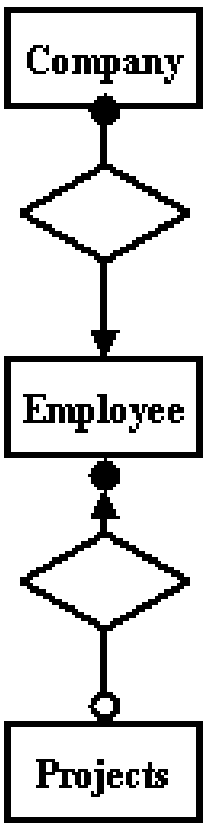
1:1
one to one



Alternative Notations

- Bachman style





Alternative Notations

- Martin style

Martin style

1 - one, and only one (mandatory)

* - many (zero or more - optional)

1...* - one or more (mandatory)

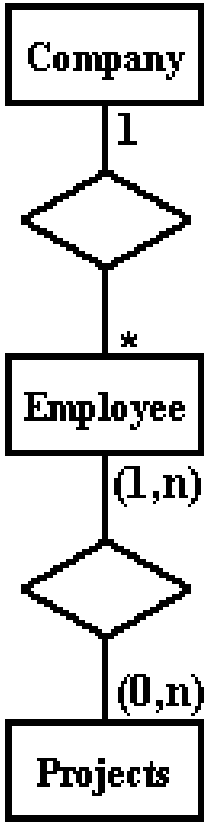
0...1 - zero or one (optional)

(0,1) - zero or one (optional)

(1,n) -one or more (mandatory)

(0,n) - zero or more (optional)

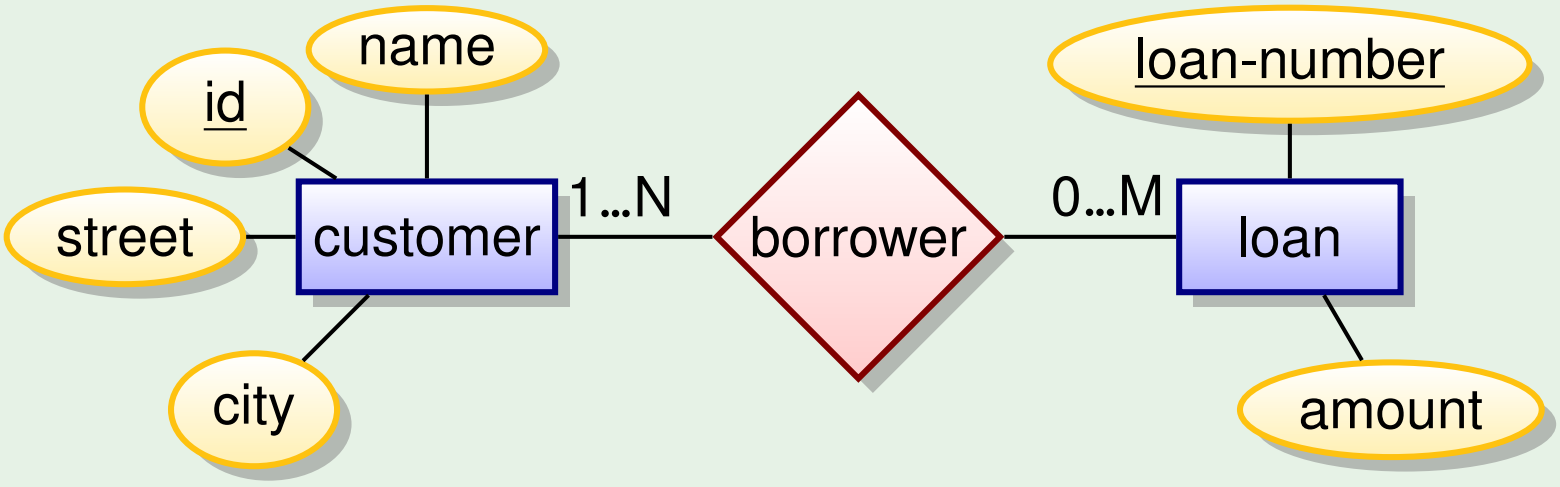
(1,1) - one and only one (mandatory)



Total Participation

Total participation means that every entity in the entity set participates in at least one relationship in the relationship set.

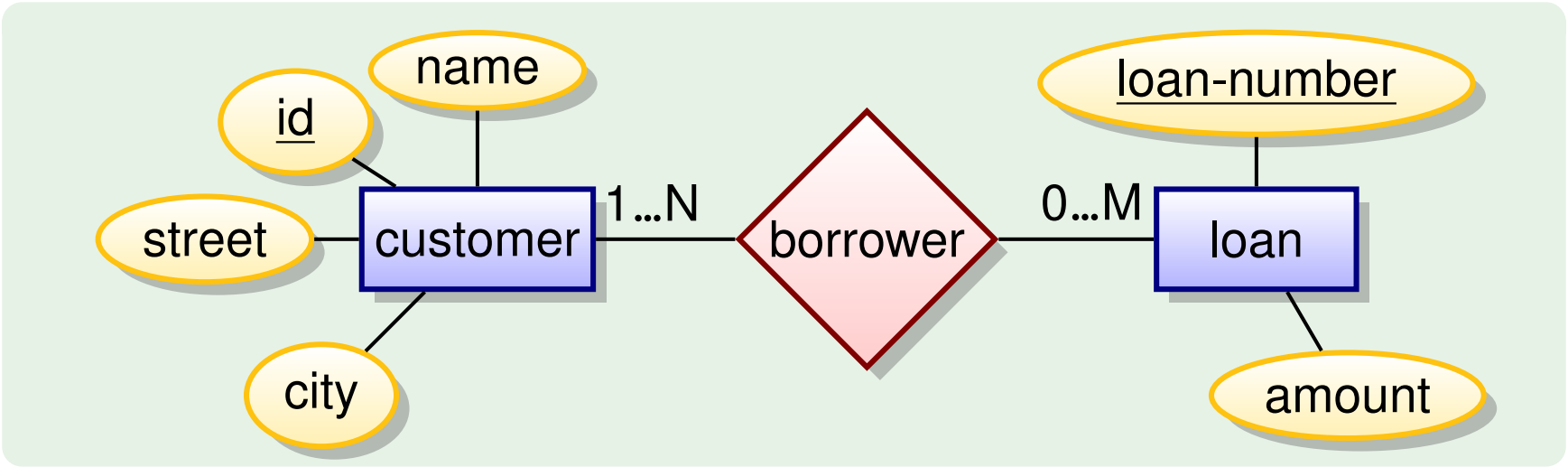
- e.g. every loan must be belong to at least one customer



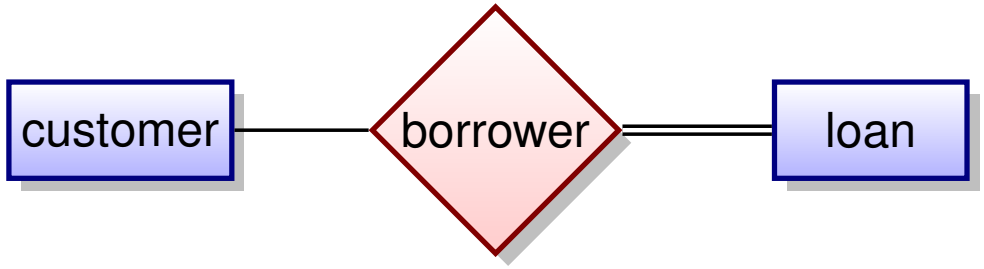
Total Participation

Total participation means that every entity in the entity set participates in at least one relationship in the relationship set.

- e.g. every loan must be belong to at least one customer



Alternative notation:

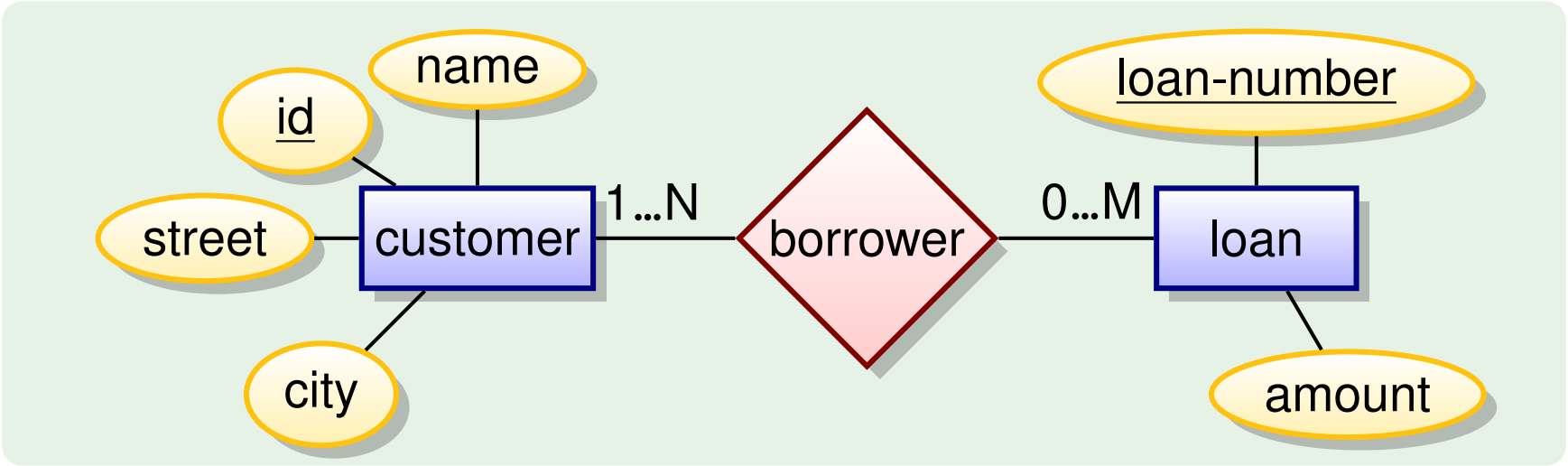


Total Participation

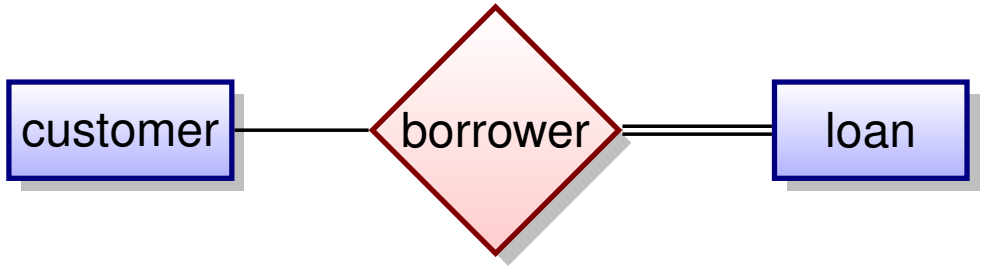
Total participation means that every entity in the entity set participates in at least one relationship in the relationship set.

- e.g. every loan must be belong to at least one customer

Partial participation means that entities may not participate in any relationship in the set.



Alternative notation:



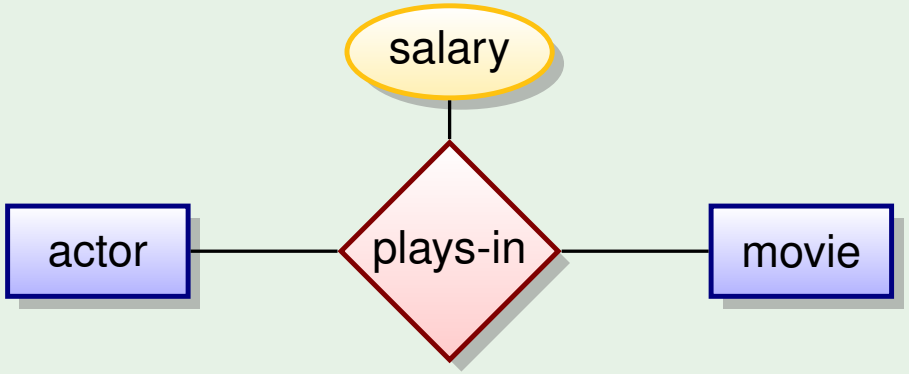
Relationship Sets with Attributes

An **attribute** can also be property of a relationship set.

Relationship Sets with Attributes

An **attribute** can also be property of a relationship set.

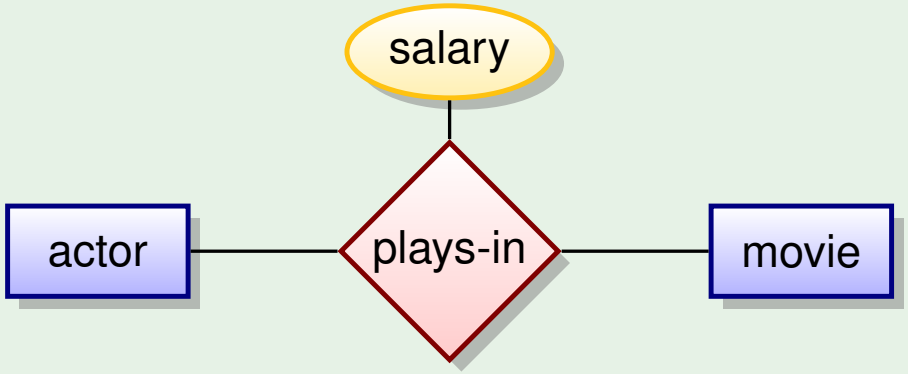
The *plays-in* relationship set between the entity sets *actor* and *movie* may have the attribute *salary*.

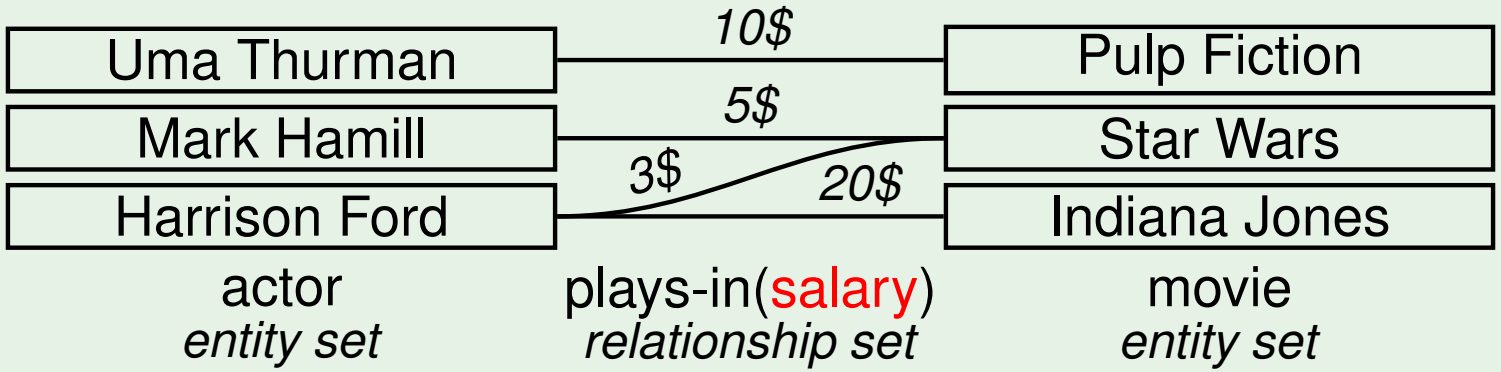


Relationship Sets with Attributes

An **attribute** can also be property of a relationship set.

The *plays-in* relationship set between the entity sets *actor* and *movie* may have the attribute *salary*.

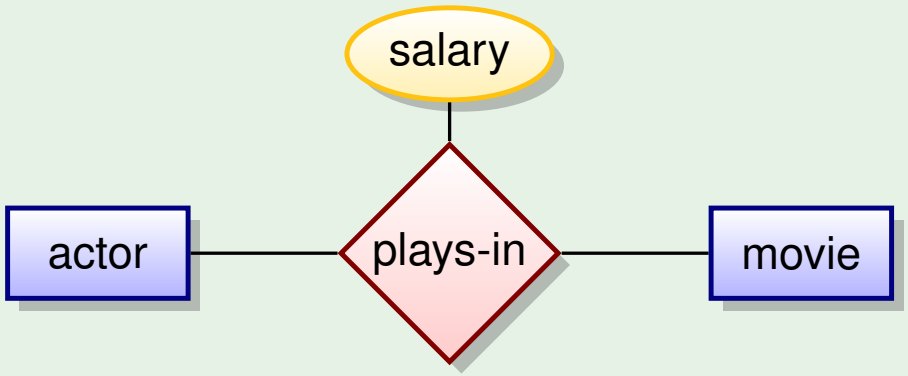


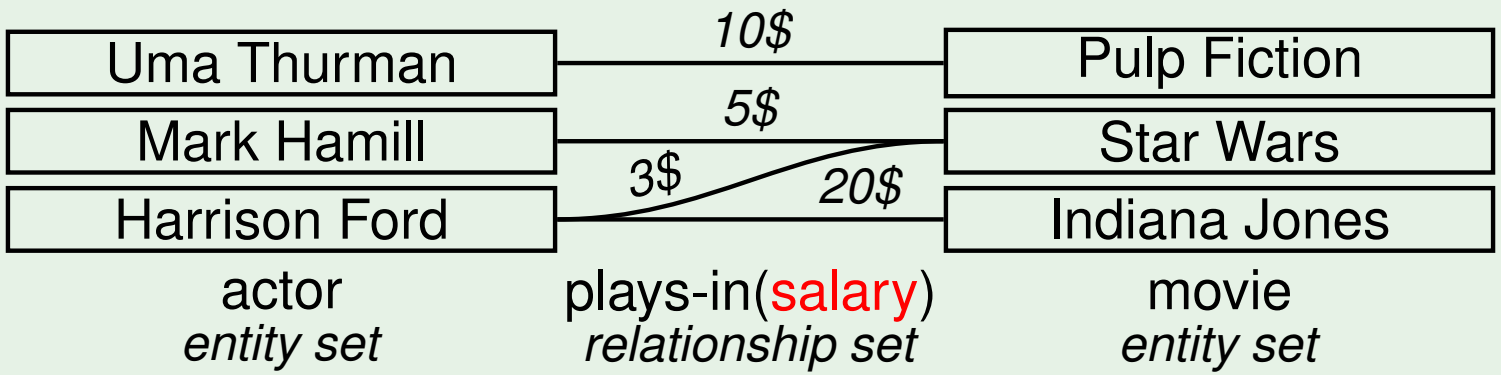


Relationship Sets with Attributes

An **attribute** can also be property of a relationship set.

The *plays-in* relationship set between the entity sets *actor* and *movie* may have the attribute *salary*.

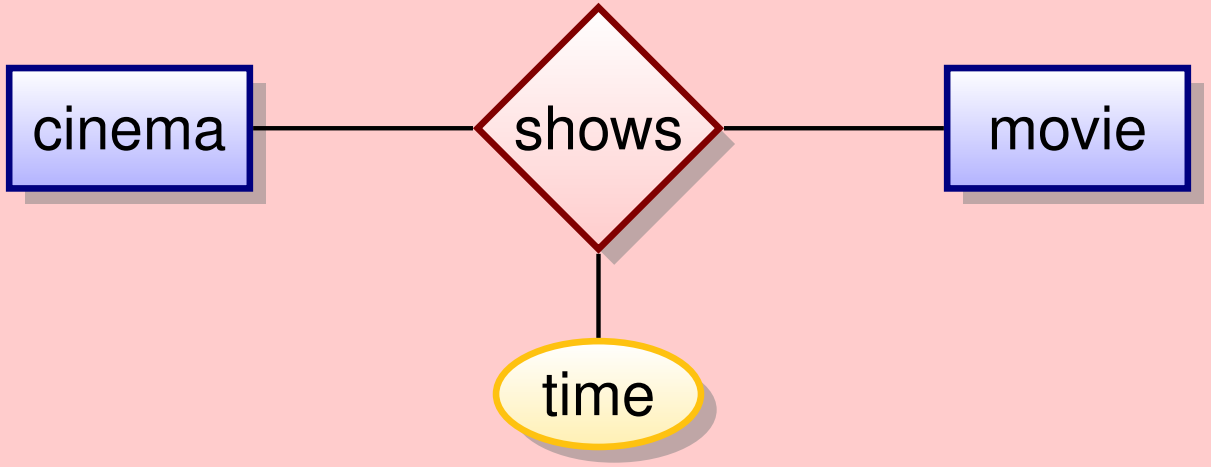




The value of the relationship attributes is functionally determined by the relationship $(e_1, \ldots, e_n)$.

Relationship Sets with Attributes

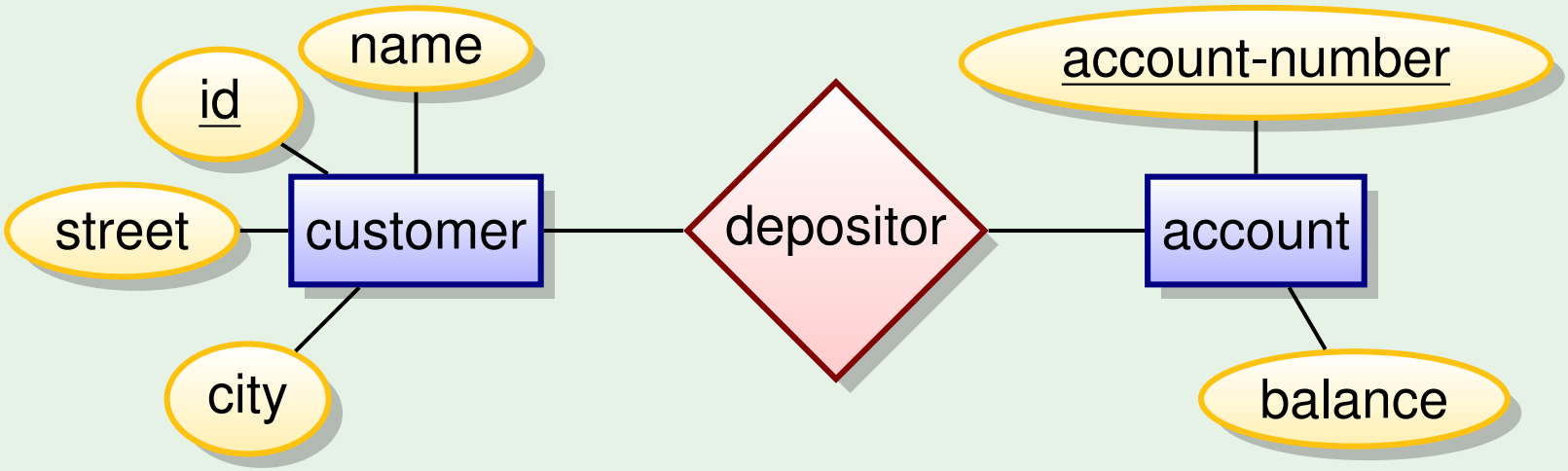
Consequences of the Semantics



Suppose a cinema shows a movie twice a day (at 3pm and 6pm).

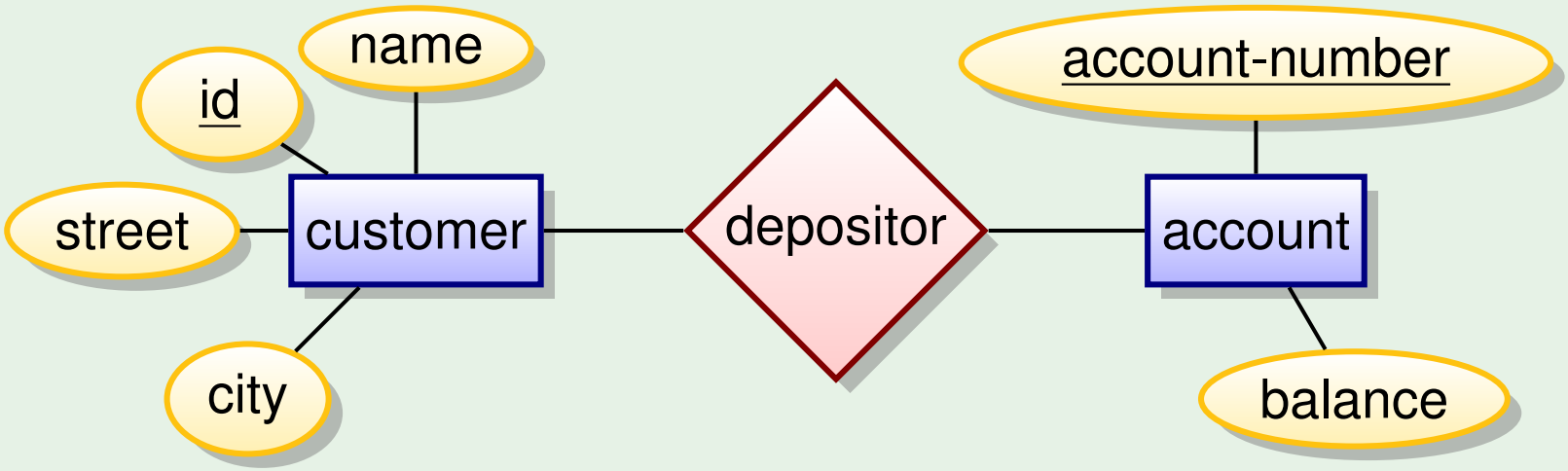
Can this information be stored in the given schema?

Cardinalities affect the E/R Design



Assume that we want to record the date of the last access of a customer to an account. We call this attribute *access-date*.

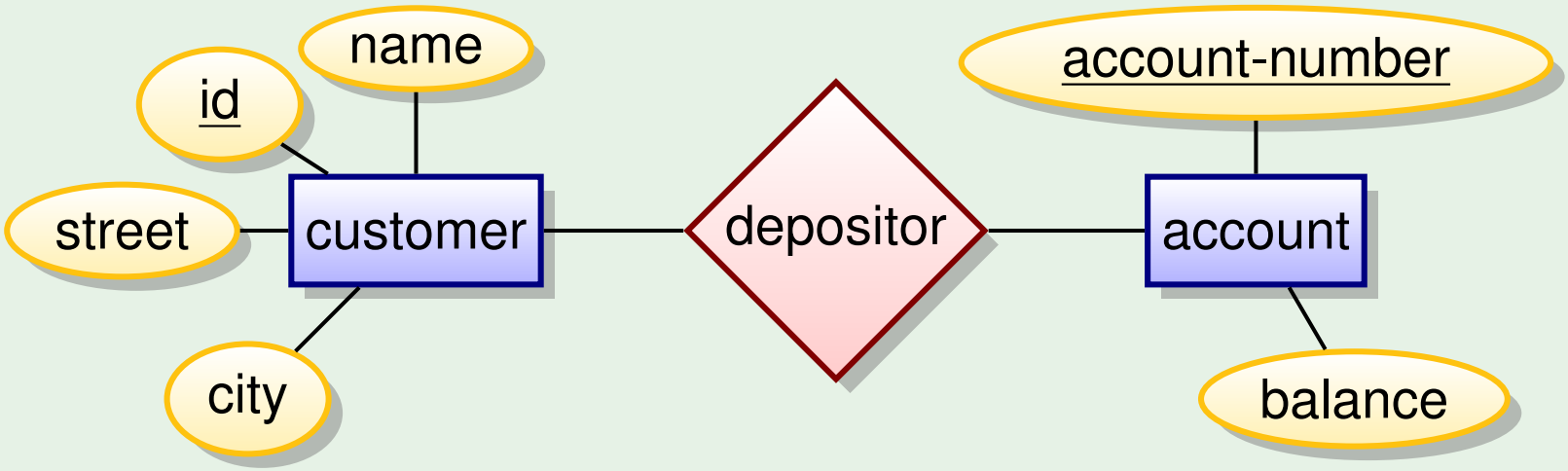
Cardinalities affect the E/R Design



Assume that we want to record the date of the last access of a customer to an account. We call this attribute *access-date*.

If the relation from customer to account is **many-to-many**:

Cardinalities affect the E/R Design

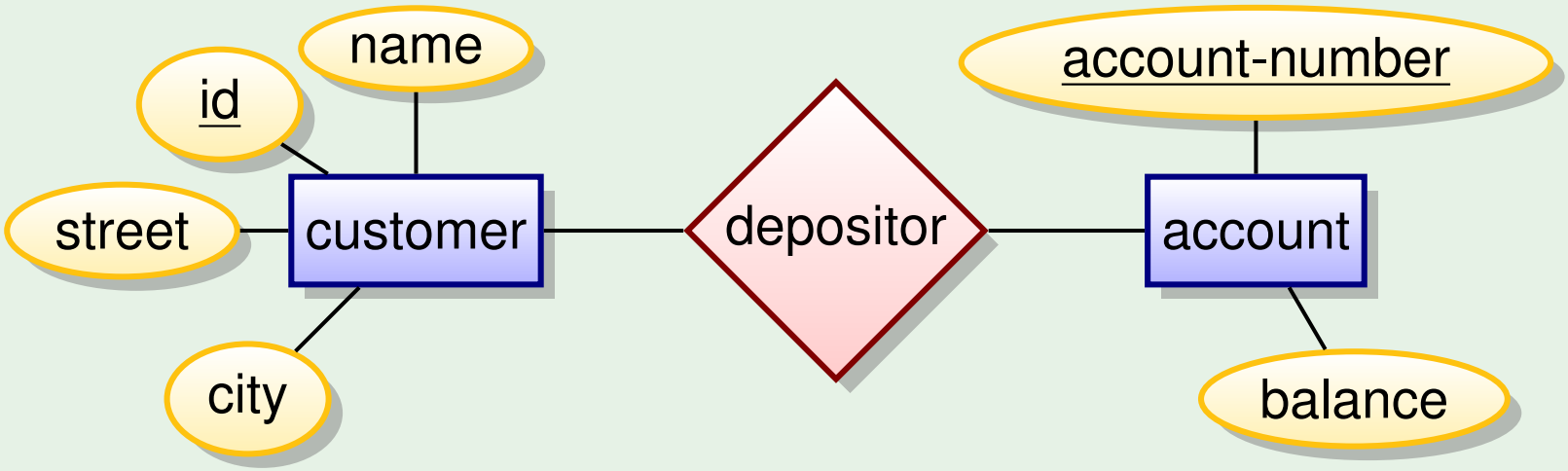


Assume that we want to record the date of the last access of a customer to an account. We call this attribute *access-date*.

If the relation from customer to account is **many-to-many**:

- then *access-date* must be an attribute of *depositor*

Cardinalities affect the E/R Design



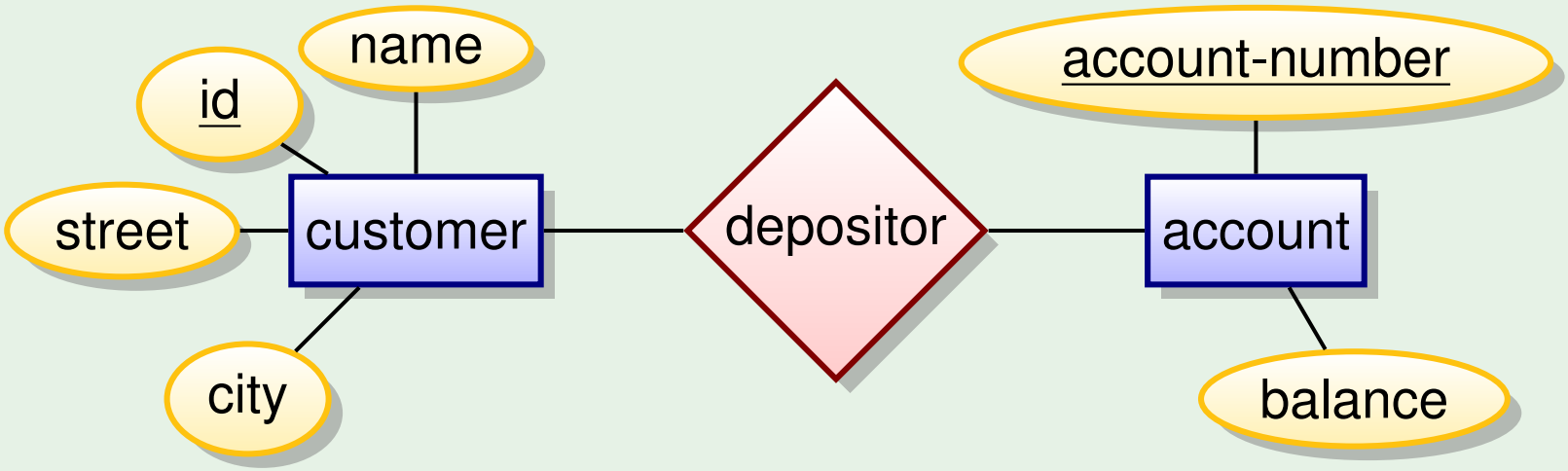
Assume that we want to record the date of the last access of a customer to an account. We call this attribute *access-date*.

If the relation from customer to account is **many-to-many**:

- then *access-date* must be an attribute of *depositor*

If the relation from customer to account is **one-to-many**:

Cardinalities affect the E/R Design



Assume that we want to record the date of the last access of a customer to an account. We call this attribute *access-date*.

If the relation from customer to account is **many-to-many**:

- then *access-date* must be an attribute of *depositor*

If the relation from customer to account is **one-to-many**:

- then *access-date* can be an attribute of *account*

Degree of a Relationship Set

The **degree** of a relationship set refers to the number of entity sets participating in the relationship.

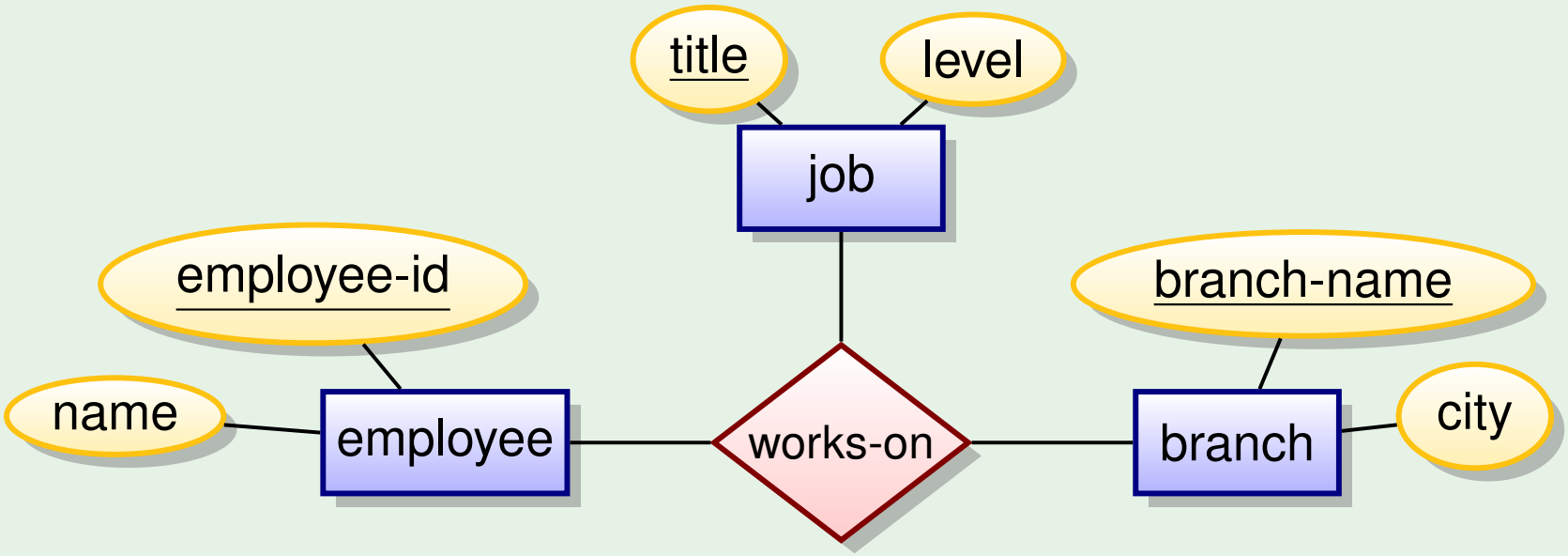
- relationship sets of degree 2 are called **binary**
- relationship sets of degree 3 are called **ternary**

Degree of a Relationship Set

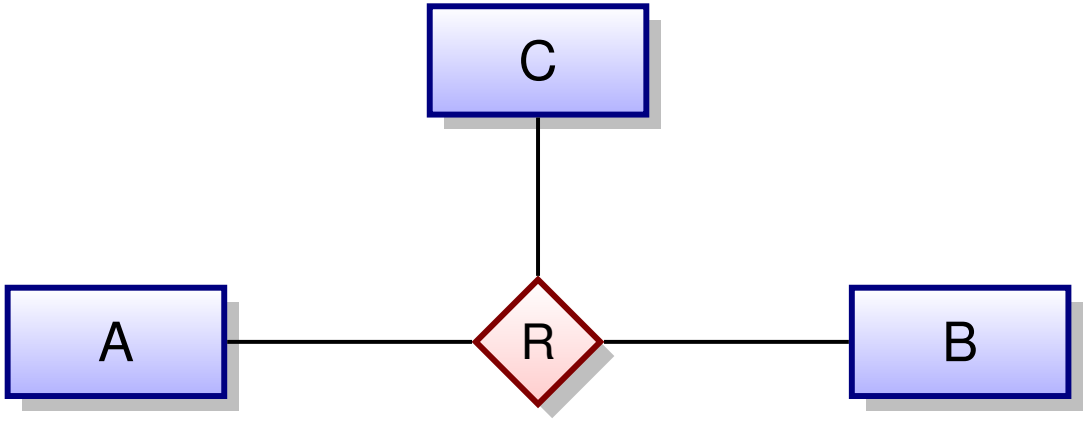
The **degree** of a relationship set refers to the number of entity sets participating in the relationship.

- relationship sets of degree 2 are called **binary**
- relationship sets of degree 3 are called **ternary**

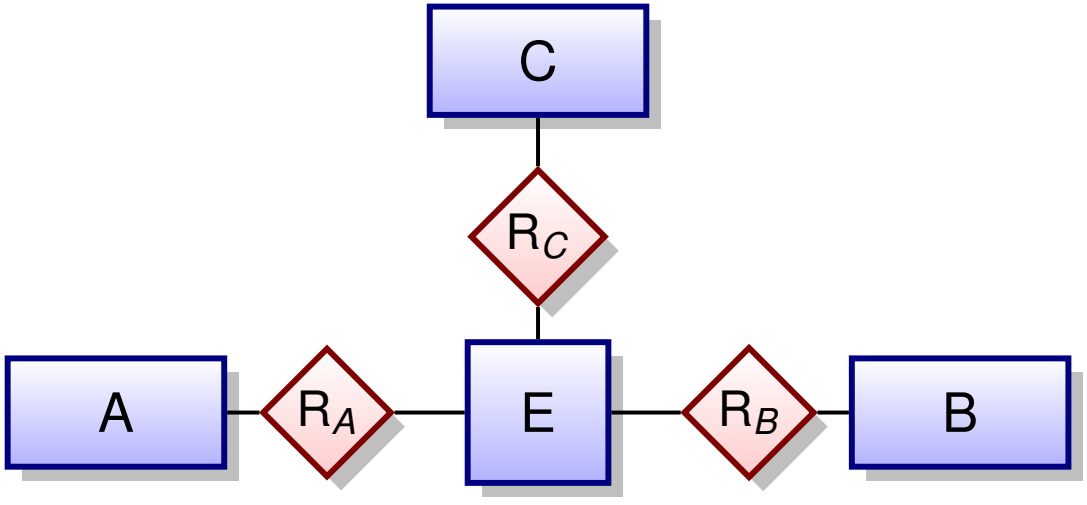
Example for a ternary relationship set *works-on*: an *employee* might work on different *jobs* at different *branches* of a company.



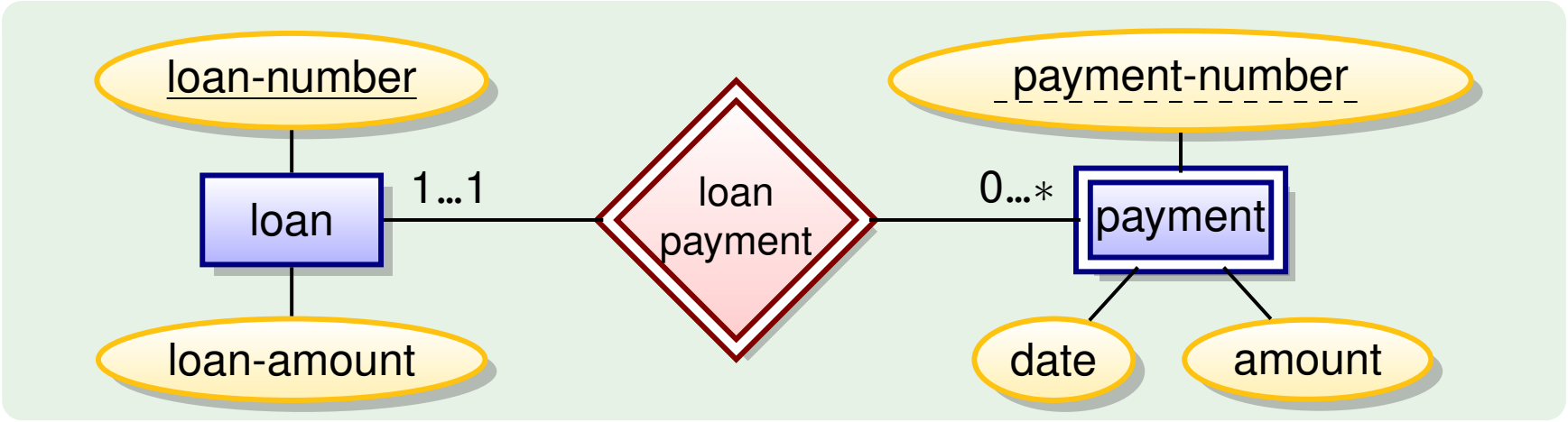
Degree of a Relationship Set



Non-binary relationship sets can be represented using binary ones by creating an artificial entity set.



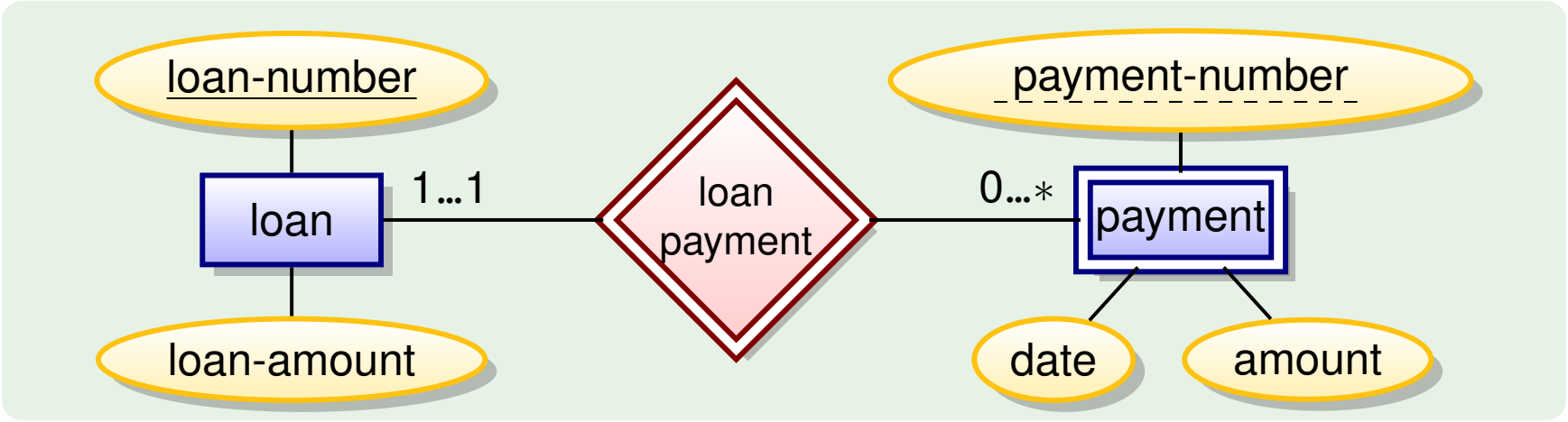
Weak Entity Sets



There can be multiple payments with equal payment-number

- the payment-number is **not a key**

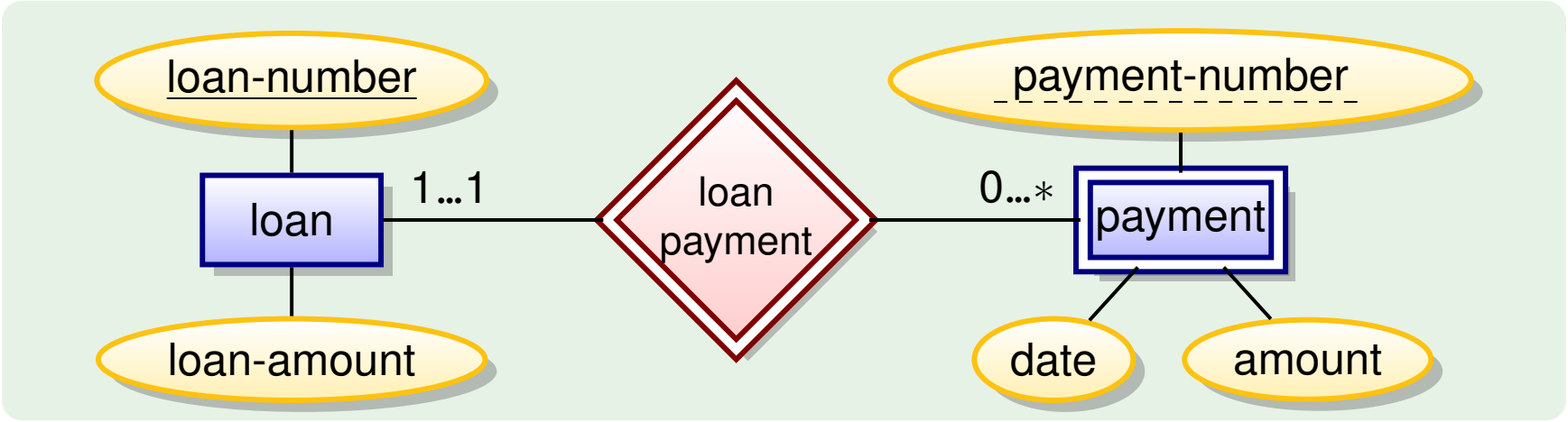
Weak Entity Sets



There can be multiple payments with equal payment-number

- the payment-number is **not a key**
- payments must always be associated to precisely one loan

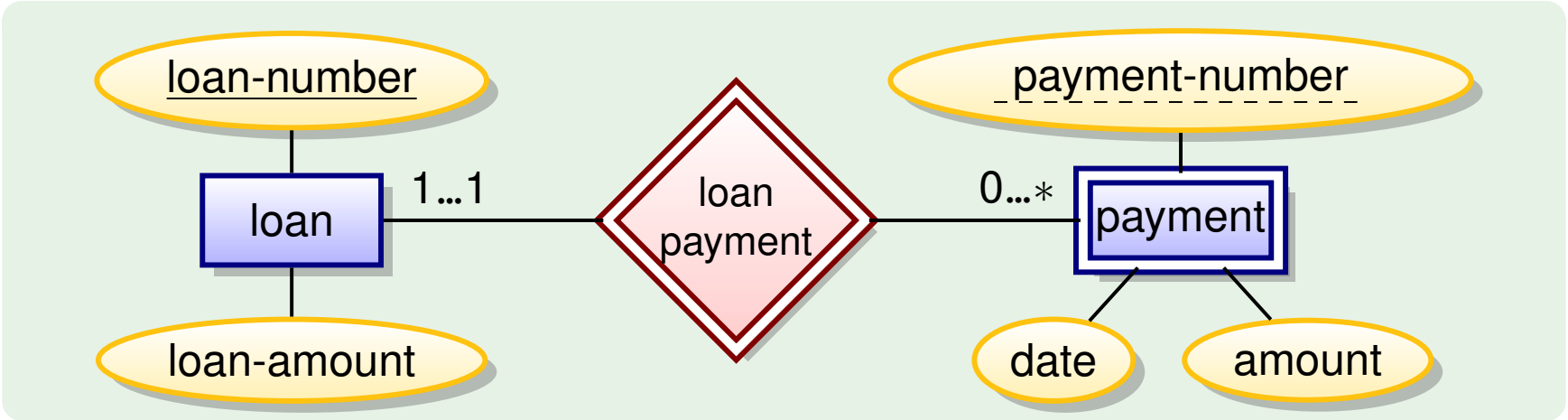
Weak Entity Sets



There can be multiple payments with equal payment-number

- the payment-number is **not a key**
- payments must always be associated to precisely one loan
- the payment-number identifies a payment uniquely only in combination with the loan-number of the associated loan

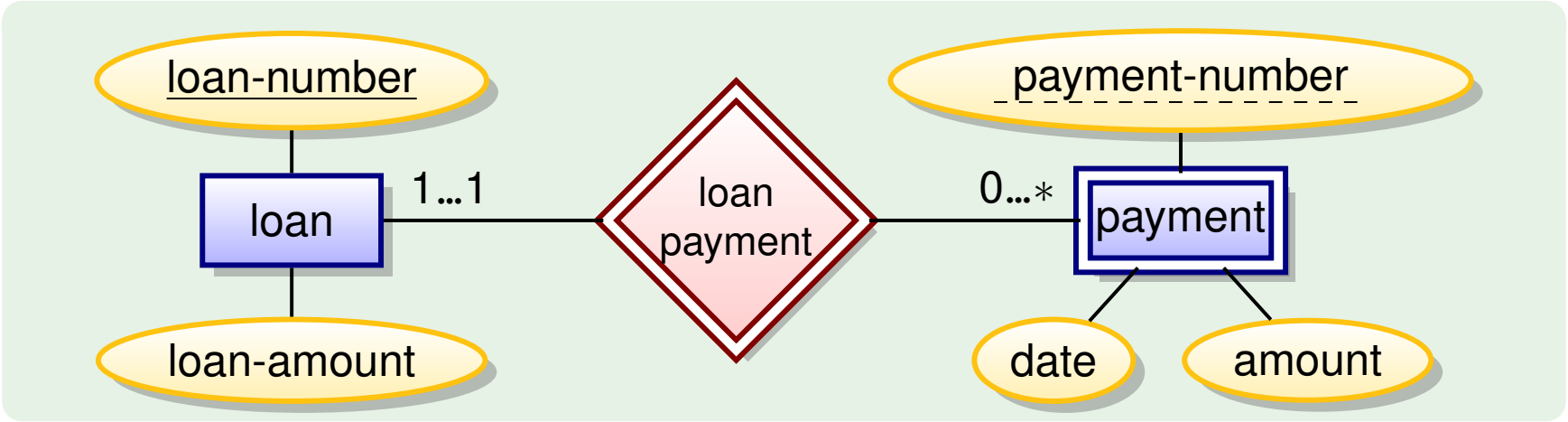
Weak Entity Sets



There can be multiple payments with equal payment-number

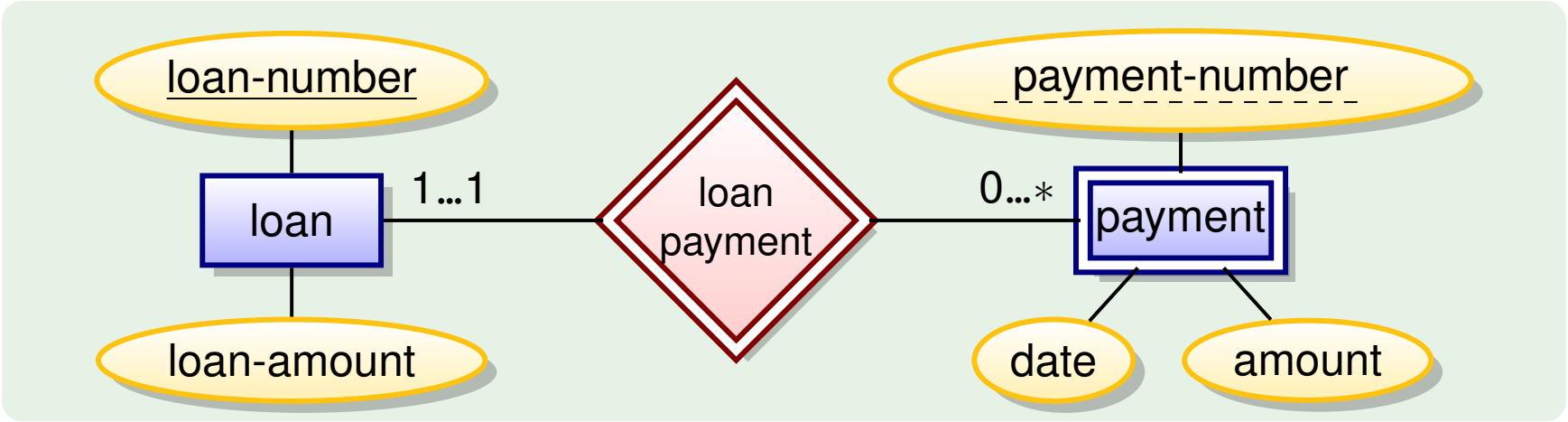
- the payment-number is **not a key**
- payments must always be associated to precisely one loan
- the payment-number identifies a payment uniquely only in combination with the loan-number of the associated loan
- in other words: the **discriminator** payment-number is unique among all payments for a certain loan

Weak Entity Sets



A **weak entity set** is an entity set without a primary key.

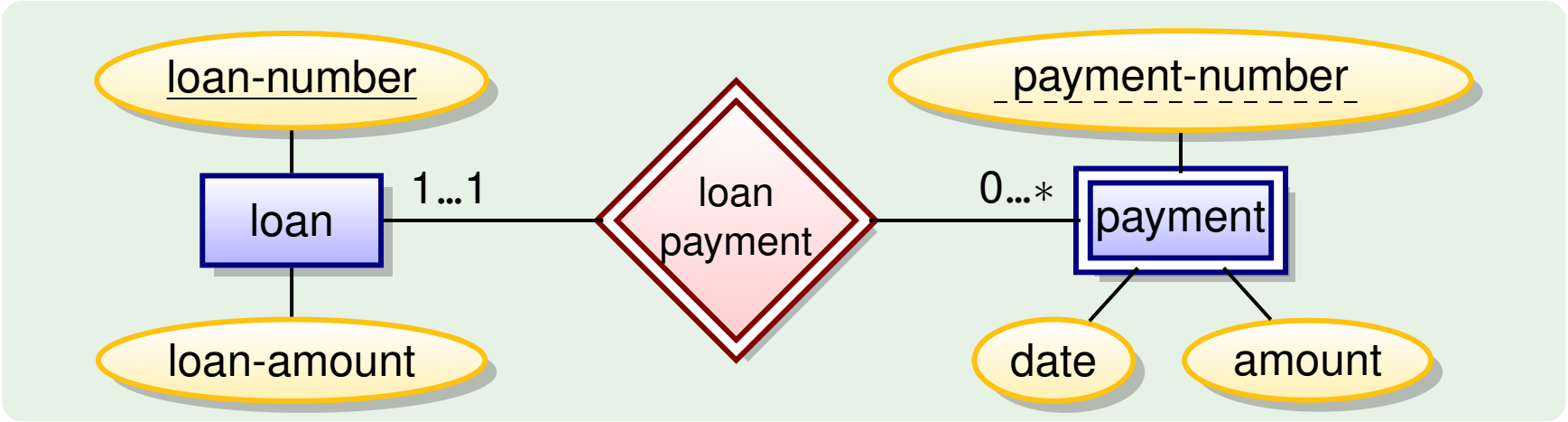
Weak Entity Sets



A **weak entity set** is an entity set without a primary key.

- The existence of a weak entity set depends on the existence of an **identifying entity set**.

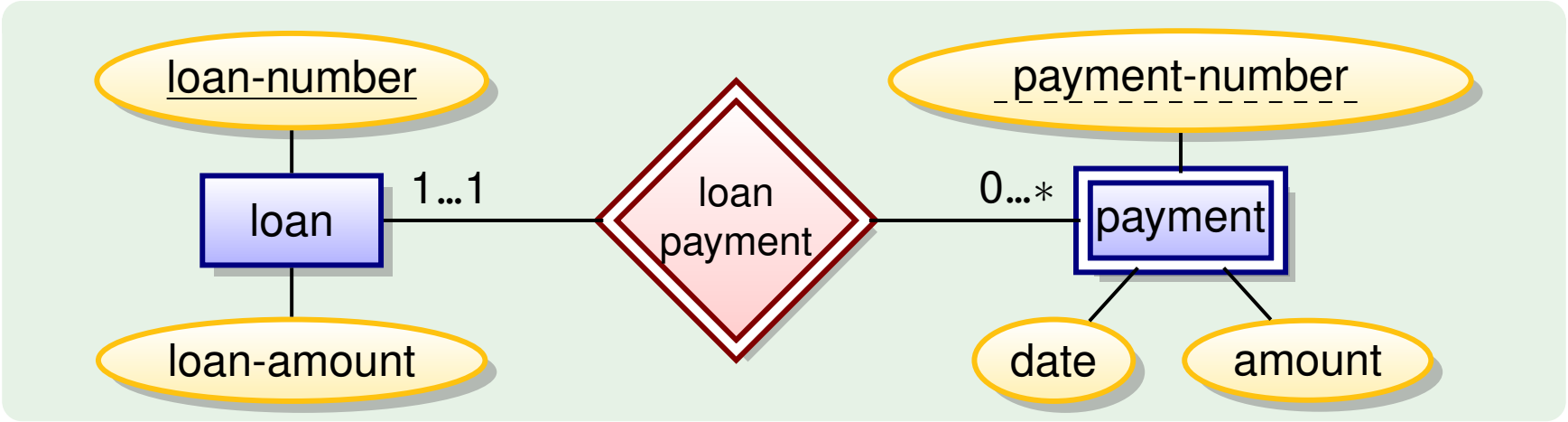
Weak Entity Sets



A **weak entity set** is an entity set without a primary key.

- The existence of a weak entity set depends on the existence of an **identifying entity set**.
- There must be a total, one-to-many relationship set from the identifying entity set to the weak entity set. This **identifying relationship** is depicted by a double diamond.

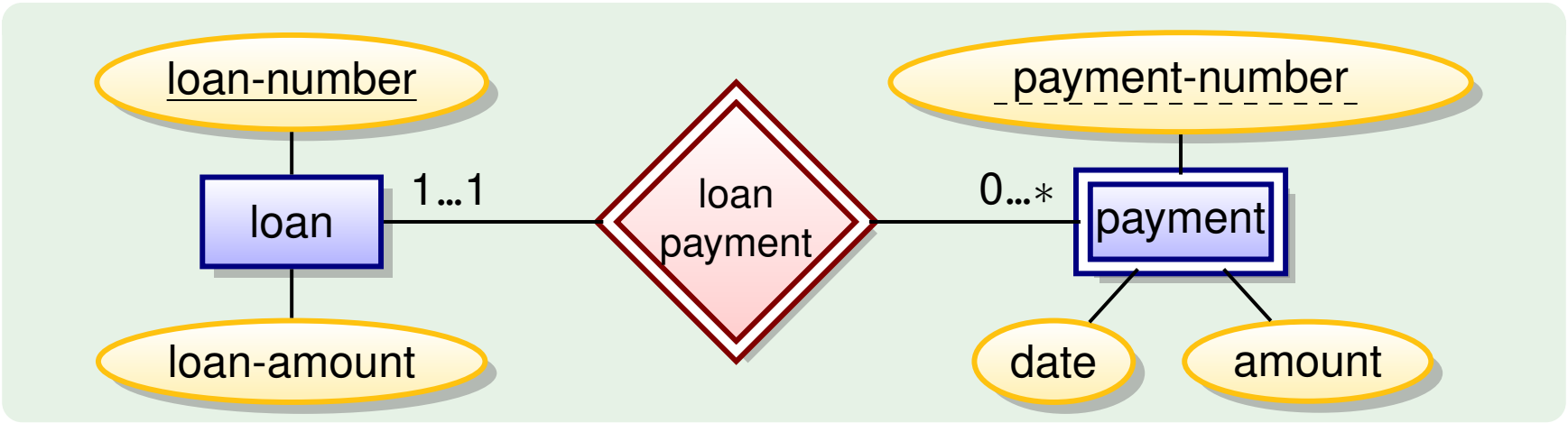
Weak Entity Sets



A **weak entity set** is an entity set without a primary key.

- The existence of a weak entity set depends on the existence of an **identifying entity set**.
- There must be a total, one-to-many relationship set from the identifying entity set to the weak entity set. This **identifying relationship** is depicted by a double diamond.
- The **discriminator** is a partial key, it distinguishes the weak entity only in combination with the identifying entity.

Weak Entity Sets



A **weak entity set** is an entity set without a primary key.

- The existence of a weak entity set depends on the existence of an **identifying entity set**.
- There must be a total, one-to-many relationship set from the identifying entity set to the weak entity set. This **identifying relationship** is depicted by a double diamond.
- The **discriminator** is a partial key, it distinguishes the weak entity only in combination with the identifying entity.
- Primary key of the weak entity set is a combination of the discriminator and primary key of the identifying entity set.

Weak Entity Sets

Modelling with Weak Entity Sets

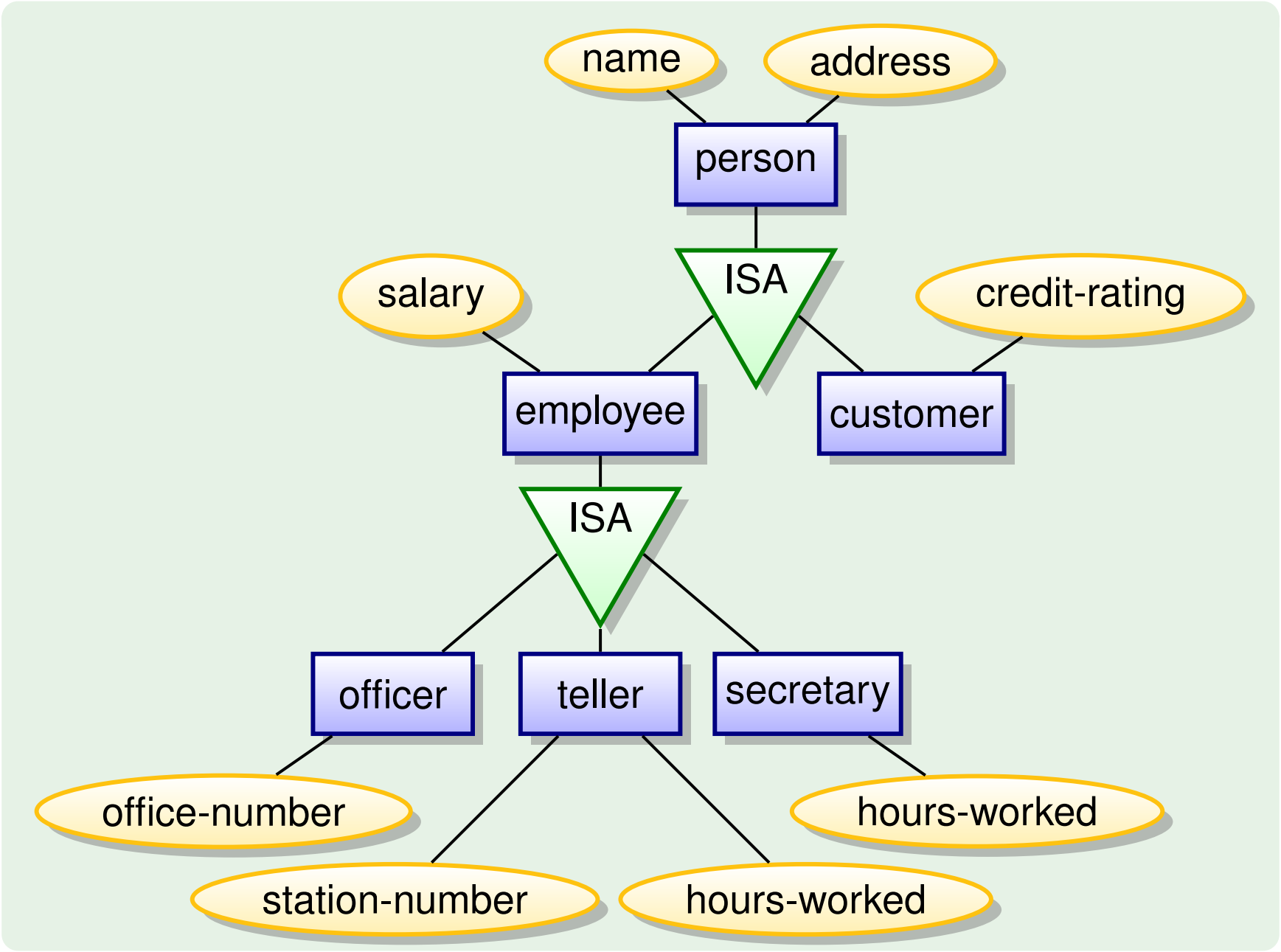
Model a set of online quizzes (multiple-choice tests).

- each quiz is identified by a title
- each question within a quiz is numbered
- each possible answer to a question is referenced by a letter
- for each question and answer the associated text is stored
- answers are classified into correct and incorrect ones

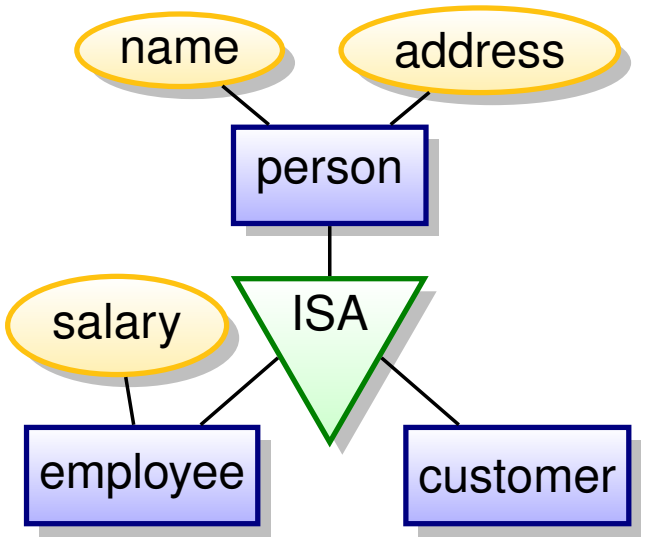
Develop an E/R diagram.

What is the complete key for each of the entity sets?

IS-A, ‘Inheritance’



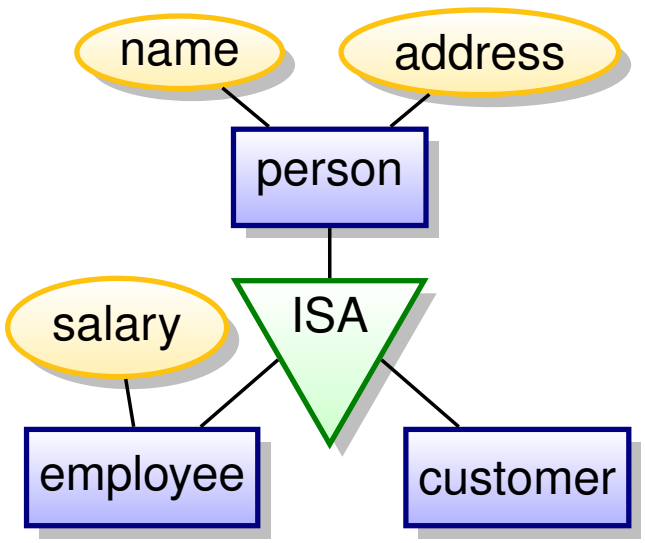
IS-A, ‘Inheritance’



Lower-level entity sets are subgroups of the of higher-level entity sets:

- e.g. an employee ‘is a’ person

IS-A, ‘Inheritance’



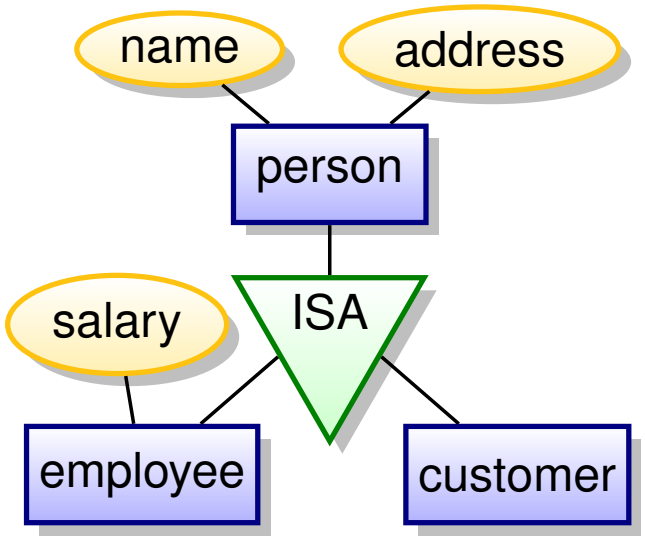
Lower-level entity sets are subgroups of the of higher-level entity sets:

- e.g. an employee ‘is a’ person

Lower-level entity sets **inherit all attributes and relationships** of the higher-level entity sets.

- e.g. an employee has attributes *name*, *address* and *salary*

IS-A, ‘Inheritance’



Lower-level entity sets are subgroups of the of higher-level entity sets:

- e.g. an employee ‘is a’ person

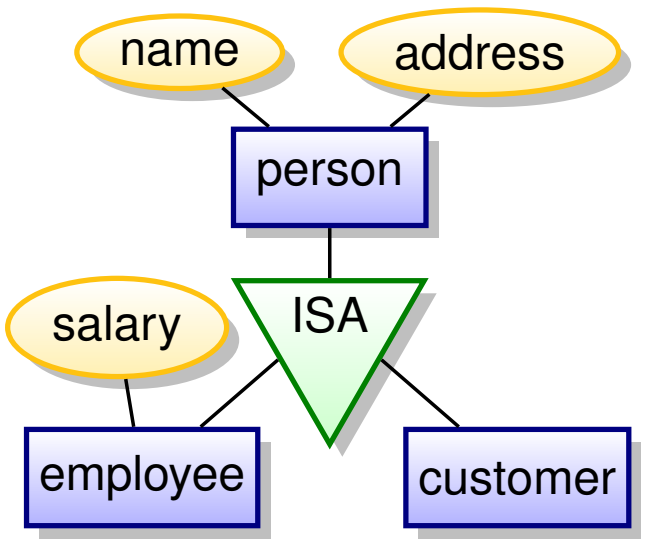
Lower-level entity sets **inherit all attributes and relationships** of the higher-level entity sets.

- e.g. an employee has attributes *name*, *address* and *salary*

Design Principle: Specialisation

- top-down design process
- identify subgroups within an entity set
- these subgroups become lower-level entity sets which may have attributes or participate in relationships that do not apply to the higher-level entity sets

IS-A, ‘Inheritance’



Lower-level entity sets are subgroups of the of higher-level entity sets:

- e.g. an employee ‘is a’ person

Lower-level entity sets **inherit all attributes and relationships** of the higher-level entity sets.

- e.g. an employee has attributes *name*, *address* and *salary*

Design Principle: Generalisation

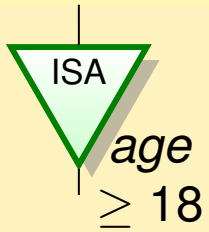
- bottom-up design process
- combine a number of entity sets that share common features into a higher-level entity set

- specialisation and generalisation are both ‘is a’-relations

IS-A, ‘Inheritance’

Membership constraints

- **value-based**: assigns an entity to a specific subclass based on attribute values
  e.g. a *person* of age ≥ 18 is an *adult*

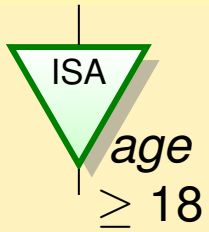


- default is **user-defined**: manual assignment to subclasses

IS-A, ‘Inheritance’

Membership constraints

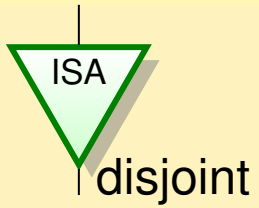
- **value-based**: assigns an entity to a specific subclass based on attribute values
  e.g. a *person* of age ≥ 18 is an *adult*



- default is **user-defined**: manual assignment to subclasses

Disjointness constraints

- **disjoint**: an entity can belong to at most one subclass; e.g. a *fruit* can be an *apple* or a *pear*, but not both

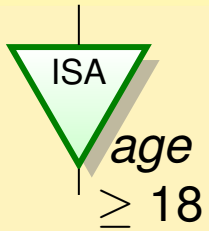


- default is **overlapping**: can belong to multiple subclasses

IS-A, 'Inheritance'

Membership constraints

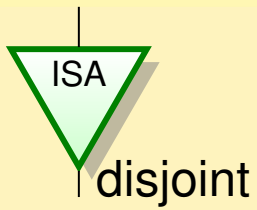
- **value-based**: assigns an entity to a specific subclass based on attribute values
  e.g. a *person* of age ≥ 18 is an *adult*



- default is **user-defined**: manual assignment to subclasses

Disjointness constraints

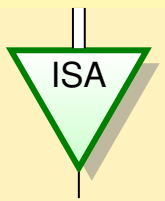
- **disjoint**: an entity can belong to at most one subclass; e.g. a *fruit* can be an *apple* or a *pear*, but not both



- default is **overlapping**: can belong to multiple subclasses

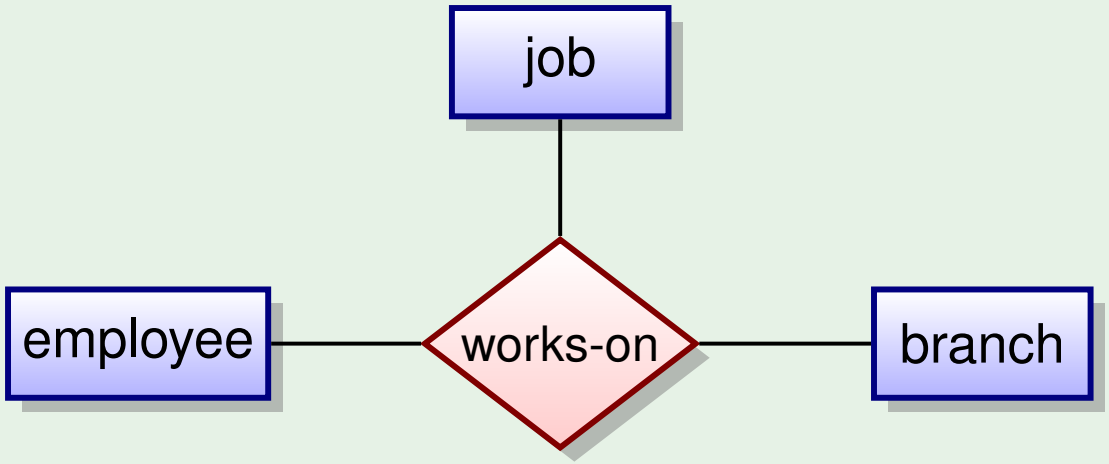
Completeness constraints

- **total specialisation (generalisation)** constraint: each superclass entity must belong to a subclass; e.g. a *person* is either a *minor* or an *adult*



Aggregation

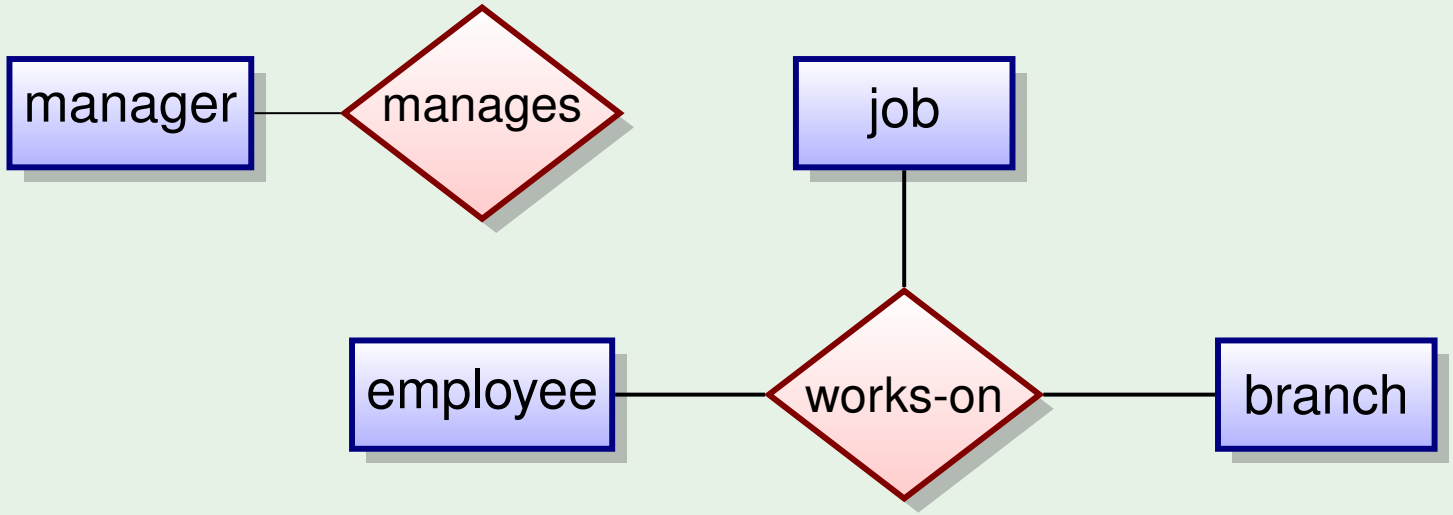
Consider the *works-on* relation we have seen before.



Aggregation

Consider the *works-on* relation we have seen before.

We now want to express that a task performed by an employee might have a manager assigned to it.

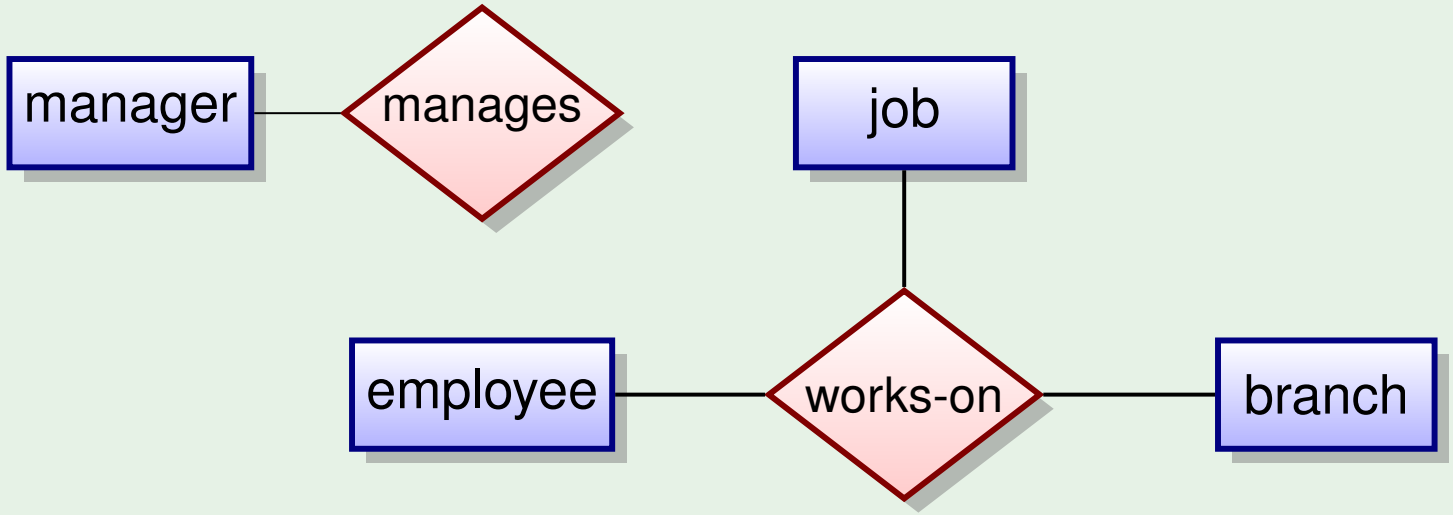


Aggregation

Consider the *works-on* relation we have seen before.

We now want to express that a task performed by an employee might have a manager assigned to it.

- E/R model has no relations between relations

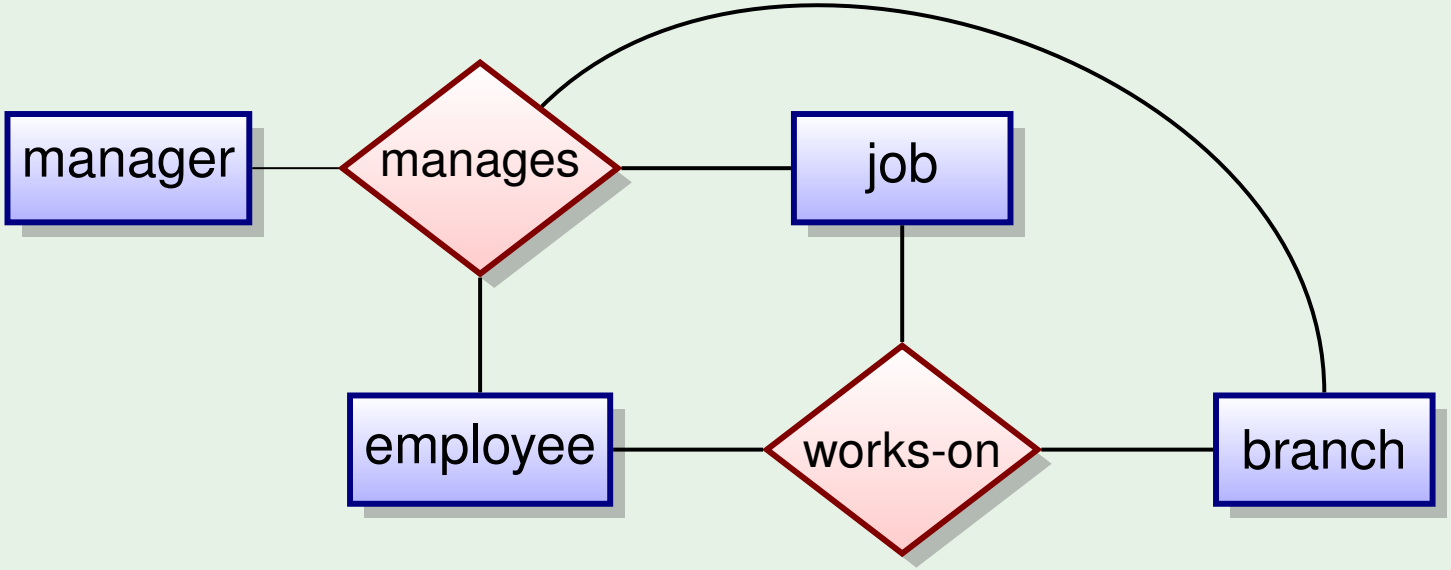


Aggregation

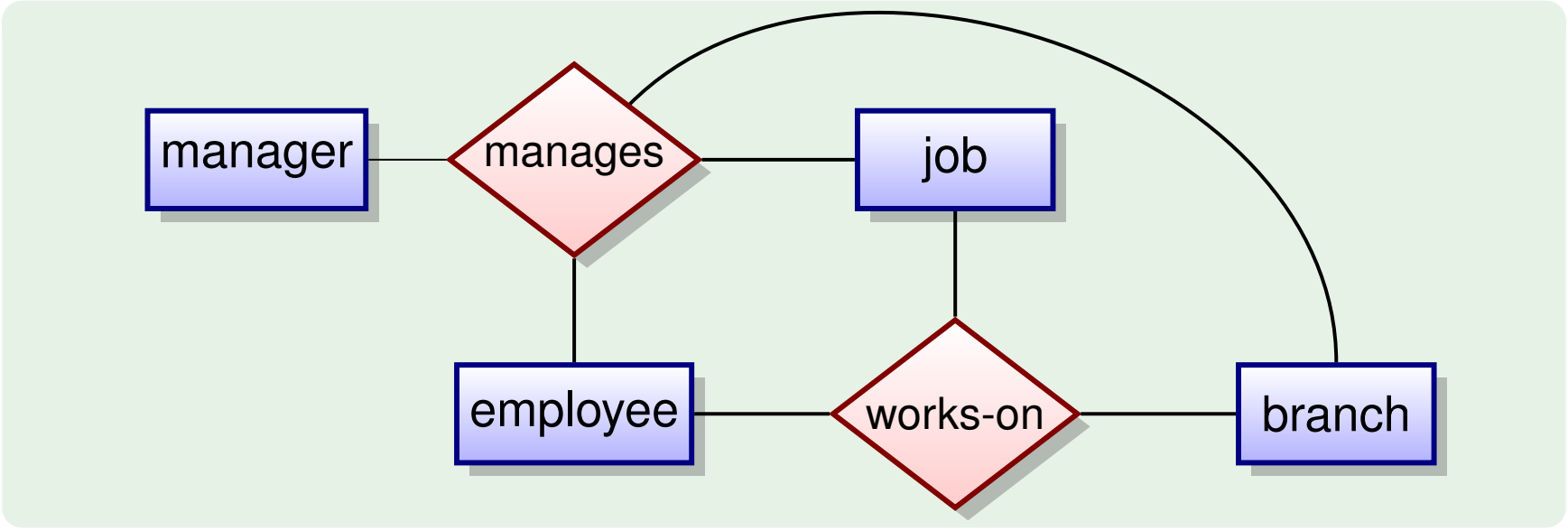
Consider the *works-on* relation we have seen before.

We now want to express that a task performed by an employee might have a manager assigned to it.

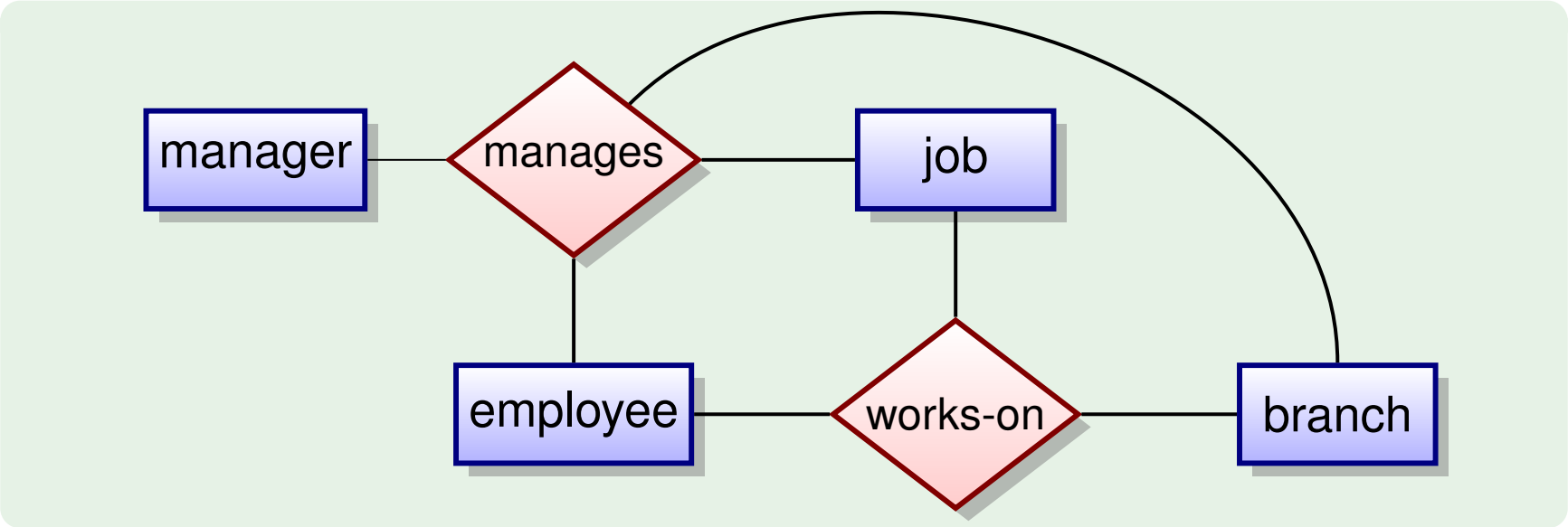
- E/R model has no relations between relations



Aggregation

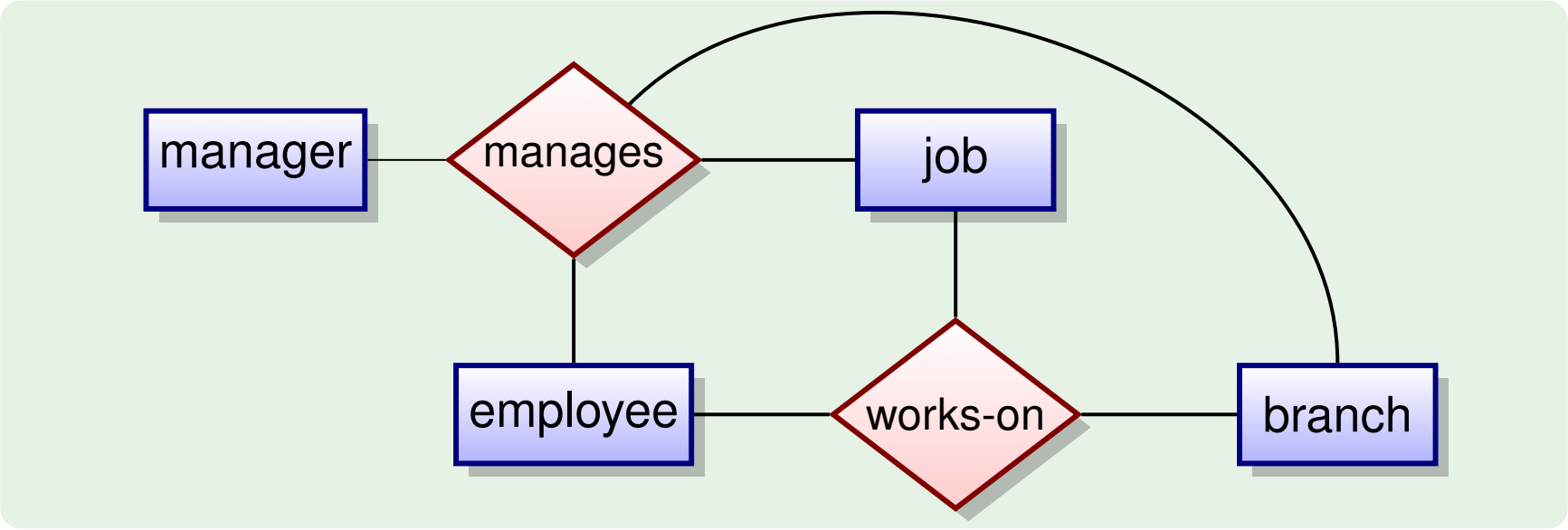


Aggregation



However, this design is not good: relationship set *works-on* and *manages* represent overlapping information

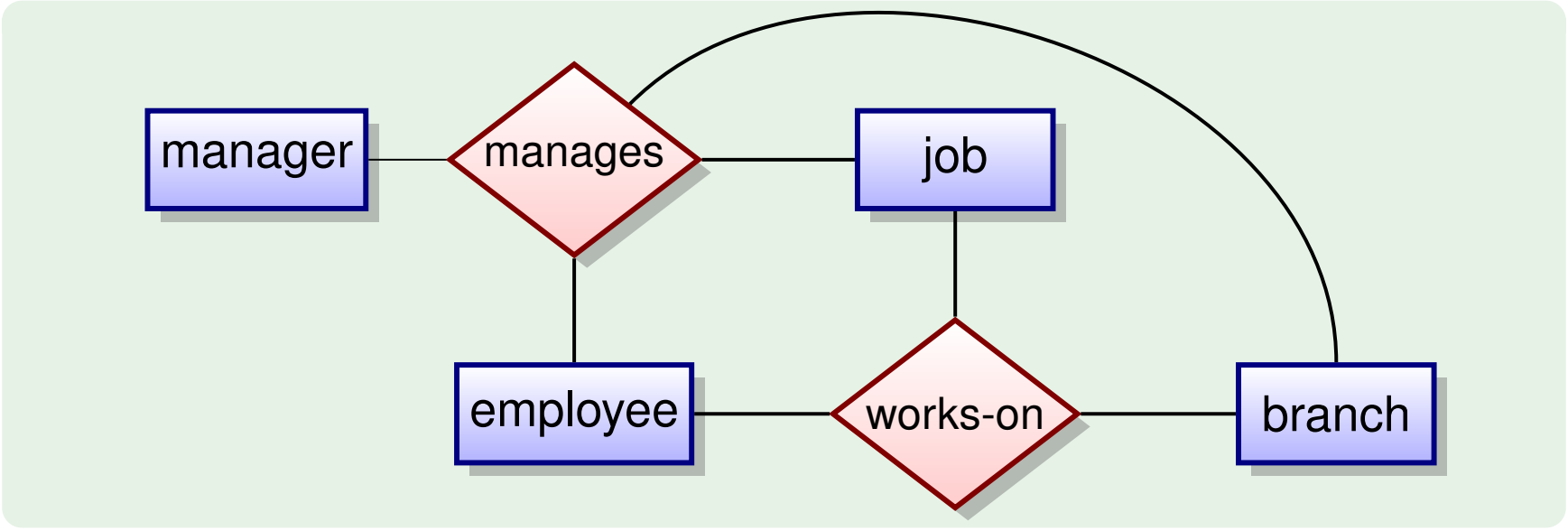
Aggregation



However, this design is not good: relationship set *works-on* and *manages* represent overlapping information

- Every *manages* relationship corresponds to a *works* relationship.
- However, some *works-on* relationships may not correspond to any *manages* relationship.
  So we cannot discard the works-on relationship set.

Aggregation



However, this design is not good: relationship set *works-on* and *manages* represent overlapping information

- Every *manages* relationship corresponds to a *works* relationship.
- However, some *works-on* relationships may not correspond to any *manages* relationship.
  So we cannot discard the works-on relationship set.

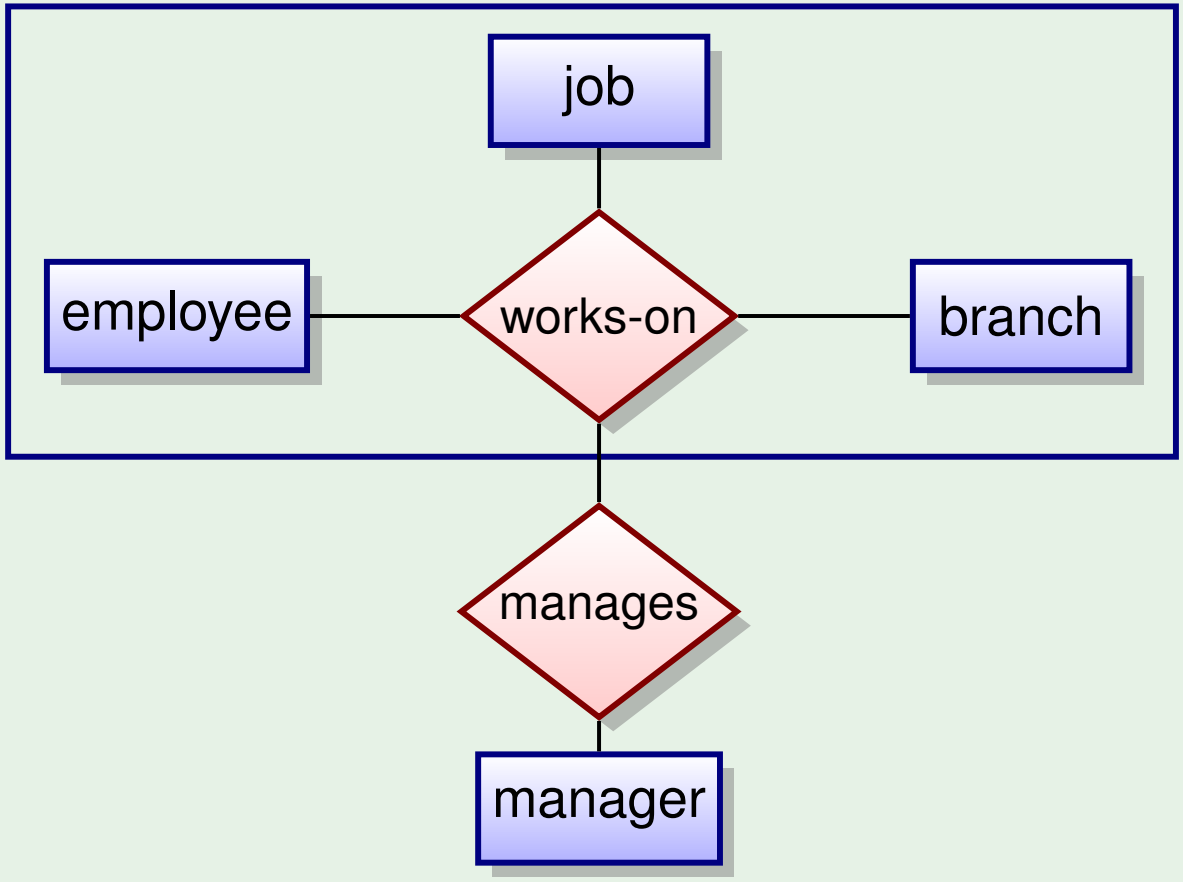
The solution is to eliminate redundancy using **aggregation**!

Aggregation

Aggregation:

- treat relationship set as an abstract entry

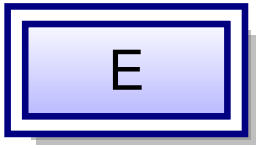
  abstraction of a relationship into a new entry
- allows relations between relations



Entity-relationship Models Summary

entity set

attribute



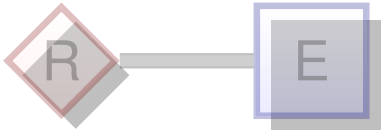
weak entity set

multi-valued attribute

relationship set

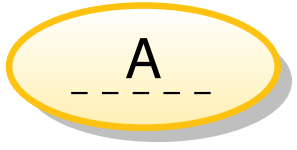
derived attribute

identifying
relationship set
for weak entity set



total participation
of entity set
in relationship

primary key



discriminating
attribute of
weak entity set

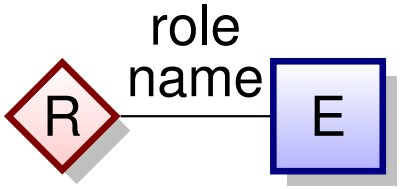
Entity-relationship Models Summary

many-to-many relationship

many-to-one relationship

one-to-one relationship

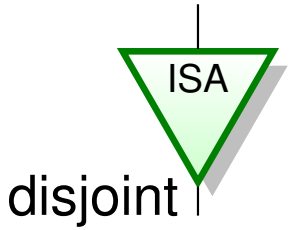
cardinality limits



role indicator

ISA (generalisation or specialisation)

total generalisation

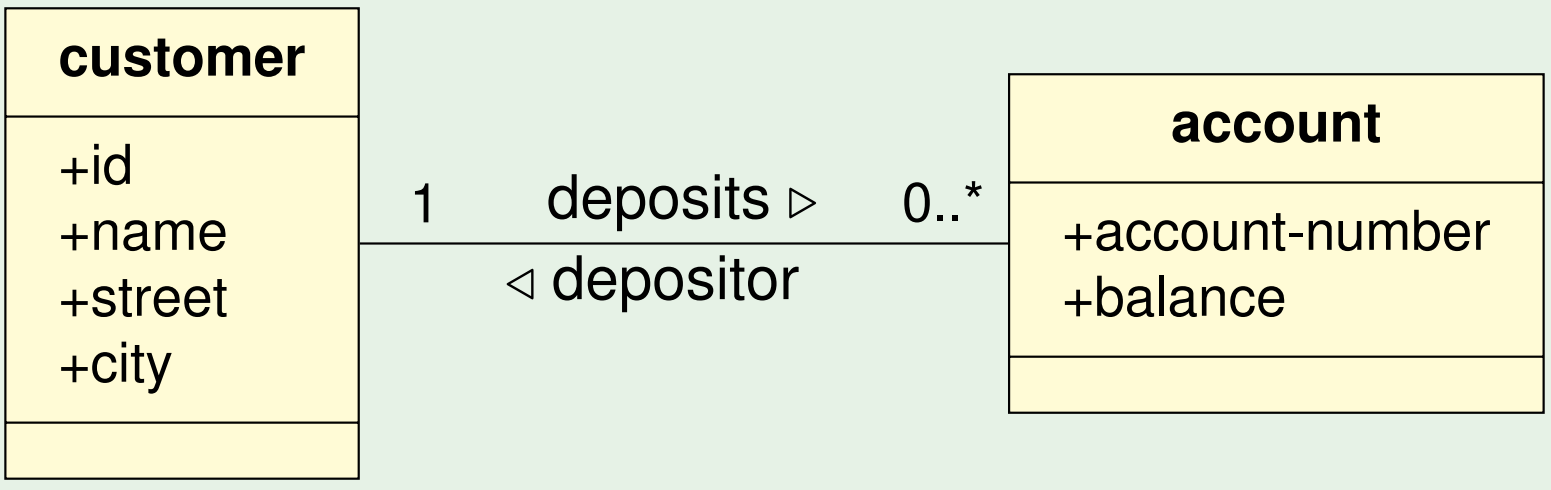


disjoint generalisation

Unified Modelling Language

UML = Unified Modeling Language

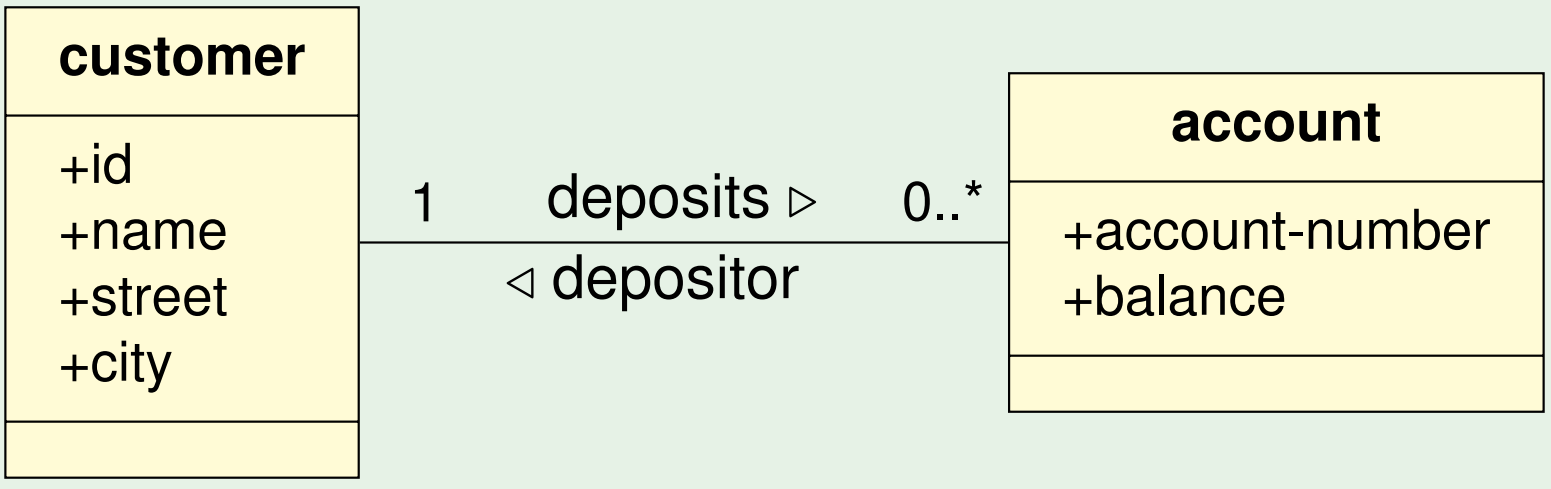
Example Schema as UML Class diagram



Unified Modelling Language

UML = Unified Modeling Language

Example Schema as UML Class diagram

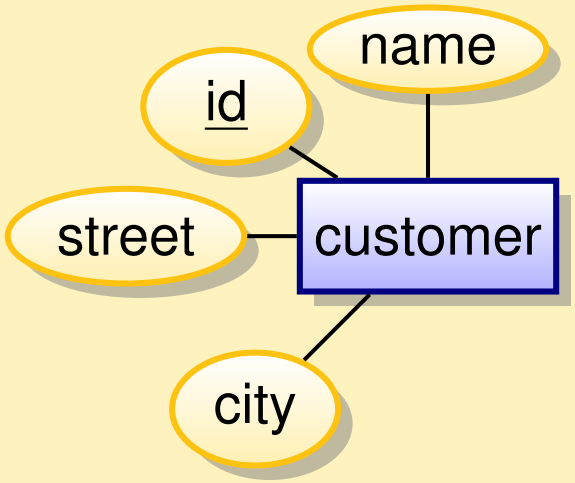


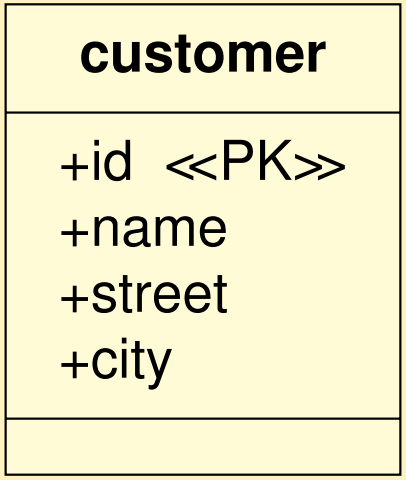
- UML diagrams are similar to E/R diagrams

  However, there are important differences!

E/R Models vs. UML Class Diagrams

Entity Sets and Attributes

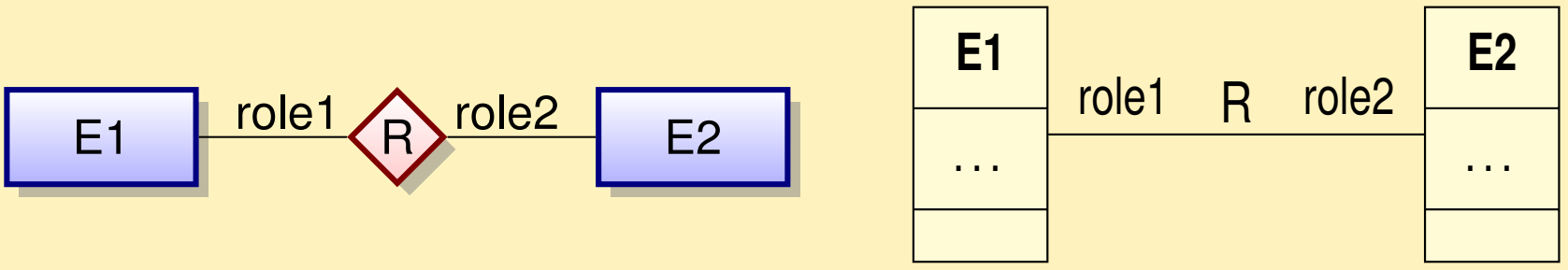




- In UML attributes are shown within the box of the entity set rather than as separate ellipses in E/R models.

E/R Models vs. UML Class Diagrams

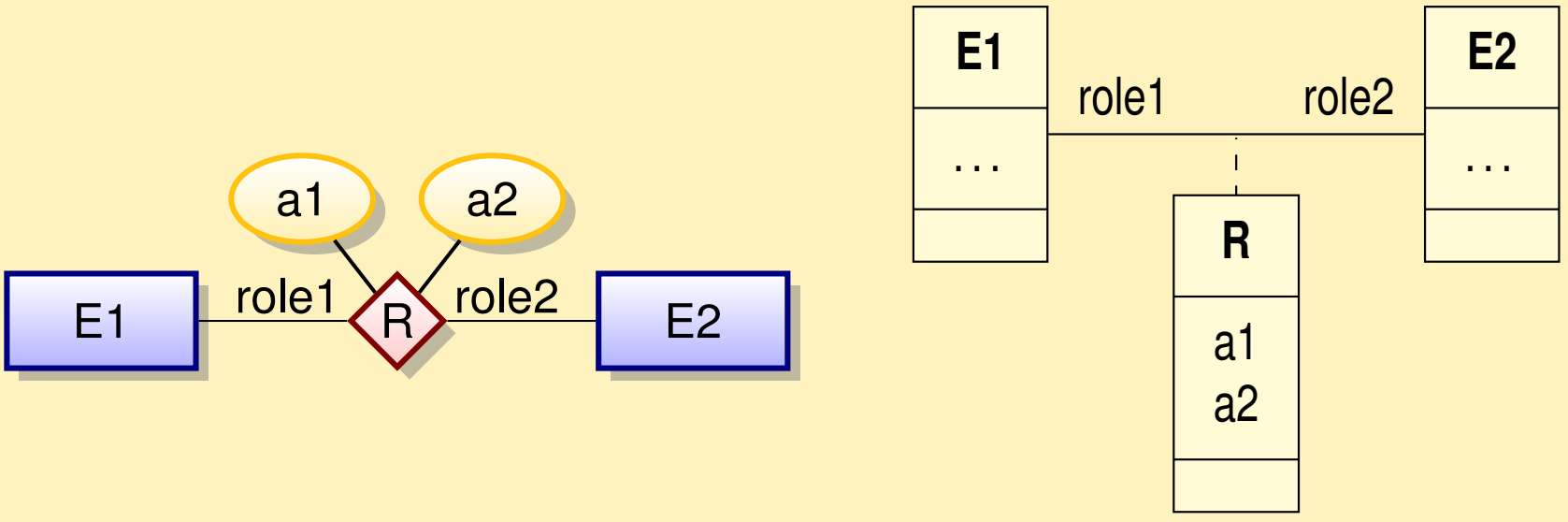
Binary Relationships



- In UML binary relationship sets are represented by a line connecting the entity sets. The name of the relationship set is written adjacent to the line.

E/R Models vs. UML Class Diagrams

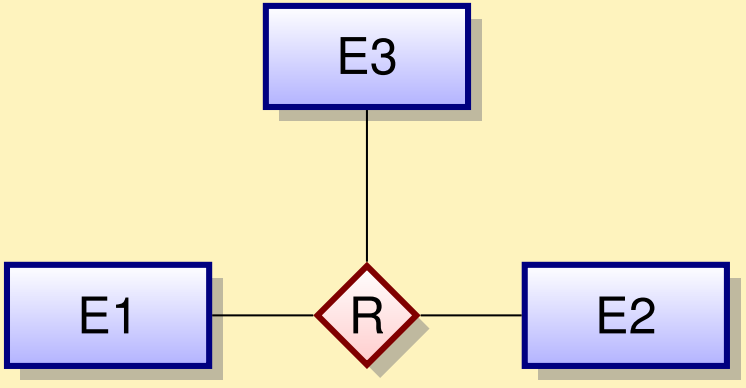
Binary Relationships with Attributes

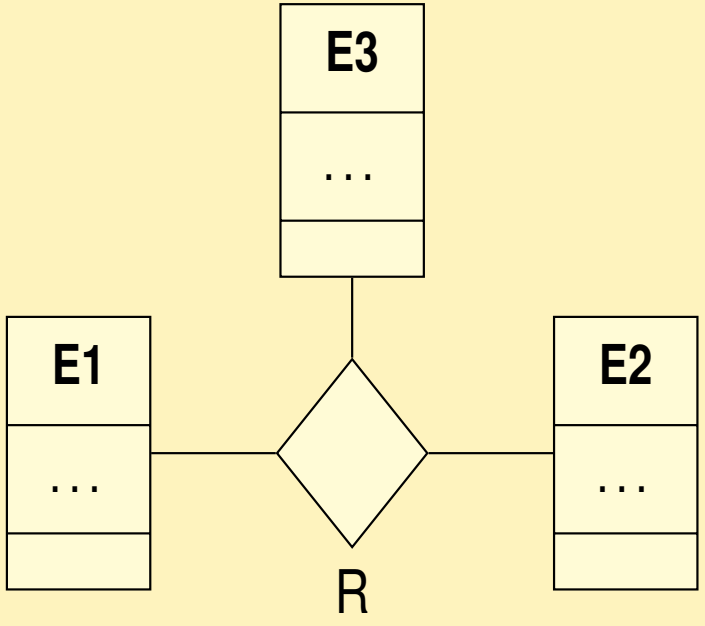


- If the relationship set has attributes, then the name of the relationship set is written in a box together with the attributes of the relation.
- The box is then connected using a dashed line to the line corresponding to the relationship set.

E/R Models vs. UML Class Diagrams

Non-Binary Relationships

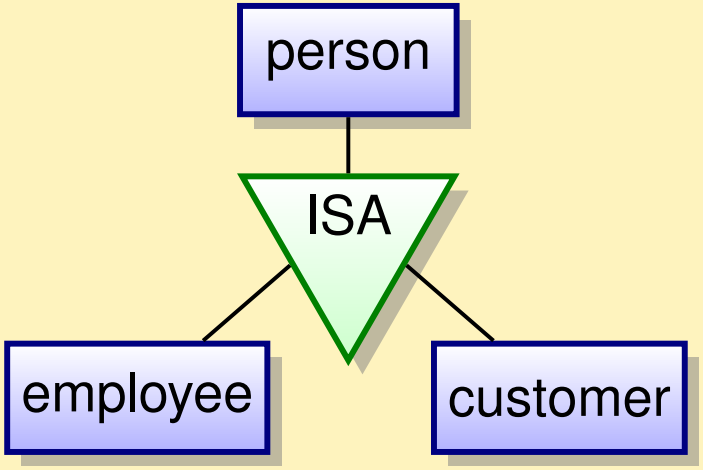


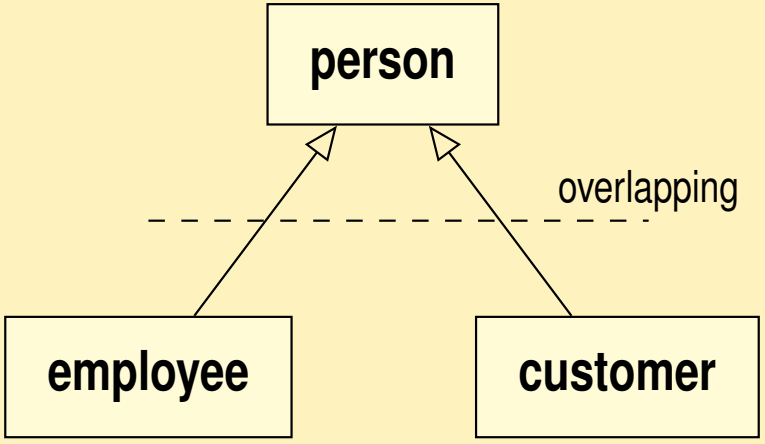


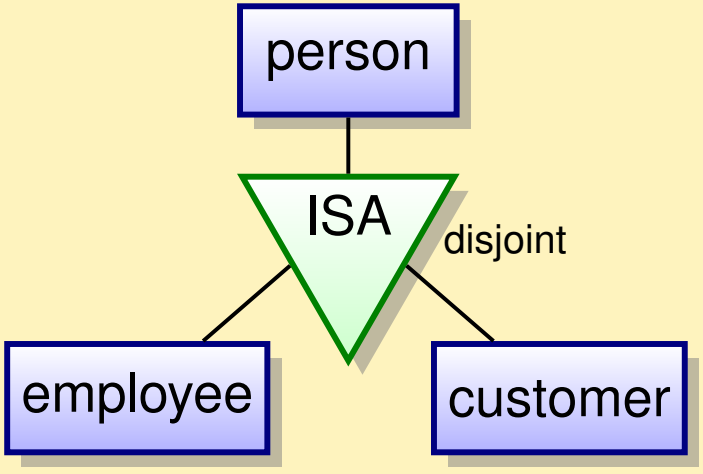
- Non-binary relationship sets are drawn using a diamond.

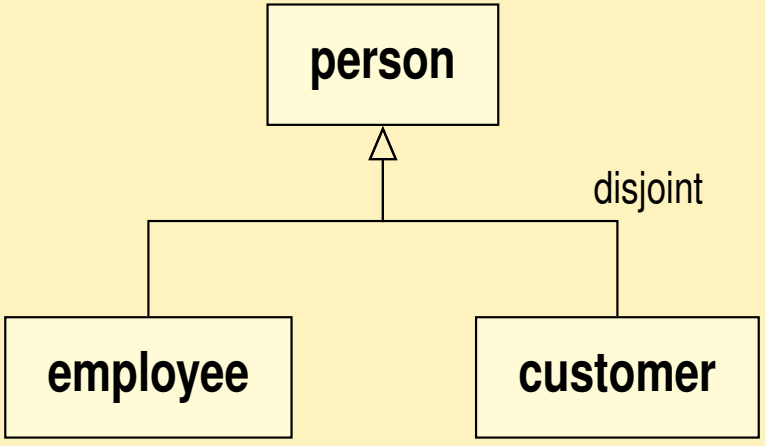
E/R Models vs. UML Class Diagrams

Generalisation and Specialisation



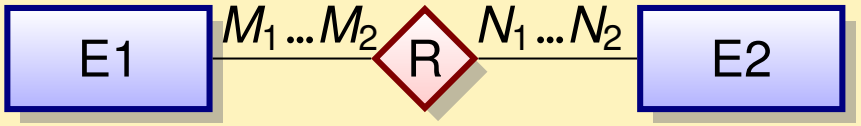


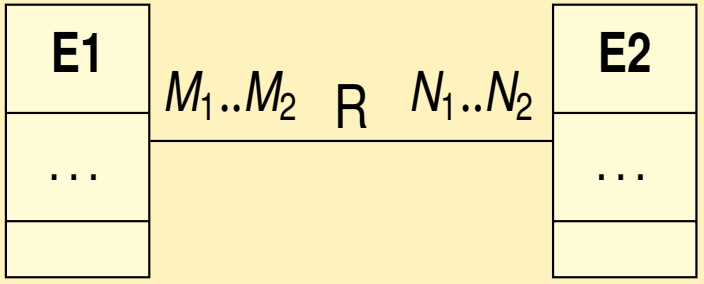




E/R Models vs. UML Class Diagrams

Cardinality Limits



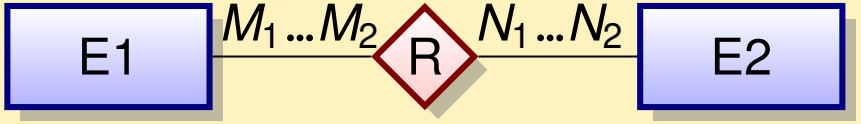


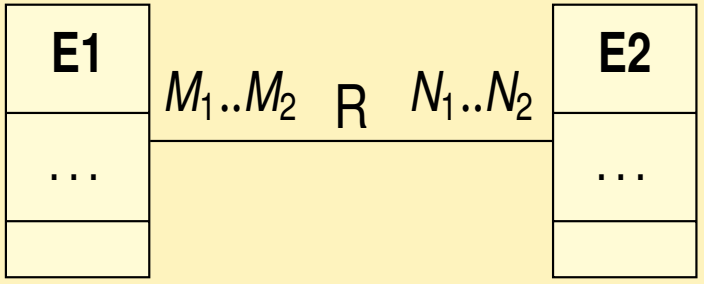
The cardinalities indicate that:

- each E2 entity is related to $\geq M_1$ and $\leq M_2$ entities in E_1
- each E1 entity is related to $\geq N_1$ and $\leq N_2$ entities in E_2

E/R Models vs. UML Class Diagrams

Cardinality Limits





The cardinalities indicate that:

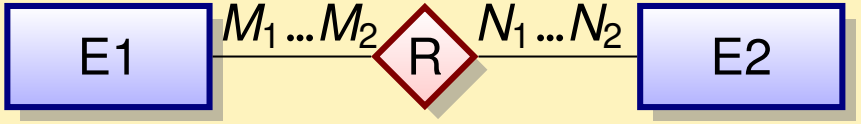
- each E2 entity is related to $\geq M_1$ and $\leq M_2$ entities in E_1
- each E1 entity is related to $\geq N_1$ and $\leq N_2$ entities in E_2

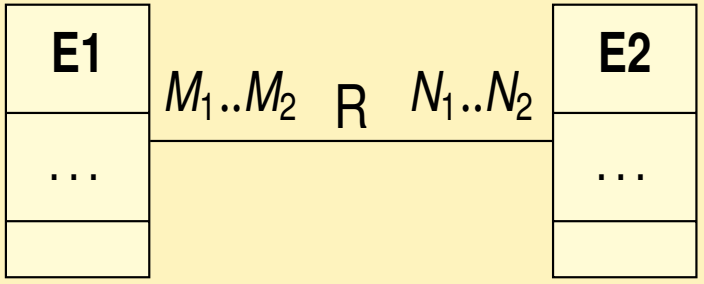
In UML we have the following abbreviations:

- 1 stands for 1..1
- $*$ stands for 0..$*$

E/R Models vs. UML Class Diagrams

Cardinality Limits





The cardinalities indicate that:

- each E2 entity is related to $\geq M_1$ and $\leq M_2$ entities in E_1
- each E1 entity is related to $\geq N_1$ and $\leq N_2$ entities in E_2

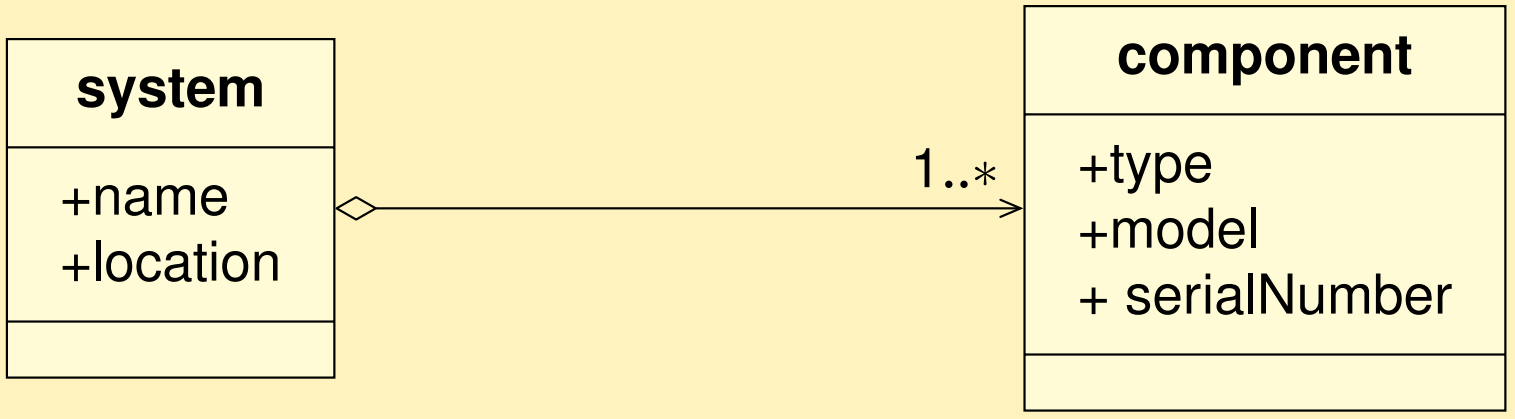
In UML we have the following abbreviations:

- 1 stands for 1..1
- $*$ stands for 0..$*$

Nevertheless, it is better to write fully 1..1 and 0..$*$.

UML: Aggregation and Composition

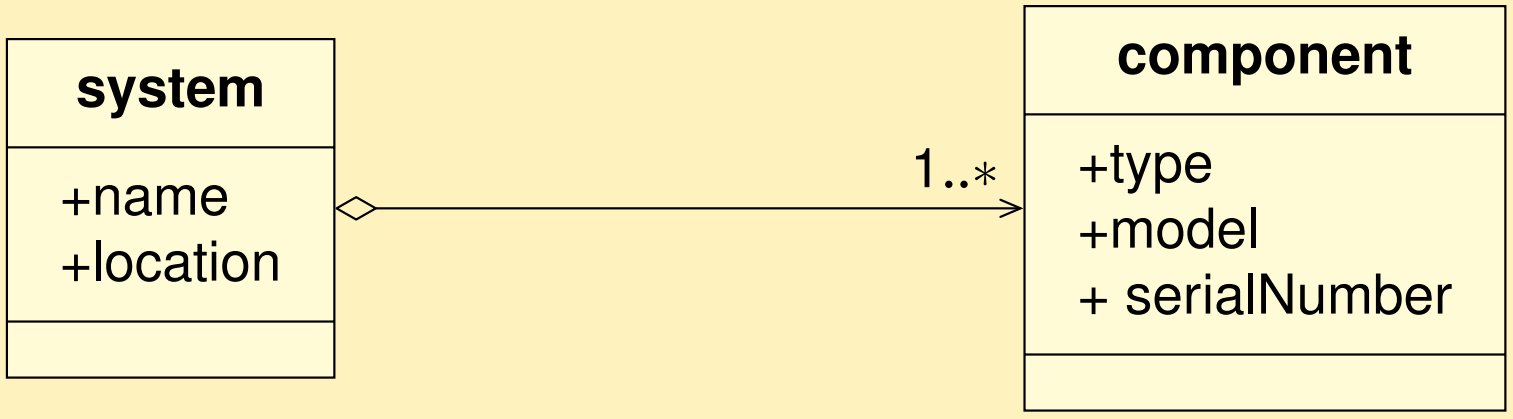
Aggregation in UML



- **Aggregation:** system is a collection of components

UML: Aggregation and Composition

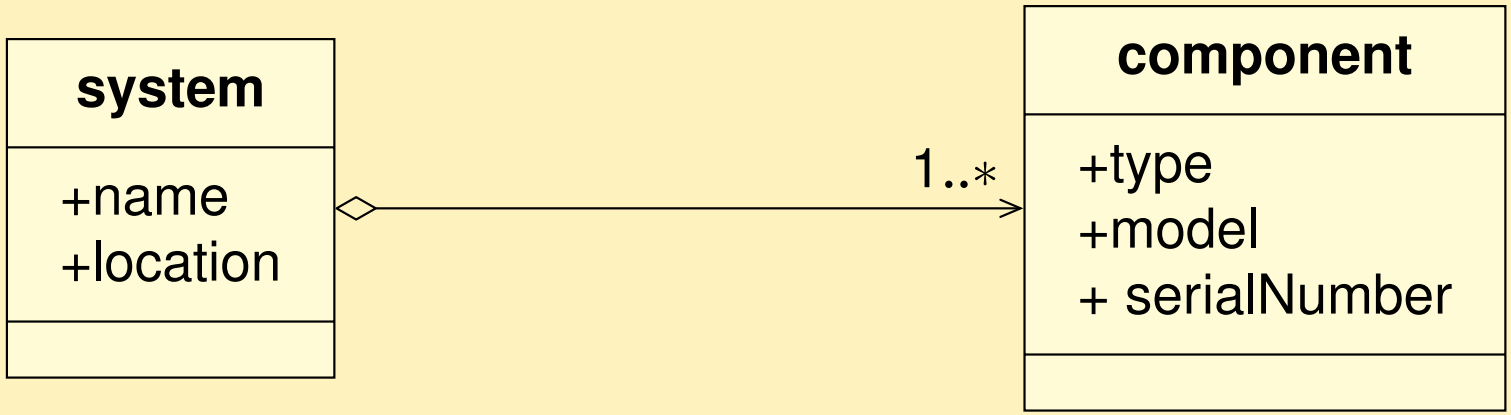
Aggregation in UML



- **Aggregation:** system is a collection of components
- **Composition:** if the diamond would be filled black, it would mean that every component belongs to one system (1..1)

UML: Aggregation and Composition

Aggregation in UML

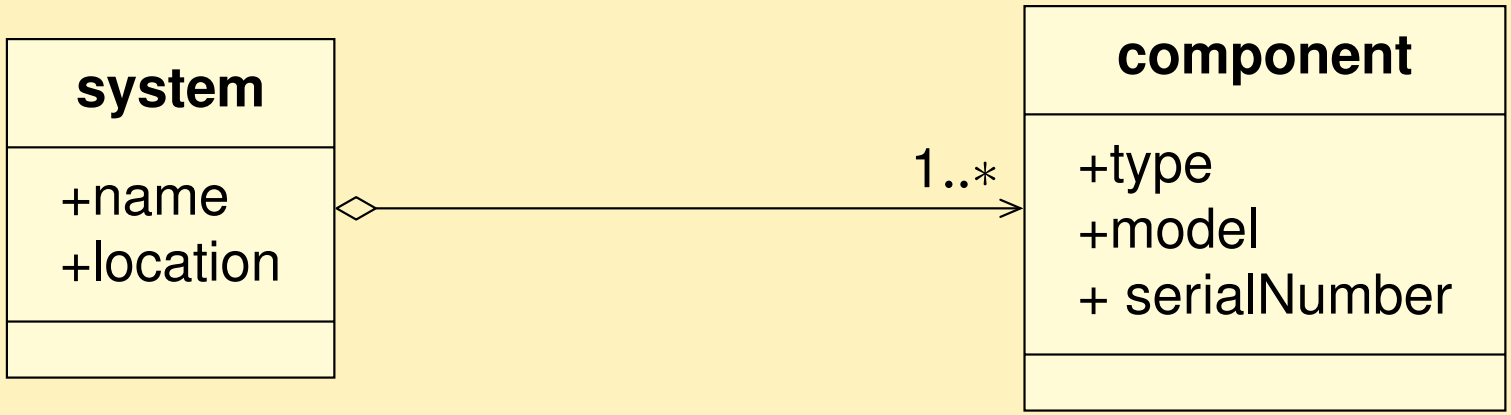


- **Aggregation:** system is a collection of components
- **Composition:** if the diamond would be filled black, it would mean that every component belongs to one system (1..1)

It is important to note the difference with E/R models:

UML: Aggregation and Composition

Aggregation in UML



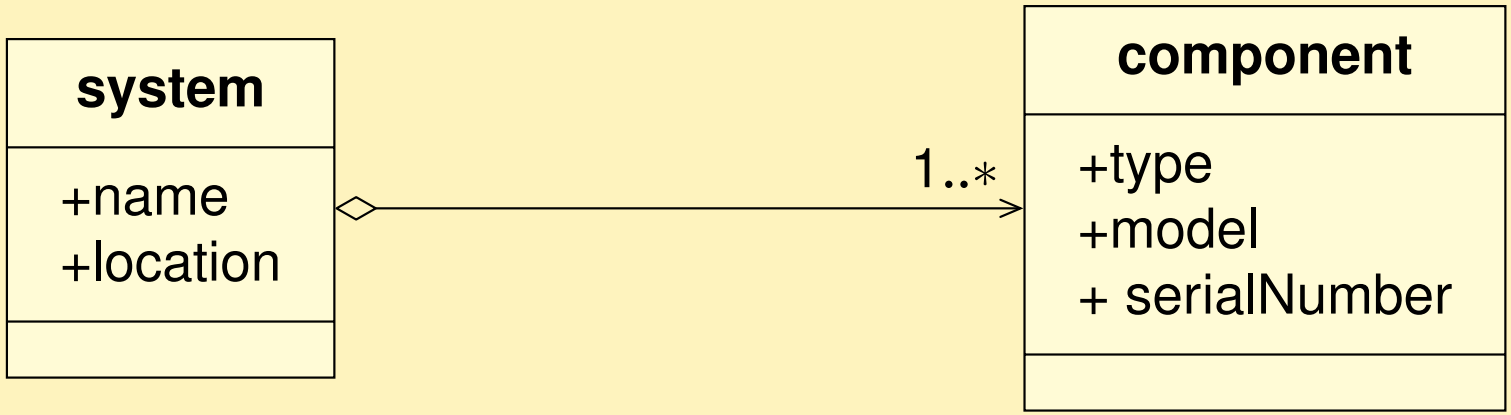
- **Aggregation:** system is a collection of components
- **Composition:** if the diamond would be filled black, it would mean that every component belongs to one system (1..1)

It is important to note the difference with E/R models:

- In E/R aggregation allows to treat relations as entities.

UML: Aggregation and Composition

Aggregation in UML



- **Aggregation:** system is a collection of components
- **Composition:** if the diamond would be filled black, it would mean that every component belongs to one system (1..1)

It is important to note the difference with E/R models:

- In E/R aggregation allows to treat relations as entities.
- Composition in UML is similar to weak entities in E/R.

  However, composition in UML says nothing about keys.

Differences: E/R Models vs. UML Class Diagrams

- visual differences — no big deal

Differences: E/R Models vs. UML Class Diagrams

- visual differences — no big deal
- **keys**:
  - E/R supports keys (underlining)
  - UML has no standard for indicating keys

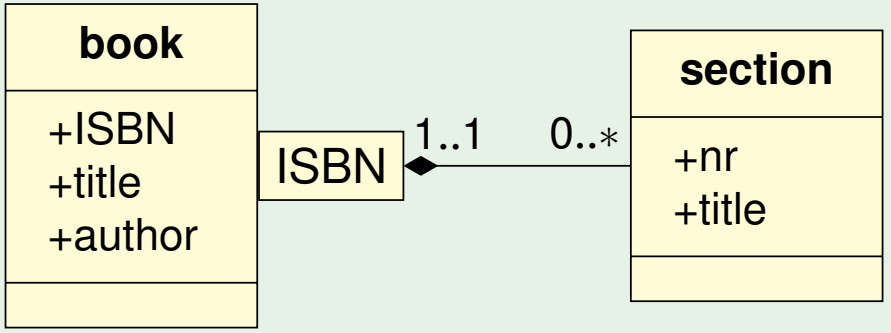
    Some people underline, others write PK after the attribute.

Differences: E/R Models vs. UML Class Diagrams

- visual differences — no big deal
- **keys**:
  - E/R supports keys (underlining)
  - UML has no standard for indicating keys

    Some people underline, others write PK after the attribute.

In case of composition in UML, one may use **association qualifiers** to indicate the key.

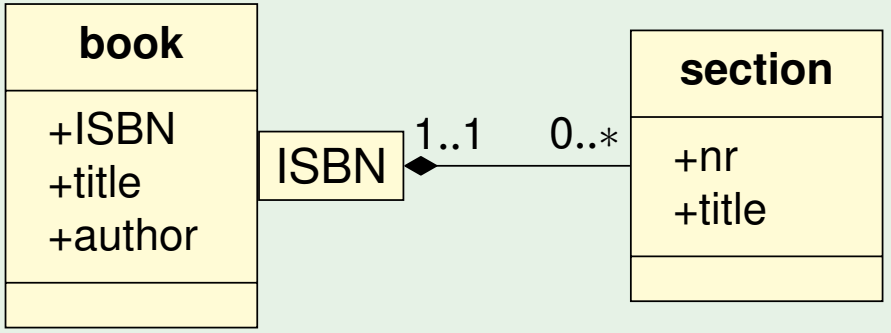


Differences: E/R Models vs. UML Class Diagrams

- visual differences — no big deal
- **keys**:
  - E/R supports keys (underlining)
  - UML has no standard for indicating keys

    Some people underline, others write PK after the attribute.

In case of composition in UML, one may use **association qualifiers** to indicate the key.



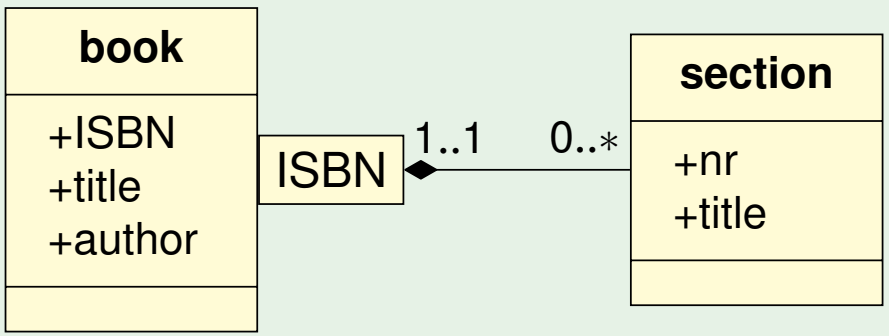
- **aggregation**: means something very different
  - in E/R: treating a relationship set as an entity
  - in UML: a non-exclusive form of composition

Differences: E/R Models vs. UML Class Diagrams

- visual differences — no big deal
- **keys**:
  - E/R supports keys (underlining)
  - UML has no standard for indicating keys

    Some people underline, others write PK after the attribute.

In case of composition in UML, one may use **association qualifiers** to indicate the key.



- **aggregation**: means something very different
  - in E/R: treating a relationship set as an entity
  - in UML: a non-exclusive form of composition
- **weak entities**:
  - in E/R: weak entities are entities without own key
  - in UML: composition is similar, but says nothing about keys

Data Modelling: Objectives

After completing this chapter, you should understand:

- **Three phases of database design**
  - Conceptual, Logical, Physical, and what these are useful for
- **Basic E/R concepts**
  - entities, attributes, relationships, ‘is a’, weak entity sets, aggregation
  - cardinality/participation constraints
- **How UML corresponds with and differs from E/R**
  - differences: basic syntax, aggregation, key specifications
- **How to make a conceptual model given a scenario**
  - in both UML and E/R