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Relational Database Systems 1

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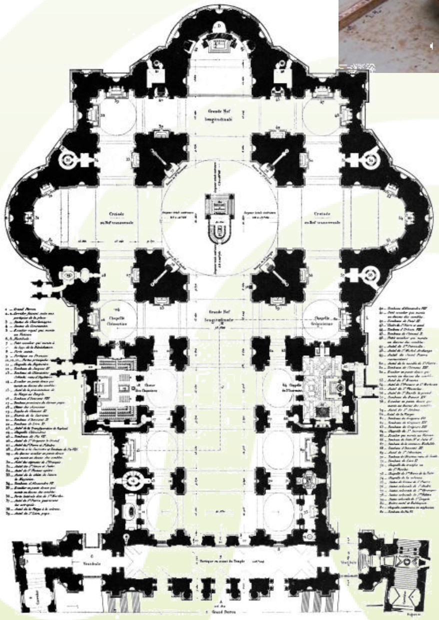
2. Data Modeling

- Introduction
- Data Models
- Phases of DB Design
- Basic ER Modeling
  - Chen notation
  - Alternative notations
- Example



2.1 Introduction

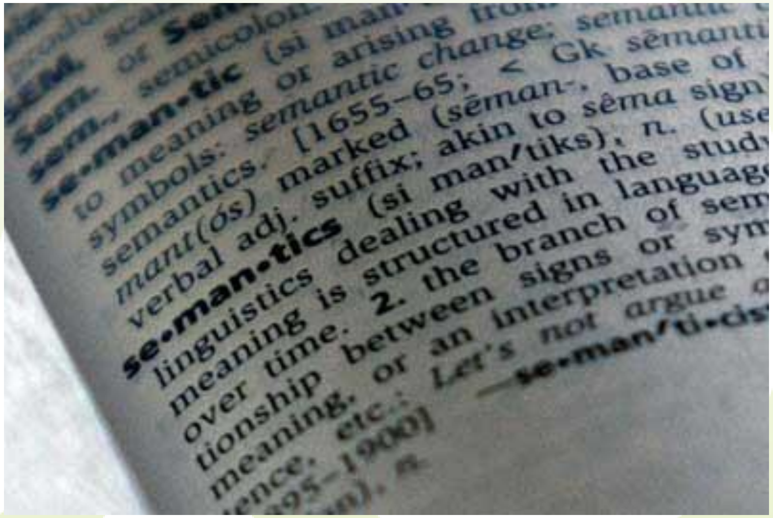
- Last week,
  - we already used the term **data model** in an intuitive way
- Today,
  - we will define the term more precisely
  - see different kinds of data models
  - learn how to create instances of such models

Question

- How would you define the term data model in your own words?

2.2 Data Models

- In databases, the data's specific **semantics** are very important
  - What is described?
  - What values are reasonable/correct?
  - What data belongs together?
  - What data is often/rarely accessed?



2.2 Data Models

- Example: Describe the **"age"** of a person
  - Semantic definition:
    The number of years elapsed since a person's birthday
  - Integer data type
  - Always: $0 \leq$ age ≤ 120
  - Connected to the person's name, passport id, etc.
  - May often be retrieved, but should be protected
  - …

2.2 Data Models

- A **data model** is an abstract model that describes how data is represented and accessed
  - Examples: network model, relational model, object-oriented model, …
  - **Warning:** The term "data model" is ambiguous
    - A data model **theory** is a formal description of how data may be structured and accessed
    - A data model **instance** or **schema** applies a data model theory to create an instance for some particular application

2.2 Data Models

- A **data model** needs three parts:
  - Structural part
    - **Data structures** which are used to create databases representing the objects modeled
  - Integrity part
    - Rules expressing the **constraints** placed on these data structures to ensure structural integrity
  - Manipulation part
    - Operators that can be applied to the data structures, to **update** and **query** the data contained in the database

2.2 Data Models

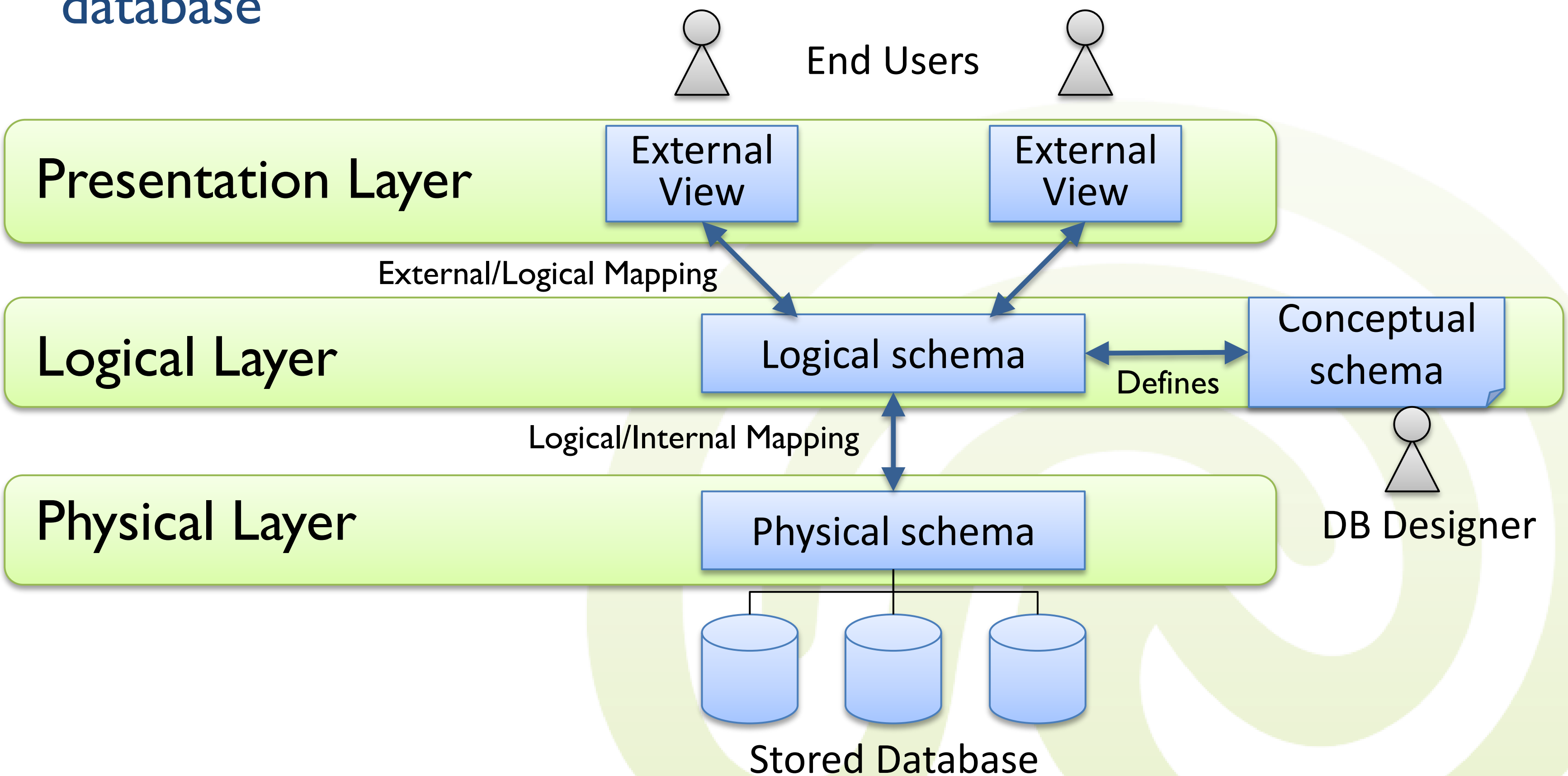
- Different categories of data models exist:
  - **High-level** or **conceptual** models
    - provide concepts that are close to the way many users perceive data
  - **Low-level** or **physical** data models
    - provide concepts that describe the details of how data is stored in the computer
  - **Representational** or **logical** data models
    - provide concepts that may be understood by end users but that are not too far removed from the way data is organized within the computer

2.2 Data Models

- Data models are instanced by **schemas**
  - A **conceptual schema** describes the semantics of a domain
    - What facts or propositions hold in this domain?
  - A **logical schema** describes the semantics, as represented by a particular data manipulation technology
    - Tables and columns, object-oriented classes, XML elements, ...
  - A **physical schema** describes the physical means by which the data is stored
    - Partitions, tablespaces, indexes, ...

2.2 Three-layer architecture

- … also called ANSI-SPARC Architecture …
  - separates the user applications and views from the physical database



2.2 Three-layer architecture

- Caution:
  - The **logical layer** in the ANSI-SPARC Architecture is often called **conceptual layer**
    - It is described using a **logical** or **representational** data model, but often based on a **conceptual schema design** in a high-level data model
  - The **external views**
    - Are also typically implemented using a **logical** data model and are possibly based on a **conceptual schema design** in a high-level data model

2.2 Data Models

- Why do we need three kinds of instances then?
- To maintain **independence!**
  - **Physical independence** means that the storage design can be altered without affecting logical or conceptual schemas
    - Logically, it does not matter where exactly the data about a person's age is stored, it is still the same data
  - **Logical independence** means that the logical design can be altered without affecting the data semantics
    - It does not matter whether a person's age is directly stored or computed from the person's birth date

2.2 Data Models

- Shortcomings of specific data models (schemas)
  - Depending on the application, modeling will often produce **different data models** for the **same domain**
    - Merging or mapping the models of **different companies** is difficult
    - **Data exchange** and **integration** between organizations is severely hampered

2.2 Data Models

- Often, differences originate in **different levels of abstraction** used in different models
  - Different in the kinds of facts that can be instantiated
  - The semantic expressiveness of the models is different
- **Extensions** are often necessary, but are difficult
  - For example, when the focus changes or new information about the domain becomes available
  - The model limits what can be expressed about a domain
  - Changes sometimes need complete re-modeling of the schema

2.2 Data Models

- **Generic data models** are generalizations of conventional data models
  - Definition of standardized general relation types, together with the kinds of things that may be related by such a relation type
  - Similar to the definition of a natural language

2.2 Data Models

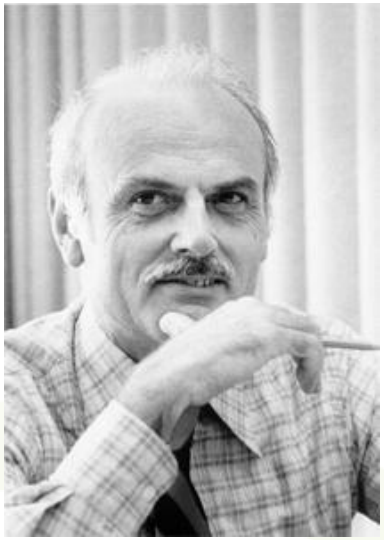
- **Example:** A generic data model may define relation types such as
  - **"classification relation"** as a binary relation between an individual thing and a kind of thing (a class)
  - **"part–whole relation"** as a binary relation between two things: one with the role of part, the other with the role of whole
    - Regardless of the kind of things that are related

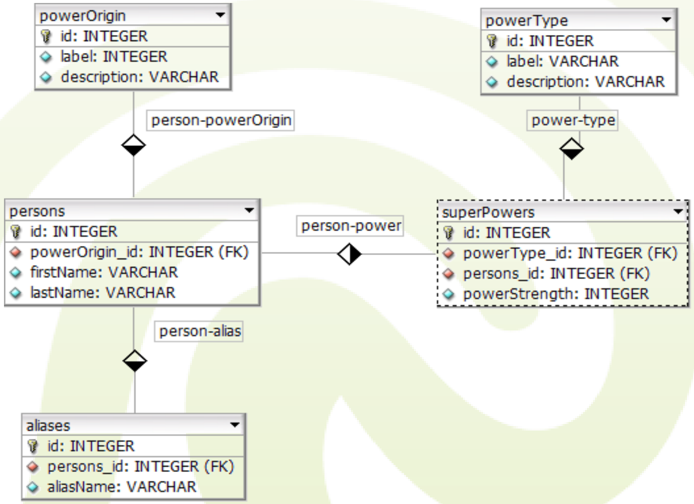
2.2 Data Models

- **Current state of the art:**
  Most data is structured best
  using **(relational) tables!**
  - Modeling data in tables is very natural and efficient
  - Often, there is no alternative to it …
- Think: Index card!
  - All data about an object on each single card
  - Ordered/Sorted by a single attribute
  - …

2.2 Data Models

- Sounds pretty obvious, huh?
  - We owe this belief to **Edgar F. Codd** (around 1970)
  - Before that, people had a very **different perspective** on what data actually is…





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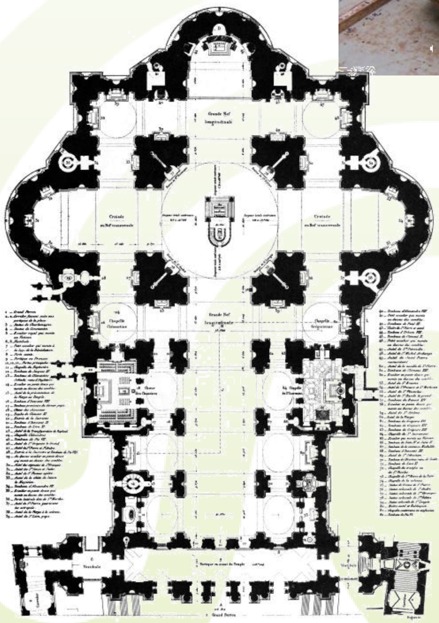
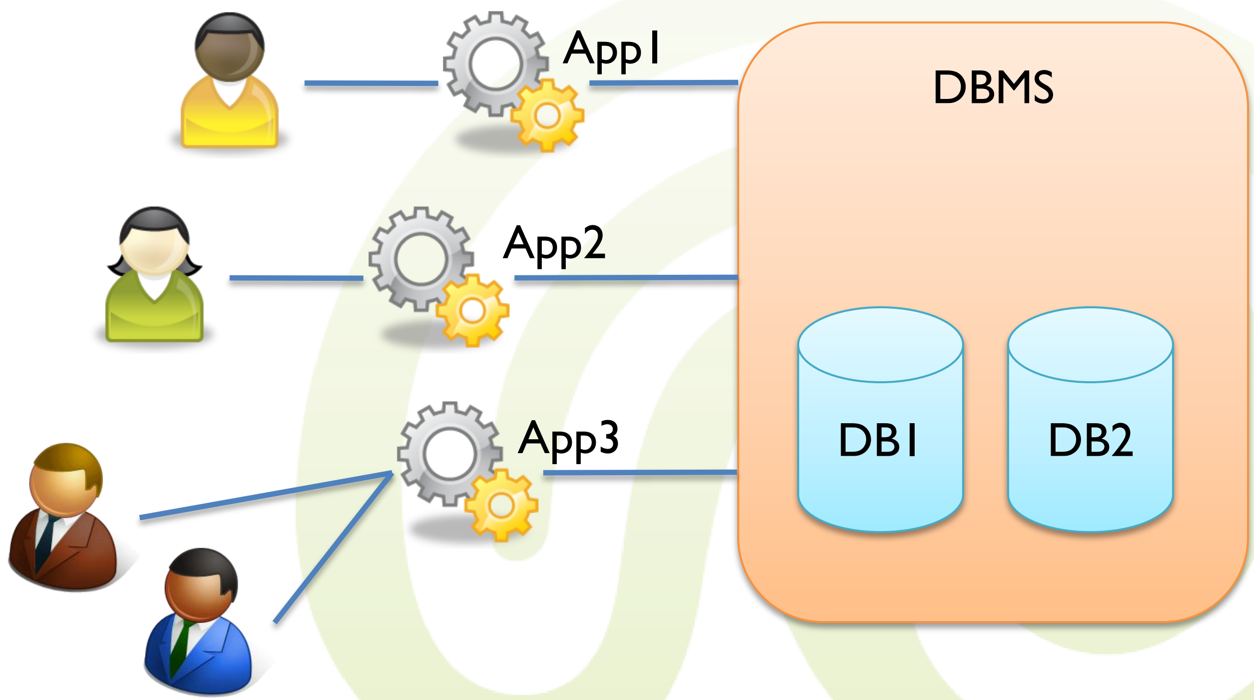


2.3 Database Applications

- **Database applications** consist of
  - **Database instances** with their respective **DBMS**
  - associated **application programs** interfacing with the users



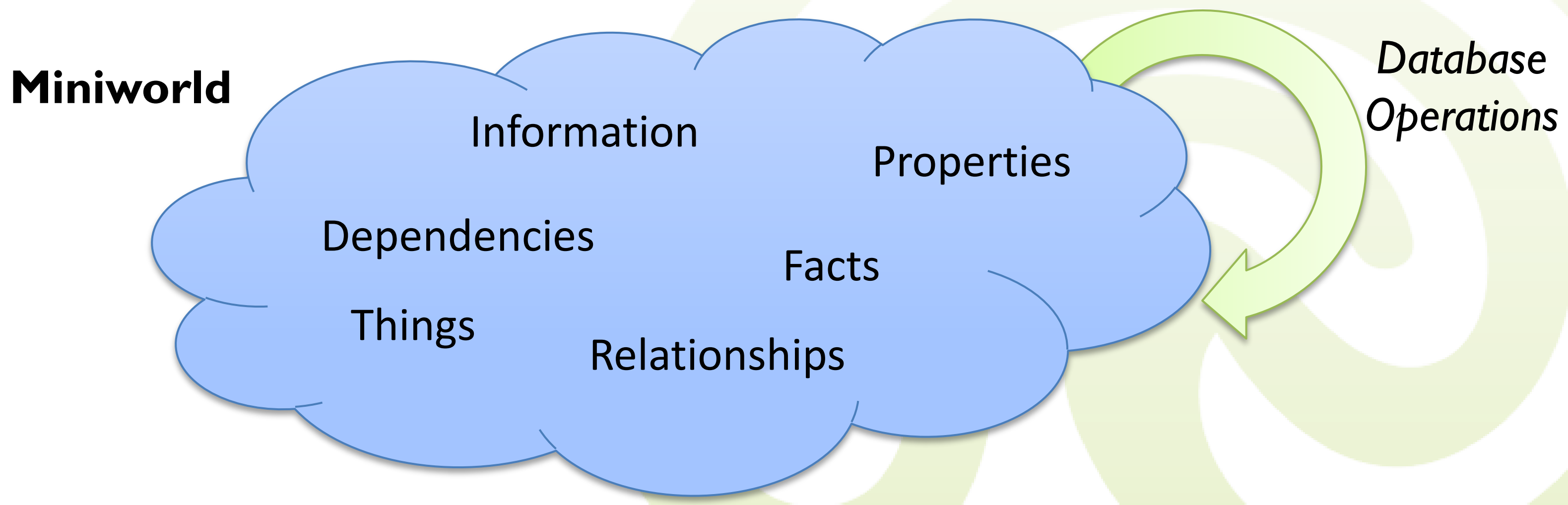
2.3 Database Applications

- Planning and developing application programs traditionally is a **software engineering** problem
  - Requirements Engineering
  - Conceptional Design
  - Application Design
  - …

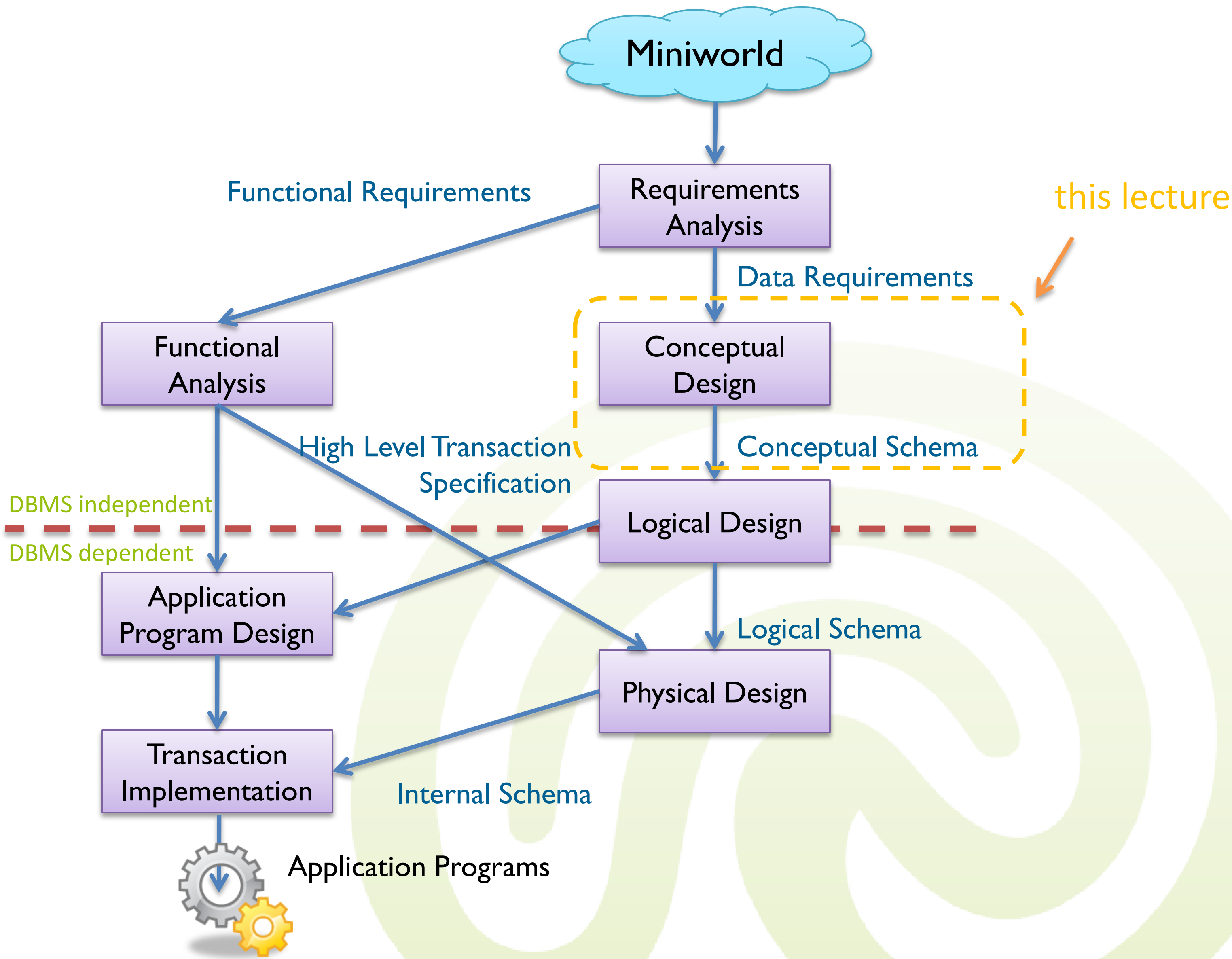
- Software engineers and data engineers cooperate tightly in planning the need, use and flow of data
  - **Data modeling**
  - **Database design**

2.3 Universe of Discourse

- DB Design models a **miniworld** into a formal representation
  - Restricted view on the real world with respect to the problems that the current application should solve



2.3 Phases of DB Design



2.3 Phases of DB Design

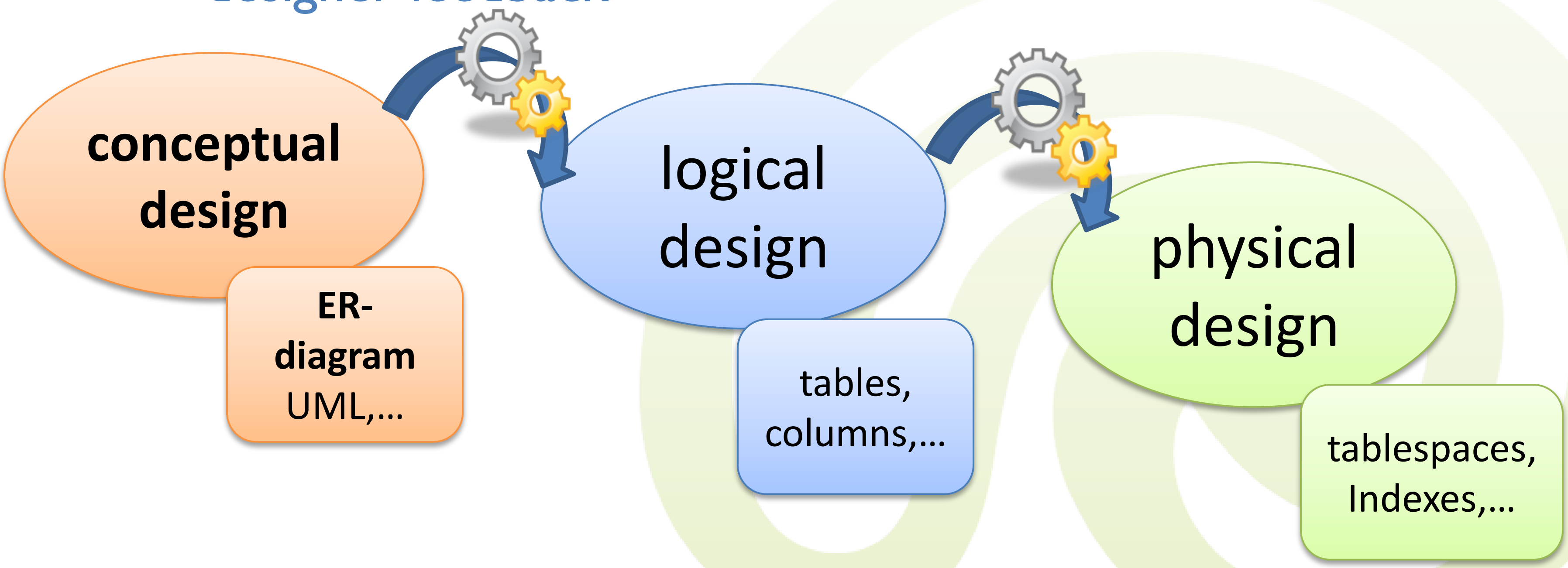
- **Requirements Analysis**
  - Database designers interview prospective **users** and **stakeholders**
  - **Data requirements** describe what kind of data is needed
  - **Functional requirements** describe the operations performed on the data
- **Functional Analysis**
  - Concentrates on describing **high-level** user operations and transactions
    - Does also not contain implementation details
    - Should be matched versus conceptual model

2.3 Phases of DB Design

- **Conceptual Design**
  - Transforms data requirements to **conceptual model**
  - Conceptual model describes data entities, relationships, constraints, etc. on **high-level**
    - Does not contain any implementation details
    - Independent of used software and hardware
- **Logical Design**
  - Maps the conceptual data model to the logical data model used by the DBMS
    - e.g. relational model, hierarchical model, …
    - Technology independent conceptual model is adapted to the used DBMS software
- **Physical Design**
  - Creates internal structures needed to efficiently store/manage data
    - Table spaces, indexes, access paths, …
    - Depends on used hardware and DBMS software

2.3 Phases of DB Design

- While modeling the data, 3 design phases have to be completed
  - The result of one phases serves as input for the next phase
  - Often, automatic transition is possible with some additional designer feedback



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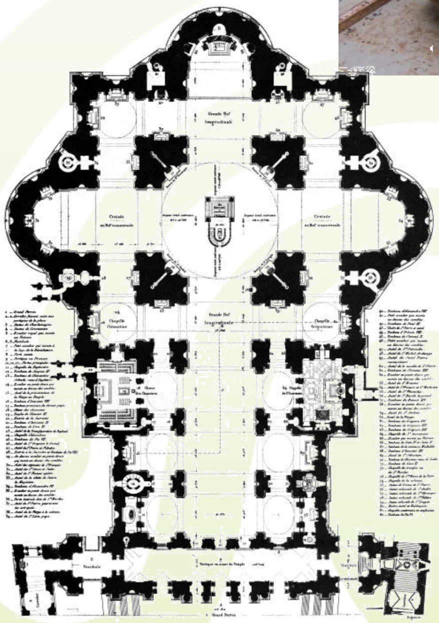


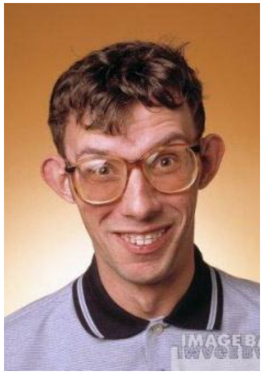
2.4 ER Modeling

- Traditional approach to **Conceptual Modeling**
  - **Entity-Relationship Models** (ER-Models)
    - Also known as Entity-Relationship Diagrams (ERD)
    - Introduced in1976 by **Peter Chen**
    - Graphical representation

- Top-Down-Approach for modeling
  - Entities and Attributes
  - Relationships
  - Constraints
- Some derivates became popular
  - ER Crow's Foot Notation (Bachman Notation)
  - ER Baker Notation
  - Later: Unified Modeling Language (UML)

2.4 ER - Entities

- **Entities**
  - An entity represents a "**thing**" in the real world with an independent existence
    - An entity has an own identity and represents just one thing
  - Example: a car, a savings account, my neighbor's house, the cat "Snowflake", a product, …



2.4 ER - Attributes

- **Attributes**
  - A **property** of an entity, entity type or a relationship type.
  - Example: name of an employee, color of a car, balance of an account, location of a house,…
  - Attributes can be classified as being:
    - **simple** or **composite**
    - **single-valued** or **multi-valued**
    - **stored** or **derived**
    - Example: name of a cat is simple, single-valued, and stored

2.4 ER – Entity Types

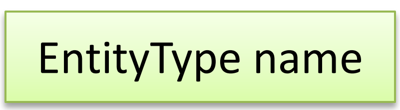
- **Entity Types** are sets of entities sharing the same characteristics or attributes
    - Each entity within the set has its own values
  - Each entity type is described by its name and attributes
    - Each entity is an **instance** of an entity type
  - Describes the so called **schema** or **intension** of similar entities

2.4 ER – Entity Sets

- An **Entity Set** is the collection of *all* entities of a given entity type
  - Entity sets often have the same name as the entity type
    - Cat may refer to the entity type as well as to the set of all Cat entities (sometimes also plural for the set: Cats)
  - Also called the **extension** of an entity type (or **instance**)

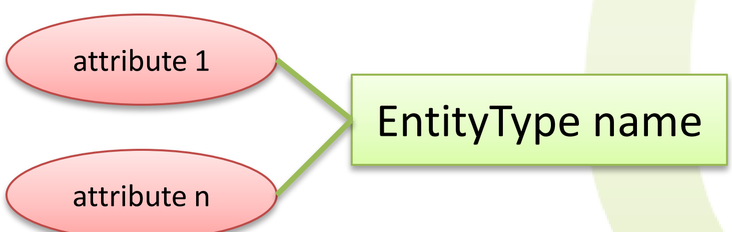
2.4 ER Diagrams

- ER diagrams represent **entity types** and **relationships** among them, not single entities
- Graphical Representation
  - Entity Type



- Rectangle labeled with the name of the entity
  - Usually, name starts with capital letters

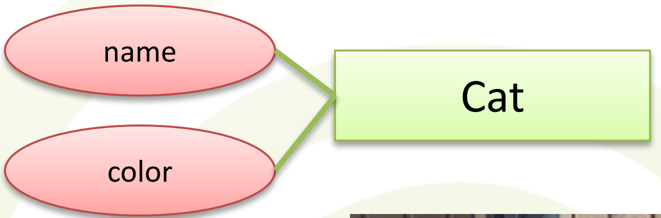
  - Attributes



- Oval labeled with the name of the attribute
- Usually, name starts with lower case letters

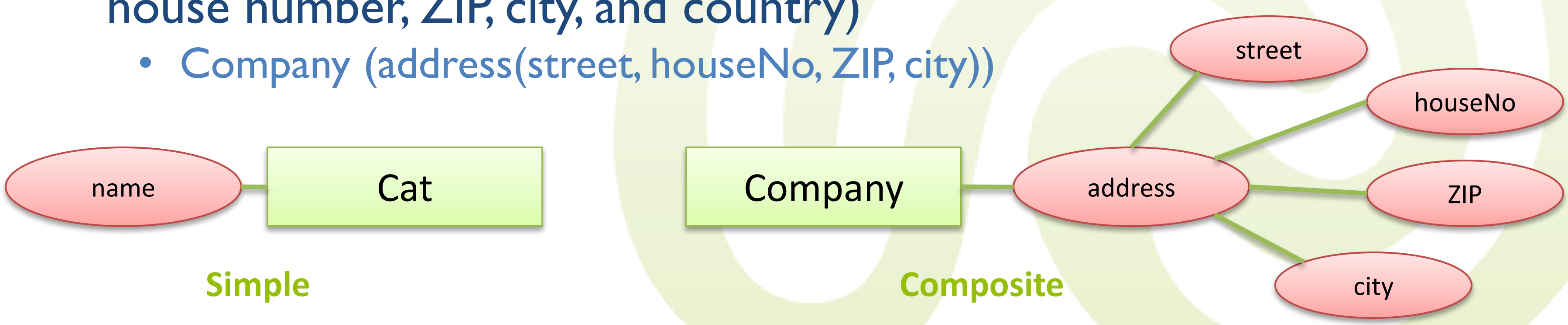
2.4 ER Diagrams

- Textual Representation
  - Entity Types
    - Written as: EntityName (attribute1, attribute2, …)
  - Entity
    - Written as: (value of attribute1, value of attribute2, …)
- Example
  - **Entity Type** *Cat*
    - Cat (name, color)
  - **Entity Set** *Cats*
    - (Fluffy, black-white)
    - (Snowflake, white)
    - (Captain Hook, red)
    - …



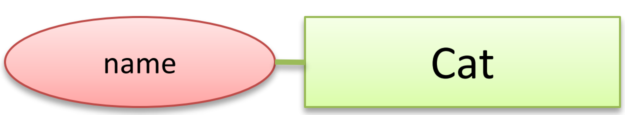
2.4 ER – Composite Attributes

- **Simple Attribute**:
  - Attribute composed of a single component with an independent existence
  - Example: name of a cat, salary of an employee,…
    - Cat (name), Employee(salary),…
- **Composite Attribute**:
  - Attribute composed of multiple components, each with an independent existence
    - Graphically represented by connecting sub-attributes to main attribute
    - Textually represented by grouping sub-attributes in ()
  - Example: address attribute of a company (is composed of street, house number, ZIP, city, and country)
    - Company (address(street, houseNo, ZIP, city))



2.4 ER Multi-Valued Attributes

- **Single-Valued Attribute**
  - Attribute holding a **single** value for each occurrence of an entity type
  - Example: name of a cat, registrationNo. of a student
- **Multi-Valued Attributes (lists)**
  - Attribute holding (possibly) **multiple** values for each occurrence of an entity type.
    - Graphically indicated by a double-bordered oval
    - Textually represented by enclosing in {}
  - Example: telephoneNo. of a student
    - Student ({phoneNo})



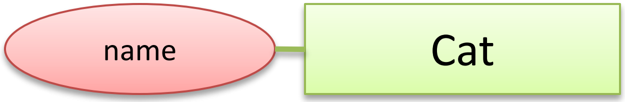
Single Valued

Multi-Valued

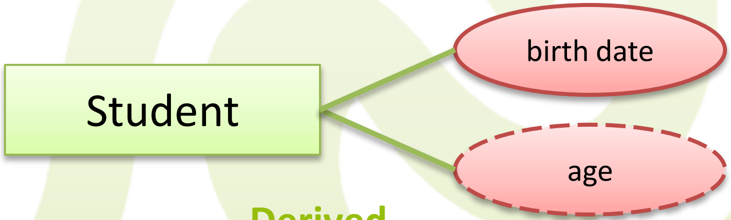
2.4 ER – Derived Attributes

- **Stored Attribute**
  – The attribute is directly stored in the database
- **Derived Attribute**
  – The attribute is (usually) not stored in the DB but derived from an other, stored attribute
    - In special cases, it might also be stored for read performance reasons

  – Indicated by dashed oval
  – Example: Age can be derived from birth date, average grade can be derived by aggregating all stored grades



Stored



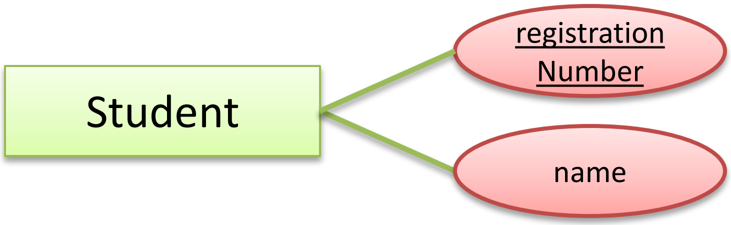
Derived

2.4 ER - Keys

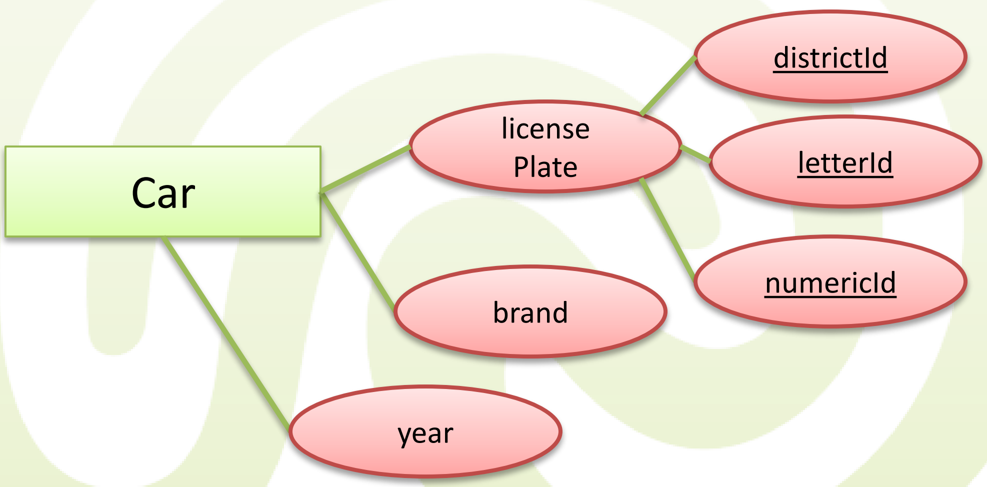
- Entities are **only** described by attribute values
  - Two entities with identical values cannot be distinguished (no OIDs, row IDs, etc.)
- Entities (usually) must be distinguishable
- Identification of entities with **key attributes**
  - Value combination of key attributes is **unique** within **all possible extensions** of the entity types
  - Key attributes are indicated by underlining the attribute name

2.4 ER - Keys

- Key attribute examples
  - Single key attribute
    - Student (<u>registrationNumber</u>, name)
    - (432451, Hans Müller)

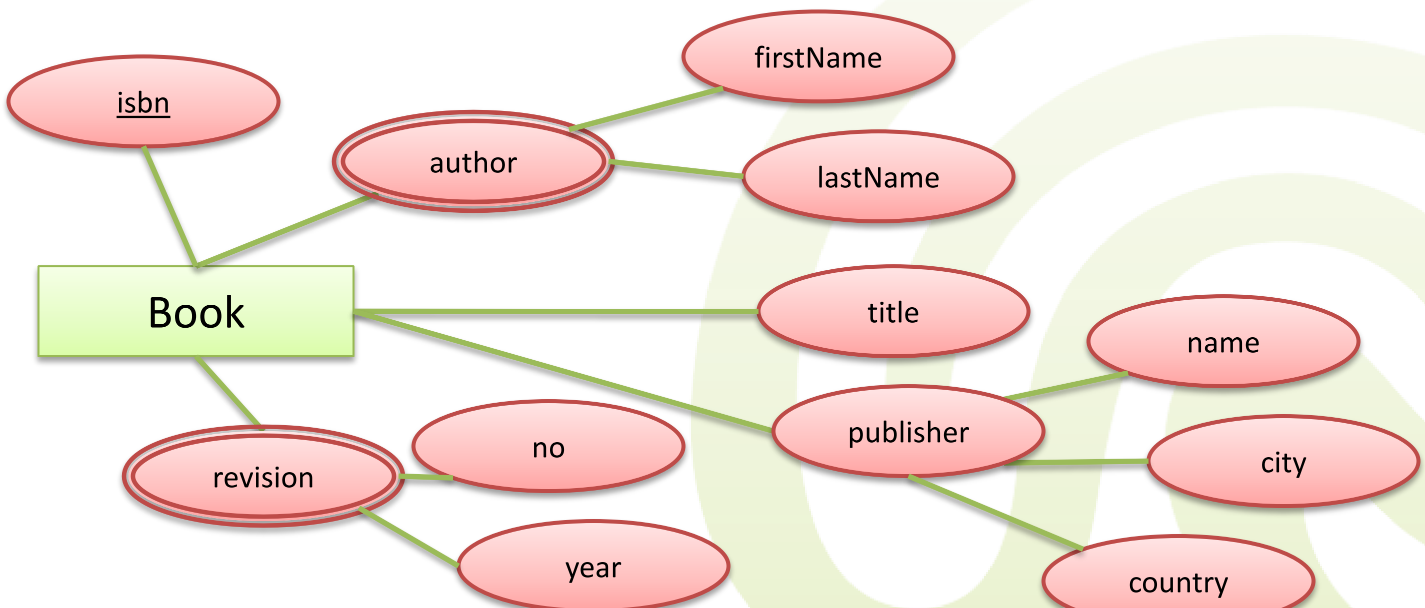


  - Composite key (multiple key attributes)
    - Car (licensePlate(districtId, letterId, numericId), brand, year)
    - ((BS,CL,797),VW,1998)
    - Please note that each key attribute itself is not unique!



2.4 ER Modeling

- **Example Entity Type**
  - Book (isbn, {author(firstName, lastName)}, title, subtitle, publisher(name,city, country), {revision(no, year)})
  - (0321204484, {(Ramez, Elmasri), (Shamkant, Navathe)}, Fundamentals of Database Systems, (Pearson, Boston, US), {(4,2004),(2, 1994)})



2.4 ER - Domains

- Attributes cannot have arbitrary values: they are restricted by the attribute **value sets (domains)**
  - Zip Codes may be restricted to integer values between 0 and 99999
  - Names may be restricted to character strings with maximum length of 120
  - Domains are not displayed in ER diagrams
  - Usually, popular **data types** are used to describe domains in data modeling
    - e.g. integer, float, string, ….

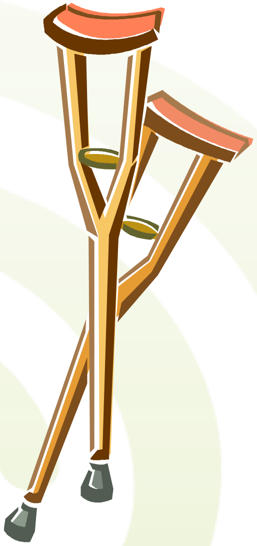
2.4 ER - Domains

- Commonly used data types

Name	Syntax	description
integer	integer	32-Bit signed integer values between -2^{31} and 2^{31}
double	double	64-Bit floating point values of approximate precision
numeric	numeric(*p*, *s*)	A number with *p* digit before the decimal and *s* digitals after the decimal
character	char(*x*)	A textual string of the exact length *x*
varying character	varchar(*x*)	A textual string of the maximum length *x*
date	date	Stores year, month, and day
time	time	Stores hour, minute, and second values

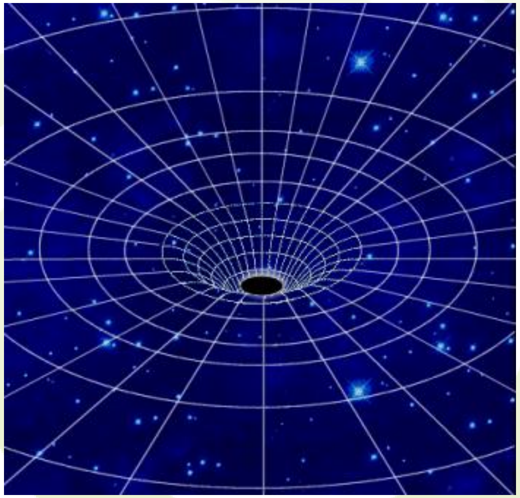
2.4 ER - Domains

- Using data types for modeling domains is actually a crutch
  - The original intention of domains was modeling all valid values for an attribute
    - Colors: {Red, Blue, Green, Yellow}
  - Using data types is very coarse and more a convenient solution
    - Colors: varchar(30) ???
  - To compensate for the lacking precision, often **restrictions** are used
    - Colors: varchar(30) restricted to {Red, Blue, Green, Yellow}



2.4 ER – NULL Values

- Sometimes, an attribute value is **not known** or an attribute does **not apply** for an entity
  - This is denoted by the special value **NULL**
    - So called **NULL-value**
  - Example: Attribute "universityDegree" of entity Heinz Müller may be NULL, if he does not have a degree
  - NULL is usually always allowed for any domain or data type unless explicitly excluded



2.4 ER – NULL Values

- What does it mean when you encounter a NULL-value?
  - Attribute is not applicable
    - e.g. attribute "maiden name" when you don't have one
  - Value is not known
  - Value will be filled in later
  - Value is not important for the current entity
  - Value was just forgotten to set
- Actually there are more than 30 possible interpretations…

2.4 ER – Relationships

- Entities are not enough to model a miniworld
  - The power to model dependencies and relationships is needed
- In ER, there can be **relationships** between entities
  - Each relationship **instance** has a **degree**
    - i.e. the number of entities it relates to
  - A relationship instance may have attributes

2.4 ER – Relationships

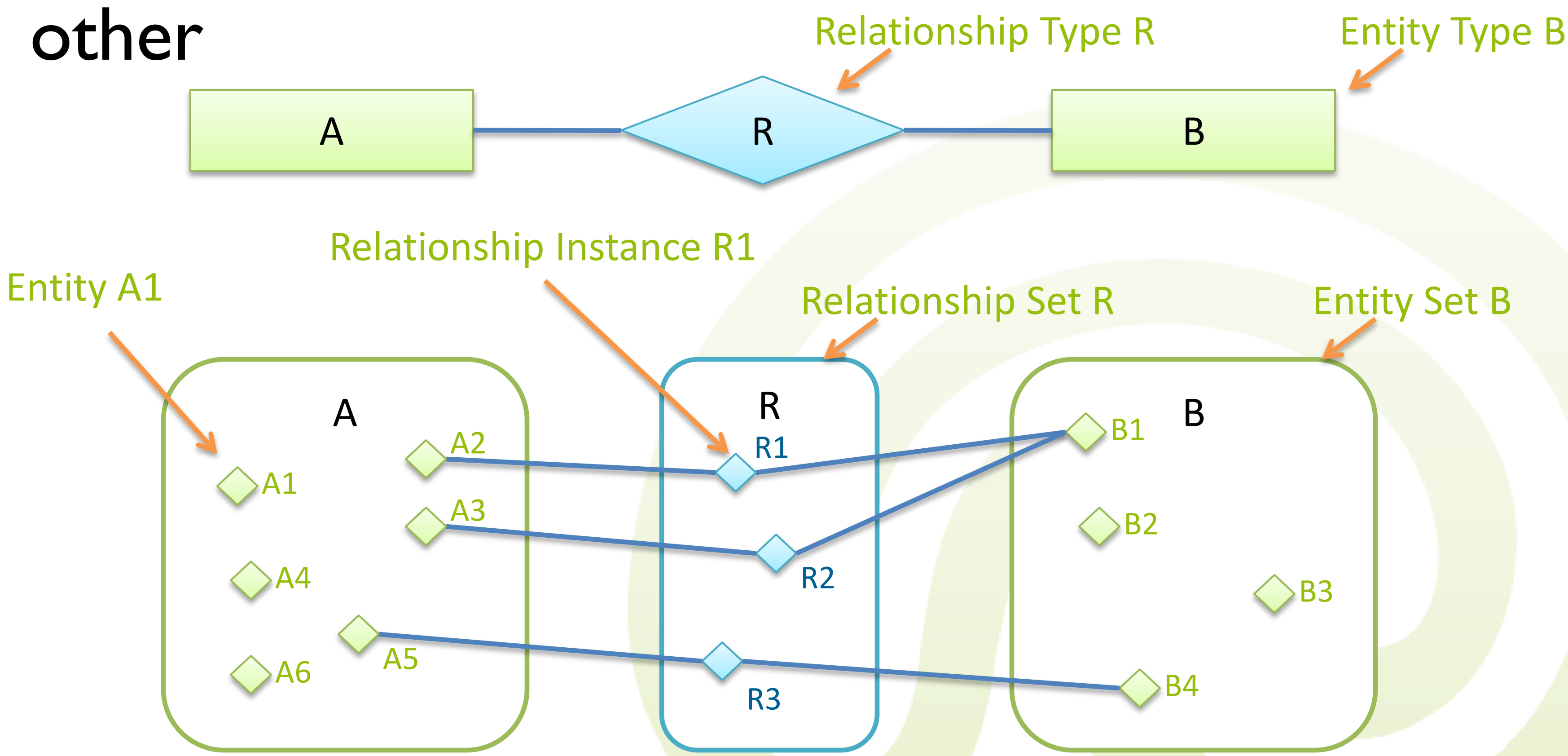
- Similar to entities, ERDs do not model individual relationships, but **relationship types**
- **Relationship type**
  - Named set of all similar relationships with the same attributes and relating to the same entity types

- Diamond labeled with the name of the relationship type
- Usually, name starts with lower-case letters

- **Relationship set**
  - Set of all **relationship instances** of a certain relationship type

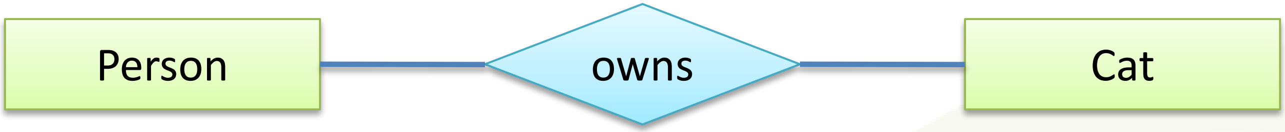
2.4 ER – Relationships

- **Relationships** relate **entities** within the **entity sets** involved in the **relationship type** to each other



2.4 ER – Relationships

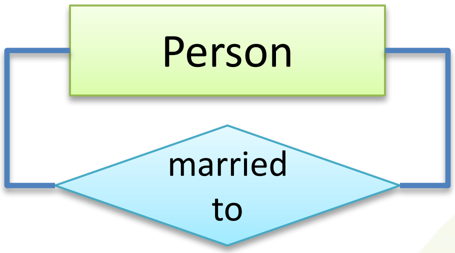
- Example:
  - There is an 'ownership' relation between cats and persons



  - But more modeling detail is needed
    - Does every person own a cat? Does every cat have an owner?
    - Can a cat have multiple owners or a person own multiple cats?
    - Since when does a person own some cat?
    - Who owns whom?

2.4 ER – Relationship Cardinality

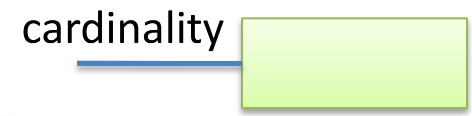
- Additionally, **restrictions** on the combinations of entities participating in an entity set are needed
  - Example: Relationship type "married to"



- Unless living in Utah, a restriction should be modeled that each person can only be married to a single person at a time
  - i.e. each person entity may only appear once in the "married to" relationship set
- **Cardinality** annotations are used for this
- Relationship types referring to just one entity type are called recursive

2.4 ER – Relationship Cardinality

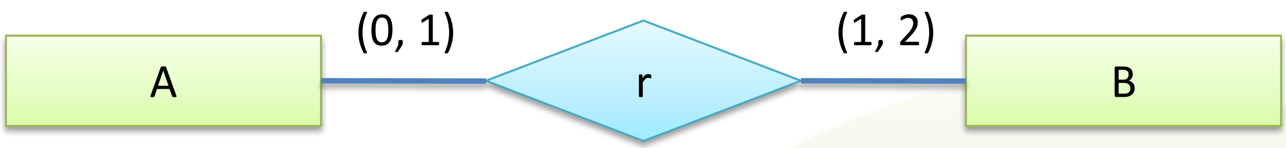
- **Cardinality** annotations
  - One cardinality annotation per entity type / relationship end
    - Minimum and maximum constrains possible



  - Common Cardinality Expressions:
    - **(0, 1)** : Each entity may participate at most once in the relationship (i.e. relationship participation is optional)
    - **(1, 1)** : Each entity is bound exactly once
    - **(0, *)** : Each entity may participate arbitrary often in the relationship
    - **(1, *)** : Each entity may participate arbitrary often in the relationship, but at least once
    - No annotation is usually interpreted as (0, *)
    - If only one symbol / number *s* is used, this is interpreted as (0, *s*)
      - * = (0, *); 4 = (0, 4)
    - Sometimes, N or M are used instead of *

2.4 ER – Relationship Cardinality

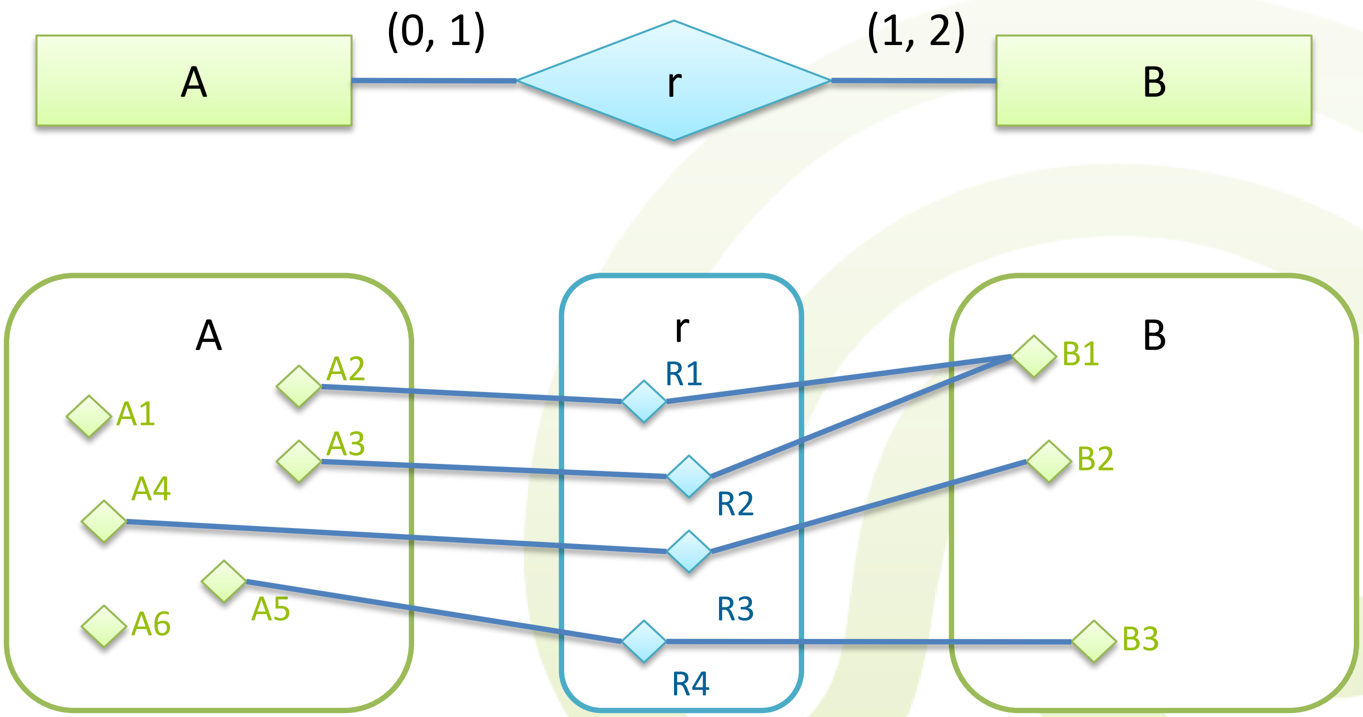
- Cardinalities express how often a specific entity may appear within a relationship set



  - A specific entity of type A may appear up to once in the relationship set, an entity of type B appears at least once and at most twice
    - This means: Up to two entities of type A may relate to one entity of type B. Some entities in A are not related to any in B. All entities in B are related to at least one in A.

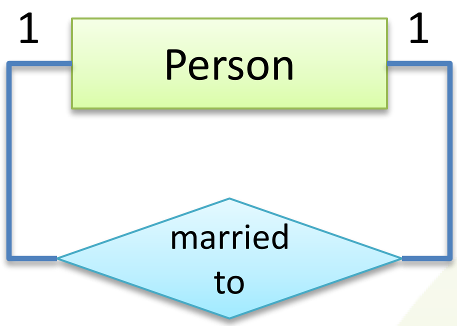
2.4 ER – Relationships

- "To each entity of type B, one or two entities of type A are related"



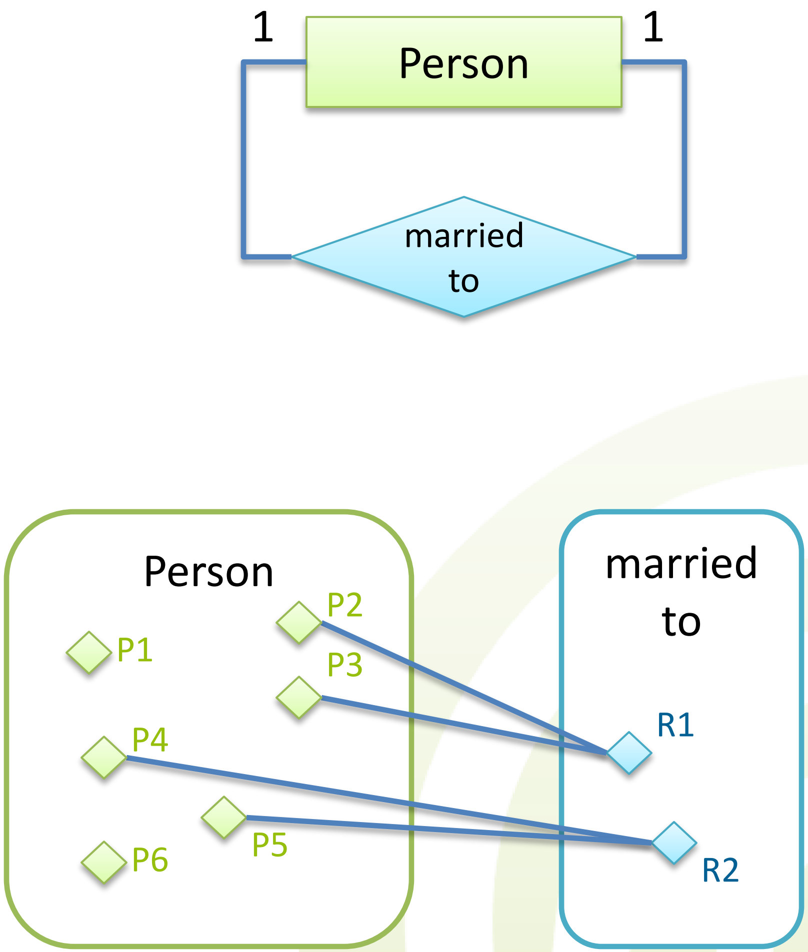
2.4 ER – Relationship Cardinality

- Example:
  - "Each person can only be married to one other person"



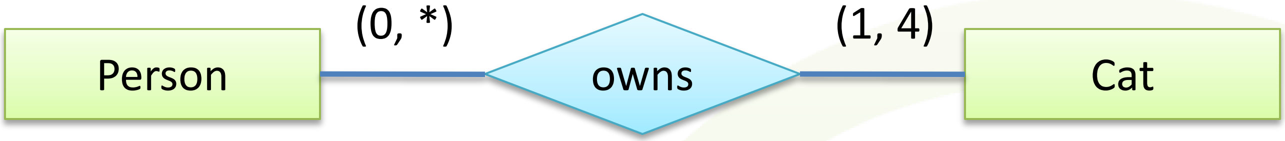
  - Each entity can only appear in one instance of the "married to" entity set

2.4 ER – Relationships

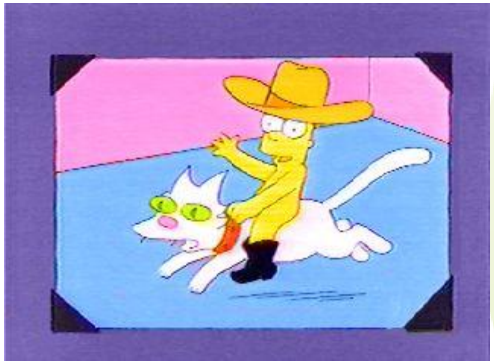


2.4 ER – Relationship Cardinality

- Example:
  - "A cat has up to 4 owners, but at least one. A person may own any number of cats."

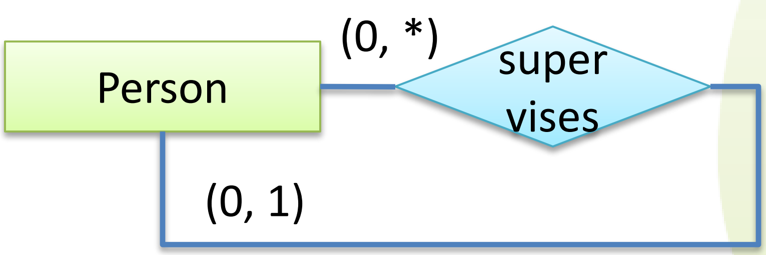


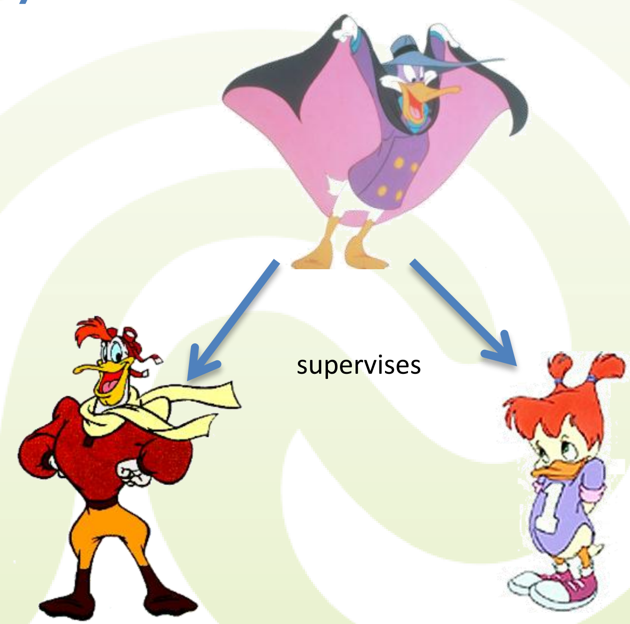
    - "Lisa owns Snowball", "Lisa owns Snowball II"



2.4 ER – Relationship Cardinality

- Example:
  - "A person may supervise any other number of persons"
    - "Drake Mallard supervises Launchpad McQuack"
    - "Drake Mallard supervises Gosaly Mallard"



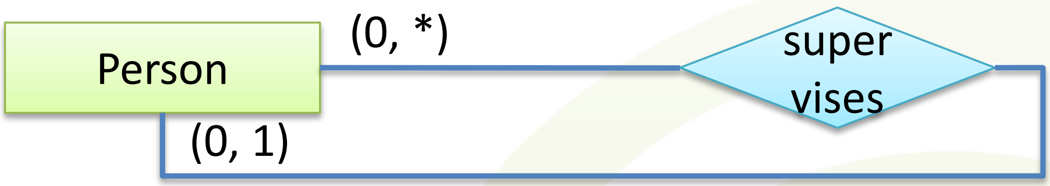


2.4 ER – Relationship Cardinality

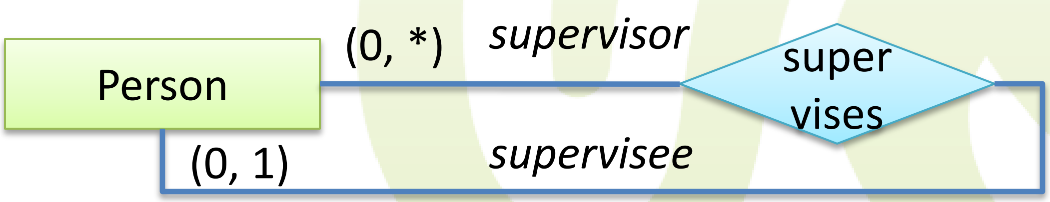
- Cardinalities for **binary** relationship types can be classified into common, more general **cardinality types**
  - These cardinality types are also often found in other modeling paradigms
    - **1:1** (**One-To-One**) – Each entity of the first type can only relate to exactly one entity of the other type
    - **1:N** (**One-To-Many**) – Each entity of the first type can relate to multiple entities of the other type
    - **N:1** (**Many-To-One**) – Multiple entities of the first type can relate to exactly one entity of the second type
    - **N:M** (**Many-To-Many**) – No restrictions. Any number of entities of first type may relate to any number of entities of second type.

2.4 ER – Relationship Roles

- Often, it is beneficial to clarify the **role** of an entity within a relationship
  - Example: Relationship "supervises"

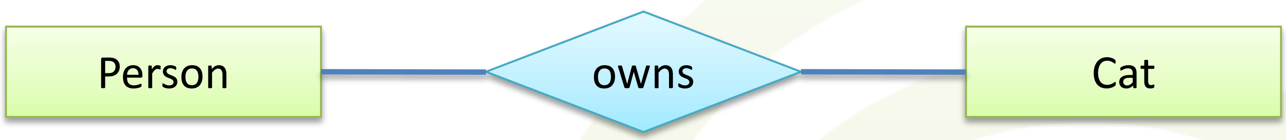


  - What is meant? Who is the supervisor? Who is the supervised person?
  - Roles can be annotated on the relationship lines

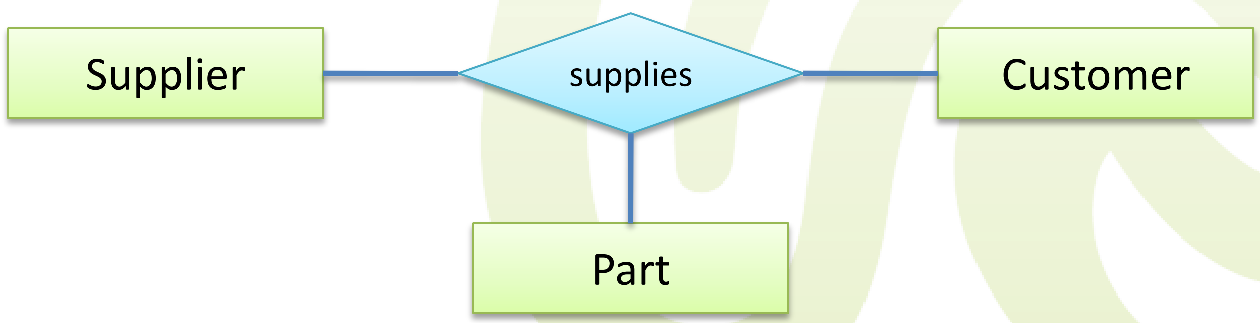


2.4 ER – Relationship Degree

- Relationship instances involve multiple entities
  - The number of entities in each relationship instance is called **relationship degree**
    - Degree=2 : Binary Relation

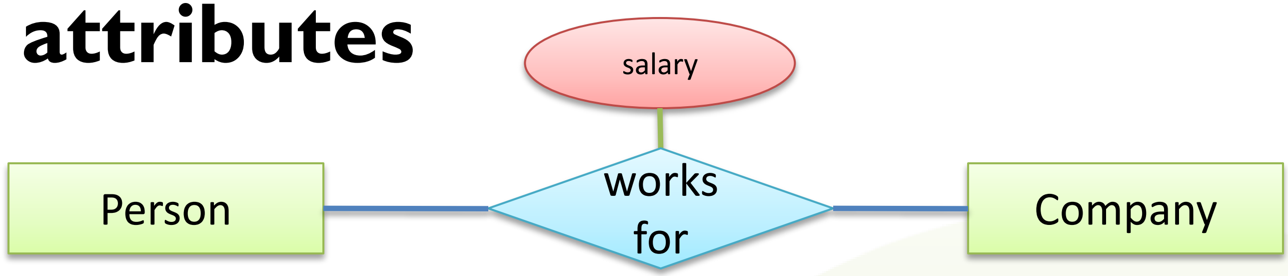


    - Degree=3: Ternary Relation



2.4 ER – Relationship Attributes

- Similar to entities, relationship types may even have **attributes**



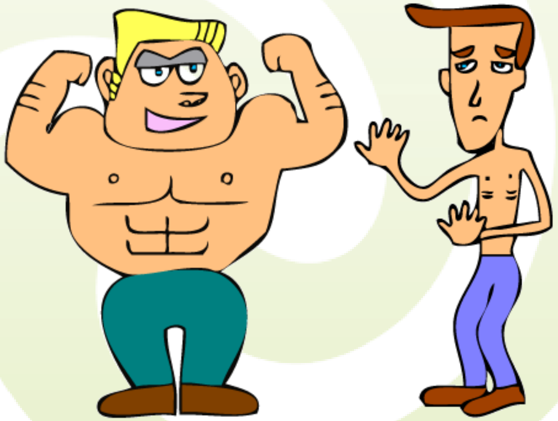
  - For 1:1 relationships, the relationship attribute may be migrated to any of the participating attributes
  - For 1:N relationships, the attribute may be only migrated to the entity type on the N-side
  - For N:M relationships, no migration is possible

2.4 ER – Total Participation

- To express that all entities of an entity type appear in a certain relationship set, the concept of **total participation** can be used
  – The entity type which is totally participating is indicated by a double line
  – Example: “Each driver’s license must belong to a person”

2.4 ER – Weak Entities

- Each entity needs to be identifiable by a set of **key attributes**
- Entities existing **independently** of the context are called **strong entities**
  - A person exists whether it is married or not
- In contrast, there may be entities without an unique key called **weak entities**

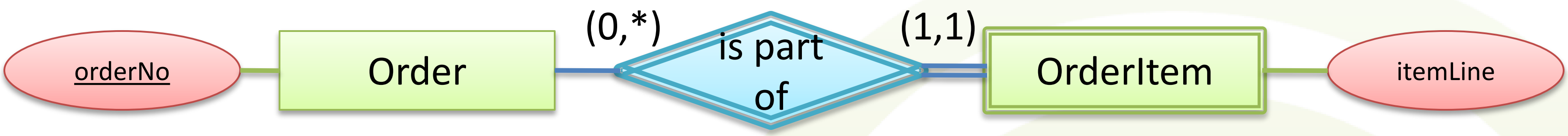


2.4 ER – Weak Entities

- **Weak entities** are identified by being related to strong entities
  - The strong entities "**own**" the weak entity
    - The weak one cannot exist without the strong ones
  - The relationships relating the strong to the weak are called **identifying relationships**
    - The weak entity is always totally participating in that relationship
  - Weak entities have **partial keys** which are unique within the identifying relationship sets of their strong entities
    - To be unique, the weak entity instance has to borrow the keys of the respective strong entity instances

2.4 ER – Weak Entities

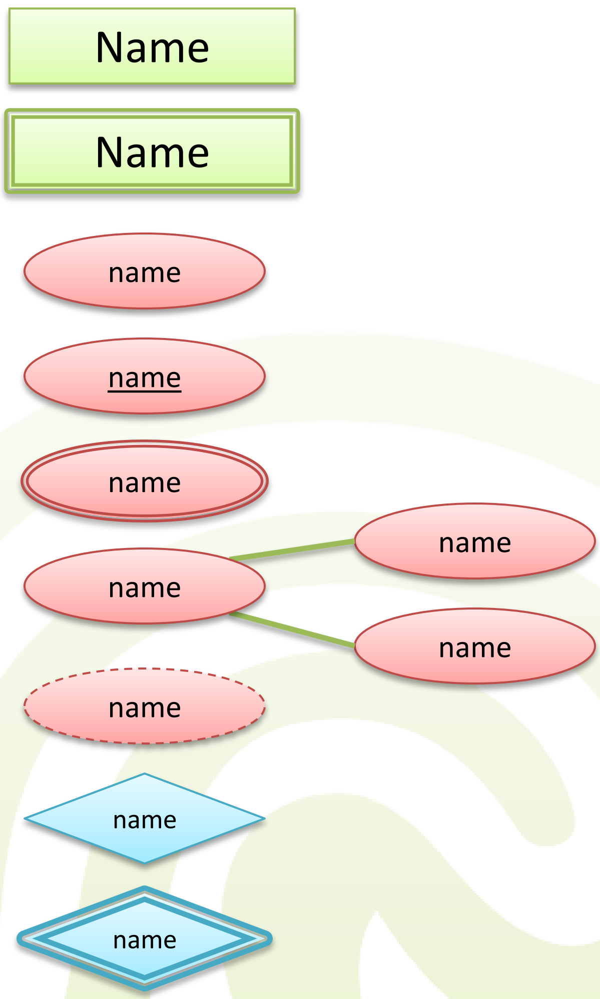
- Weak entity types and identifying relationship types are depicted by double-lined rectangles
- Example:
  - "An online shopping order contains several order items"



  - An order item can only exits within an order
  - Each order item can be identified by the orderNo of it's owning order and its itemLine

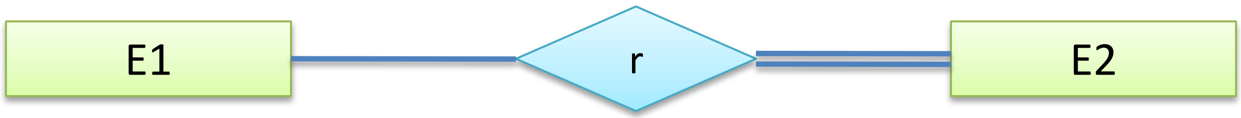
2.4 ER – Overview

- Entity Type
- Weak Entity Type
- Attribute
- Key Attribute
- Multi-valued Attribute
- Composite Attribute
- Derived Attribute
- Relationship Type
- Identifying Rel. Type

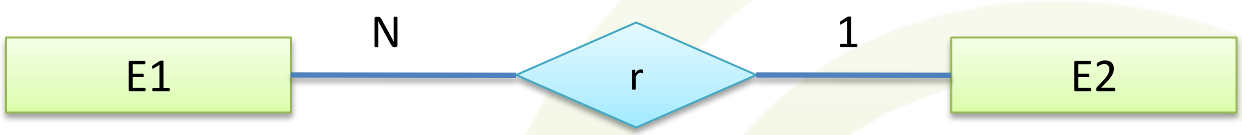


2.4 ER – Overview

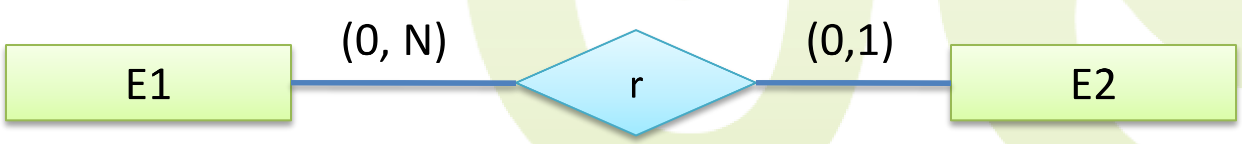
- Total participation of E2 in R



- Cardinality
  - An instance of E1 may relate to multiple instances of E2



- Specific cardinality with min and max
  - An instance of E1 may relate to multiple instances of E2



2.4 ER – Mathematical Model

- Mathematically, an **attribute** *A* of **entity type** *E* with **domain** *V* is a function from *E* to the power set *P(V)*
  - **$A : E \rightarrow P(V)$**
    - The power set P(V) of V is the set of all subsets of V
  - The **value** of an attribute of the entity e is denoted as A(e)
  - This definition covers
    - null values (empty set)
    - single-valued attributes (restricted to singleton sets)
    - multi-valued attributes (no restrictions)
  - For a composite attribute $A(A_1, A_2, \ldots, A_n)$, V is defined as
    - $V = P(V_1) \times P(V_2) \times \ldots \times P(V_n)$

2.4 ER – Mathematical Model

- A **relationship type** R among n **entity types** $E_1, E_2, \ldots, E_n$ defines a **relationship set** among instances of these entity types
  - Each relationship instance r_i within the relationship set R associates n individual entities $(e_1, e_2, \ldots, e_n)$, and each entity e_j in r_i is member of the entity type E_j, $1 \leq j \leq n$
  - Alternatively, the relationship type R can be seen as a subset of the Cartesian product of the entity types
    - $R \subseteq E_1 \times E_2 \times \ldots, \times E_n$

An example

Detour

- We want to model a simple university database
  - In our database, we have students. They have a name, a registration number, and a course of study.
  - The university offers lectures. Each lecture may be part of some course of study in a certain semester. Lectures may have other lectures as prerequisites. They have a title, provide a specific number of credits and have an unique ID
  - Each year, some of these lectures are offered by a professor at a certain day at a fixed time in a specific room. Students may register for that lecture.
  - Professors have a name and are member of a specific department.

An example

Detour

- How to start? What to do?
  - Find the basic **entity types**
  - Find the **attributes** of entities
    - Decide to which entity an attribute should be assigned
    - Which attributes are key attributes?
    - Some attributes are better modeled as own entities, which ones?
  - Define the **relationship types**
    - Which role do entities play?
    - Do relationships require additional entity types?
    - Are the relationships total? Identifying? Are weak entities involved?
    - What are the cardinalities of the relationship type?

An example

Detour

- Which are our entity types?
  - In our database, we have students. They have a name, a registration number and a course of study.
  - The university offers lectures. Each lecture may be part of some course of study in a certain semester. Lectures may have other lectures as prerequisites. They have a title, provide a specific number of credits and have unique ID
  - Each year, some of these lectures are offered by a professor at a certain day at a fixed time in a specific room. Students may attend that lecture.
  - Professors have a name and are member of a specific department.

An example

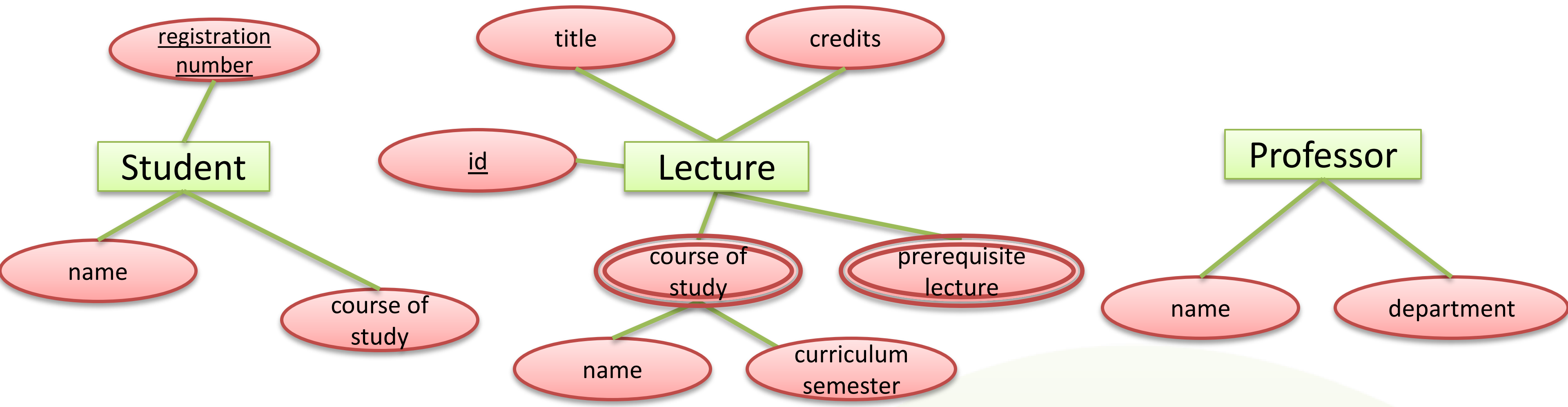
Detour

Student | Lecture | Professor

- What attributes are there?
  - In our database, we have students. They have a name, a registration number and a course of study.
  - The university offers lectures. Each lecture may be part of some course of study in a certain semester. Lectures may have other lectures as prerequisites. They have a title, provide a specific number of credits and have unique ID
  - Professors have a name and are member of a specific department.

An example

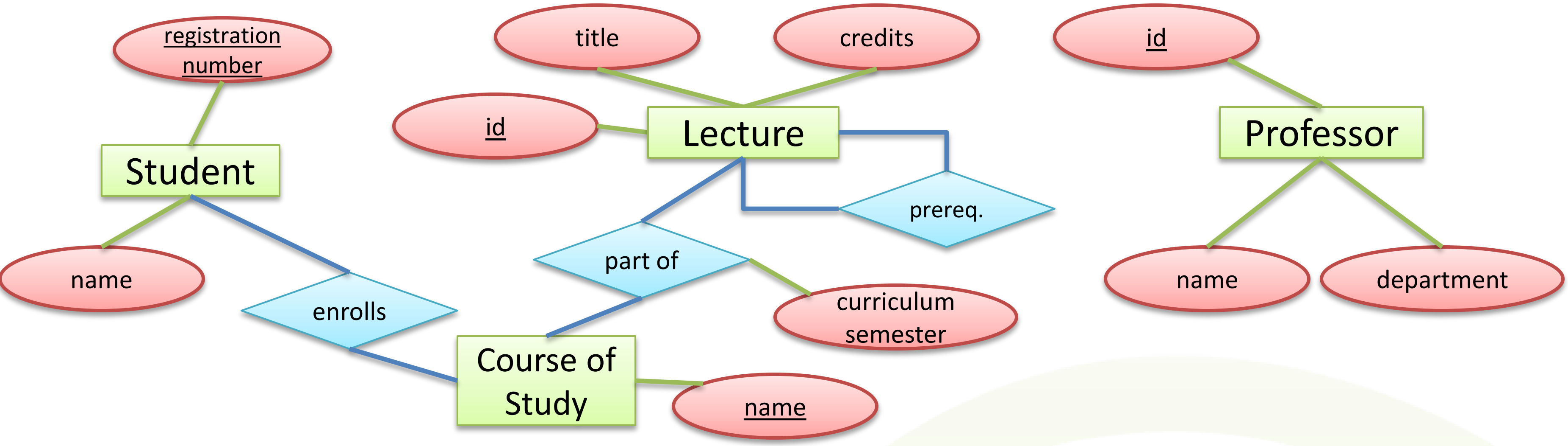
Detour



- First try…
  - This model is **really crappy**!
  - "Course of study" does not seem to be an attribute
    - Used by student and lecture. Even worse, lecture refers to a course of study in a specific curriculum semester.
    - Use additional entity type with relationships!
  - "Prerequisite lecture" also is not a good attribute
    - Prerequisite lectures are also lectures. Use a relationship instead!
  - "Professor" does not have key attributes

An example

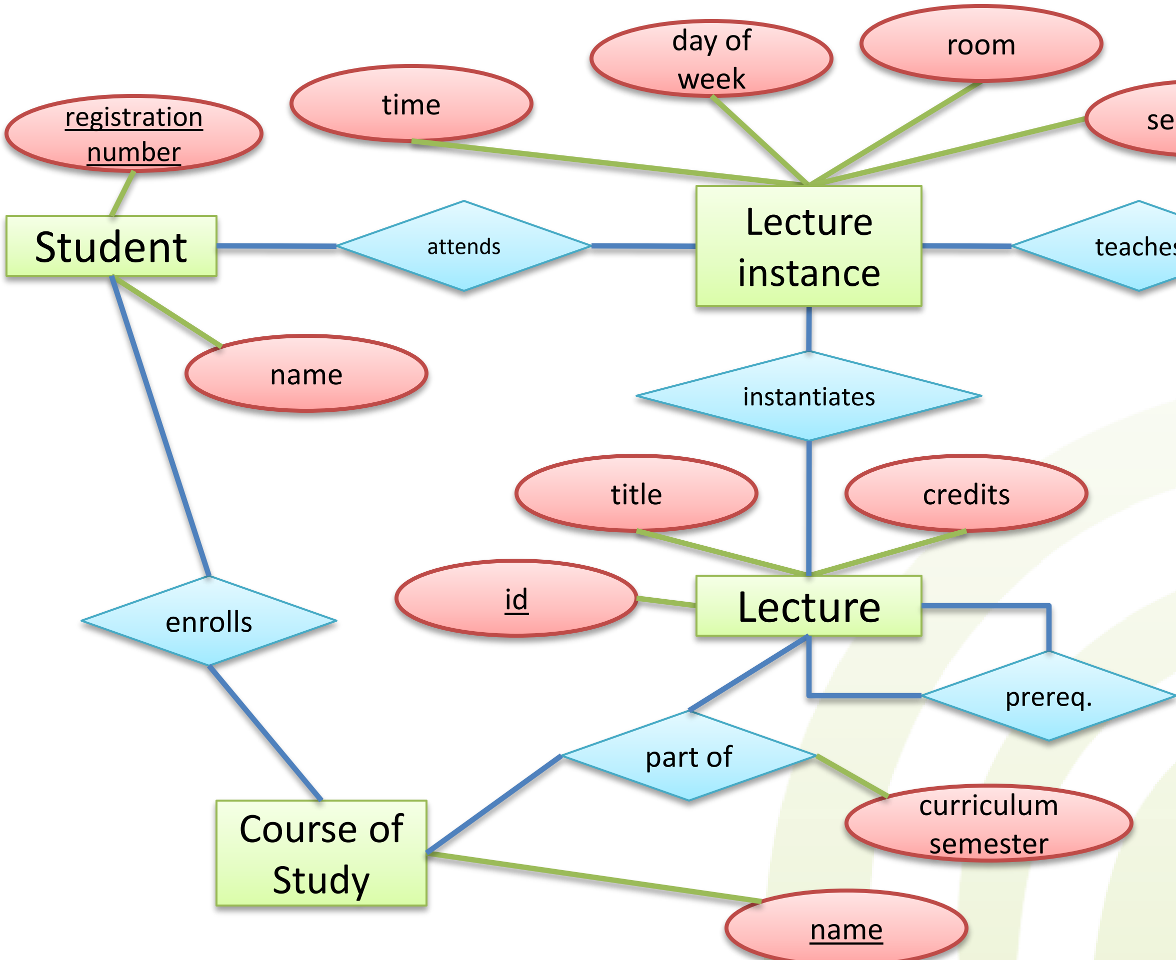
Detour



- Second try
  - Professors use a **surrogate** key now
    - Key is automatically generated and has no meaning beside unique identification
  - Course of study is an entity type now
- Which entity types are additionally related?
  - "Each year, some lectures of the pool of all lectures are offered by a professor at a certain day at a fixed time in a specific room. Students may attend that lecture."

An example

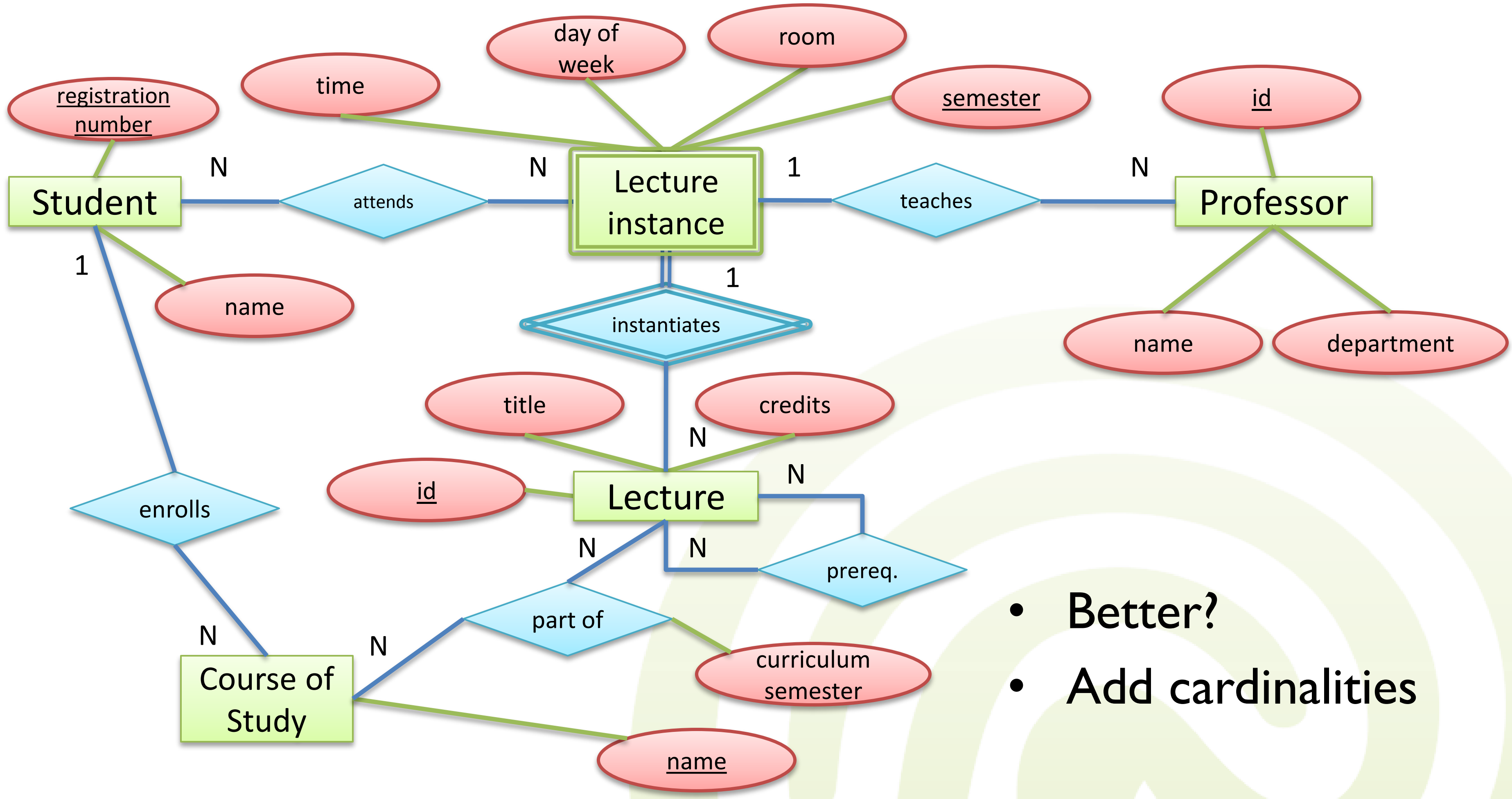
Detour



- Better?
- Add cardinalities
- Add total and identifying annotations
- Lecture instance has no key

An example

Detour



- Better?
- Add cardinalities

An example

Detour

- Modeling is not that simple
- Many possible (and also correct) ways of modeling the same miniworld
  – Some are more elegant, some are less elegant
- Models alone are not enough, they need to be documented
  – What are the meanings of the attributes? The meanings of the relationships?

Summary

- Data models
  - **3 parts** (structural, integrity, manipulation)
  - **3 categories** (conceptual, logical, physical)
  - Schemas are **instances** of data models
- Database Applications
  - ANSI-SPARC architecture
    - 3 Layers (presentation, logical, physical)
    - Data independence
- ER Modeling
  - **Chen notation**