Applied Databases

Lecture 5
ER Model, normal forms

Sebastian Maneth

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Outline

1. Entity Relationship Model
2. Normal Forms

Keys and Superkeys

Superkey = Set of attributes of an entity type so that
for each entity e of that type,
the set of values of the attributes *uniquely* identifies e.

e.g. a Person may be uniquely identified by { Name, NI# }

Key = is a superkey which is *minimal* (aka "Candidate Key")

e.g., a Person is uniquely identified by { NI# }.

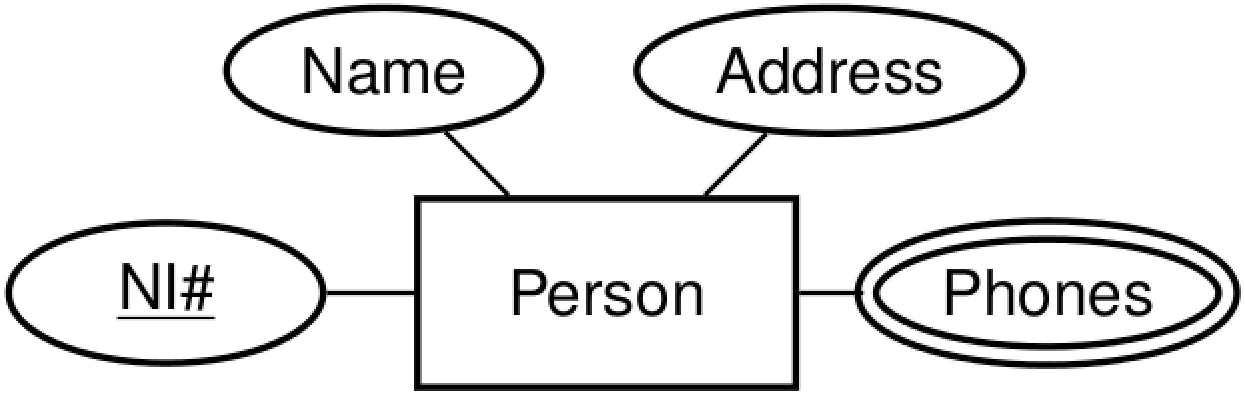
Prime Attribute = attribute that appears in a candidate key
Non-Prime Attribute = attribute that appears in no candidate key

Simple Key consists of one attribute
Composite Key consists of more than one attribute

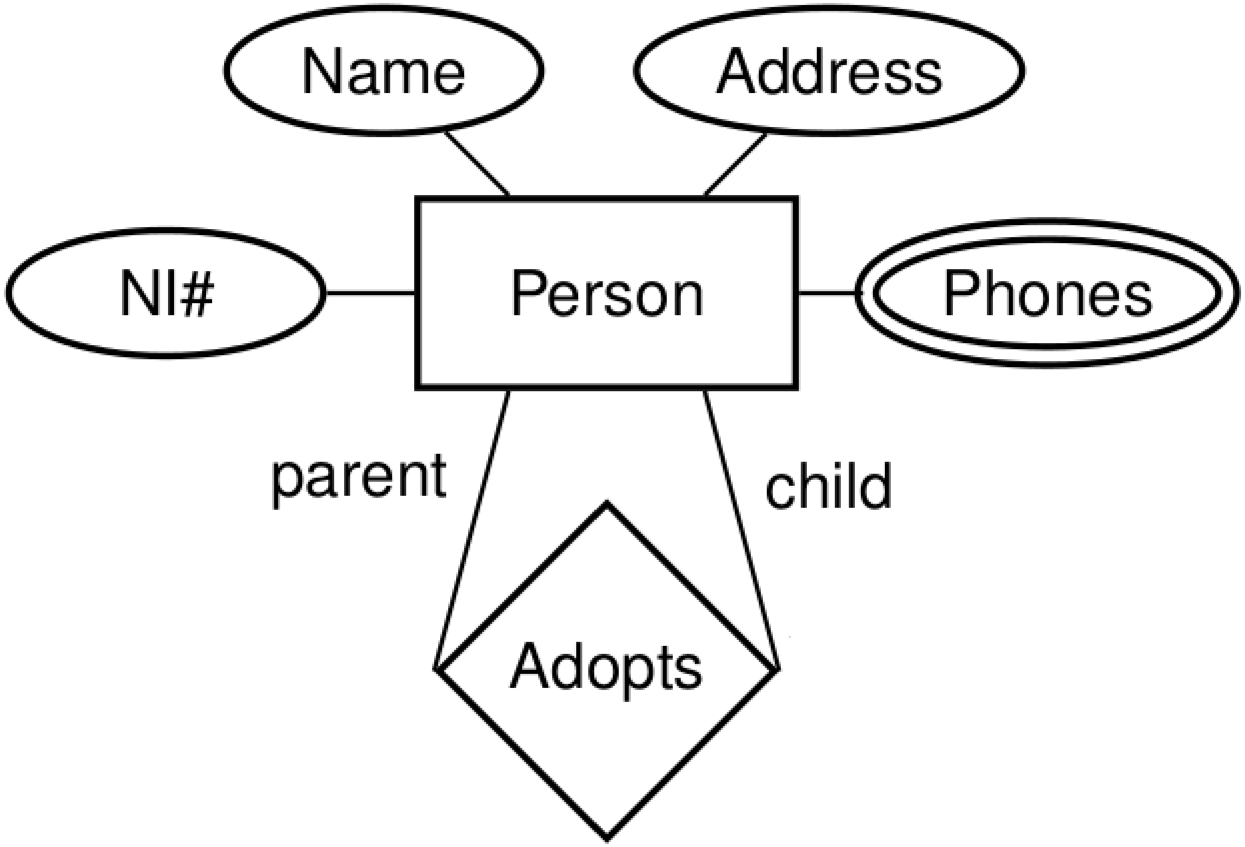
Primary Keys

Primary Key = a *candidate key* that has been chosen as such by the database designer

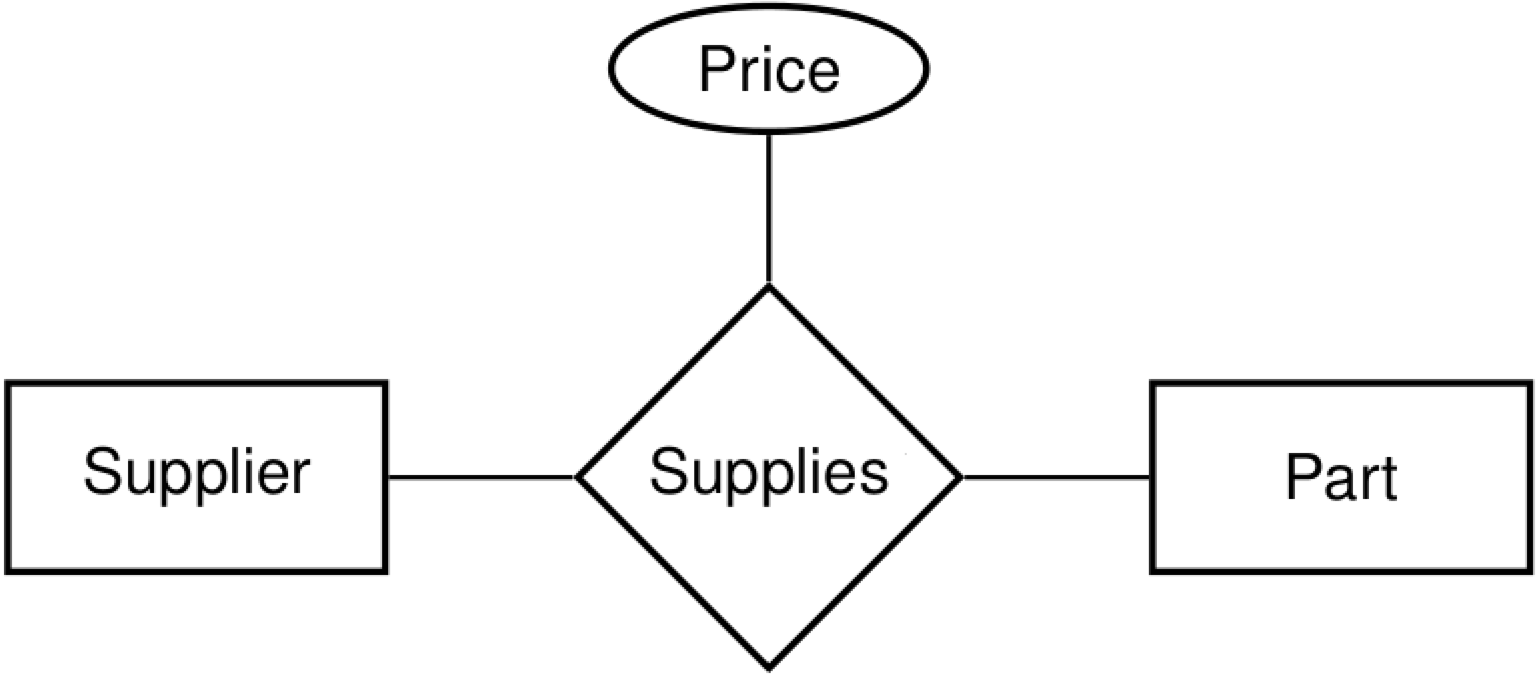
→ primary key guarantees logical access to every entity (attributes of a primary key are underlined)



Cyclic Relationship Type with Roles



Relationship Type with Attributes



→ Each Supplier Supplies a Part at a certain Price

Weak Entity Types

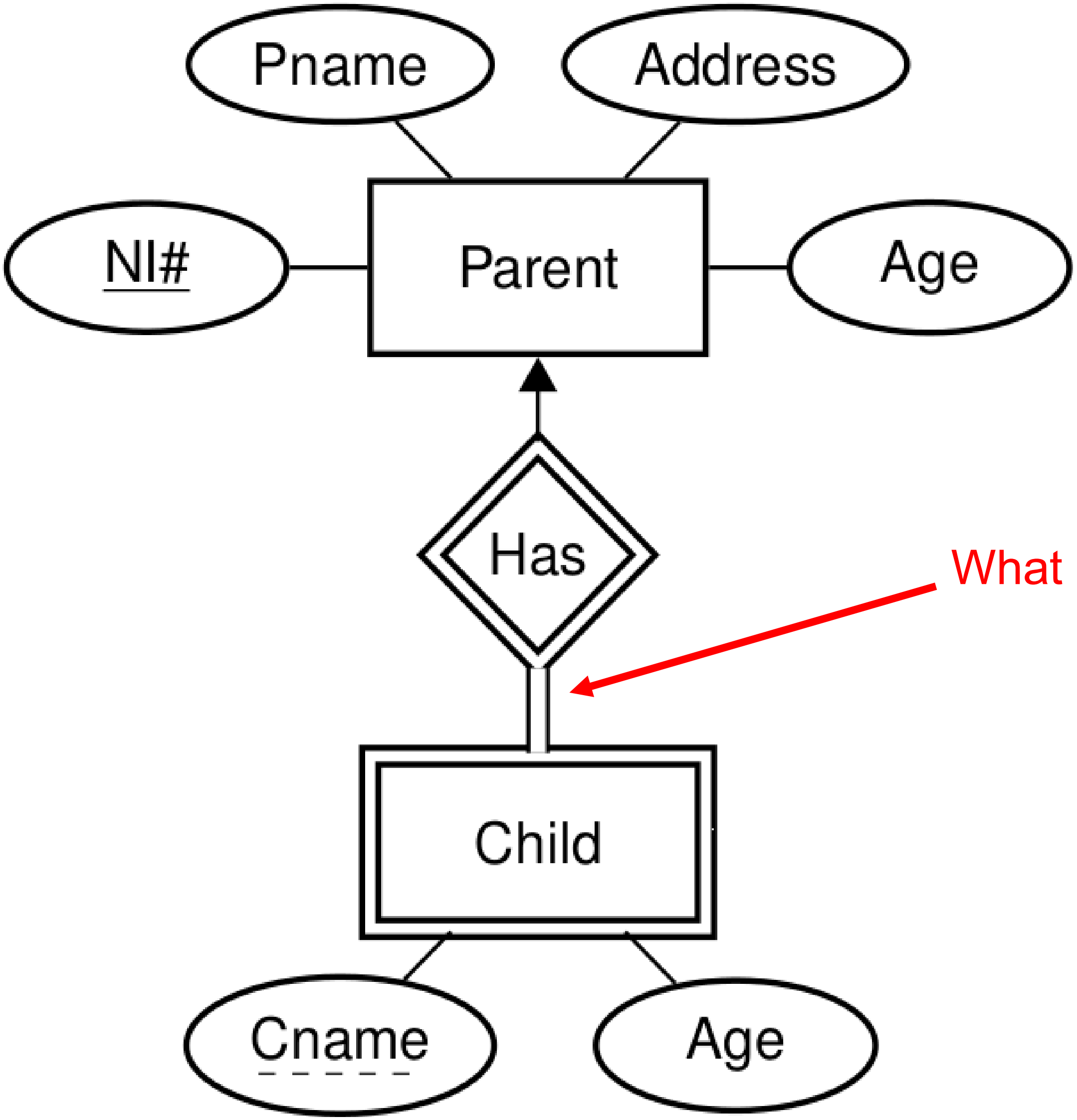
Weak Entity Type = an entity type that does not have sufficient attributes
to form a primary key (double rectangle)

→ depends on the existence of an identifying (or “owner”) entity type
(they have an “identifying (ID) relationship – double diamond)
→ must have a *discriminator* (dashed underline) for distinguishing its entities

E.g. in an employee database, Child entities exist only if their corresponding Parent employee entity exists.

The primary key of a weak entity type is the combination of the primary key of its owner type and its discriminator.

Weak Entity Types



What does this mean?

ISA Relationship Types

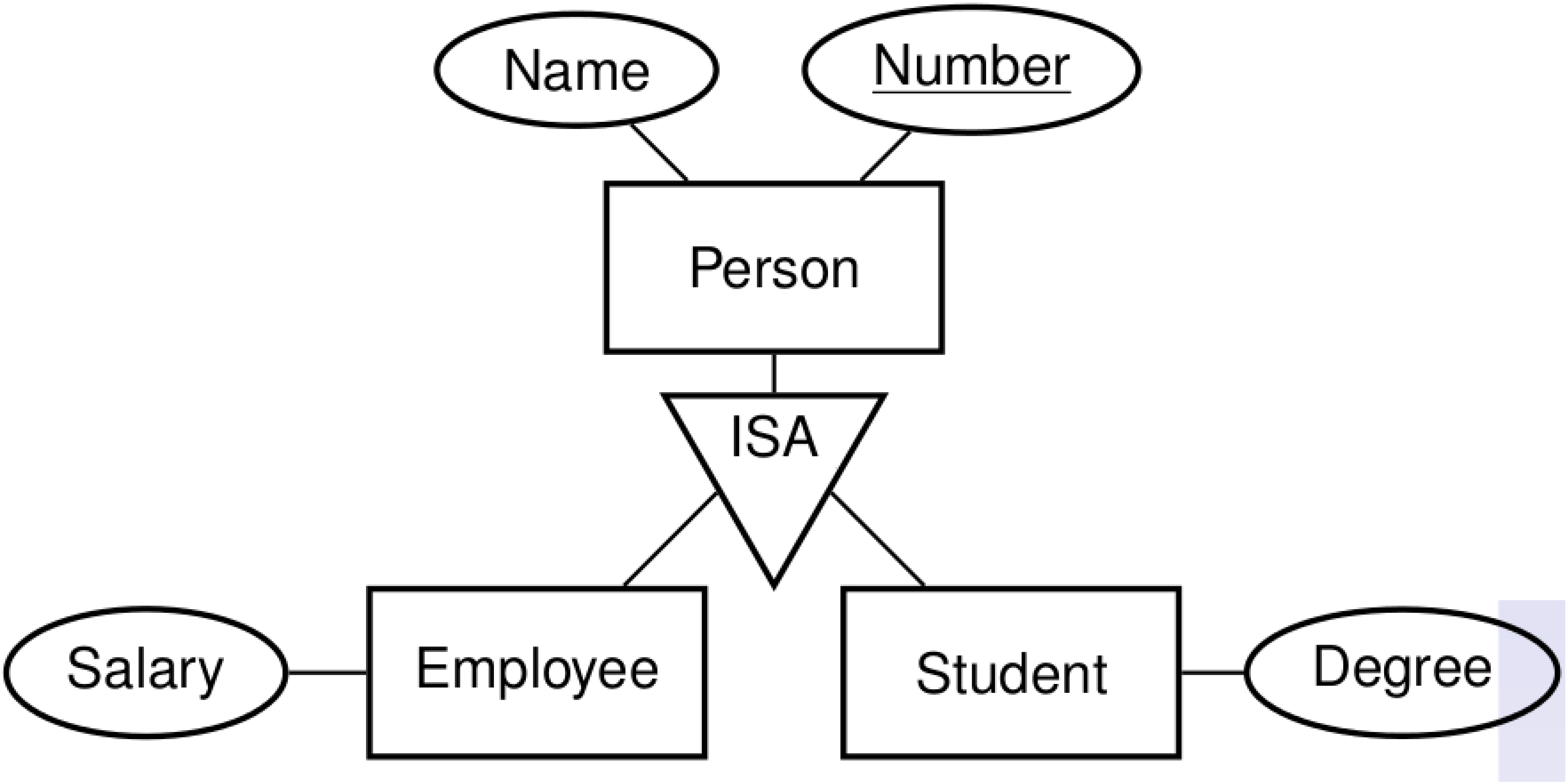
→ If entities of a type have special properties not shared by all entities, then this suggests two entity types with an ISA relationship between them

→ AKA generalization / specialization.

E.g. an Employee ISA Person and a Student ISA Person

→ If Employee ISA Person, then Employee inherits all attributes of Person.

ISA Relationships

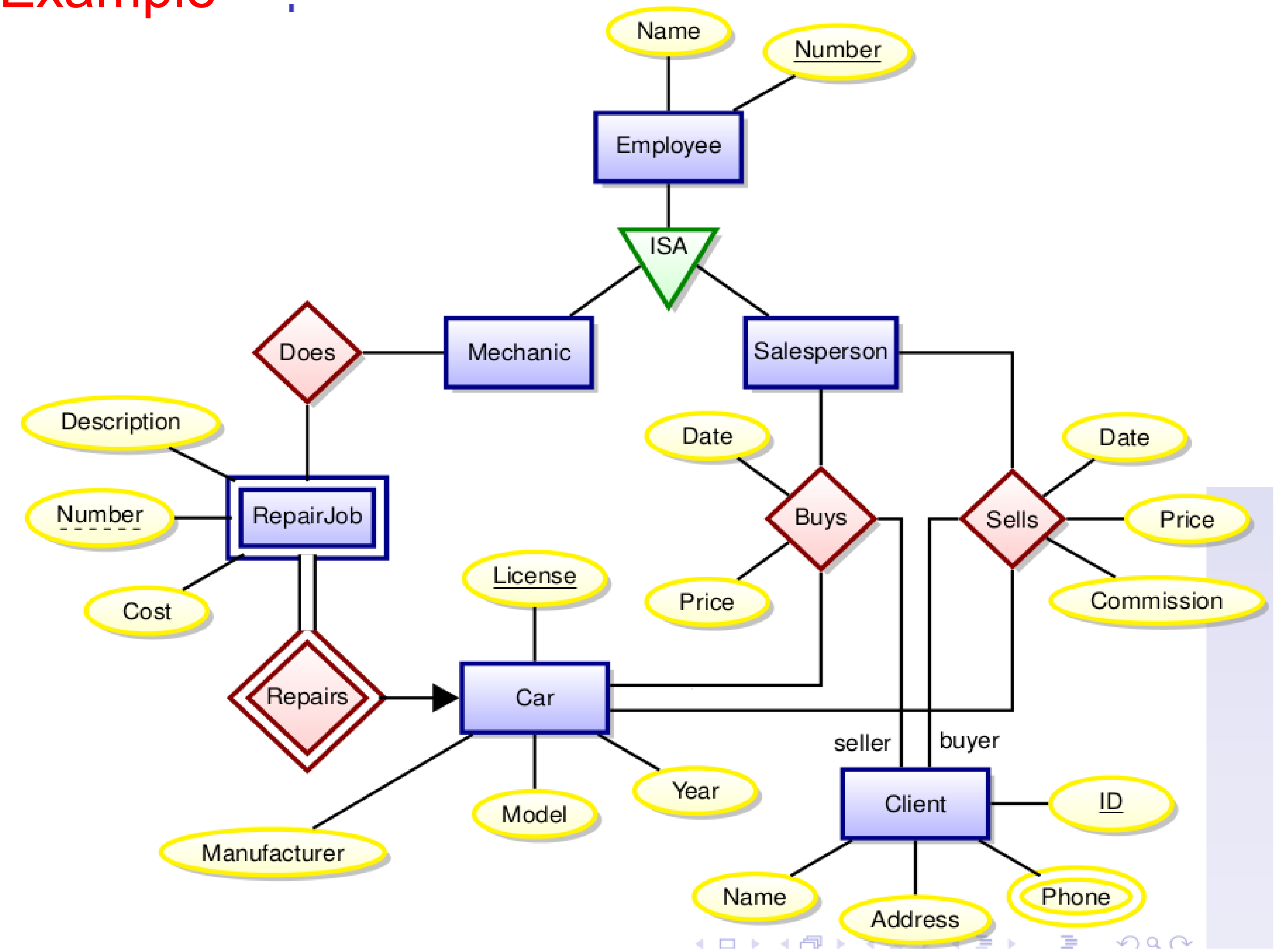


→ Attributes of Employee: Name, Number, and Salary.

Informal Methods for ERD Construction

1. Identify the entity types (including weak entity types) of the application.
2. Identify the relationship (including ISA and ID) types.
3. Classify each relationship type identified in step 2 according to its multiplicity, i.e. if it is a one-to-one, many-to-one or many-to-many.
4. Determine the participation constraints for each entity type in each relationship type.
5. Draw an ERD with the entity types and the relationship types between them.
6. Identify the attributes of entity and relationship types and their underlying domains
7. Identify a primary key for each entity type.
8. Add the attributes and primary keys to the ERD drawn in step 5.

Example


Name
Number
Employee
ISA
Mechanic
Salesperson
Does
Description
Number
RepairJob
Cost
Repairs
License
Car
Manufacturer
Model
Year
Date
Buys
Price
Date
Sells
Price
Commission
seller
buyer
Client
ID
Name
Address
Phone

2. Normal Forms

→ relational model

→ RDBMS and SQL

2. Normal Forms

Relational Model

→ **attributes** & domains: **attribute A** takes values from Dom(**A**)

→ relation schemas and database schemas

Relation Schema (or “table header”) R

→ a set schema(R) of attributes (or “column headers”)

Database Schema S

→ a set { R1, R2, …, Rn } of relation schemas.

Book

ISBN	Title	Price
0-321-32132-1	Balloon	$34.00
0-55-123456-9	Main Street	$22.95
0-123-45678-0	Ulysses	$34.00
1-22-233700-0	Visual Basic	$25.00

S = { Book }
schema(Book) = { **ISBN**, **Price**, **Title** }

Database Instance D of S =
set { T1,…, Tn } of tables Tk
(finite relations) of *type* schema(Rk) = { **A1**, .., **Am** }

Tk *fixes* an order **A1**, .., **Am**.
If (v1,..,vm) is row of Tk, then vk in Dom(**Ak**)

Warning on NULL values

If (v1,..,vm) is row of Tk, then vk in Dom(**Ak**)

With **SQL implementations**, this is not entirely correct.
The ANSI specification of **SQL** states that a column is NULLable by default.

→we only know that vk in Dom(**Ak**) union { NULL }

NULL is a condition.
It means, a value is *unknown*, *missing*, or *irrelevant*.

→ Using NULLs can cause a lot of problems, from implementation to logic.
→ Check articles on the web!

Do not use NULLs!!!

None of the normal forms we discuss introduce NULLs!

Warning on Duplicate Rows

In relational algebra, duplicate rows are not permitted.

In SQL, the are permitted.

→ be careful about this
→ do not design tables that contain duplicates
(if you need them, administer them in a different way)

→ do not design queries that return duplicates
(or return the count of duplicates; unless that is *really* what you want!)

Duplicate Rows

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We would like that

→ the set of all attributes is a trivial superkey!

→ Then: every table has a PRIMARY KEY. (SQL: you must declare it!!)

Duplicate Rows

```
mysql> create table col (number int, color text);
mysql> insert into col values(1,"red");
mysql> insert into col values(1,"red");
mysql> select * from col;
+--------+-------+
| number | color |
+--------+-------+
|      1 | red   |
|      1 | red   |
+--------+-------+
```

Duplicate Rows

```
mysql> create table col (number int, color text,
                         primary key (number, color));
ERROR 1170 (42000): BLOB/TEXT column 'color' used in key specification
without a key length

mysql> create table col (number int, color varchar(1000),
                         primary key (number, color));
ERROR 1071 (42000): Specified key was too long;
max key length is 767 bytes

mysql> create table col (number int, color varchar(100),
                         primary key (number, color));
mysql> insert into col values(1,"red");
mysql> insert into col values(1,"red");
ERROR 1062 (23000): Duplicate entry '1-red' for key 'PRIMARY'
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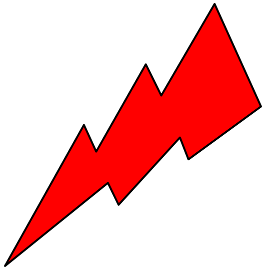
→ if your mysql script loads csv-files via LOAD DATA,
then you do not see these error messages!!!



Duplicate Rows

→ depending on your PRIMARY KEY, the LOADer of mysql will silently eliminate duplicates for you

→ this is bad practise

→ if you do it, you loose points on Assignment 1!

→ if your mysql script loads csv-files via `LOAD DATA`, then you do not see these error messages!!!

SQL

Most queries have Multiset Semantics, i.e., answers contain duplicates.

SELECT **height** FROM population;

```
1.83
1.83
1.83
1.75
```

Unless you use Set Operators (UNION, DIFFERENCE, INTERSECT, etc)
(or the DISTINCT operator)

→ duplicates are removed!

2. Normal Forms

Normal Forms

→ prevent modification anomalies
→ prevent data inconsistency
→ make tables less redundant

while preserving information (and dependencies)

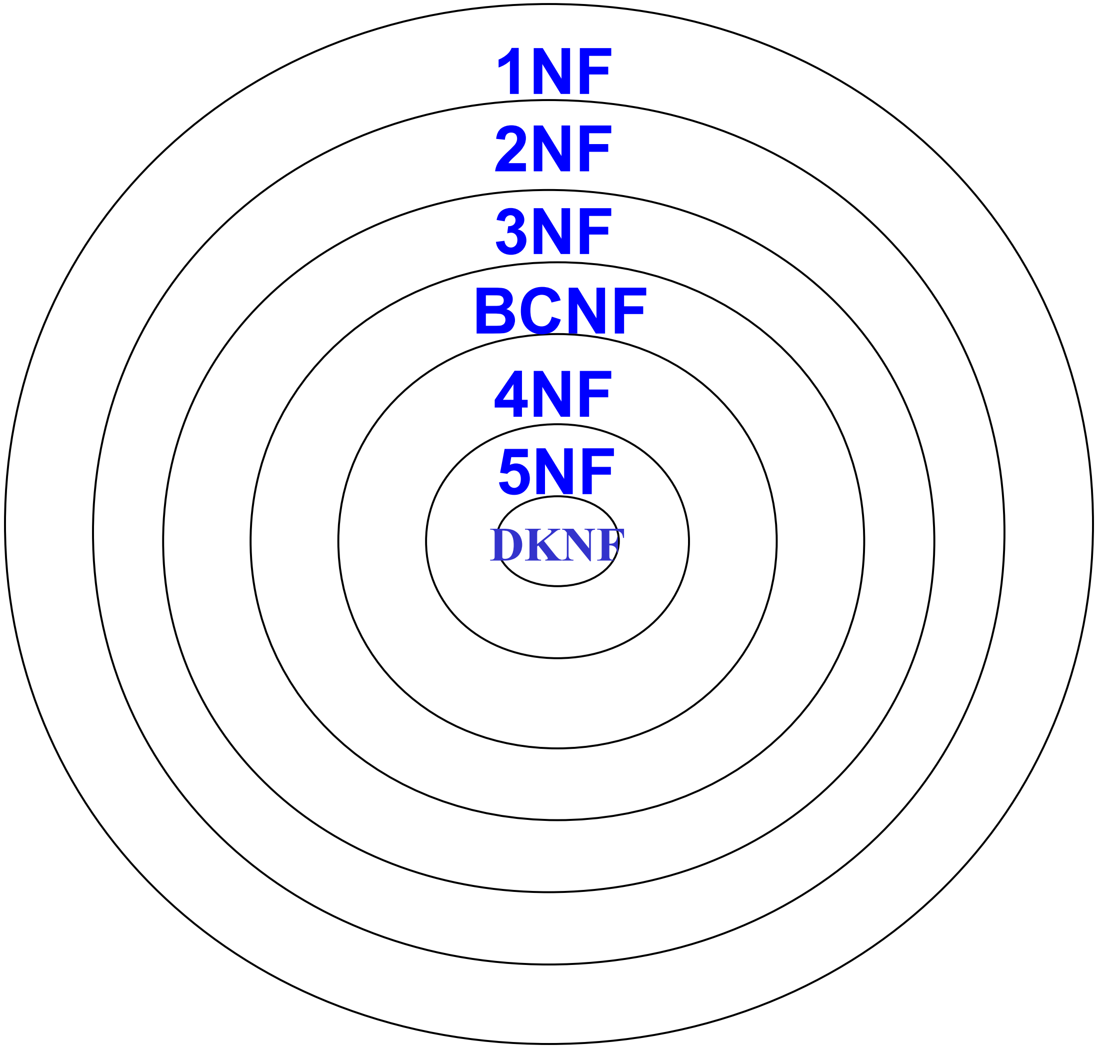
Modification anomalies:

→ same information present in multiple rows. Partial updates may result in inconsistent table (i.e., providing conflicting anwers) "update anomaly"

→ certain facts cannot be recorded at all "insertion anomaly"

→ deletion of data representing a fact may necessitate deletion of other completely different facts "insertion anomaly"

2. Normal Forms



2. Normal Forms

1NF = Choose Appropriate Data Types

2NF
3NF
BCNF } = Do Not Represent the Same Fact Twice

↕

4NF = Do not Store Unrelated Information in the Same Relation

Normalization

Normalization = process of bringing a given database into a given normal form

Typically, normalization is achieved decomposing tables into smaller tables.

Decomposition in turn is realized via *projections*.

Lossless Join Property

Let S be a relation schema that is decomposed into relation schemas R1, R2, .., Rn.
The decomposition has the **lossless join property**, if for every instance D of S:
PROJ_R1(D) JOIN PROJ_R2(D) JOIN … PROJ_Rn(D) = D.

First Normal Form (1NF)

→ for every attribute **A**, Dom(**A**) contains only atomic (indivisible) values

→ value of each attribute contains only a single value from the domain

[Codd,1971]

ISBN	Title	AuName	AuPhone
0-321-32132-1	Balloon	Sleepy, Snoopy, Grumpy	321-321-1111, 232-234-1234, 665-235-6532
0-55-123456-9	Main Street	Jones, Smith	123-333-3333, 654-223-3455
0-123-45678-0	Ulysses	Joyce	666-666-6666
1-22-233700-0	Visual Basic	Roman	444-444-4444

First Normal Form (1NF)

Bring a table into 1NF through **decomposition**:

1) place all items of a repeating group into new table
2) duplicate in new table the primary key of the original table

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0-55-123456-9	Jones	123-333-3333
0-55-123456-9	Smith	654-223-3455
0-123-45678-0	Joyce	666-666-6666
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ISBN	Title
0-321-32132-1	Balloon
0-55-123456-9	Main Street
0-123-45678-0	Ulysses
1-22-233700-0	Visual Basic

First Normal Form (1NF)

→ for every attribute **A**, Dom(**A**) contains only *atomic* (indivisible) values
→ value of each attribute contains only a single value from the domain

[Codd,1971]

“atomic value” = “value that cannot be decomposed”

Problematic

→ Character string?
→ Fixed-point number?
→ ISBN (includes language and publisher identifiers)?

C. J. Date: “The notion of atomicity *has no absolute meaning*”

Second Normal Form (2NF)

A table is in 2NF, if

[Codd,1971]

→ it is in 1NF
→ every non-prime attribute *depends* on the whole of every candidate key

---

functional dependency

Example (Not 2NF)

Schema(R) = {City, Street, HouseNumber, HouseColor, CityPopulation}

1. {City, Street, HouseNumber} → {HouseColor}
2. {City} → {CityPopulation}
3. CityPopulation is non prime
4. CityPopulation depends on { City } which is NOT the whole of the (unique) candidate key {City, Street, HouseNumber}

Functional dependency D → E: for every D-tuple, there is at most one E-tuple
"E (functionally) depends on D"

Second Normal Form (2NF)

Bring a 1NF table into 2NF

→ move an attribute depending on a strict subset of a candidate key into a new table, together with this strict subset

→ the strict subset becomes the key of the new table

Example (Convert to 2NF)

Old Schema → {City, Street, HouseNumber, HouseColor, CityPopulation}

New Schema → {City, Street, HouseNumber, HouseColor}

New Schema → {City, CityPopulation}

END
Lecture 5