Applied Databases

Lecture 5
ER Model, Normal Forms

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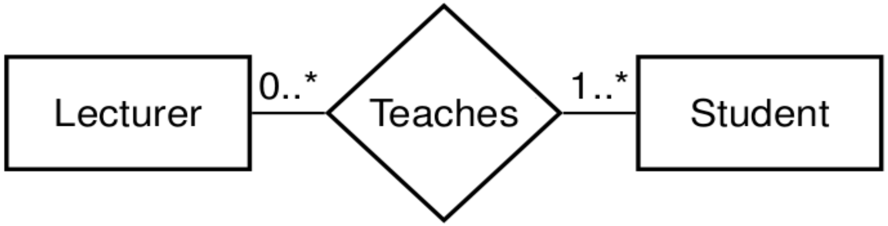
Outline

1. Entity Relationship Model
2. Normal Forms

From Last Lecture



→ the Lecturer participation in Teaches is optional, so there is a 0 as minimum cardinality on the link between Lecturer and Teaches.

→ the Student participation is mandatory, so the minimum cardinality is 1.

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# }.

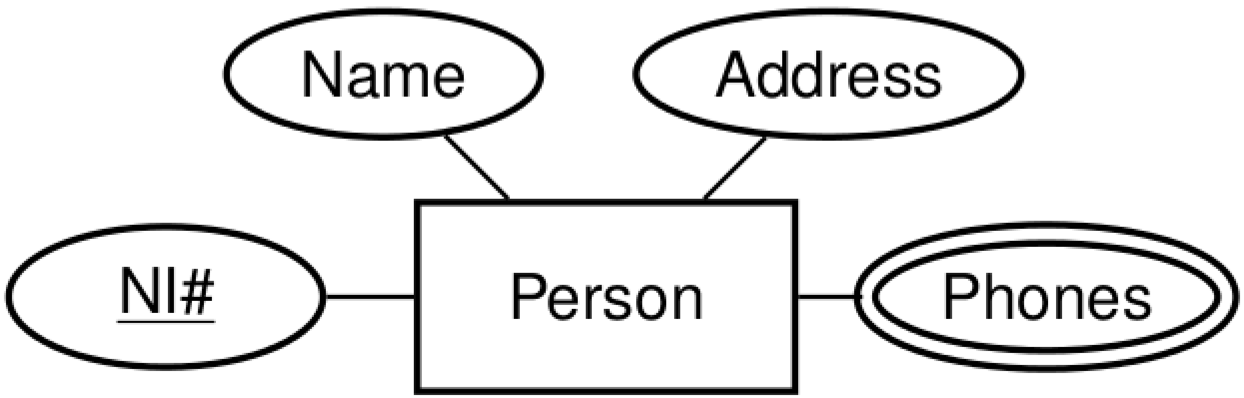
Prime Attribute = attribute that appears **in a key**
Non-Prime Attribute = attribute that appears **in no key**

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

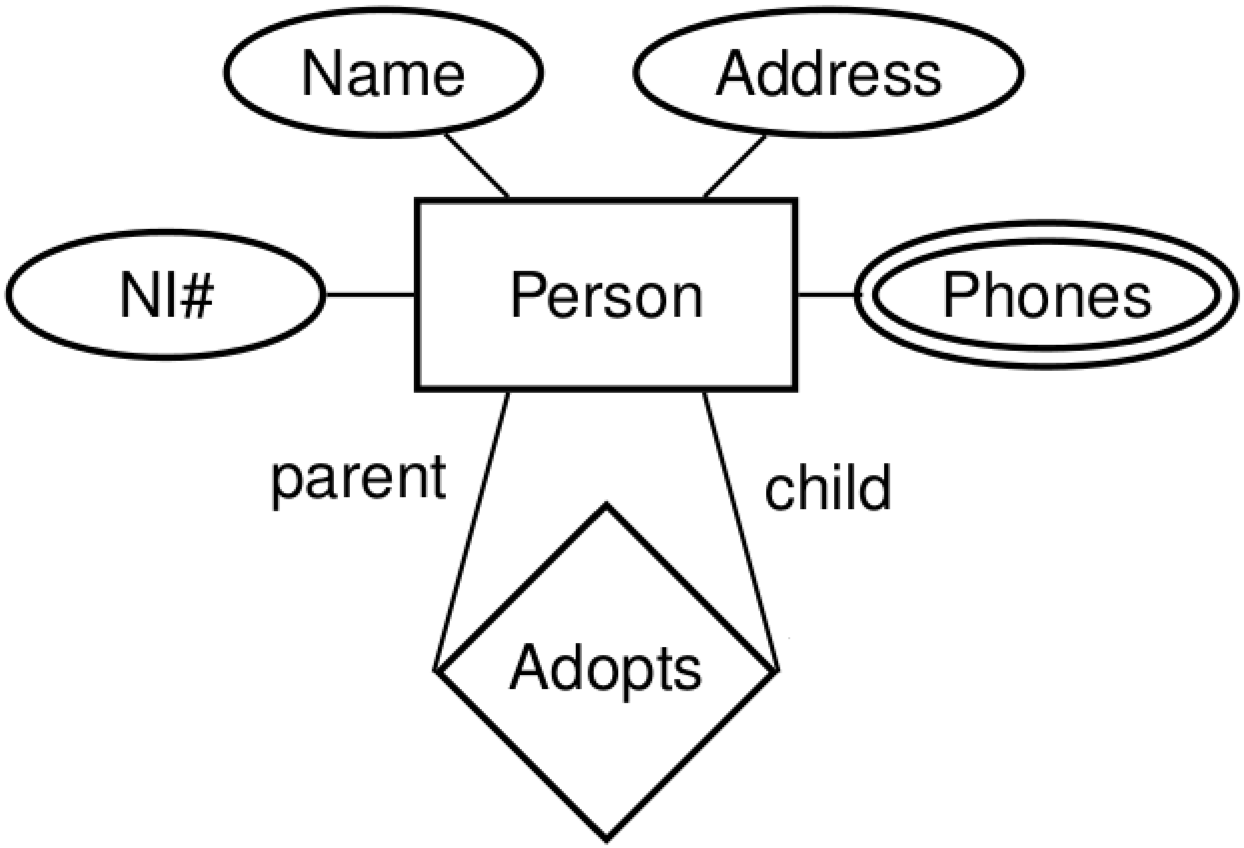
Primary Keys

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

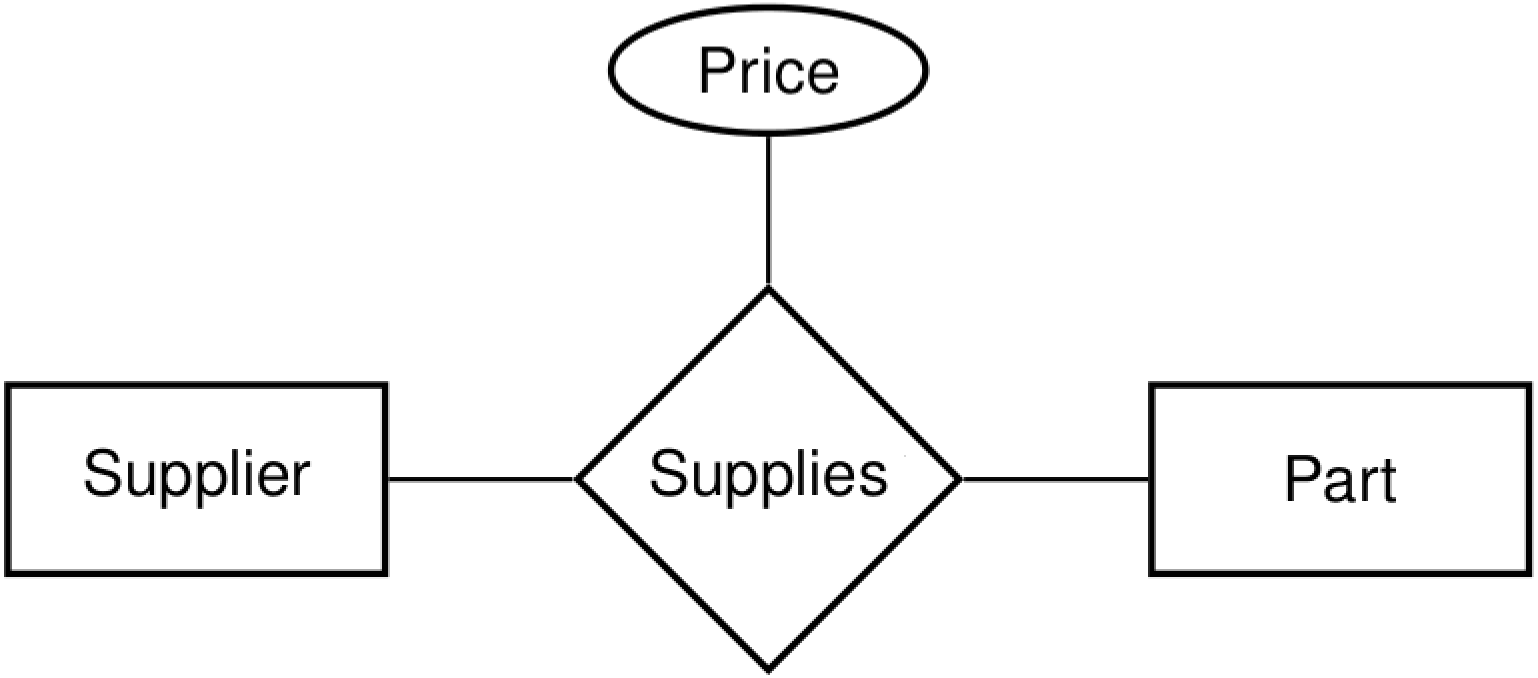
→ primary key guarantees logical access to every entity (attributes of a primary key are underlined)



Cyclic Relationship Type with Roles



Relationship Type with Attributes



→ Each Supplier Supplies a Part at a certain Price

Weak Entity Types

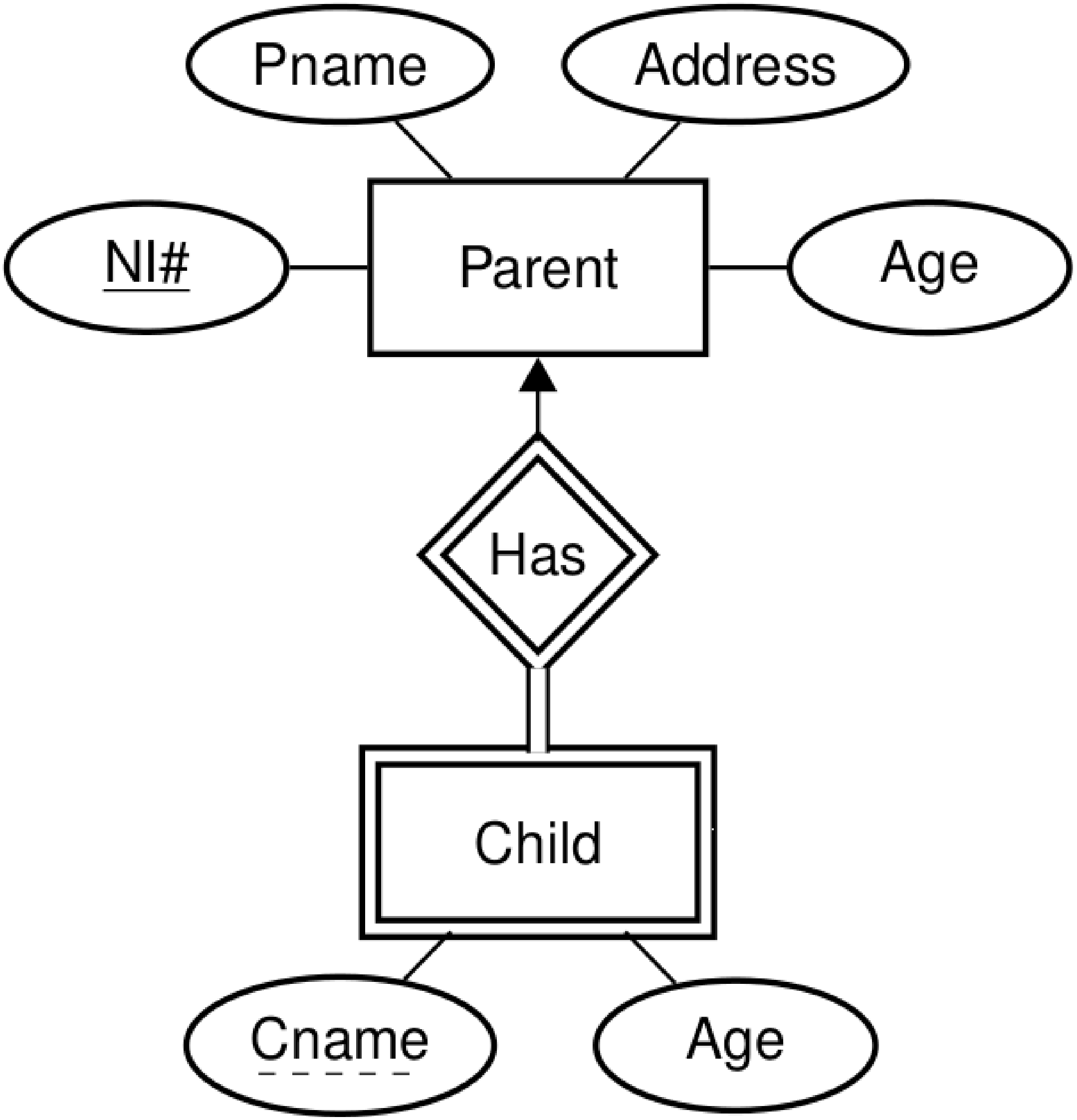
Weak Entity Type = an entity type that does not have sufficient attributes to form a primary key (double rectangle)

→ 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



ISA Relationship Types

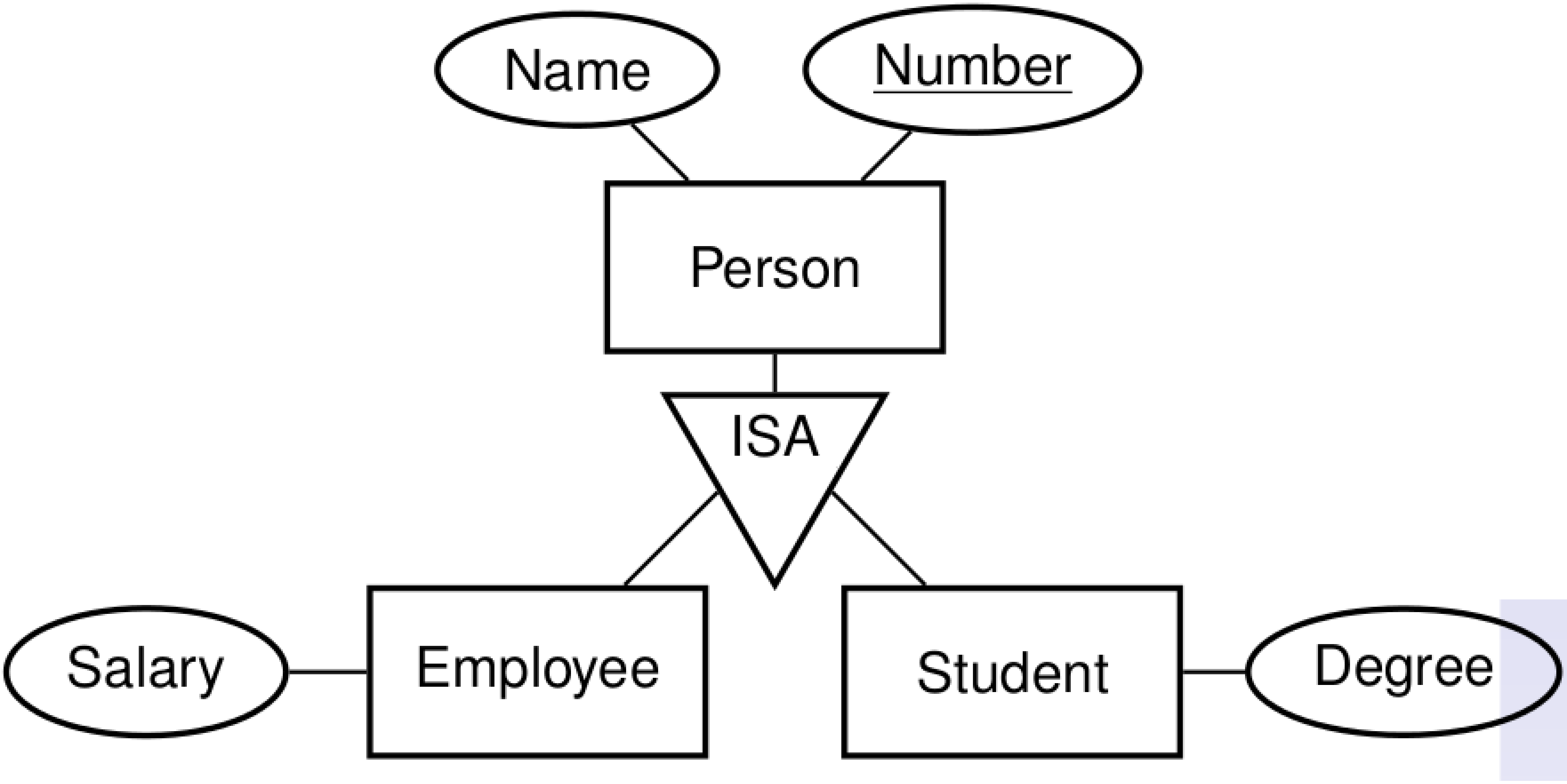
→ If entities of a type have special properties not shared by all entities, then this suggests two entity types with an ISA relationship between them

→ AKA generalization / specialization (supertype / subtype rel.)

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

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

ISA Relationships

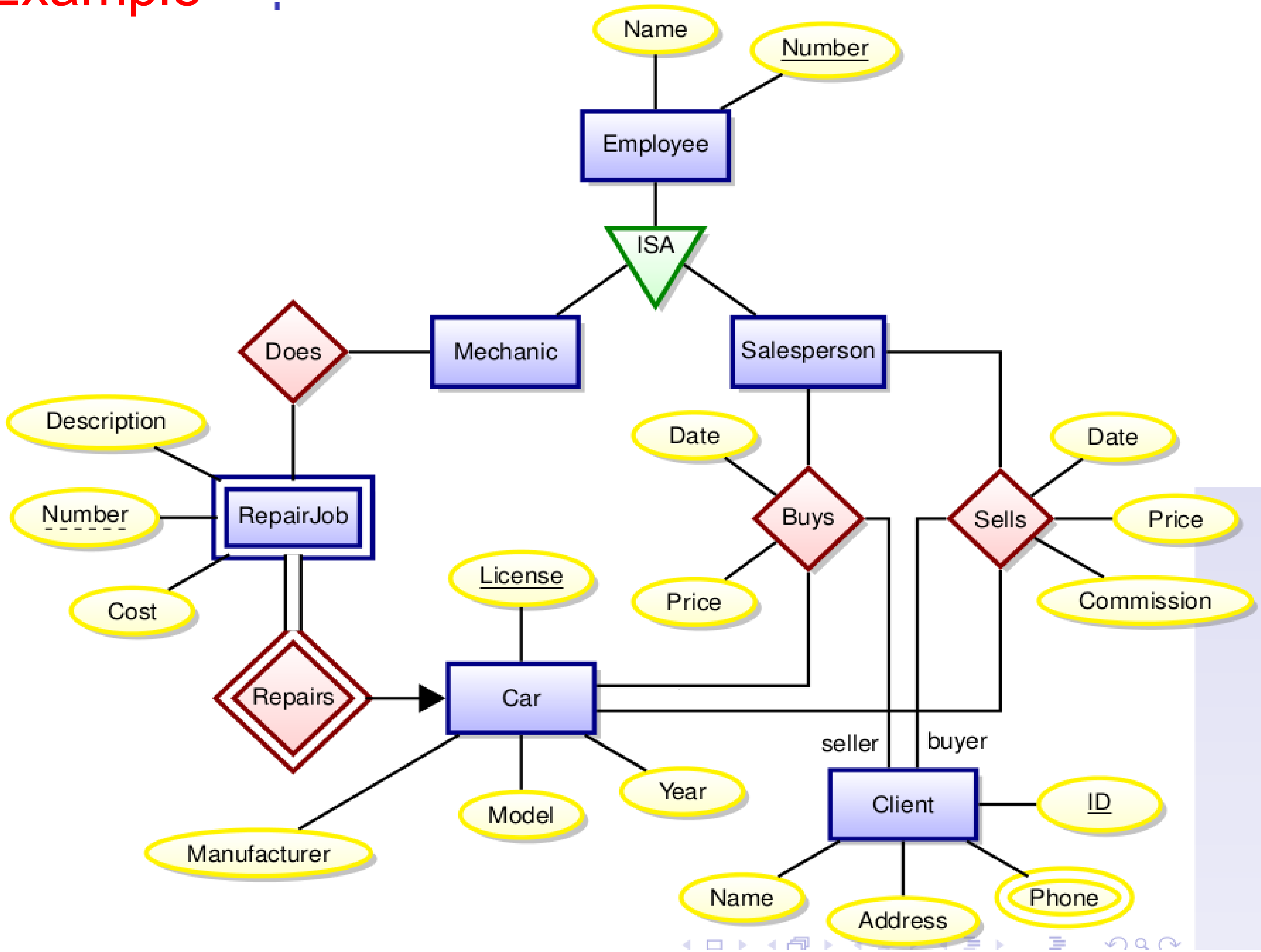


→ Attributes of Employee: Name, Number, and Salary.

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

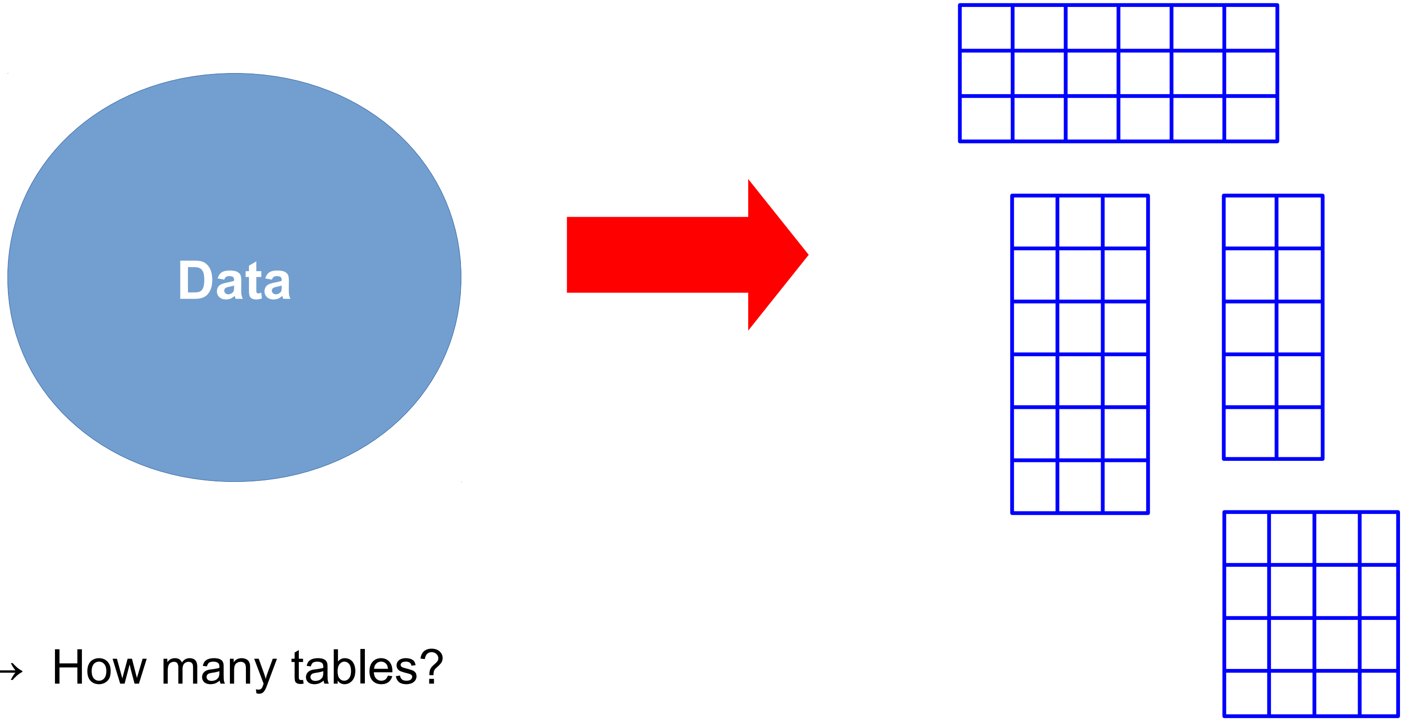

Name
Number
Employee
ISA
Mechanic
Salesperson
Does
Description
Number
RepairJob
Cost
Repairs
License
Car
Manufacturer
Model
Year
Date
Buys
Price
Date
Sells
Price
Commission
seller
buyer
Client
ID
Name
Address
Phone

2. Normal Forms

2. Normal Forms

→ Relational database design

→ What is a good database design?



→ How many tables?

→ What goes into which table?

2. Normal Forms

Bad database design causes problems, e.g.,

→ **redundancy** (facts are stored more than once)

→ **inconsistency** through update anomalies

→ **complexity** of queries and constraints

2. Normal Forms

Bad database design causes problems, e.g.,

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→ **inconsistency** through update anomalies

→ **complexity** of queries and constraints

We study several **rules of thumb**
for good database design

Normal Forms
→ First Normal Form (1NF)
→ Boyce-Codd Normal Form (BCNF)
→ Fourth Normal Form (4NF)

Normal Forms

Relational Model

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

→ relation schemas and database schemas

Schema (or "table header") of a relation (name) R

→ set schema(R) of attributes (or "column headers")

Database Schema

→ set of relation names together with their 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.
By ANSI specification of **SQL**: every 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 allows NULLs!

Warning on NULL values

Example

Name	HasDog	NI#	...
Alice	0		
Bob	1		
.	0		
.	.		
.	.		
Steve	1		
.			

OK. (but could be inefficient)

Warning on NULL values

Example

Name	HasDog	NI#	...
Alice	0		
Bob	1		
.	0		
.	.		
.	.		
Steve	1		
.			

OK. (but could be inefficient)

Name	DogName	NI#	...
Alice	NULL		
Bob	Einstein		
.	NULL		
.	.		
.	.		
Steve	Rex		
.			

Not OK.

→ create new table(s)
e.g. DogName

Warning on Duplicate Rows

In relational algebra, duplicate rows are not permitted.

In SQL, they 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
(unless that is *really* what you want! – often it is better to return a *histogram*)

Duplicate Rows

In relational algebra, duplicate rows are not permitted.

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(unless that is *really* what you want! – often it is better to return a *histogram*)

We would like that

→ the set of all attributes is a trivial superkey!

→ Then: every table has a PRIMARY KEY.

SQL

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

SELECT **Height** FROM population;
1.83
1.83
1.75
1.83

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

→ duplicates are removed!

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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```

→ when 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!

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

Normal Forms

Normal Forms

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

while preserving information (and dependencies)

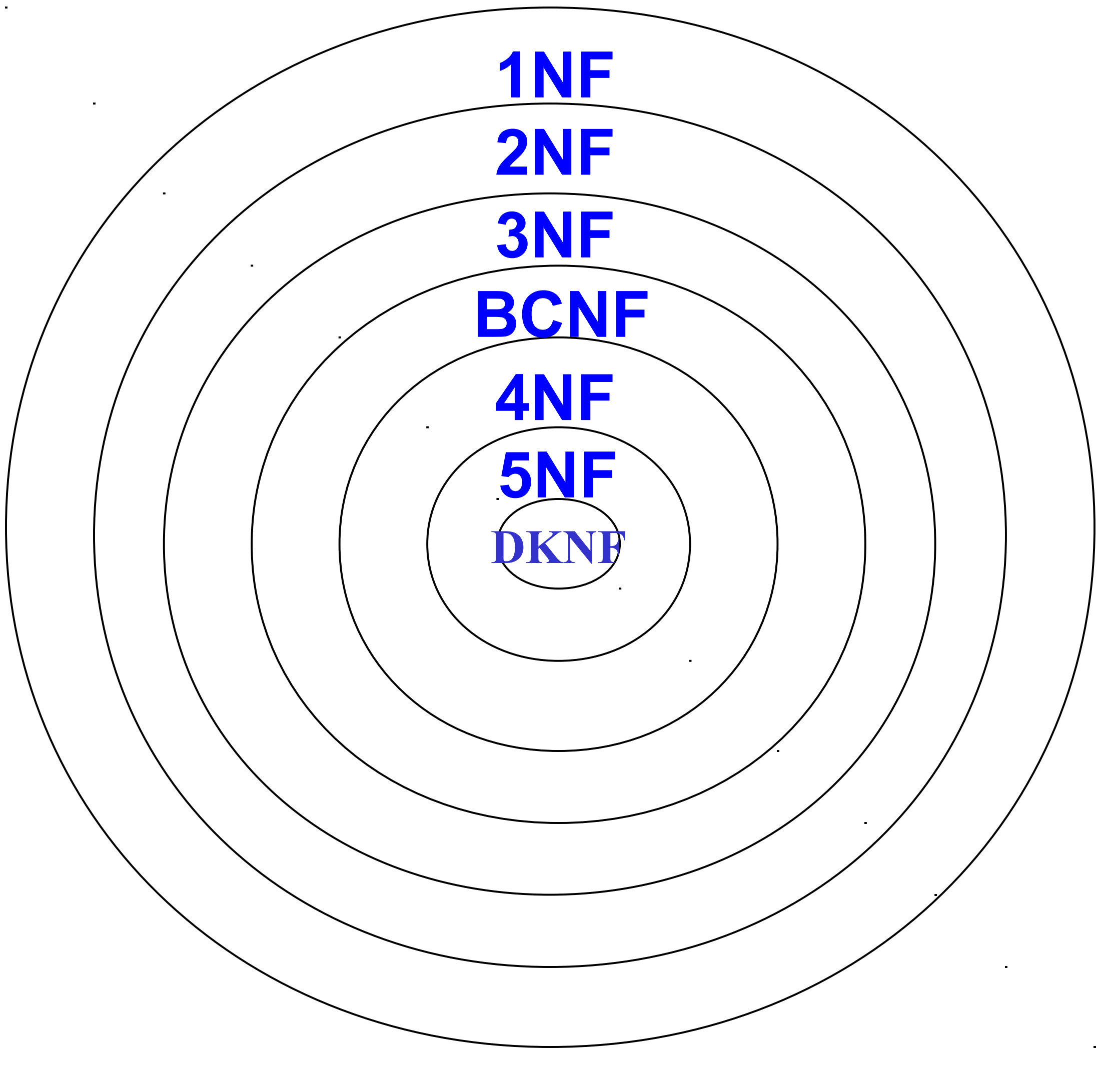
Modification anomalies:

→ 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 "deletion anomaly"

Normal Forms



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 by decomposing tables into smaller tables.

Decomposition in turn is realized via *projections*.

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]

→ most database systems do not allow to define tables inside tables

→ you could insert long strings (comma separated)
Never do that!

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	Smith	654-223-3455
0-123-45678-0	Joyce	666-666-6666
1-22-233700-0	Roman	444-444-4444

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*"

Table versus Relation

Chris Date, “What First Normal Form Really Means” (2000)

A table **is in 1NF** if and only if it is “isomorphic to some relation”, specifically:

1. There is no top-to-bottom ordering on the rows.
2. There is no left-to-right ordering on the columns.
3. There are no duplicate rows.
4. Every row-and-column intersection contains exactly one value from the applicable domain (and nothing else).
5. All columns are regular [i.e. rows have no hidden components such as row IDs, object IDs, or hidden timestamps].

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

---

Example (Not 2NF)

Schema(R) = {<u>City, Street, HouseNumber</u>, 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

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

Second Normal Form (2NF)

→ do you see the potential **Redundancy** in this table?

↓

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

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