3. Schema Design:

Logical Design using the Relational Data Model

Kemper/ Eickler: chap. 3.1-3.3, Elmasri / Navathe: chap. 9

SQL/DDL: Melton/Simon: chap 2, 3.3, 4

System documentation (e.g. Postgres, Oracle, MySQL, see references)

Context

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Requirements analysis	System analyst DB designer Application programmer
Conceptual Design	
Schema design - logical (“create tables”)	Application programmer DB administrator
Schema design - physical (“create access path”)	
Loading, administration, tuning, maintenance, reorganization	DB administrator

3.1 Logical schema design

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Logical Schema design is the transformation of the conceptual schema (e.g. ERM) into the logical schema (e.g RDM)

Easy: Algorithmic transformation
using development tools
(Oracle, Visio, DBDesigner, several Eclipse plugins,...)

Main concerns:
- how to map relationships to tables
- how to represent integrity constraints

3.1.1 The Relational Data Model in a nutshell

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The Relational Data Model

Simplicity and formal rigor as the guiding principle

KISS - Keep It simple, students

Basically: an **algebra of tables**

Table: data structure with a **fixed number of named columns** and an **arbitray number of rows** .

Basics

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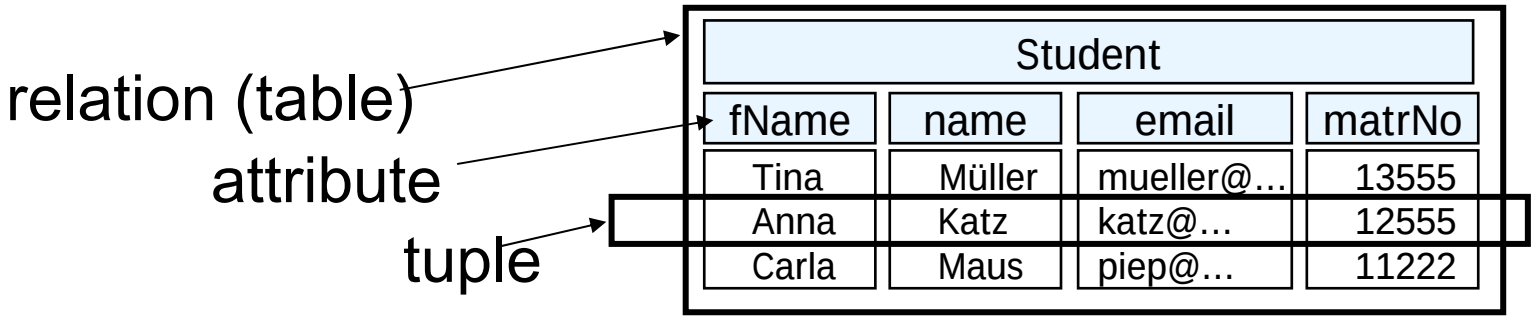

Relation schema (simplified notation omitting types):

Student(fname, name, email, matrNo)

SQL Data Definition Lanuage

```
CREATE TABLE Student(
  fname          VARCHAR (20),
  name           VARCHAR (30)    NOT NULL ,
  email          VARCHAR (40),
  matrNo         INTEGER )
```

Properties of the RDM

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- **No duplicate** rows
- **No** tuple **order**

R is a set

- Attributes have a **primitive type**, **no constructed type**
- **single-valued**

most DBS today allow constructed and multivalued types

- Attributes may have no value (**NULL** value)
- **Integrity constraints** must hold for all states of the DB over time ("invariant")
- **Unique names** in the relation and the DB namespace using dot-notation: R.a, db.S.b
- Database relations are **time variant**
  update, insertion, deletion of tuples

Keys and candidate keys

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Def.: A **key** of R(a1,…,an) is a subset of its its attributes, which **uniquely determines** the **tuples (= rows)** of R **and is minimal**

```
CREATE TABLE Student(
  fname          VARCHAR (20),
  name           VARCHAR (30)NOT NULL,
  email          VARCHAR (40),
  matrNo         INTEGER PRIMARY KEY)
```

But `matrNo ++ name` is not a PK – not minimal

But two or more attributes together *may* constitute a key:
`name ++ fname` ??

Primary and Candidate keys

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(i) A relation R may have **more than one potential key,** i.e. identifying, minimal attribute subset of R.

(ii) A potential key of R is called **Candidate key** * of R.

(iii) The **Primary Key** of R is an arbitrary candidate key

```
CREATE TABLE Employee(
  fname          VARCHAR (20),
  name           VARCHAR (30)NOT NULL,
  birthdate      DATE,
  email          VARCHAR (40),
  jobDesc        VARCHAR(200)
   CONSTRAINT region_pk
   PRIMARY KEY (name,birthdate))
```

Primary key with more than one attribute as separate, **table constraint**.

user defined **constraint name**, .. why?

* Schlüsselkandidat – nie Kandidatenschlüssel

Artificial Keys

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Sometimes useful, to assign an artificial key to relation R

```
CREATE TABLE Employee(
  p#              INTEGER PRIMARY KEY,
  fname           VARCHAR (20),
  name            VARCHAR (30),
   ...)
```

Not an artificial key, exists in reality.

```
CREATE TABLE LogRecords(
  seq#            INTEGER PRIMARY KEY,
  logType         CHAR,
  logEntry        VARCHAR (300),
  time            TIMESTAMP)
```

Artificial, should be e.g.: 1,2....
Postgres: **SERIAL**
Oracle:use sequence generator

Surrogates: system internal row keys for special purposes

Operations on tables

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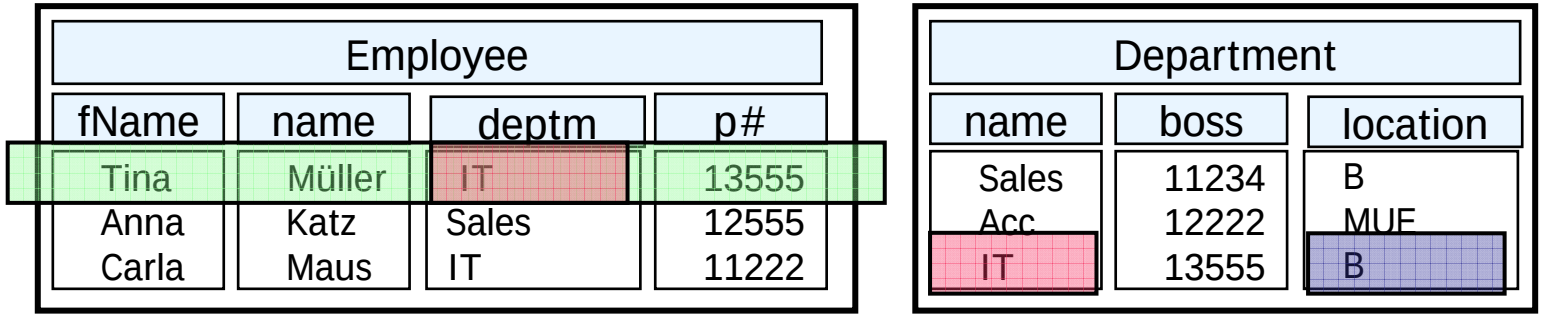
Why "**Relational Algebra**"?

Employee			
fName	name	deptm	p#
Tina	Müller	IT	13555
Anna	Katz	Sales	12555
Carla	Maus	IT	11222

Department		
name	boss	location
Sales	11234	B
Acc	12222	MUE
IT	13555	B

Operations on tables result in tables!

e.g. select some rows: "Employees in IT-Department"
project columns: "Names of all employees"
"join" columns: "Department location of Tina Müller"



RDM: Foreign Keys

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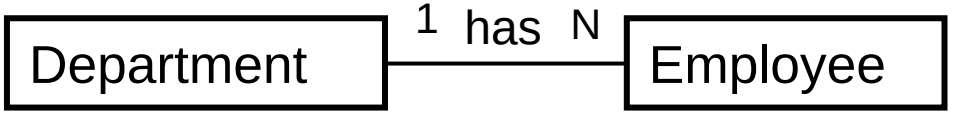
```
CREATE TABLE Employee(
  p#              INTEGER PRIMARY KEY,
  fname           VARCHAR (20),
  name            VARCHAR (30),
  deptm           VARCHAR(20)
                  FOREIGN KEY FK_Dep REFERENCES Department )

CREATE TABLE Department(
  name            VARCHAR (20) PRIMARY KEY,
  boss            Integer,
  location        VARCHAR (5)
      Foreign Key FK_Boss REFERENCES Employee )
```

Implements 1:N relationship



Foreign key

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Def: A **<u>foreign key</u>** is one or more attributes FK of a **relation S**, with the properties:

(1) attributes of FK have the **same domains** as the **attributes of key* p_k** of a **relation R**

and

(2) a **value of FK** in row of S **either occurs** as a **value of the primary key** for some row in **R** **or is NULL**.

Def.: **<u>Referential integrity</u>** of a database is preserved, if **all** (explicit) **foreign key constraint hold.**

***** Usually the primary key, but not required!

What next: From entities to tables

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Map E-R design to relational schema

Define relational schema, table names, attributes and types, invariants

Design steps:

- Translate **entities into relations**
- Translate **relationships** into relations
- **Simplify** (consolidate) the design
- Formal analysis of the schema (postponed)
- Define **tables in SQL**
- Define additional **invariants**

3.2 From Conceptual to Logical schema…

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Entity (types) with keys $\Rightarrow$ tables (schema relations)

- Key attributes in the Conceptual model are primary keys in the RDM

Weak entities:

add primary key of superior entity to partial key of weak entity

Example: `country(c_id, name, gnp, ..)`

`region(name, population, area,..)`

↑ partial key

$\Rightarrow$ `region (c_id name,...)`

↑ never NULL, why?

Mapping Relationships

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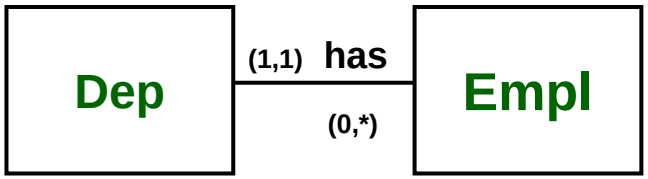
Relationships in general: tables (schema relations)

- Attributes: **keys of the involved relations**
  and attributes of the relationship
- Key of the "relationship" table:
  one or all keys of the related relations



Has	d_name	emp#
	1	32
	2	47
	1	33

Each Employee has unique emp#
⇒ row in D_E identifies by emp# ⇒ key is emp#

3.2.1 Relationships to tables

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1:1-relationship

Chose as key one of the keys of the involved relations


```
Country(c_id,
   ...)
```

```
isCapital
(c_id, name,r_id)
```

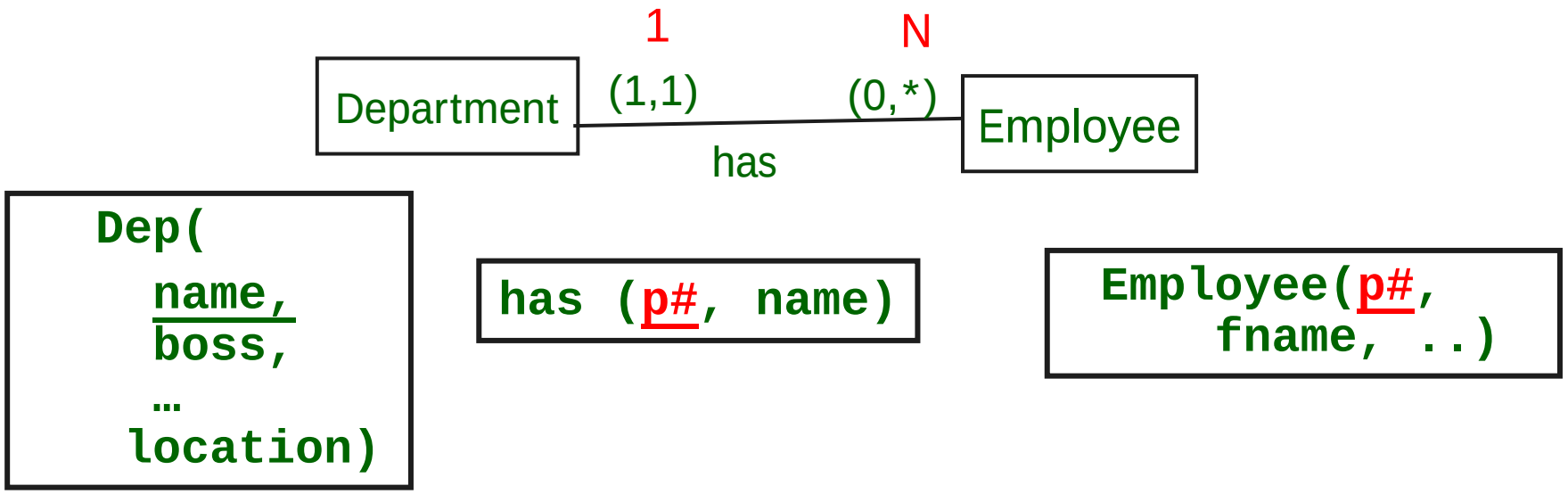
```
City
(name, r_id,...)
```

or

```
isCapital
(c_id, name,r_id)
```

Relationships to tables

1:N relationship



A table R representing an 1:N – E-R-relationship has

- **as attributes** the keys of both relations and relationship attribute – of any
- **as** its key the **key of the "N-side entity type"**

N:M relationship

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user(account, name,...)	hasMail(account, msgId)	MM(msgId ...)

Neither **account** nor **msgId** alone have key property

A separate table R representing an M:N – E-R relationship has

- **as attributes** the keys of both relations and relationship attribute – of any
- as key the **keys of both entities**
  N-ary relationship: **all keys** make up the new key

Multi-valued attributes

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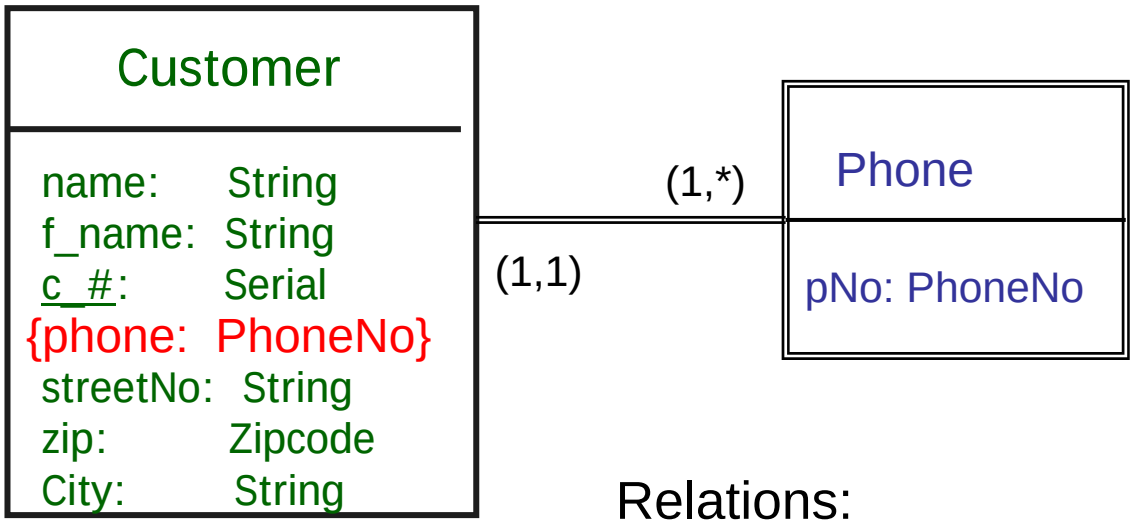
Multiple value attribute

⇨ weak entity with a single attribute



Relations:

Customer(name, c_#,..)

Phone(c_#, pNo)

... or array-type / list type for attribute (Oracle, PostgresSQL and others).

3.2.3 Consolidation

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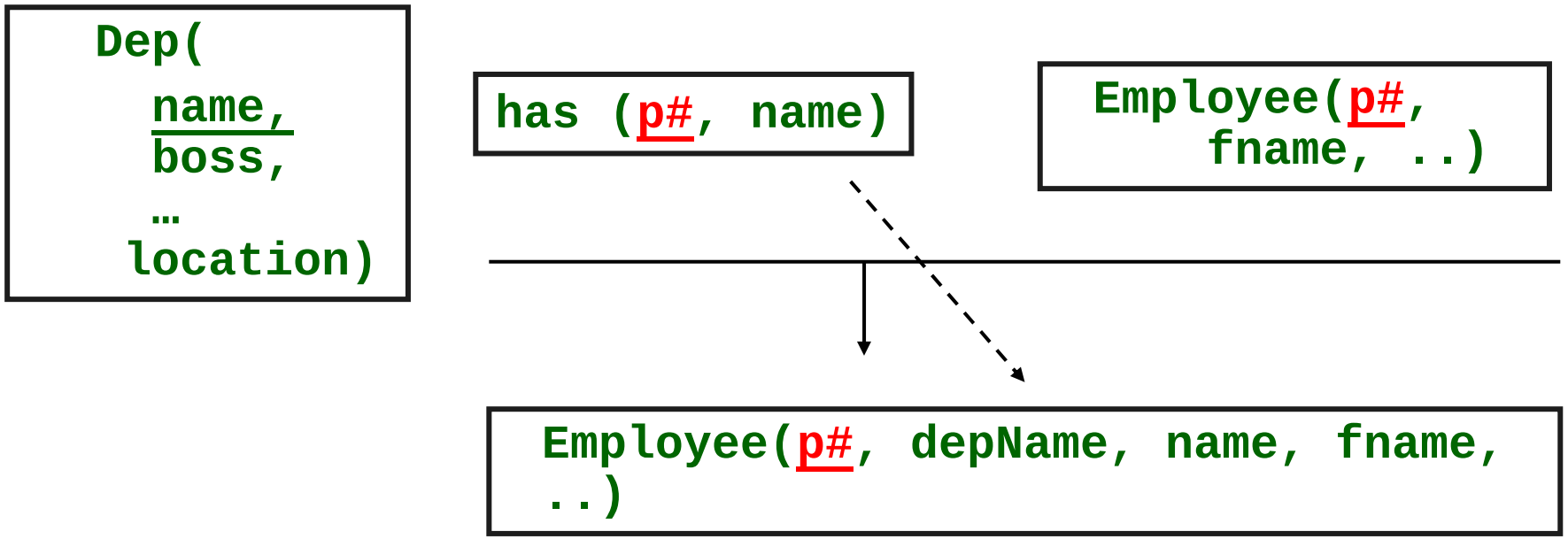
Def.: **Consolidation** (simplification) of a relational scheme is

the process of merging those table (schemas) having the ***same key*** attributes **into one** table schema (recursively)

R(**k1,..,kn**, a1,…an), S(**k1,…,kn**, b1,…bm)

⇨ RS(**k1,…,kn**, a1,…an,b1,…,bm)



Example

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1 : 1 - relationship

```
Country
(c_id, name,  ...)

isCapital
  (c_id,  name, region)
```

renamed, path expression **Region.name** not allowed

⇨ **Country(c_id, name, capital, region,…)**

Foreign key

Consolidation: example

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```
CREATE TABLE Country
(name                VARCHAR(32) NOT NULL,
 C_ID                VARCHAR(4)  PRIMARY KEY,
 population          INT,
 growth              NUMERIC(4,1),
 area                      INT,
 GNP                 INT,
 capital             VARCHAR(25) NOT NULL, -- renamed
 region              VARCHAR(4) NO NULL,
 type_of_Gov         VARCHAR(35),
 head_of_Gov         VARCHAR(70)
 CONSTRAINT fk_capital FOREIGN KEY
    (capital, region) REFERENCES City)
```

E-R to RDM mapping: discussion

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Transformation

- unambiguous for relations representing 1:N relationship, ... but *consolidation optional*.
- 1:1 relationships: choice - merge with one of the "entity- tables"
- **M:N** relationships: never merge
  Represented **always by separate tables** in the RDM

Very simple process:
Many DB-Design tools model relationships directly by means of foreign keys!

Schema reengineering

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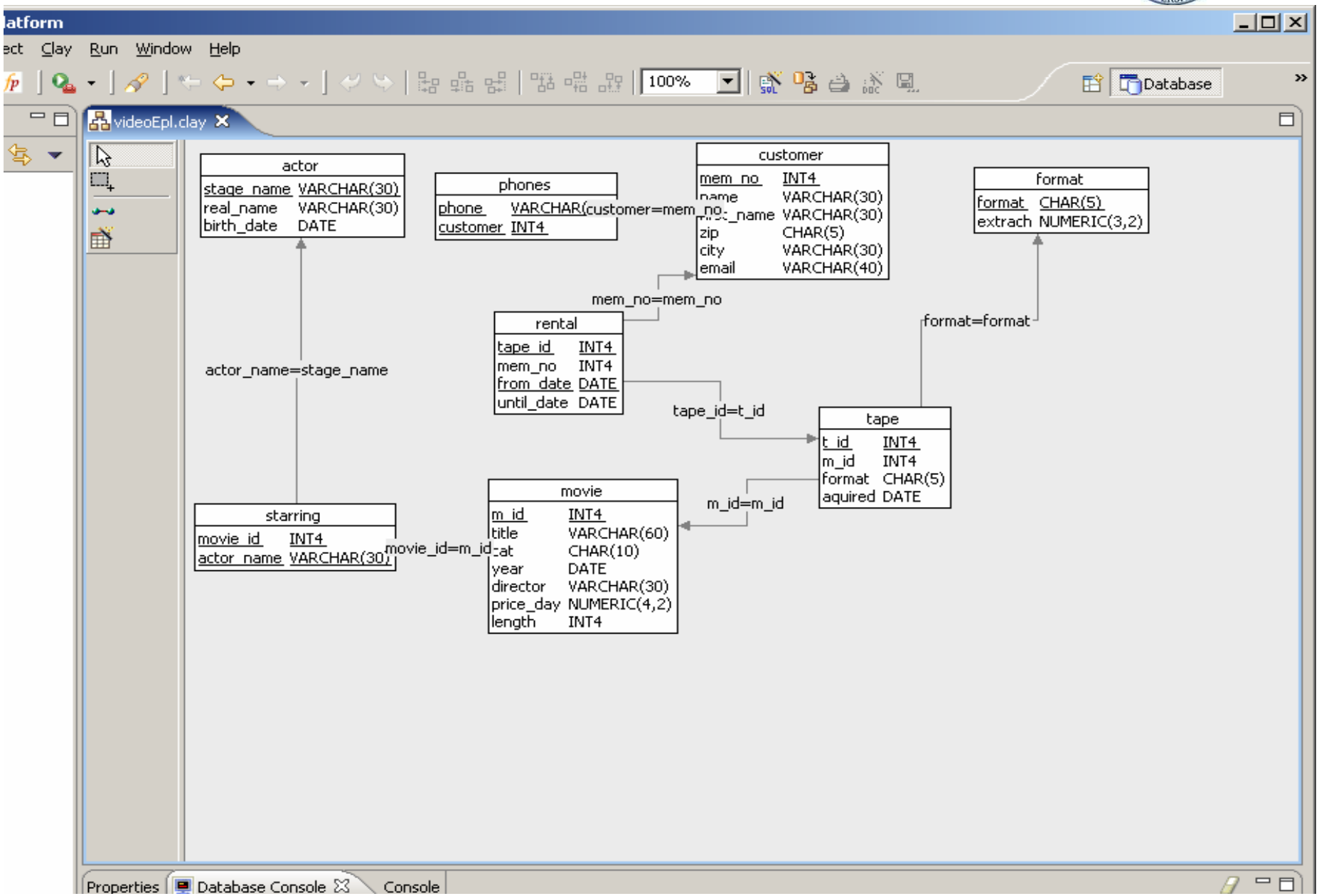

Discussion continued

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Always merge 1:N relationships?

Example:

```
Person(id, name, phone#,...)
Room (rNo, building#, size, netSocket# ...)
Sits_in(id, rNo,b#, since, gotKey,
        numberOfKey, ...)
```

Merge would result in a relation with many NULL values

- **Merging 1:N relationships makes sense in most cases**
  - If relationship has many attributes do not merge when many NULL values expected
  - If attributes of relationship are used infrequently by applications, do not merge (*)

(*) efficiency argument: avoid unnecessary data transfers

Discussion(2)

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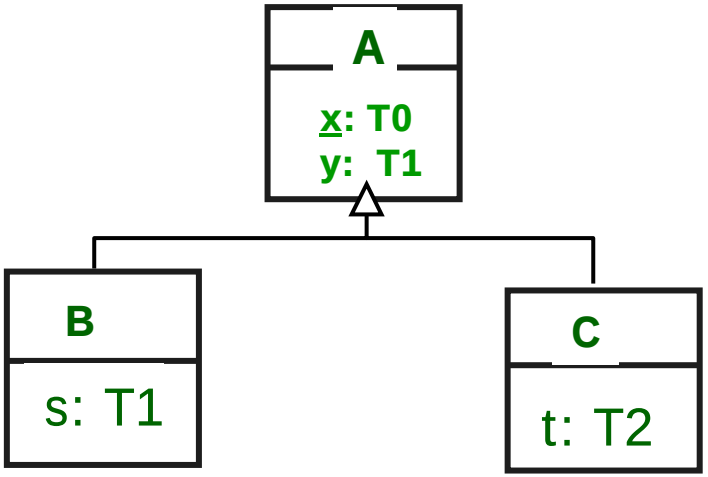
Never merge M:N relationships

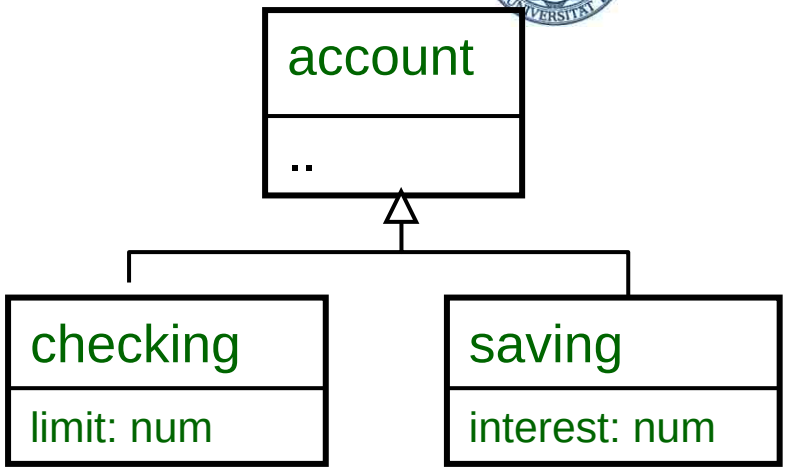
```
Person(id, name,...)
Hobby (hobby, kind, class_of_risk)
has_H(id, hobby, casualty)
```

⇨ ~~`Person(id, name,..., hobby, casualty...)`~~

Key has been changed, redundancy introduced

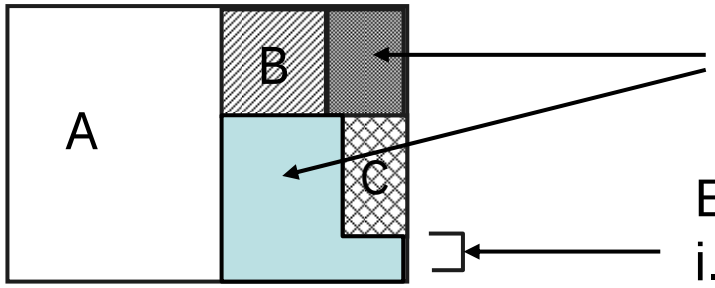
3.2.3 E-R to RDM mapping: Generalization





First alternative: **One "big" A-table** with attributes from all specializations

A(x, y, s, t)



NULLs, if subtypes are disjoint

Empty, if subtypes are exhaustive
i.e. each must belong to a subtype

Generalization: separate tables

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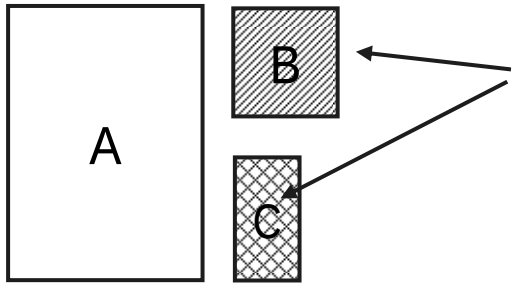
Second Alternative:

- **separate relations for A, B and C**
- make a one-to-one correspondence between every tuple from B and the appropriate A's
- ..and the same for the C's



B and C are separate relations
In this example:
- disjoint specializations
- not exhaustive

```
A(x, y)
B(x, s)

C(x, t)
```

Key of A as foreign key and part of primary key in B and C (existence dependency)

E-R to RDM mapping: Generalization

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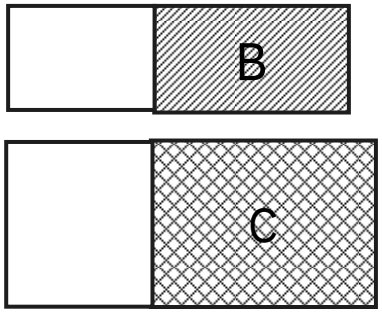
Third alternative
Extend A by B and C, respectively




```
AB(x,y,s)
AC(x,y,t)
```

Required: Subtypes must be exhaustive, i.e. complete specialization

Think about the **pros and cons** of each solution!

E-R to RDM mapping

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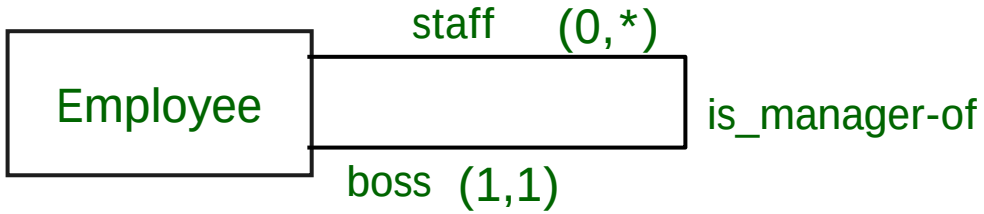
Recursive relationships




```
Employee (eid, …., managed_by_eid,…)
```

Transformation step depending on cardinalities
just like non-recursive relationships