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

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")	DB administrator
Loading, administration, tuning, maintenance, reorganization	

3.1 Logical schema design

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

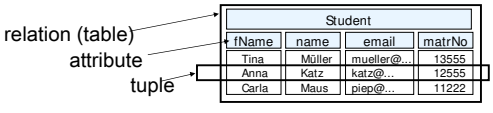
The Relational Data Model
Simplicity and formal rigor as the guiding principle

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



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

- **No duplicate** rows
- **No** tuple **order** — R is a set
- Attributes have a **primitive type**, **no constructed type** — most DBS today allow constructed and multivalued types
- **single-valued**
- 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

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

(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

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

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"

Employee			
fName	name	deptm	p#
Tina	Müller	IT	13555
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Carla	Maus	IT	11222

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

RDM: Foreign Keys

```
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

Department — 1 has N — Employee

Foreign key

Def: A **foreign key** 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.: **Referential integrity** 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

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…

Entity (types) with keys ⇒ 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

⇒

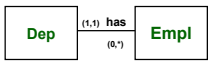
```
region (c_id name,...)
```

never NULL, why?

Mapping Relationships

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

1:1-relationship
Chose as key one of the keys of the involved relations


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

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

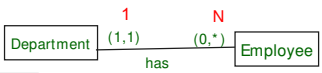
```
City
(name, r_id,...)
```

or

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


Relationships to tables

1:N relationship




```
Dep(
  name,
  boss,
  ...
  location)
```

```
has (p#, name)
```

```
Employee(p#,
  fname, ..)
```

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


```
user(account,
  name,...)
```

```
hasMail(account,
  msgId)
```

```
MM(msgId
  ...)
```

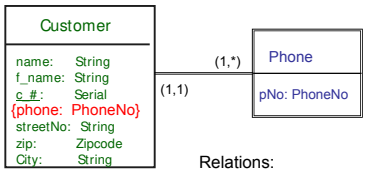
Neither **account** nor **msgId** alone have key property

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

Multiple value attribute
⇨ weak entity with a single attribute



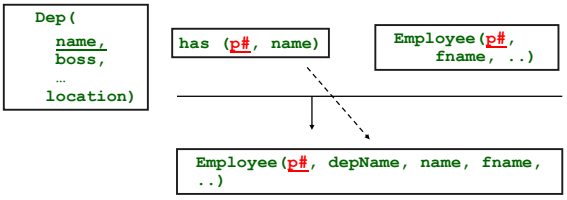
Relations:
`Customer(name, c_#,..)`
`Phone(c_#, pNo)`

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

3.2.3 Consolidation

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

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

```
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)
```

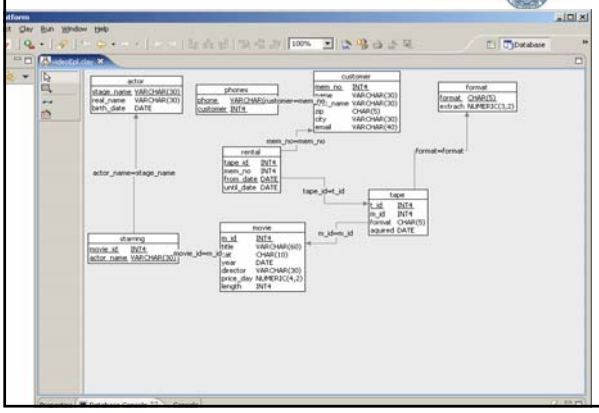

E-R to RDM mapping: discussion

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



Discussion continued

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)

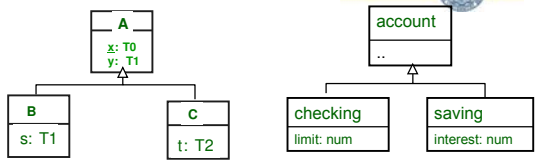
Never merge M:N relationships

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

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

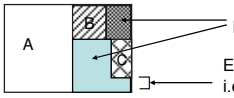
Key has been changed, redundancy introduced

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)
```



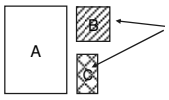
NULLs, if subtypes are disjoint

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

Generalization: separate tables

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

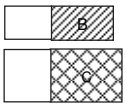
```
A(x, y)
B(x, s)

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

Third alternative
Extend A by B and C, respectively



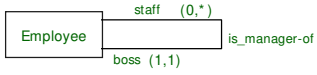

```
AB(x,y,s)
AC(x,y,t)
```

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

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

E-R to RDM mapping

Recursive relationships




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

Transformation step depending on cardinalities
just like non-recursive relationships