



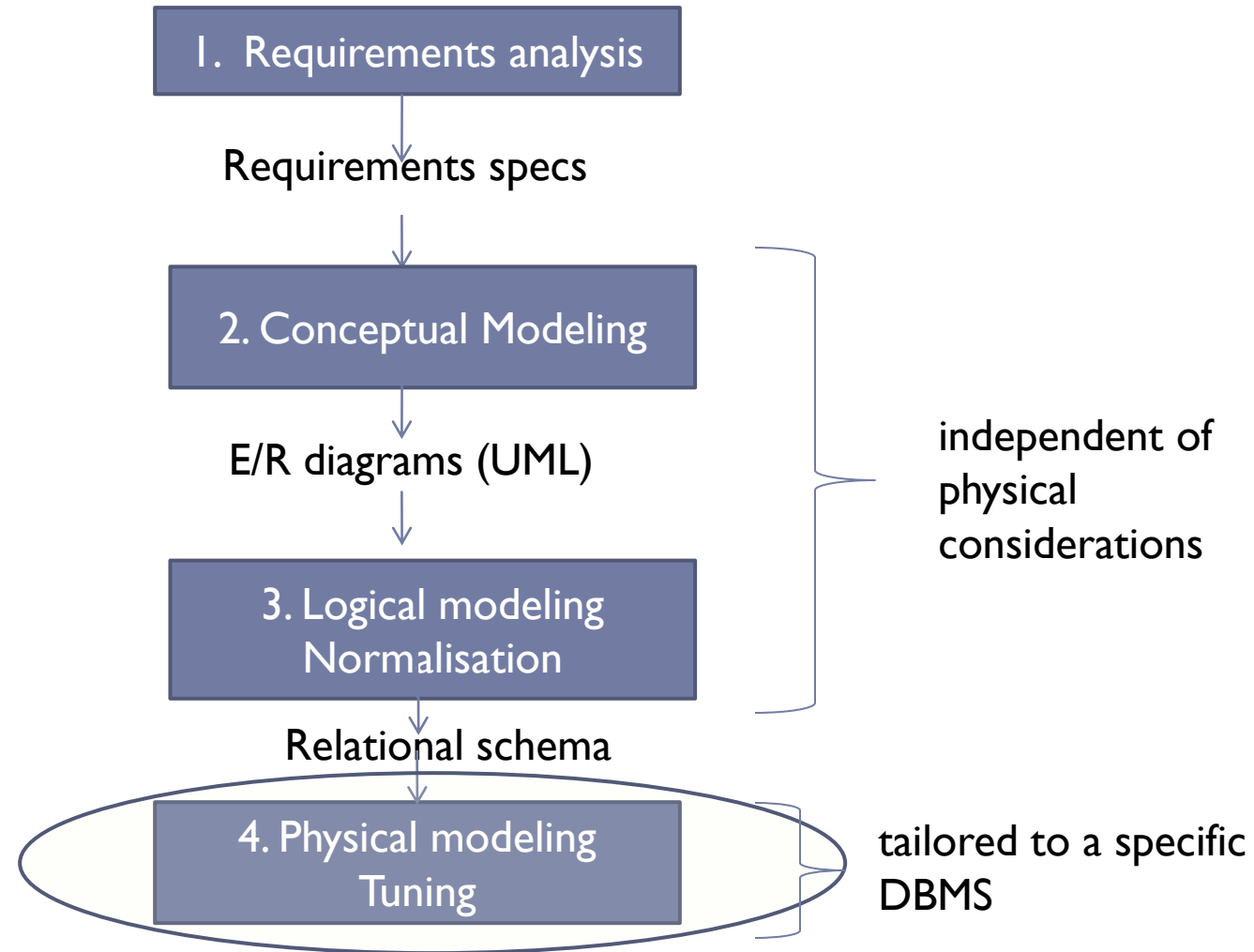
```
CREATE MATERIALIZED VIEW lecture10 AS  
SELECT lecture  
FROM Databases
```

```
WHERE topic = 'Physical Design';  
INSERT INTO lecture10 VALUES ('Constraints,Triggers,Views');
```

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Relational Database Design Methodology



Outline

- ▶ Declaring integrity constraints
- ▶ Triggers
- ▶ Views

Static integrity constraints

(1)

- ▶ **Restrict the possible states of the database**
 - ▶ Describe conditions that every instance of a database must satisfy
 - ▶ Avoid erroneous insertions, updates, deletions
 - ▶ Enforce data consistency
 - ▶ Tell the DBMS information that is useful for data storing and retrieval (query optimization)

- ▶ **Types**
 - ▶ Domain constraints
 - ▶ Non-null constraints
 - ▶ Keys – unique constraints
 - ▶ Referential integrity
 - ▶ General constraints at tuple level
 - ▶ Assertions

Static integrity constraints

(2)

- ▶ **Declaration**
 - ▶ At (table) creation(CREATE TABLE)
 - ▶ After (table) creation (ALTER TABLE)
- ▶ **Validation**
 - ▶ At every DML statement
 - ▶ At the end of the transaction

Integrity constraints over 1 attribute

Inline declaration

CREATE TABLE *table_name* (

a1 type **not null**, -- does not allow null entries

a2 type **unique**, --candidate key consisting of one attribute

a3 type **primary key**, -- primary key consisting of one attribute, implies {not null, unique}

a4 type **references** *table_name2* (*b1*), --foreign key consisting of one attribute

a5 type **check** (*condition*) – the condition is a Boolean expression built with attribute *a5*: (*a5*<11 and *a5*>4), (*a5* between 5 and 10), (*a5* in (5,6,7,8,9,10))...

)

Integrity constraints over several attributes

Out-of-line declaration

CREATE TABLE *table_name* (

a1 type,

a2 type,

a3 type,

a4 type,

primary key (*a1,a2*), -- primary key consisting of two (or more)attributes

unique(*a2,a3*), -- candidate key consisting of two (or more)attributes

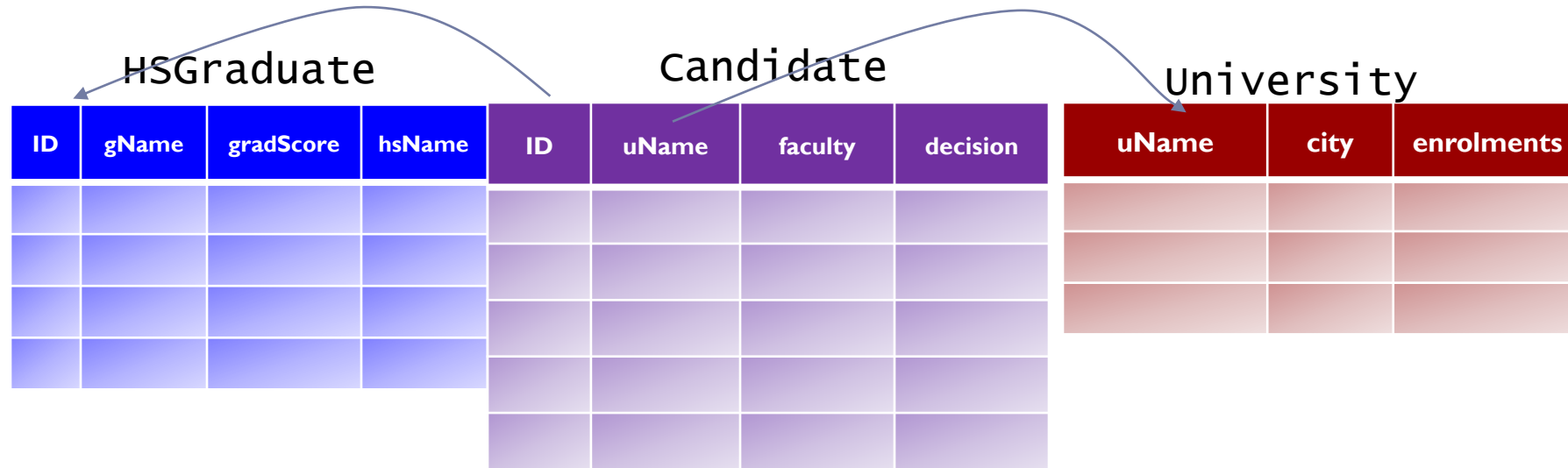
check (*condiție*), -- a Boolean expression built over several attributes: $((a1+a3)/2 \geq 5)$

foreign key (*a3,a4*) **references** *table_name2*(*b1,b2*) – multi-valued foreign key

)

Referential integrity

Definitions



- ▶ *Referential integrity from R.A to S.B:*
 - ▶ Every value in column A of table R must appear in column B of table S
 - ▶ A is called a foreign key
 - ▶ B must be declared as primary key or unique for table S
- ▶ There may exist multi-valued foreign keys

Referential integrity Validation

- ▶ Statements that may generate violations:
 - ▶ Insertions in R
 - ▶ Deletions in S
 - ▶ Updates of R.A or S.B

- ▶ Special actions that can be enforced:
 - ▶ At deletions in S:
`ON DELETE RESTRICT` (by default) | `SET NULL` | `CASCADE`
 - ▶ At updates on S.B:
`ON UPDATE RESTRICT` (by default) | `SET NULL` | `CASCADE`

Referential integrity

egg or chicken?

```
CREATE TABLE chicken (cID INT PRIMARY KEY,  
                       eID INT REFERENCES egg(eID));  
CREATE TABLE egg(eID INT PRIMARY KEY,  
                  cID INT REFERENCES chicken(cID));
```

Referential integrity

egg or chicken?

```
CREATE TABLE chicken (cID INT PRIMARY KEY,  
                        eID INT REFERENCES egg(eID));  
CREATE TABLE egg(eID INT PRIMARY KEY,  
                  cID INT REFERENCES chicken(cID));
```

```
CREATE TABLE chicken(cID INT PRIMARY KEY, eID INT);  
CREATE TABLE egg(eID INT PRIMARY KEY, cID INT);
```

```
ALTER TABLE chicken ADD CONSTRAINT chickenREFegg  
  FOREIGN KEY (eID) REFERENCES egg(eID)  
  DEFERRABLE INITIALLY DEFERRED; -- Oracle  
  
ALTER TABLE egg ADD CONSTRAINT eggREFchicken  
  FOREIGN KEY (cID) REFERENCES chicken(cID)  
  DEFERRABLE INITIALLY DEFERRED; -- Oracle
```

```
INSERT INTO chicken VALUES(1, 2);  
INSERT INTO egg VALUES(2, 1);  
COMMIT;
```

How do you solve insertions if the constraints are validated at each statement?

What about table drops?

Assertions

-defined in the SQL standard -

```
create assertion Key
```

```
check ((select count(distinct A) from T) =  
       (select count(*) from T));
```

```
create assertion ReferentialIntegrity
```

```
check (not exists (select * from Candidate  
                  where ID not in (select ID from HSGraduate)));
```

Integrity constraints

DBMS implementations

- ▶ Postgres, SQLite, Oracle, MySQL(innodb) implement and validate all constraints above
- ▶ No DBMS allows queries in the check constraint (deviation from the SQL standard)
- ▶ No DBMS implements assertions – their functionality can be provided by triggers

...DEMO...
(file *constraints.sql*)



Triggers

Dynamic constraints

- ▶ Monitor all the changes in a database, check conditions and initiate actions
- ▶ *Event-condition-action* rules
 - ▶ Bring within the DBMS elements from the application logic
 - ▶ Enforce constraints that cannot be expressed otherwise
 - ▶ Are expressive
 - ▶ May implement repairing actions
- ▶ The implementation may differ among DBMSs, the examples in the presentation are in accordance with the SQL standard

Triggers

Implementation

Create Trigger *name*

Before|After|Instead Of *event*

[*Referenced-variables*]

[**For Each Row**] -- the action is executed for each row altered by the event (row vs. statement types)

[**When (condition)**] – a boolean expression – exactly as within the WHERE clause in SQL queries

action -- în standardul SQL e o comandă SQL, în SGBD-uri poate fi bloc procedural

▶ *event:*

▶ **INSERT ON** *table*

▶ **DELETE ON** *table*

▶ **UPDATE [OF *a1,a2,...*] ON** *table*

▶ *Referenced-variables* (they are declared and then used in *condition* and *action*):

▶ **OLD TABLE AS** *var*

▶ **NEW TABLE AS** *var*

▶ **OLD ROW AS** *var* – only for *DELETE, UPDATE*

▶ **NEW ROW AS** *var* –only for *INSERT, UPDATE*

} Only for ROW triggers

Triggers

Example

- ▶ Referential integrity from R.A to S.B implementing cascade deletes

```
Create Trigger Cascade_Deletes
After Delete On S
Referencing Old Row As O
For Each Row
[ no conditions ]
Delete From R Where A = O.B
```

```
Create Trigger Cascade_Deletes
After Delete On S
Referencing Old Table As OT
[ For Each Row ]
[ no condition ]
Delete From R Where
    A in (select B from OT)
```

Triggers

Problems to consider

- ▶ Several triggers are activated simultaneously: which one is the first to be executed?
- ▶ The trigger action activates other triggers: chaining that can create cycles

Triggers

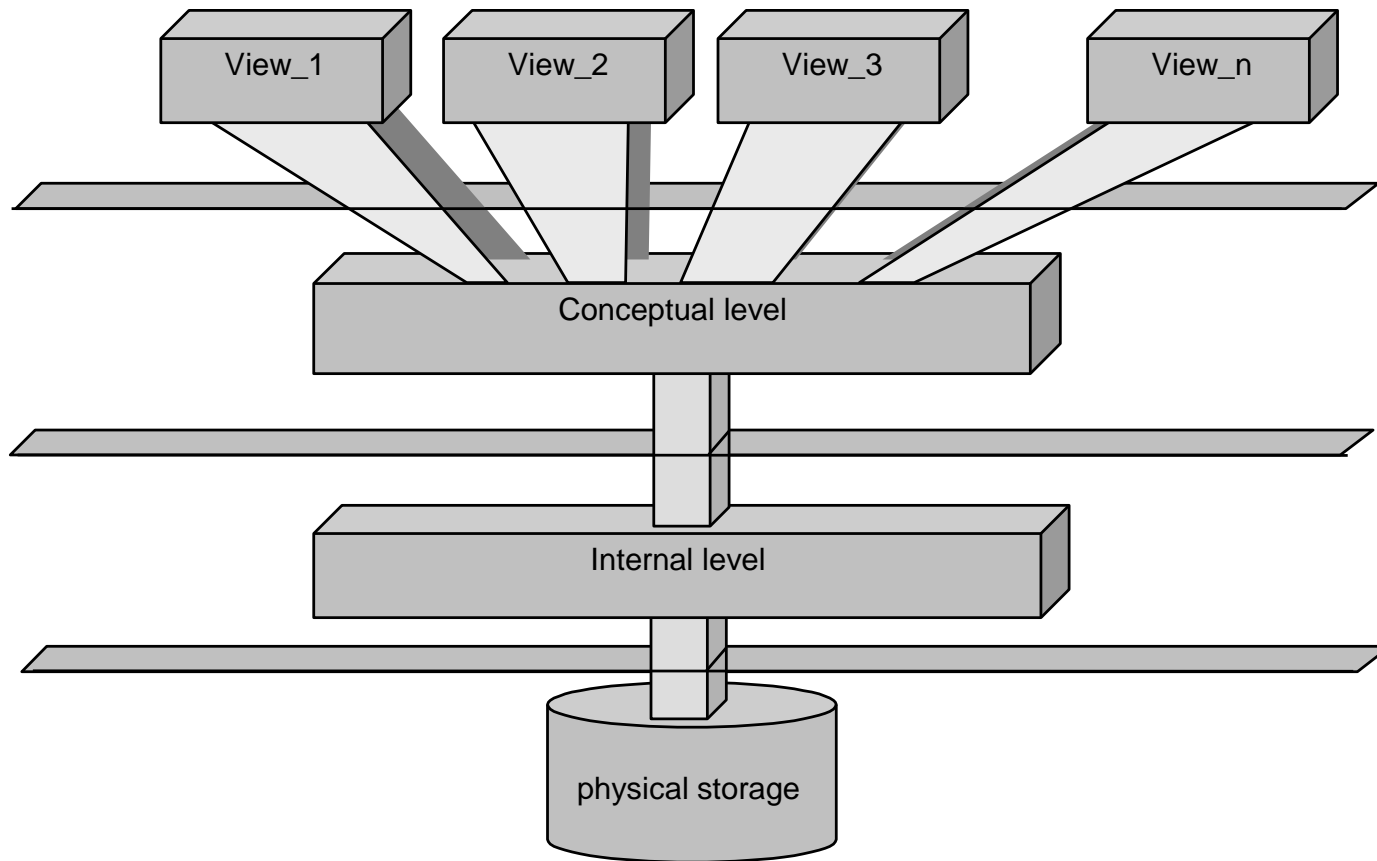
Implementation

- ▶ **Postgres**
 - ▶ The closest to the standard
 - ▶ implements row+statement -> {old,new}x{row,table} variables
 - ▶ The syntax suffers some changes
- ▶ **SQLite**
 - ▶ Only row (no old/new table)
 - ▶ Are executed after each row modification
- ▶ **MySQL**
 - ▶ Only row (no old/new table)
 - ▶ Are executed after each row modification
 - ▶ Allows only one trigger per event per table
- ▶ **Oracle**
 - ▶ Implements the standard: row+statement, some syntax changes
 - ▶ Instead-of triggers are allowed only for views
 - ▶ Allows the use of procedural blocks
 - ▶ Introduced the “FOLLOWS” clause in `||g`
 - ▶ Introduced restrictions to avoid cycling
 - ▶ Studied at the lab in the second semester

...DEMO...
(file *triggers.sql*)



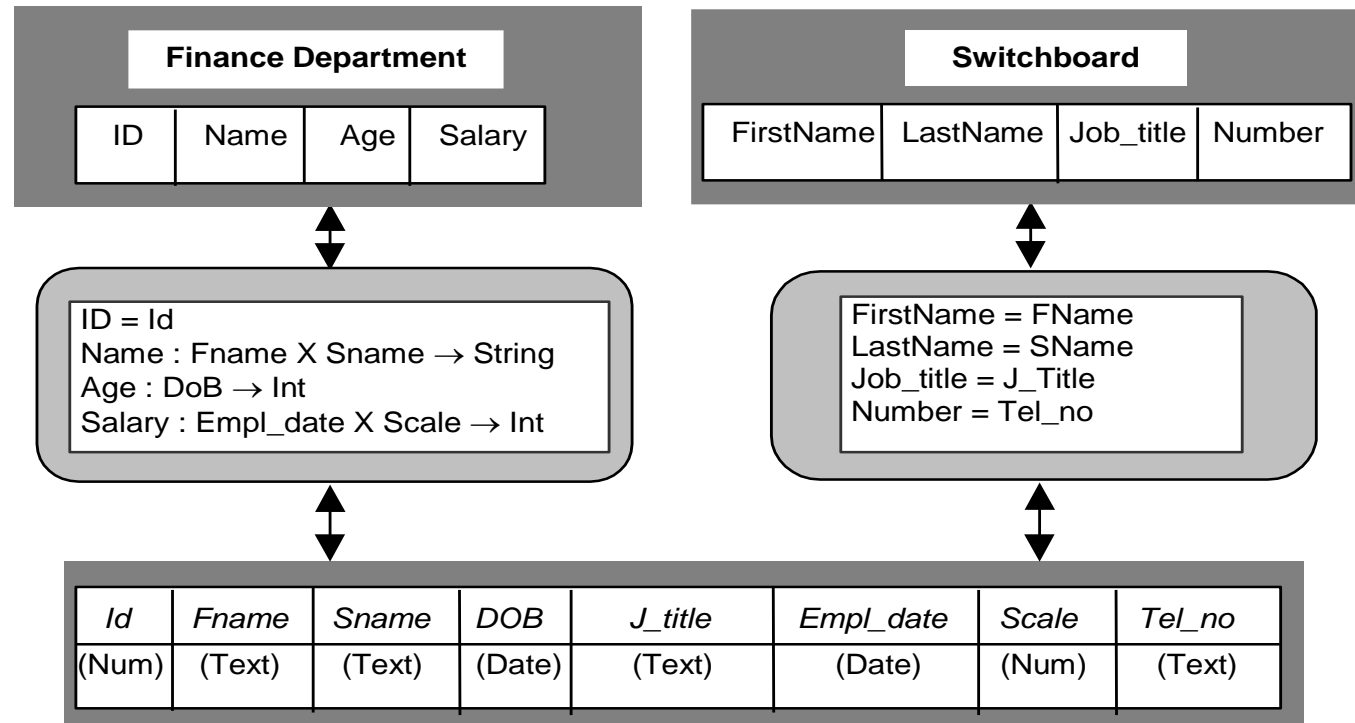
Views



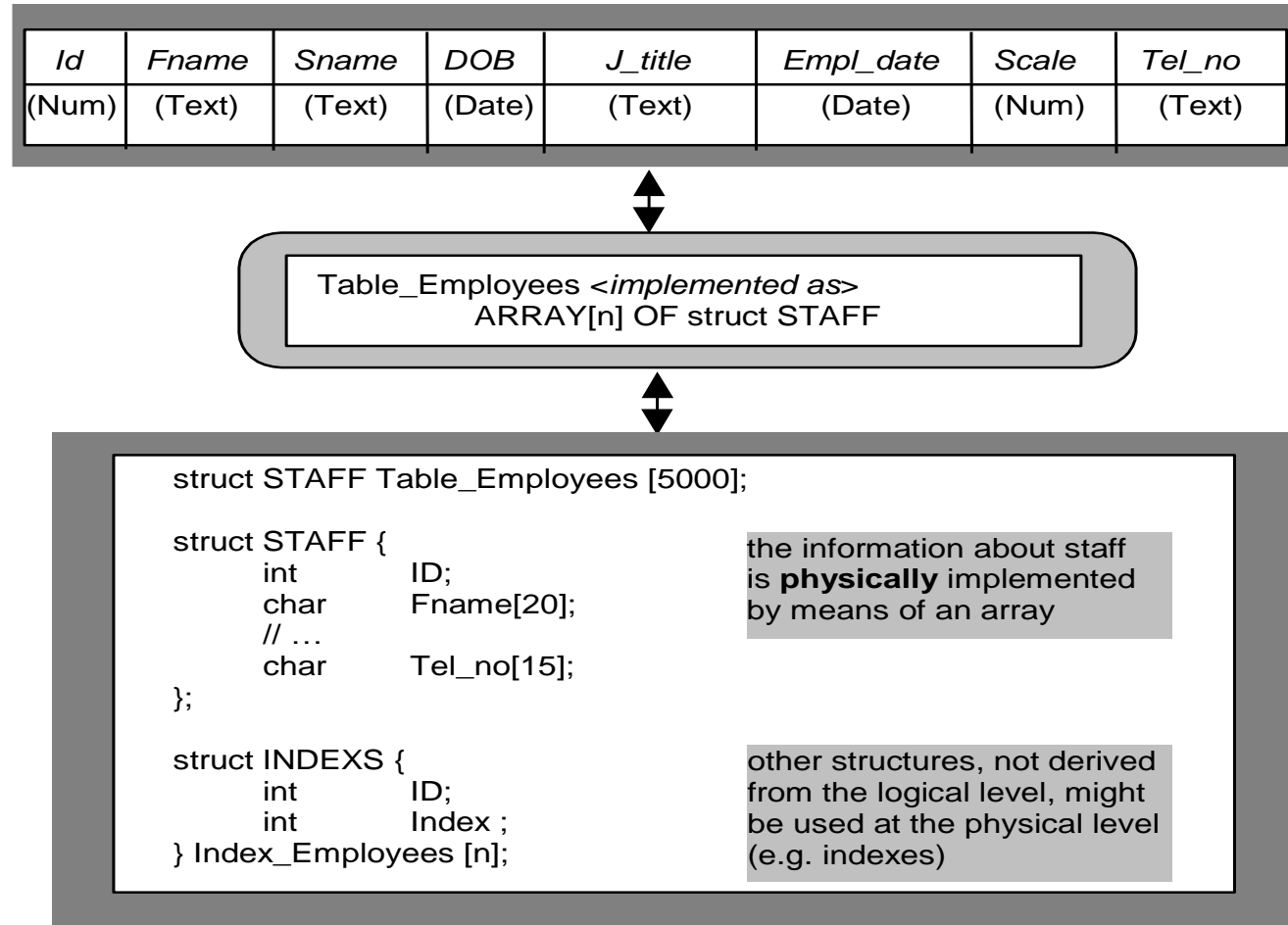
Codd's 12 rules

1. Information Rule
2. Guaranteed Access Rule
3. Comprehensive Data Sub-language Rule
4. View Update Rule
5. High Level Insert, Update and Delete
6. Physical Data Independence
7. Logical Data Independence
8. Integrity Independence
9. Non Subversion Rule
10. Systematic Treatment of Null Values
11. Database Description Rule
12. Distribution Independence

External level/conceptual level mapping



Conceptual level/internal level mapping



Motivation

- ▶ **Controlled access to the data:**
 - ▶ hide data from specific users
 - ▶ restrict DML statements
- ▶ **Reduce the complexity of queries**

- ▶ **Real applications tend to use many views**

Definition and use

- ▶ A view is actually a stored query formulated over tables or other views
- ▶ Its schema is generated based on the schema of the query result
- ▶ Conceptually, a view is queried just like a table
- ▶ In reality, a query over a view is rewritten by replacing the name of the view with the query defining the view; query optimization takes place, as implemented by the DBMS
- ▶ Syntax

Create View *view_name* [(*a1,a2,...*)] **As** <*select_statement*>

Modifying views

- ▶ Although the main operation/statement executed on a view is querying it, they may allow DML operations
- ▶ Modification commands on views must be rewritten as modification commands over base tables
 - ▶ Usually is simple
 - ▶ Sometimes several ways exist
- ▶ **Example 1**
 - ▶ $R(A,B), V(A)=R[A];$
 - ▶ `INSERT INTO V VALUES(3);`
- ▶ **Example 2**
 - ▶ $R(N), V(A)=avg(N),$
 - ▶ `UPDATE V SET A=7;`

Modifying views

Approaches

1. The view owner must rewrite all DML statements launched on the view as DML statements on the tables using the **INSTEAD OF** trigger
 - ▶ Covers all the cases
 - ▶ Guarantees data consistency
2. The SQL standard defines the existence of (inherently) **updatable views**:
 - ▶ The view must be created based on a single table T
 - ▶ The attributes in T that are not used in the view may have NULL entries or DEFAULT values
 - ▶ There is no aggregation used: no GROUP BY, no DISTINCT keyword

Materialized views

Create Materialized View $V [a_1, a_2, \dots]$ **As** `<select_statement>`

- ▶ A new table V is created with schema defined by the select statement
- ▶ The tuples result of the query are inserted into V
- ▶ Any query on V is executed directly on table V

- ▶ **Advantages:**
 - ▶ Specific to regular views + increased query execution speed
- ▶ **Disadvantages:**
 - ▶ V may increase in size
 - ▶ Any DMLs on the base tables require modifications on V
 - ▶ Any DMLs on V still must be translated into DMLs on base tables

How decide if materialize?

- ▶ Data size
- ▶ Query complexity
- ▶ The number of queries on the view
- ▶ The number of modifications on the base tables and the possibility of incrementally updating the view
- ▶ Trade-off the time for query processing over the time for propagating updates on the view when DML commands occur on the base tables

...DEMO...
(file *views.sql*)



Bibliografie

- ▶ Hector Garcia-Molina, Jeff Ullman, **Jennifer Widom**: *Database Systems: The Complete Book (2nd edition)*, Prentice Hall; (June 15, 2008)
- ▶ *Codd's 12 Rules for Relational DBMSs (important to understand the architecture of RDBMSs)*:
<https://computing.derby.ac.uk/c/codds-twelve-rules/>
- ▶ **Oracle**:
 - ▶ http://docs.oracle.com/cd/B28359_01/server.111/b28310/general005.htm
 - ▶ <http://www.oracle-base.com/articles/9i/MutatingTableExceptions.php>
 - ▶ http://www.dba-oracle.com/t_avoiding_mutating_table_error.htm