Chapter 5
Relational Databases and SQL: Further Issues

- Data Definition Language (DDL):
  schema generation
- Data Manipulation Language (DML):
  - queries
  - insertions, deletions, modifications
- Database behavior?

5.1 Database Schema

The database schema is the complete model of the structure of the application domain (here: relational schema):

- relations
  - names of attributes
  - domains of attributes
  - keys
- additional constraints
  - value constraints
  - referential integrity constraints
- storage issues of the physical schema: indexes, clustering etc. also belong to the schema

5.1.1 Schema Generation in SQL

Definition of Tables

Basic form: attribute names and domains

```
CREATE TABLE <table>
   (<col> <datatype>,
    ⋮
    <col> <datatype>)
```

domains: NUMBER, CHAR(n), VARCHAR2(n), DATE ...

```
CREATE TABLE City
      ( Name          VARCHAR2(35),
        Country       VARCHAR2(4),
        Province      VARCHAR2(32),
        Population    NUMBER,
        Latitude      NUMBER,
        Longitude     NUMBER );
```


Integrity constraints

Simple constraints on individual attributes are given with the attribute definitions as “column constraints”:

- domain definitions are already integrity constraints
- further constraints on individual attribute values
  more detailed range restrictions:
  City: CHECK (population $\geq$ 0) or CHECK (longitude BETWEEN -180 AND 180)
- NULL values allowed? : Country: name NOT NULL
- Definition of key/uniqueness constraints:
  Country: code PRIMARY KEY or name UNIQUE

Integrity constraints (Cont'd)

Multi-attribute constraints are given separately as "table constraints":

```
CREATE TABLE <table>
   (<column definitions>,
    <table-constraint>, ... ,<table-constraint>)
```

- table-constraints have a name;
- must state which columns are concerned;
- e.g. multi-column keys and foreign keys.

```
CREATE TABLE City
 ( Name VARCHAR2(35),
   Country VARCHAR2(4),
   Province VARCHAR2(32),
   Population NUMBER CONSTRAINT CityPop CHECK (Population >= 0),
   Latitude NUMBER CONSTRAINT CityLat CHECK (Latitude BETWEEN -90 AND 90),
   Longitude NUMBER CONSTRAINT CityLong CHECK (Longitude BETWEEN -180 AND 180),
   CONSTRAINT CityKey PRIMARY KEY (Name, Country, Province));
```

... for details see "Practical Training SQL".

Integrity constraints (Cont'd)

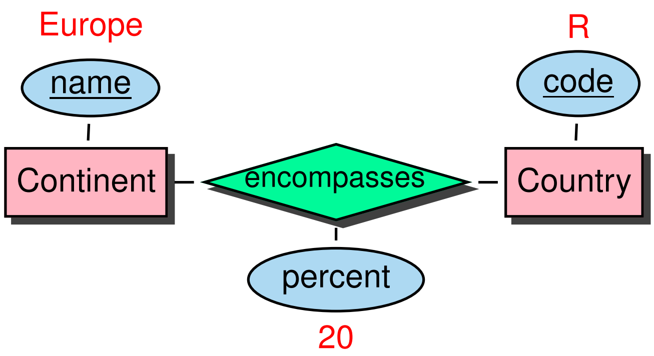
- up to now: only intra-table constraints

General Assertions

- inter-table constraints
  e.g., "sum of inhabitants of provinces equals the population of the country",
  "sum of inhabitants of all cities of a country must be smaller the than population of the country"
- SQL standard: CREATE ASSERTION
- not supported by most systems
- other solution: later

5.1.2 Referential Integrity Constraints

- important part of the schema; especially for tables corresponding to relationship types;
- relate foreign keys with their corresponding primary keys:



encompasses (cf. Slide 47)		
Country	**Continent**	**Percent**
VARCHAR(4)	VARCHAR(20)	NUMBER
R	Europe	20
R	Asia	80
D	Europe	100
...	...	...

encompasses.country → country.code and
encompasses.continent → continent.name

Tables corresponding to entity types have foreign keys that correspond to 1:n relationships:

city.country → country.code and
country.(capital,province,code) → city.(name,province,country)

Referential Integrity Constraints: SQL Syntax

- as column constraints (only single-column foreign keys):

```
<column-name> <datatype> REFERENCES <table>(<column>)
```

- as table constraints (also compound foreign keys):

```
[CONSTRAINT <name>] FOREIGN KEY (<column-list>)
                    REFERENCES <table>(<column-list>)
```

```
CREATE TABLE encompasses
  (Country       VARCHAR2(4) REFERENCES Country(Code),
   Continent     VARCHAR2(12) REFERENCES Continent(Name),
   percent       NUMBER CHECK (0 < percent <= 100),
   PRIMARY KEY (Country, Continent));

CREATE TABLE City
 ( Name VARCHAR2(35),
   Country VARCHAR2(4) REFERENCES Country(Code),
   Province VARCHAR2(32),
   Population NUMBER ..., Latitude NUMBER ..., Longitude NUMBER ...,
   CONSTRAINT CityKey PRIMARY KEY (Name, Country, Province),
   FOREIGN KEY (Country,Province) REFERENCES Province (Country,Name) );
```

5.1.3 Virtual Tables: Views

Views are tables that are not materialized, but *defined* by a query against the database:

```
CREATE VIEW <name> AS <query>
```

```
CREATE OR REPLACE VIEW symm_borders AS
SELECT * FROM borders
UNION
SELECT Country2, Country1, Length FROM borders;

SELECT country2
FROM symm_borders
WHERE country1='D';
```

- classical views: the content of a view is always computed when it is queried.
- *Materialized Views*: view is materialized and automatically maintained
  → *view maintenance problem*: when a base table changes, what modifications have to be applied to which views?

5.2 SQL: Data Manipulation Language

... everything is based on the structure of the SELECT-FROM-WHERE clause:

- Deletions:
  ```
  DELETE FROM <table> WHERE ...
  ```
  - specifies in which table to delete,
  - where-clause can contain arbitrary subqueries to other tables
- Updates:
  ```
  UPDATE <table>
  SET <attribute> = <value>, ..., <attribute> = <value>
  WHERE ...
  ```
  - specifies in which table to update,
  - value can be a subquery (also a correlated one)
- Insertions:
  ```
  INSERT INTO <table> VALUES (<const_1>, ..., <const_n>)
  INSERT INTO <table> (SELECT ... FROM ... WHERE ...)
  ```
  - where the <const_i> are constants (strings, numbers, dates, ...).

5.3 SQL: The DATE Datatype ... and Customization

- many applications in business and administration use dates
- computations on dates (e.g., “last of the third month after ...”, “number of days between”)

⇒ SQL provides comprehensive datatypes DATE, TIME, TIMESTAMP

A More General View I: Datatypes

DATE etc. are just some (important and typical) examples of *built-in* datatypes

- specific operators (and behavior, cf. the XMLTYPE datatype in the SQLX standard)
- handled via one or more lexical representations as strings

A More General View II: Internationalization and Customization

Database systems are used anywhere in the world (like most software), *and* their contents is exchanged all over the world

- people use different languages (e.g. for error messages!)
- people use different representations
  - even for numbers: 3,1415 vs. 1.000.000 (german), 3.14 vs. 1,000,000 (anywhere else)
  - for dates: ’31.12.2007’, ’12/31/2007’ or ’12-31-2007’ (USA), ’01-JAN-2003’ etc., ’01 Janeiro 2003’ even language dependent.

SQL: Internationalization and Customization

This issue is handled syntactically differently (but using the same idea) between different products.

Oracle: Natural Language Support

NLS_LANG (language and localization issues in general), NLS_NUMERIC_CHARACTERS (decimal point/dezimalkomma) and NLS_DATE_FORMAT (date format), NLS_SORT (sorting order)

- ALTER SESSION SET NLS_LANGUAGE = '*Language Territory.CharacterSet*';
  Language: error messages, etc, Territory: more detailed formats (America/Canada/UK) including default for decimal point and date format.
  ALTER SESSION SET NLS_LANGUAGE = 'portuguese'
- ALTER SESSION SET NLS_NUMERIC_CHARACTERS =',.'; (german style),
  ALTER SESSION SET NLS_NUMERIC_CHARACTERS ='.,'; (english style),
- ALTER SESSION SET NLS_DATE_FORMAT = '*string-pattern*', e.g. 'DD.MM.YYYY', 'DD-MON-YY', 'DD hh:mm:ss'

SQL: Internationalization and Customization

Then, e.g., `INSERT INTO Politics VALUES('D','18.01.1871','federal republic')`

is correctly interpreted. In the output, DATE values are always represented in the currently specified format.

⇒ SQL provides comprehensive datatypes DATE, TIME, TIMESTAMP

- semantics: year/month/date/hour/minute/second
  timestamp: additionally fractions of seconds as decimal
  (Oracle: only DATE and TIMESTAMP)
  built-in calendar knows about length of months, leap years etc.
- operators on date and time:
  - $date + days$
  - MONTHS_BETWEEN($date_1, date_2$), ADD_MONTHS($date, n$), LAST_DAY($date$)
  - SYSDATE

to_char(*string,pattern*) and to_date(*string,pattern*) functions

```
SELECT to_char(independence,'MM/DD/YYYY') from Politics;  -- 01/18/1871
SELECT to_char(independence,'DAY') from Politics;  -- wednesday
SELECT to_date('25-FEB-2012','DD-MON-YYYY')+5 from dual;   -- 01-MAR-12
```

The DATE Datatype: Example

```
CREATE TABLE Politics
 ( Country VARCHAR2(4),
   Independence DATE,
   Government VARCHAR2(120));
ALTER SESSION SET NLS_DATE_FORMAT = 'DD MM YYYY';
INSERT INTO politics VALUES
  ('B','04 10 1830','constitutional monarchy');
```

All countries that have been founded between 1200 und 1600:

```
SELECT Country, Independence
FROM Politics
WHERE Independence BETWEEN
'01 01 1200' AND '31 12 1599'
ORDER BY Independence;
```

Country	**Independence**
THA	01 01 1238
MC	01 01 1419
E	01 01 1492
NL	01 01 1579

5.4 Beyond Relational Completeness

- The Relational Algebra and SQL are only *relationally complete*.
- can e.g. not compute the transitive closure of a relation
- applications require a more complex behavior:
  - SQL as the "core query language"
  - with something around it ...

Making SQL Turing-complete

- embedded SQL in C/Pascal:

  ```
  EXEC SQL SELECT ... FROM ... WHERE ...
  ```

  embedded into Java: JDBC (Java Database Connectivity)

- SQL-92: Procedural Extensions to SQL:
  - CREATE procedures and functions as compiled things *inside* the database
  - standardized concepts, but product-specific syntax
  - basic programming constructs of a "typical" Turing-complete language: Variables, BEGIN ... END, IF ... THEN ... ELSIF ..., WHILE ... LOOP ..., FOR ... LOOP
  - SQL can be used inside PL/SQL statements

"Impedance Mismatch" between DB and Programming Languages

(cf. Slide 3)

Set-oriented (relations) vs. value-oriented (variables)

- how to handle the result of a query in C/Pascal/Java?

Iterators (common programming pattern for all kinds of collections)

- explicit:
  - new/init(<query>)/open()
  - first(), next(), isempty()
  - fetch() (into a record/tuple variable)
- implicit (PL/SQL's "Cursor FOR LOOP"):

  ```
  FOR <record-variable> IN <query>
  LOOP
     do something with <record-variable>
  END LOOP;
  ```

... for details see "Practical Training SQL".

5.5 Integrity Maintenance

- if a tuple is changed/inserted/deleted it is immediately checked whether all constraints in the current database state are satisfied afterwards.
  Otherwise the operation is rejected.
- if a constraint is defined/enabled, it is immediately checked whether it is satisfied by the current database state.
  Otherwise the operation is rejected.

Any further possibilities?

Integrity Maintenance (Cont'd): referential integrity

Consider again country - organization - is member:

isMember.organization → organization.abbreviation
isMember.country → country.code

- deletion of a membership entry: no problem
- deletion of a country: any membership entries for it are now "dangling"

⇒ remove them!

Referential Actions

FOREIGN KEY isMember(country) REFERENCES country(code) ON DELETE CASCADE

- ON DELETE CASCADE: delete referencing tuple
- ON DELETE RESTRICT: referenced tuple cannot be deleted
- ON DELETE NO ACTION: referenced tuple can be deleted if the same transaction also deletes the referencing tuple
- ON DELETE SET NULL: foreign key of referencing tuple is set to NULL
- ON DELETE SET DEFAULT: foreign key of referencing tuple is set to a default value
- same for ON UPDATE

Referential Actions: a simple example

Country

Name	Code	Capital	Province
Germany	D	Berlin	Berlin
United States	USA	Washington	Distr. Columbia
...	...	...	...

CASCADE

NO ACTION

City

Name	Country	Province
Berlin	D	Berlin
Washington	USA	Distr. Columbia
...	...	...

```
1.  DELETE FROM City
    WHERE Name='Berlin';

2.  DELETE FROM Country
    WHERE Name='Germany';

3.  UPDATE Country
    SET code='DE'
    WHERE code='D';
```


Referential Actions: Problems

Country

Name	Code	Capital	Province
Germany	D	Berlin	Berlin
United States	US	Washington	Distr.Col.
...	...	...	...

CASCADE

Province

Name	Country	Capital
Berlin	D	Berlin
Distr.Col.	US	Washington
...	...	...

SET NULL

CASCADE

City

Name	Country	Province
Berlin	D	Berlin
Washington	USA	Distr.Col.
...	...	...

```
DELETE FROM Country
 WHERE Code='D'
```

... ambiguous semantics!

see `http://dbis.informatik.uni-goettingen.de/RefInt`.

... active behavior/reaction on events!

5.6 Active Databases/Triggers

- reacting on an event
  - external event/signal
  - internal event: modification/insertion/deletion
  - internal event: time
- if a condition is satisfied
- then do something/execute an action

ECA: Event-Condition-Action rules

ECA-Rules

Consider database updates only: one or more tuples of a table are changed.

- Granularity:
  - execute action once for “all updates together” (e.g., afterwards, update a sum)
  - execute action for each changed tuple (e.g. cascading update)
- Timepoint:
  - after execution of original update
  - before execution of original update
  - instead of original update
- Actions:
  - can read the before- and after value of the updated tuple
  - read and write other tables

Triggers

The SQL standard provides “Triggers” for implementation of ECA rules:

`CREATE TRIGGER`

- specify event:
  `ON {DELETE | UPDATE | INSERT} OF <table> <pl/sql-block>`
- specify condition: `WHEN <condition>`
- specify granularity: `FOR EACH STATEMENT | ROW`
- specify action by `pl/sql-block`.

Actions are programmed using the above-mentioned procedural extensions to SQL.

Applications

- implementation of application-specific *business rules*,
- integrity maintenance,
- monitoring of assertions.

... for details see “Practical Training SQL”.