# Query languages 1 (NDBI001) part 2

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# *Content*

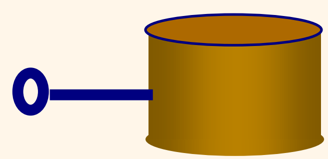
# *Why more DB technologies*

New Application Requirements:

- new types objects and functions
- OO analysis and design vs. relational DB

> *"Relational database reminds a garage, that forces you to disassemble your car and save parts to the drawers..."*

DBMS

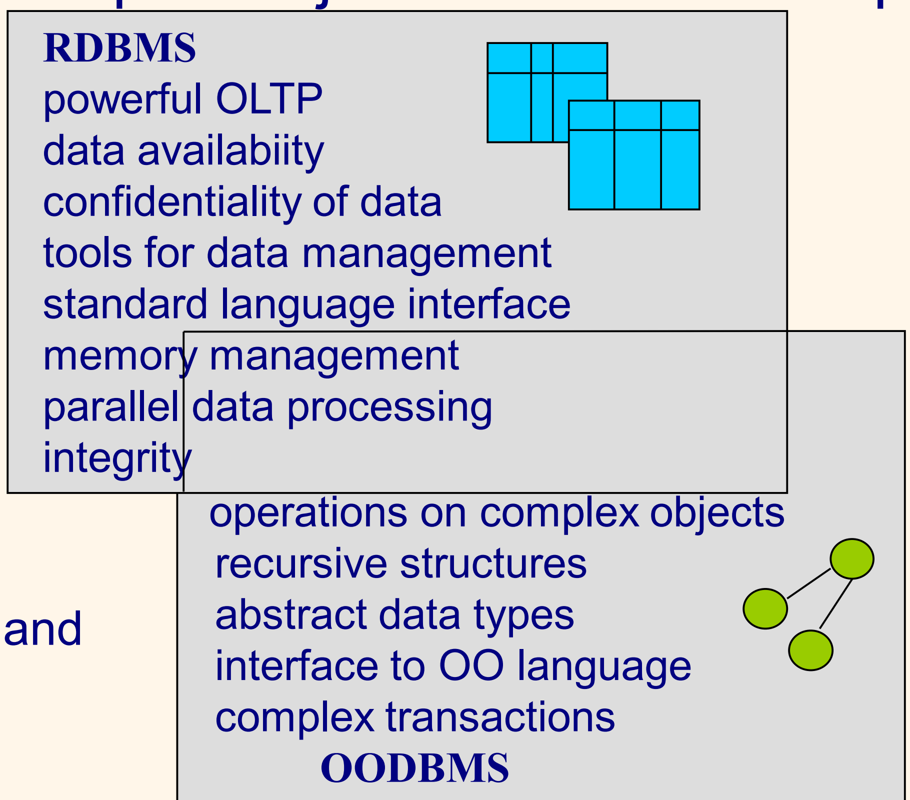



Goal: integration and data management in one system

# Object-oriented databases

object data model

- in accordance with the natural world view (entity $\Rightarrow$ object)
- definition of complex objects and their manipulation




Functionality of relational and OO DBMSs

# *Object-oriented databases*

- 1993: consortium ODMG (Object Data Management Group) of leading OODBMS vendors ⇒ design of the ODMG-93 standard.
  – superset of the more general Common Object Model (COM) created by the Object Management Group (OMG). Its definition language IDL was adopted.
  – a query part Object Query Language (OQL), which is related to the concept of the query part of the SQL92 standard.
  – interface k OO PL C++, Smalltalk (to Java: replaced by Java Data Objects (JDO))
- 2001: the ODMG disbanded (version ODMG 3.0)

*OOPL + DBMS = OODBMS*

# *Basic concepts of ODMG-93*

- class (or type), instance (or object), attribute, method and integrity constraint
  - class - template for instances (objects), which can share attributes and methods.
    - attribute domain: primitive data type, abstract data type (ADT), or reference to a class.
    - method is a function (its implementation is hidden) applicable to class instances (calculation is based on the values of attributes).
- object identifier (OID)
  - each object has a unique identifier, through which a corresponding object can be obtained from DB.

# Basic concepts of ODMG-93

- encapsulation
  - data is “captured” with methods. An encapsulation unit is an object. Methods hold only on objects, with which they are encapsulated.
- class hierarchy, inheritance
  - subclass $\Rightarrow$ hierarchy
  - inheritance is a process that means for a subclass to use all attributes and methods from its superclass.
  - multiple-inheritance ($\Rightarrow$ problems, e.g., conflict resolution the same names inherited attributes and methods).

# Emergence of OO DB technology

Sources: OO programming, OO analysis and design, relational DBMS

- object-relational mapping (ORM)

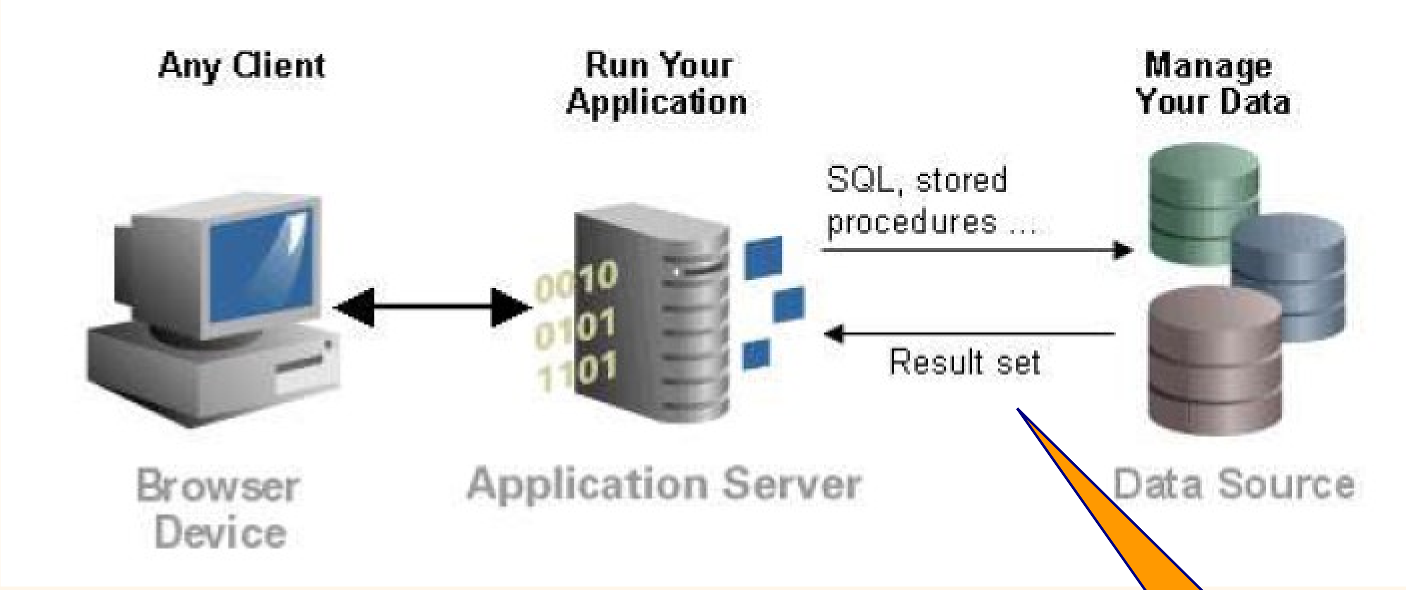
  Ex.: Hibernate (interface: Session, Transaction, Query)

  TopLink (ORM application owned by Oracle, Inc.)

  Access to objects: e.g. Hibernate Query Language $\rightarrow$ SQL; programming language + methods for entering the SQL database

  Problem: less semantics in relations, impedance mismatch in an access to objects.

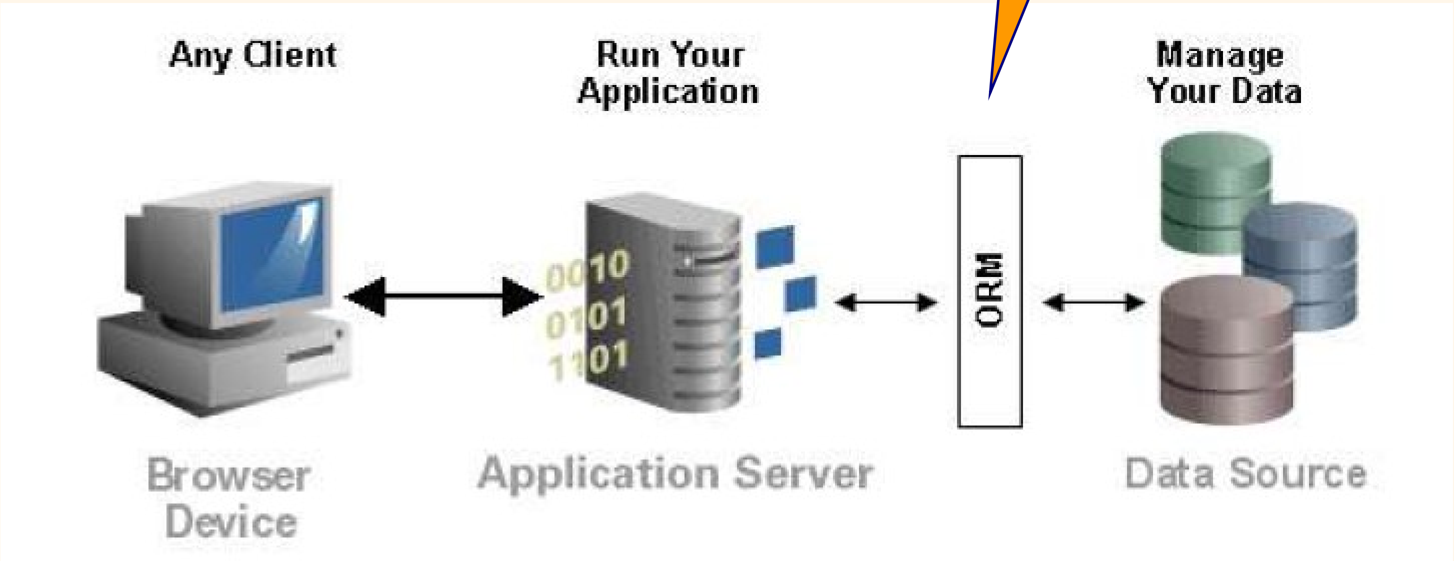
# Running without ORM



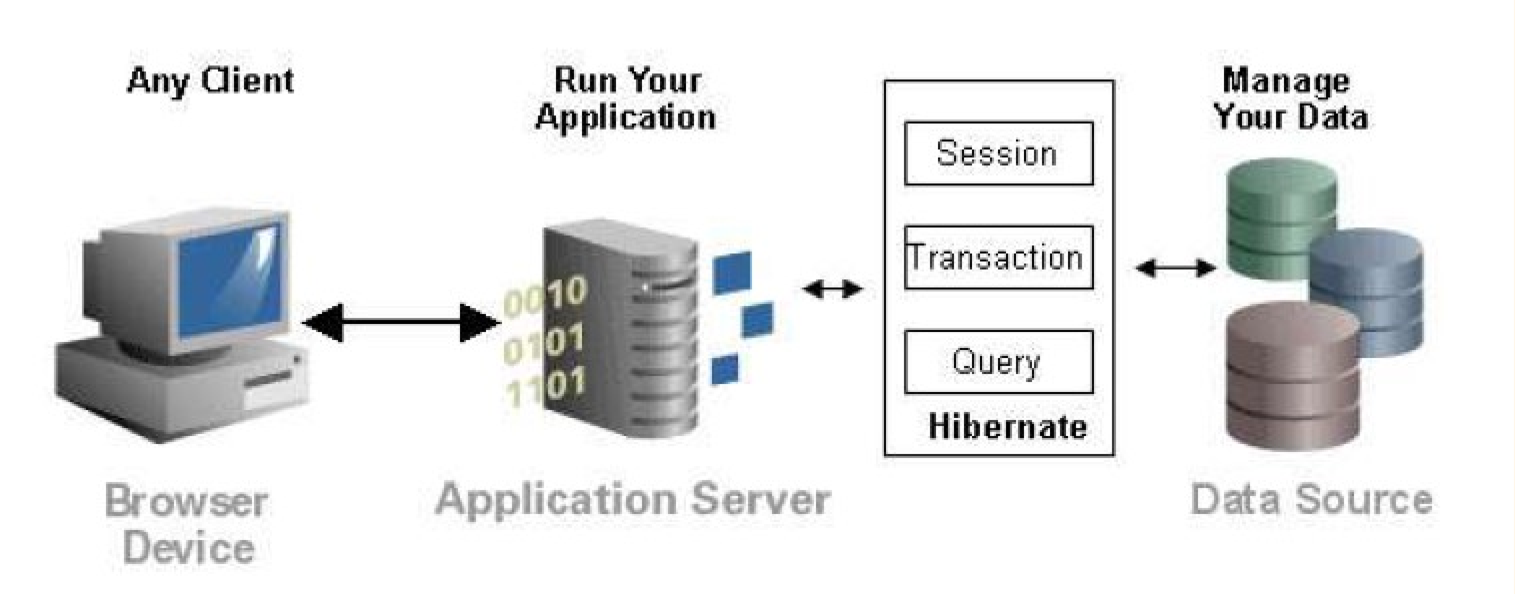

through API
JDBC

# Running with ORM

15%-20% slower than with JDBC



# Example: Hibernate



# *Emergence of new technologies*

- 2nd half of the 1980s -- OO databases
  - O2 (→ Unidata → Informix → IBM)
  - ObjectStore (Ignite Technologies from 2015)
  - Versant Object Database (version 9.2 in 2016),
  - Objectivity/DB, InterSystems Caché (version 2016.1.1),
  - GemStone (GemTalk Systems from 2013),
  - Jasmine
  - newer: db4o (database for objects),
- Principle: top-down (from application to data)
- Querying: OQL – not complete, others: e.g., Objectivity/SQL++



1

# OR DB Technologies

Reasons:

- partial failure: OO technologies did not offer the flexibility and performance of relational DBMS
- even later descent - e.g. db4o ceased to be supported in 2014
- DBMS manufacturers target:
  - get the most out of large investments in relational technology (data, experience gained)
  - take advantage of the flexibility, productivity and running benefits of OO modeling,
  - integrate database services into production systems and other applications.

# OR DB Technologies

- 90ies - OR databases (OR DBMS)
  - combination of OO and relational DBMS
  - 1992: UniSQL/X, then: HP - OpenODB (later Odapter)
  - 1993: Montage Systems (later Illustra) –
  - the commercial version of Postgres
  - 2000+: DB/2, INFORMIX, ORACLE, Sybase Anywhere (integrated to SAP, 2012), Unidata, Microsoft SQL Sever

# OR DB Technologies

Two approaches:

universal memory, all kinds of data is

managed in DBMS; integration (in many different ways!)

$\Rightarrow$ universal servers

- universal approach, all data is in their original (autonomous) systems

  Technique: middleware

  - gateways (at least two independent servers)
  - schemes mapping, query transformations
  - object envelops: Persistence Software, Ontologic, HP, Next, ... (problems: efficiency)
  - DB based on Web

# *Extensibility, user defined types and functions*

*ADT possibilities :*
*black box*
*white box*

Requirement: manipulation of BLOBs (atomic in RDBMS)

Extensibility: possibility to add new data types + programs (functions) „wrapped“ into and special module

$\Rightarrow$ UDT (user defined types)

UDF (user defined functions)

Problem: integration into relational DBMS (including SQL!)

DB/2: relational extenders

Informix: DataBlades

ORACLE: cartridges

Sybase: Component Integration Layer.

**universal servers**

# *Extensibility, user defined types and functions*

Ex.: DB/2 in r. 2006:

- MapInfo
- NetOwl (business intelligence language)
- EcoWin (time sequences, macroeconomical time sequences, …)
- GIS and spatial objects
- SQL expander (mathematical, financial, conversion and other functions)
- VideoCharger (audio and video objects in real-time)
- text, XML, audio, video, pictures
- FormidaFire (heterogeneous data integration)
- …

Ex.: Informix in r. 2006:

- C-ISAM, Excallibur Text Search, Geodetic, Image Foundations, Spatial, TimeSeries, Video Foundation, Web

# *Extensibility, user defined types and functions*

- Implementation: technology „plug in“ using various techniques:
  - DataBlades - direct access to the database engine
  - ORACLE 7.3 - more servers and API
- Today: direct part of database engines DB/2, INFORMIX, ORACLE, Sybase Adaptive Server+Java, OSMOS, Unidata

# *Extensibility, user defined types and functions*

- partial standardization:
  - SQL/MM (e.g., Full-Text - provides ADT + appropriate functions)
  - more generally: SQL99, SQL:2003 enable to build rather complex data types based on several built-in basic data types
  - extending apparatus of built-in basic types – XML (2003 …), JSON (2016)

# Example - text extender

```
SELECT journal, date, title
FROM Articles
WHERE CONTAINS(article_text, ‘(“database” AND
                    (“SQL” | “SQL92”) AND NOT “dBASE”)‘) = 1;
```

Other functions: NO_OF_MATCHES ((how many times a sample appears in the text), RANK (ranking of values of the order in the result based on a measure).

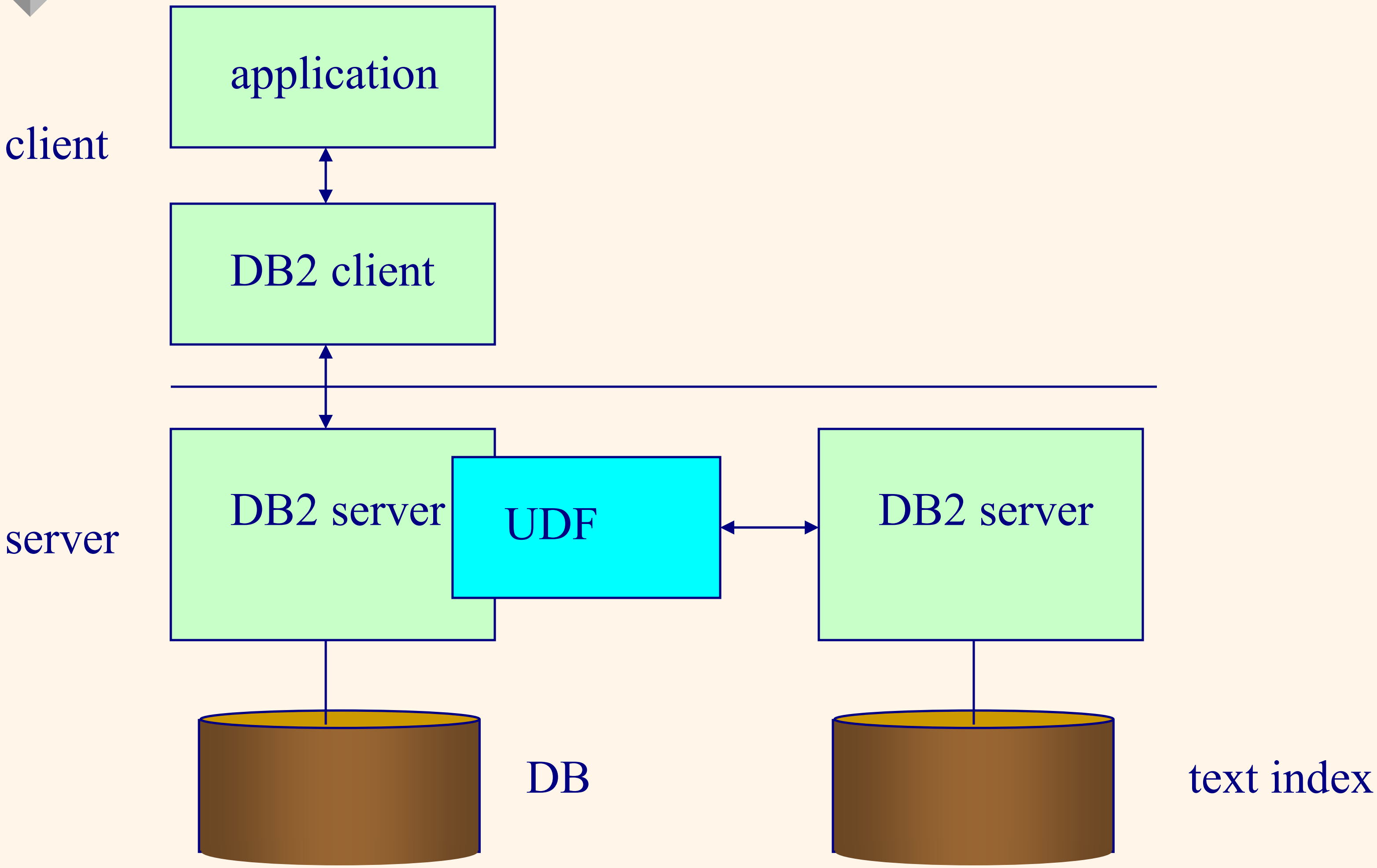
```
SELECT journal, title
FROM Articles
WHERE NO_OF_MATCHES (article_text, ‘database‘) > 10;
```

```
SELECT journal, date, RANK(article_text, ‘(“database” AND
(“SQL” | “SQL92”) )’) AS relevance
FROM Article
ORDER BY relevance DESC;
```

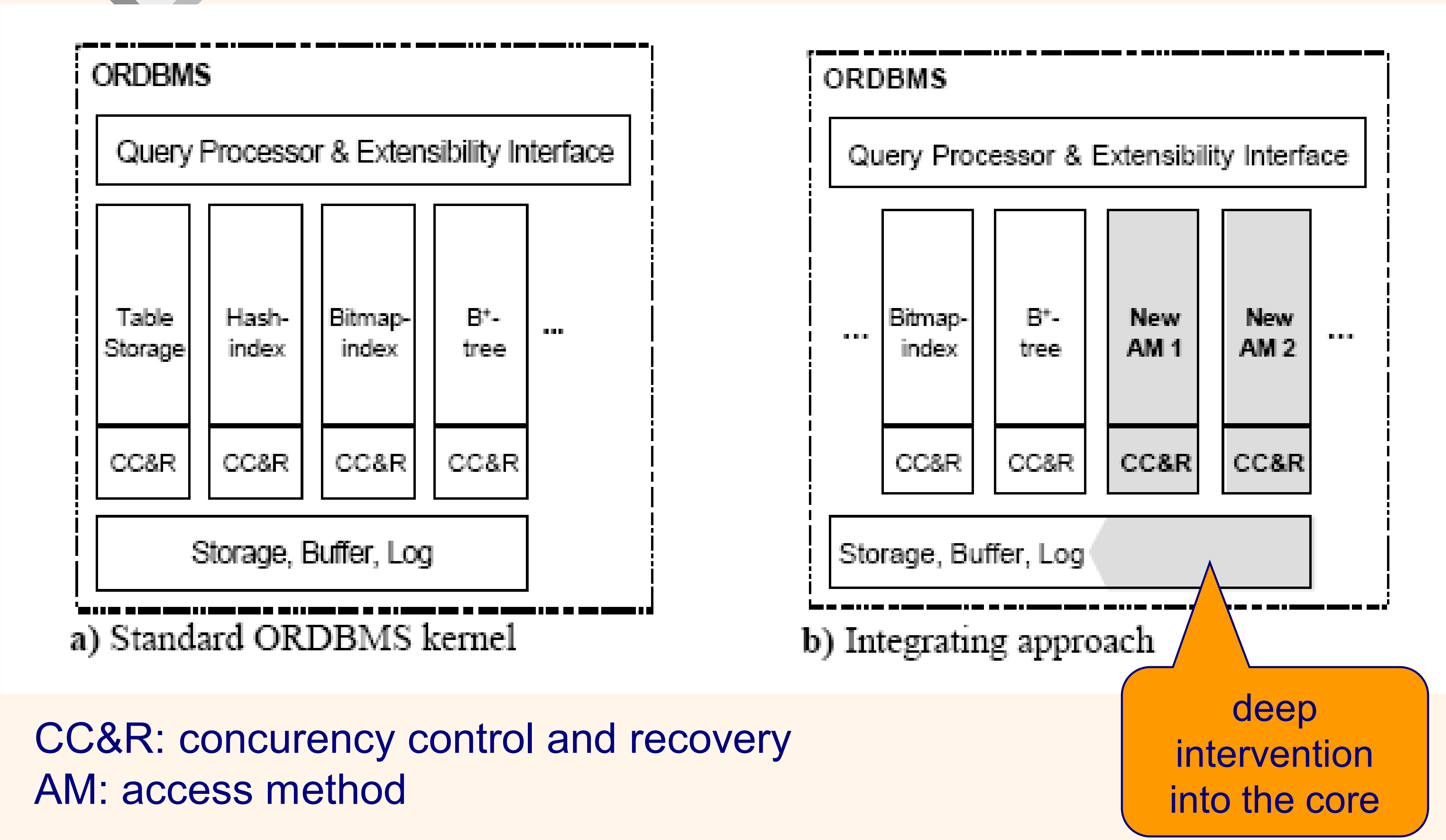
# Architecture of known products

- adding a special application interface (API) and special servers (also ORACLE 7.3 – see ,e.g., CONTEXT, Media Server, OLAP),
- simulation OR on the middleware level (also ORACLE 7.3 – see, e.g., the part Spatial Data Option),
- total remaking a database machine (e.g., Illustra Information Technology),
- adding an OO layer to a relational machine (e.g. INFORMIX Universal Server, IBM D2/6000 Common Server, Sybase Adaptive Server + Java).

# Interaction of DB and the text extender in DB2



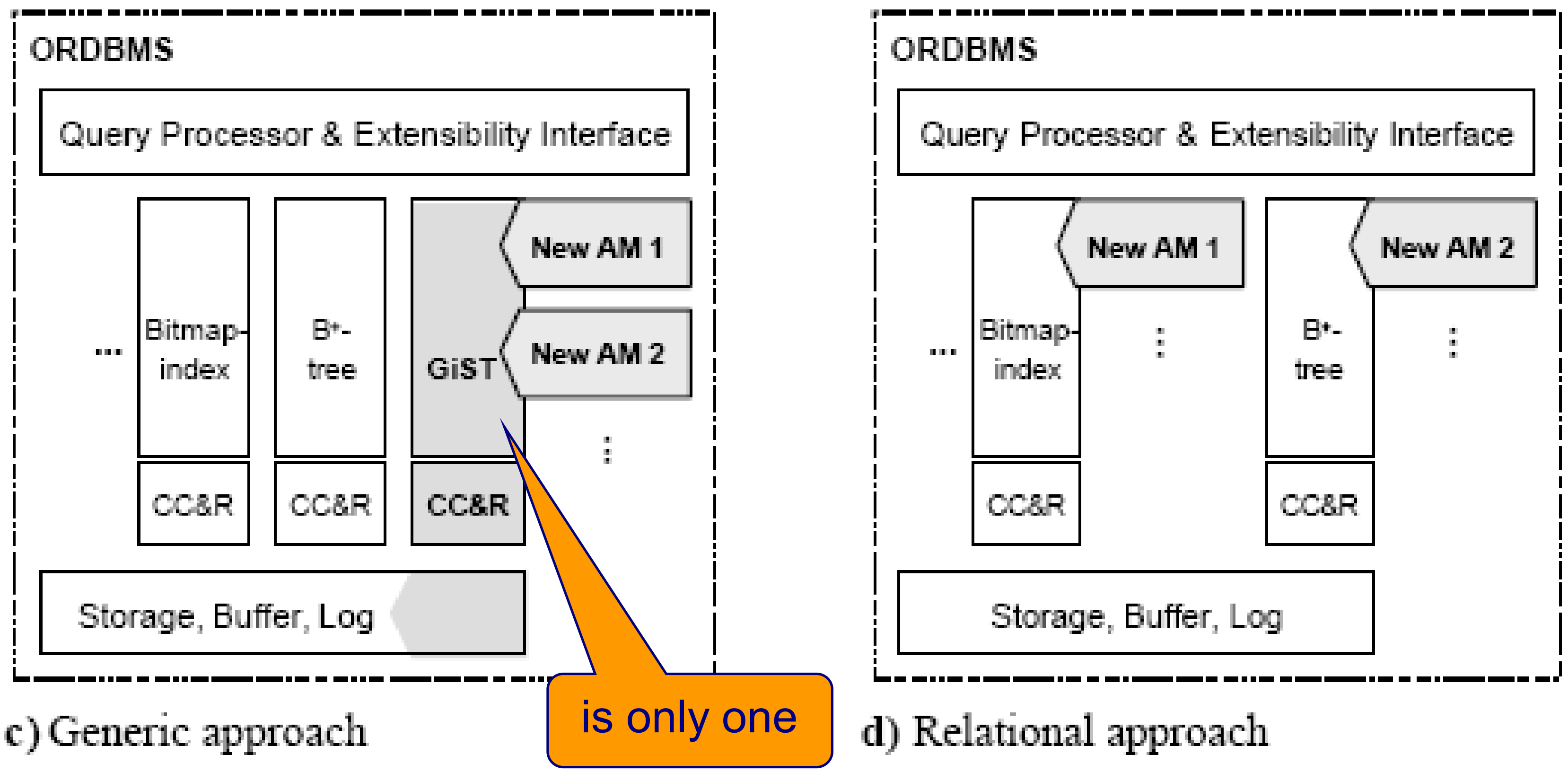
# Architectures of extendibility (1)




CC&R: concurency control and recovery

AM: access method

# Architectures of extendibility (2)




c) Generic approach

d) Relational approach

GiST: Generalized Search Tree

AM on the top of relational DBMS

# Problems with ORDBMS

- implementation of VITA data types (video, image, text, audio)
- integration of data types
  - how to optimize queries?
- old solutions:
  - modification of the DBMS core (expensive, demanding)
  - functionality available only for some types of requirements
- newer solutions:
  - specialized servers

# „Real“ ORDBMS

Won Kim: „extendibility is only a secondary, although useful, feature of the OO approach“

Stonebraker: „extendibility of type “plug-in” (e.g., in ORACLE) is suitable for connectivity application-application, nevertheless has nothing to do with database “plug-in”. It is only a middleware, which does not establish OR technology“.

Requirements:

- data model with the features of ODMG-93
- associated high-level object language

Solution: OO extension of SQL fulfills (approx.) these requirements

Today: standards SQL:1999, SQL:2003 + further development

# *Object-relational modelling*

- Extension of the relational model by type definition, objects and relevant constructs for their manipulation,
- attributes of tuples are of complex types, including nested relations,
- relational background is preserved (including a declarative approach to data processing,
- compatibility with relational languages (they form a subset).

# Example: nested vs. normalized relation

| journal | title | authors | keywords | date | | |
|---|---|---|---|---|---|---|
| | | | | day | month | year |
| CW | OLAP | {Kusý, Klas} | {star, dimension} | 23 | April | 1998 |
| SN | Database | {Novák, Fic} | {RDM, schema} | 15 | May | 1998 |

| journal | title | authors | keyword | day | month | year |
|---|---|---|---|---|---|---|
| CW | OLAP | Kusý | star | 23 | April | 1998 |
| CW | OLAP | Kusý | dimension | 23 | April | 1998 |
| CW | OLAP | Klas | star | 23 | April | 1998 |
| CW | OLAP | Klas | dimension | 23 | April | 1998 |
| SN | Database | Novák | RDM | 15 | May | 1998 |
| SN | Database | Novák | schema | 15 | May | 1998 |
| SN | Database | Fic | RDM | 15 | May | 1998 |
| SN | Database | Fic | schema | 15 | May | 1998 |

# Normalization into 4NF

| journal | title |
|---|---|
| CW | OLAP |
| SN | Database |

| title | author |
|---|---|
| OLAP | Kusý |
| OLAP | Klas |
| Database | Novák |
| Database | Fic |

| title | keyword |
|---|---|
| OLAP | star |
| OLAP | dimension |
| Database | schema |
| Database | RDM |

| title | day | month | year |
|---|---|---|---|
| OLAP | 23 | April | 1998 |
| Database | 15 | May | 1998 |

Negatives of 4NF

- joins in queries

Negatives of only 1NF

- the loss of relation 1 row = 1 object

# Normalization into 4NF

| journal | title |
|---|---|
| CW | OLAP |
| SN | Database |

eventually *

| title | day | month | year |
|---|---|---|---|
| OLAP | 23 | April | 1998 |
| Database | 15 | May | 1998 |

| title | author |
|---|---|
| OLAP | Kusý |
| OLAP | Klas |
| Database | Novák |
| Database | Fic |

| title | keyword |
|---|---|
| OLAP | star |
| OLAP | dimension |
| Database | schema |
| Database | RDM |

Negatives of 4NF:

- joins in queries

Negatives of simple 1NF:

- the loss of relation 1 row = 1 object

# *SQL:1999*

5 parts:

- SQL/Framework 75 pgs.
- SQL/Foundations 1100 pgs.
- SQL/CLI (Call Level Interface*) 400 pgs.
- SQL/PSM (Persistent Store Modules**) 160 pgs.
- SQL/Bindings 250 pgs.
  (SQL Embedded, Dynamic SQL, Direct invocation)

* alternative to SQL calling from application programs (implementations: ODBC, JDBC)

** procedural language for transactions managements

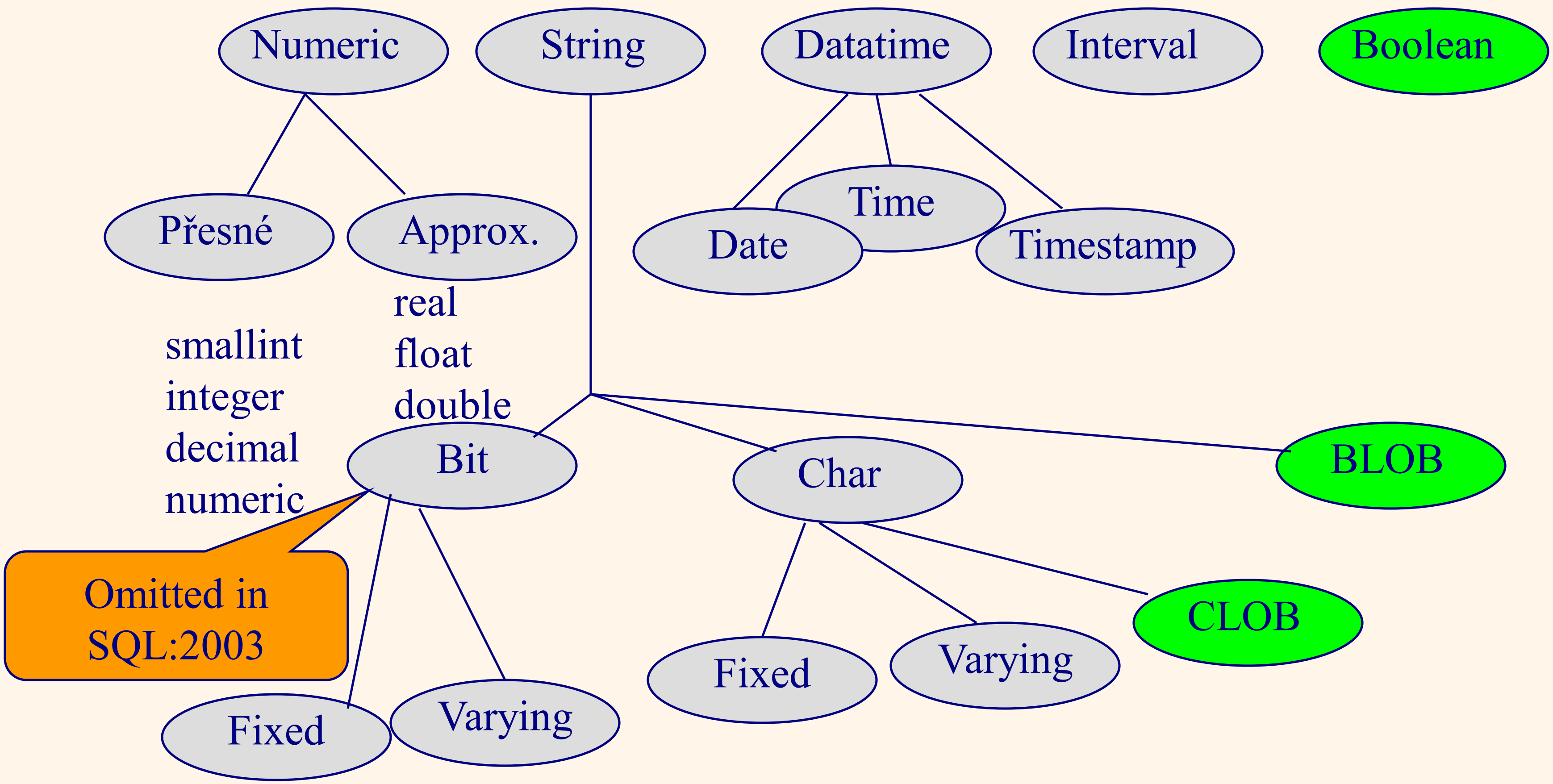
# *SQL:1999*

- object support
- stored procedures
- triggers
- recursive queries
- extension for OLAP
- procedural constructs
- expressions in ORDER BY
- save points
- updates and inserts using join operations

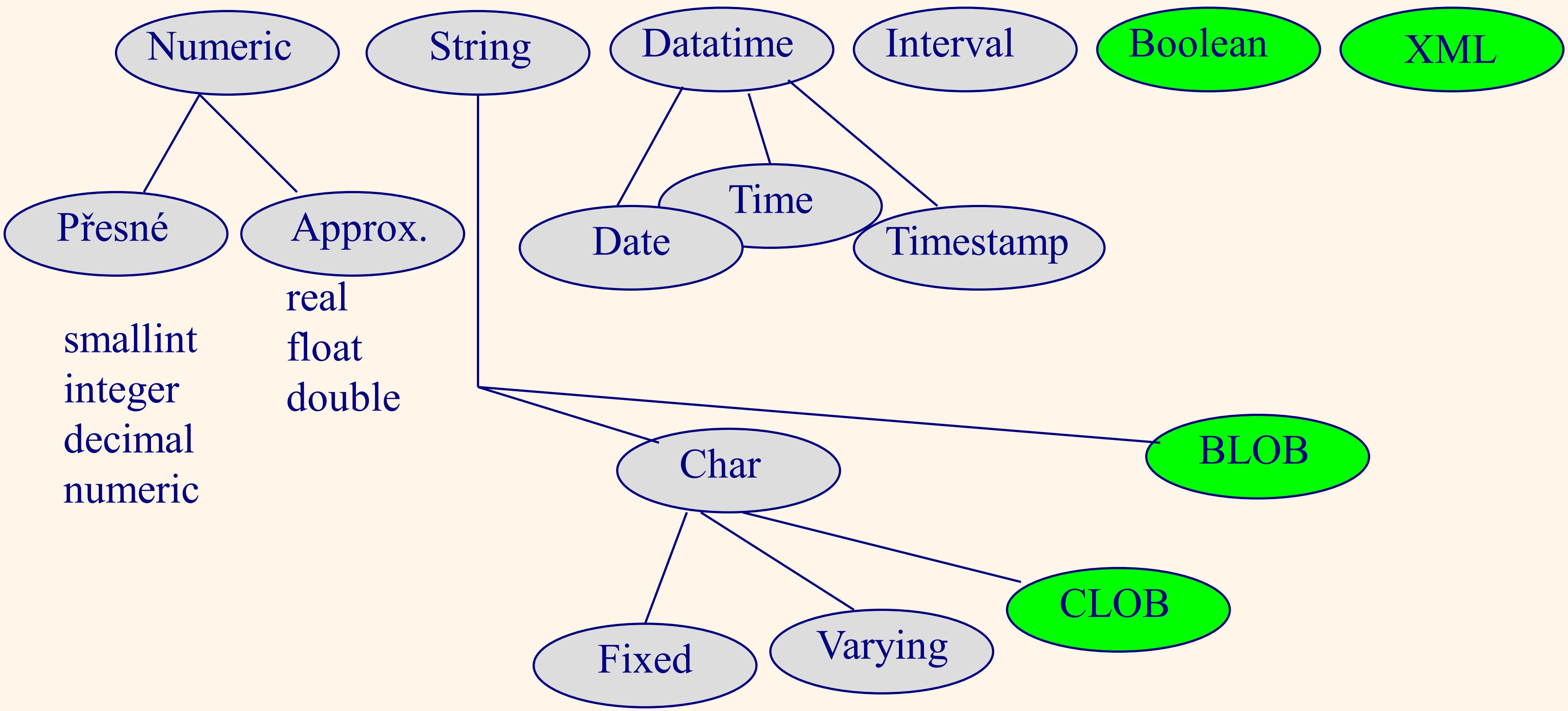
# *Objects: from SQL3 to SQL:1999*

- The original SQL3 used for object support:
  - user defined types (UDT): ADT, named row types and differentiate types,
  - type constructors for row types and references,
  - type constructors for collections (sets, list and multisets),
  - user defined functions (UDF) and procedures (UDP),
  - large objects (LOB).
- Standard SQL:1999 - subset of original concept

# Predefined types in SQL:1999



# Predefined types in SQL:2003



# Type Boolean

```
SELECT č_odd, EVERY(salary > 20000) AS all_rich,
    SOME(salary > 20000) AS some_rich
FROM emp
GROUP BY č_odd;
```

Result:

| č_odd | all_rich | some_rich |
|---|---|---|
| A35 | FALSE | FALSE |
| J48 | TRUE | TRUE |
| Z52 | FALSE | TRUE |

# Other types in SQL:1999

constructed atomic types:

– reference

constructed composite types:

– array /* subtype collection */
  ordered list with the maximum cardinality;
  arrays of arrays or multidimensional arrays are not allowed

– row

Note: originally considered more subtype collections (in implementation as well)

Note: there are new functions to types (BIT_LENGHT, POSITION, SUBSTRING, …)

# Array type

```
CREATE TABLE messages(
    ID          INTEGER
    authors     VARCHAR(15) ARRAY[20]
    title       VARCHAR(100)
    abstract    FULLTEXT
```

- accessing elements of array by subscript numbers, e.g. authors[3],
- function CARDINALITY, comparison =, <>, concatenation ||, CAST
- UNNEST,
- possibility WITH ORDINALITY (to generate the offset column corresponding to subscript numbers of the elements in array)

```
SELECT m.ID, a. name
FROM messages AS m, UNNEST(m.authors) as a(name)
```

# Other types in SQL:1999

UDT:

- distinct types (are formed by a single predefined type)
- structured types (can be defined with more attributes, which are of predefined types, type ARRAY, or of another structured type)
  - ADT
    - behavior is specified by functions, procedures and methods
    - ADTs can be organized into hierarchies with inheritance
  - named row types

# Distinct types

Principle: renaming (distinguishing) predefined types + different behavior

```
CREATE TYPE ROOM_TYPE
AS CHAR(10) FINAL;

CREATE TYPE METERS
AS INTEGER FINAL;

CREATE TYPE Q_METERS
AS INTEGER FINAL;

CREATE TABLE rooms(
m_id           ROOM_TYPE
m_lenght       METERS
m_width        METERS
m_perimeter    METERS
m_area         Q_METERS);
```

reports an error

```
UPDATE rooms
SET m_area = m_lenght
```

OK

```
UPDATE rooms
SET m_width = m_lenght
```

Attention: compare with the DOMAIN notion!

Note: weak semantics: addition operator is not defined on METERS (Q_METERS)

# Row type - unnamed

```
CREATE TABLE persons (
        name VARCHAR(20),
        address ROW(street          CHAR(30),
                    house_n         CHAR(6),
                    town            CHAR(20),
                    zip_code        CHAR(5)),
        birthdate DATE);

INSERT INTO persons
VALUES('J. Novák', ('Svojetická’, '2401/2', Praha 10,
   10000), 1948-04-23);

SELECT p.address.town
FROM persons p
```

# *Row type – named*

- Comparing to ADT, it is not encapsulated.

```
CREATE ROW TYPE account_t (
    account_n   INT,
    client      REF(client_t),
    type        CHAR(1),
    opened      DATE,
    interest    DOUBLE PRECISION,
    balance     DOUBLE PRECISION,
    );
CREATE TABLE accounts OF account_t
  (PRIMARY KEY account_n );
```

- statement is not a part of the SQL standard. There is, e.g., in DB/2.

# *Row type – named ADT*

really a class definition

- data structure (+ methods)
- suitable for entity modelling and their behavior

  Ex.: person, student, departure, …

```
CREATE TYPE employee_t AS(
empID          INTEGER
name           VARCHAR(20));
```

Use

**as a type column**

| movie | role | actor |
|---|---|---|
| Evita | servant | (23, Kepka) |
| … | … | ... |

**as a row type**

| id | empID | name |
|---|---|---|
| 23712 | 23 | Kepka |
| … | … | ... |

id reminds OID in OO

# Row type – named ADT

CREATE TABLE employees OF employee_t
(PRIMARY KEY empID);

What is actually the resulting table??

- Unary relation, whose tuples are objects with two components.
- IOs are a function of tables and not of types

# User defined procedures and functions

- programs called in SQL: procedures and functions
  - procedures have parameters of type IN, OUT, INOUT
  - functions have parameters only of type IN, they return a value
- programs construction:
  - head and body in SQL (either 1 SQL statement or BEGIN…END)
  - head in SQL, body externally defined

**in SQL/PSM**

- programs calling:
  - procedure: CALL name_of_procedure(p1,p2,…,pn)
  - function: functionally as f(x,y)
  - stored procedure: CALL statement from a client program, which is called under direction of a database manager.

In UDT methods will be added.

# User defined procedures and functions

**Ex.: DB2 UDB/OSF White Box ADT**

```
CREATE TYPE bod AS (
      x DOUBLE,
      y DOUBLE,
      );

CREATE FUNCTION distance(p1 BOD, p2 BOD) RETURNS INTEGER
LANGUAGE SQL INLINE NOT VARIANT
RETURN sqrt((p2..y-p1..y)*(p2..y-p1..y) + (p2..x-p1..x)*(p2..x-p1..x));

SELECT E.name
FROM emp E, town T
WHERE T.name = 'Ostrava'
          AND distance(E.residence, T.centre) < 25;
```

# *(User defined) methods*

- SQL:1999 adds methods.
- Differences in methods and functions:
  - methods are always tied to a type, functions do not,
  - the given data type is always the type of the first (undeclared) method argument,
  - methods are always stored in the same schema, in which the type, to which they are closed, is stored. Functions are not restricted to a specific schema.
  - functions and methods can be polymorphic, they differ in mechanism of choosing specific methods in run time,
  - signature and body of methods are specified separately,
  - methods calls (dot notation + arguments in brackets).

# ADT in SQL:1999

```
CREATE TYPE employee_t AS(
    empID           INTEGER
    name            CHAR(20),
    address         address_t,
    manager         employee_t,
    hire_date       DATE,
    basic_salary    DECIMAL(7,2),
    supplement      DECIMAL(7,2))
INSTANTIABLE
NOT FINAL
REF empID
METHOD worked_years() RETURNS INTEGER
METHOD salary() RETURNS DECIMAL);
```

```
CREATE METHOD
worked_years FOR
employee_t
BEGIN … END;

CREATE METHOD salary
FOR employee_t
BEGIN … END;
```

# ADT in SQL:1999

NOT FINAL … can have another subtype

in SQL:1999 structured types have to be NOT FINAL, distinct types have to be FINAL (in SQL:2003 released)

REF enables to understand data (rows) in tables of given type as objects. In the table definition, it is possible to name this „identification“ attribute.

# ADT in SQL:1999

Possibilities of specification:

- system-generated

  REF IS SYSTEM GENERATED

  or

  its values are „visible“

  REF IS PID SYSTEM GENERATED
- user-generated

  REF USING <predefined type>
- derived

  REF(<list of attributes>)

Here: reference with empID

# Subtypes

```
CREATE TYPE person_t AS(
    name                CHAR(20),
    address             address_t,
NOT FINAL
CREATE TYPE employee_t UNDER person_t(
    empID               INTEGER
    manager             employee_t,     /∗employee_t  is a
    hire_date           DATE,           subtype of person_t ∗/
    basic_salary        DECIMAL(7,2),
    supplement          DECIMAL(7,2))
NOT FINAL
REF empID
METHOD worked_years() RETURNS INTEGER
METHOD salary() RETURNS DECIMAL);
```

# Subtypes

subtypes

CREATE TYPE clerk_t UNDER employee_t …
CREATE TYPE worker_t UNDER employee_t …

- structured type can be a subtype of another ADT
- ADT inherits the structure (attributes) and behaviour (methods) of its supertypes
  - single inheritance is allowed (multiple one is postponed in SQL standard, some special cases, e.g., in ORACLE)
  - can define additional attributes and methods and can override inherited methods.
- substitutability: a value of subtype can occur in the place a given type

# Subtables

employee_t has to be a subtype of persons_t

- apparatus dependent the type apparatus

  CREATE TABLE persons OF person_t

  CREATE TABLE employees OF employee_t

  UNDER persons;

- inherits columns, IO, triggers, … of the given supertable

# Subtables

- consistence requirements for subtables and supertables
  - each tuples in supertable (e.g. persons) can correspond mostly to one tuple in subtables (e.g. employees and external_users)
  - tj. each entity has to have the most specified type
- selection limited to the X table using

  FROM ONLY (X)

  – otherwise also from the subtables of X.

# Access to the values of attributes

Each attribute has automatically methods generator and mutator

- values selection

SELECT e.name()
FROM employees e

application of the generator method

- update in 3 steps

SET newEmp = employee_t()
newEmp.empID('7897890')
newEmp.name('John')
INSERT INTO employees(newEmp)

generates a new instanci

# Reference and dereference

```
CREATE TYPE account_t AS (
    account_n       INT,
    client          REF(client_t),
    type            CHAR(1),
    opened          DATE,
    interest        DOUBLE PRECISION,
    balance         DOUBLE PRECISION,
    )
FINAL REF IS SYSTEM GENERATED;
CREATE TABLE accounts OF account_t
  (PRIMARY KEY account_n );
```

reference

table

accounts table has a special attribute similar to oid so called self-referencing column

# Reference and dereference

What happens when referenced object is removed:

- nothing – implicitly REFERENCES ARE NOT CHECKED
- possibility of an action, if REFERENCES ARE CHECKED ON DELETE (then SET DEFAULT, SET NULL, CASCADE, NO ACTION, RESTRICT)

Dereference

- possible only when location of objects of REF type is defined (one table in SQL:1999)

```
CREATE TABLE clients OF client_t;
CREATE TABLE accounts OF account_t
        (PRIMARY KEY account_n,
         client WITH OPTIONS SCOPE clients
        );
```

allocation

Note: reminds a referential integrity

dereference,

path

```
SELECT a.client -> name
FROM accounts a
WHERE a.client->address.town = "Suchdol“ AND a.balance > 100000;
```

# *Reference and dereference*

- dereference by a path and/or by function DEREF

compare

```
SELECT a.opened, a.client
FROM accounts a;
```

and

```
SELECT a.opened, DEREF(a.client)
FROM accounts a;
```

**DEREF returns a tuple**

# Reference and dereference

- benefits of using REF:
  - sharing objects
    - unnecessarily duplicated data
    - the change is done in one place
- link to a method:

```
SELECT a.client() -> name
FROM accounts a
WHERE a.client() -> salary() > 10000;
```

Note: methods without parameters do not require ()

# Beyond SQL:1999, 2003

```
CREATE TABLE employees
    (id INTEGER PRIMARY KEY,
    name VARCHAR(30),
    address ROW(    street CHAR(30),
                    house_n CHAR(6),
                    town CHAR(20),
                    zip_code CHAR(5)),
    projects INTEGER SET,
    children person,
    benefits MONEY MULTISET
```

collection

is in SQL:2003

# *Multisets*

| | |
|---|---|
| *nt1* MULTISET EXCEPT [DISTINCT] *nt2* | *nt1* - *nt2* |
| *nt1* MULTISET INTERSECT [DISTINCT] *nt2* | *nt1* ∩ *nt2* |
| *nt1* MULTISET UNION [DISTINCT] *nt2* | *nt1* ∪ *nt2* |
| CARDINALITY(*nt*) | \| *nt* \| |
| *nt* IS [NOT] EMPTY | |
| *nt* IS [NOT] A SET | |
| SET(*nt*) | remove duplicates z *nt* |
| *nt1* = *nt2* | equality of multisets |
| *nt1* IN ( *nt2*, *nt3*, ...) | to be in a list of multisets |
| *nt1* [NOT] SUBMULTISET OF *nt2* | comparison of multisets |
| *r* [NOT] MEMBER OF *nt* | *r* ∈ *nt*? |
| CAST(COLLECT(*col*)) | nested table based on *col* |
| POWERMULTISET(*nt*) | set of all non-empty subsets *nt* |
| POWERMULTISET_BY_CARDINALITY(*nt*,*c*) | set of all non-empty subsets *nt* with cardinality *c* |

Note:

- from SQL:2003: MULTISET without constraint cardinality
- ARRAY without specification of maximal cardinality – it is given by implementation

# O-R in commercial products

- INFORMIX: collection - set, multiset, list (without constraint length)
- Oracle from 8i version (since 1999):
  - instead of ADT -- object types
  - notation: CREATE TYPE … AS OBJECT(…);
  - collections
    - VARRAY (equivalent to ARRAY from SQL:1999), but it is not allowed DELETE element from an array
    - for a given array NESTED TABLE (unordered, unrestricted collection of elements)

      Note: multilevel nesting, e.g., in Oracle 11g

CREATE TYPE WhereEverywhere AS VARRAY(4) OF Address

# *O-R in commercial products*

– Id visibility

```
SELECT REF(p) INTO reftoperson
 FROM persons AS p
 WHERE p.name = ‘Novák, J.’
```

# O-R in commercial products

CREATE TYPE Cars AS TABLE OF Auto_t

CREATE TABLE COMPANIES (

fleet Cars

…)

NESTED TABLE fleet STORE AS cars;

Follow the position of ;

Note: You can specify where "subtables" Cars are to be stored.

```
SELECT *
FROM COMPANIES AS c, c.fleet AS f
WHERE 'Buick' IN (SELECT f.car_brand FROM f);
```

# *O-R in commercial products*

Queries a nested table:

- using THE
- can be treated similarly as with other relations

```
SELECT vp.licence_plate
FROM THE (
   SELECT fleet FROM COMPANIES
   WHERE c_name= ‘Komix’)
) vp
WHERE f.car_brand=‘Buick’;
```

D.: Find license plates of all Buicks owned by the Komix company.

# O-R in commercial products

- Methods in ORACLE
  - specification in CREATE TYPE with MEMBER FUNCTION, MEMBER PROCEDURE
  - body in the statement CREATE TYPE BODY
- Access:

```
SELECT a.client.name
FROM accounts a
WHERE a.client.salary > 10000;
```

# *Problems with OO in SQL*

- tables are the only named entities
- REF type is applicable only on objects given by a row
- UDT is the first step to OO
  - to enable persistency, the object has to be in a table,
  - it is not possible to assign a name to individual instance,
  - it is not possible to query for all instances of an ADT

# *OR DB design : Transformation E-R → OR*

- 1. phase: types
  - entity types → structured types
  - composite attributes → named row types, unnamed row types in structured type, also a structured type is possible
  - multivalued attributes → array of typed values (estimation of max is somewhere important)
  - derived attributes → add a method into the structured type definit

removed in SQL:2003 with SET as well as ARRAY

# *OR DB design : Transformation E-R → OR*

- relationship types – both single- or bidirectional
  - N:1 → with REF + array of typed values (if bidirectional)
  - M:N → with one or two arays containing typed values (if single or bidirectional).
- ISA hierarchies → hierarchies of types

• 2. phase: typed tables

# Conclusions

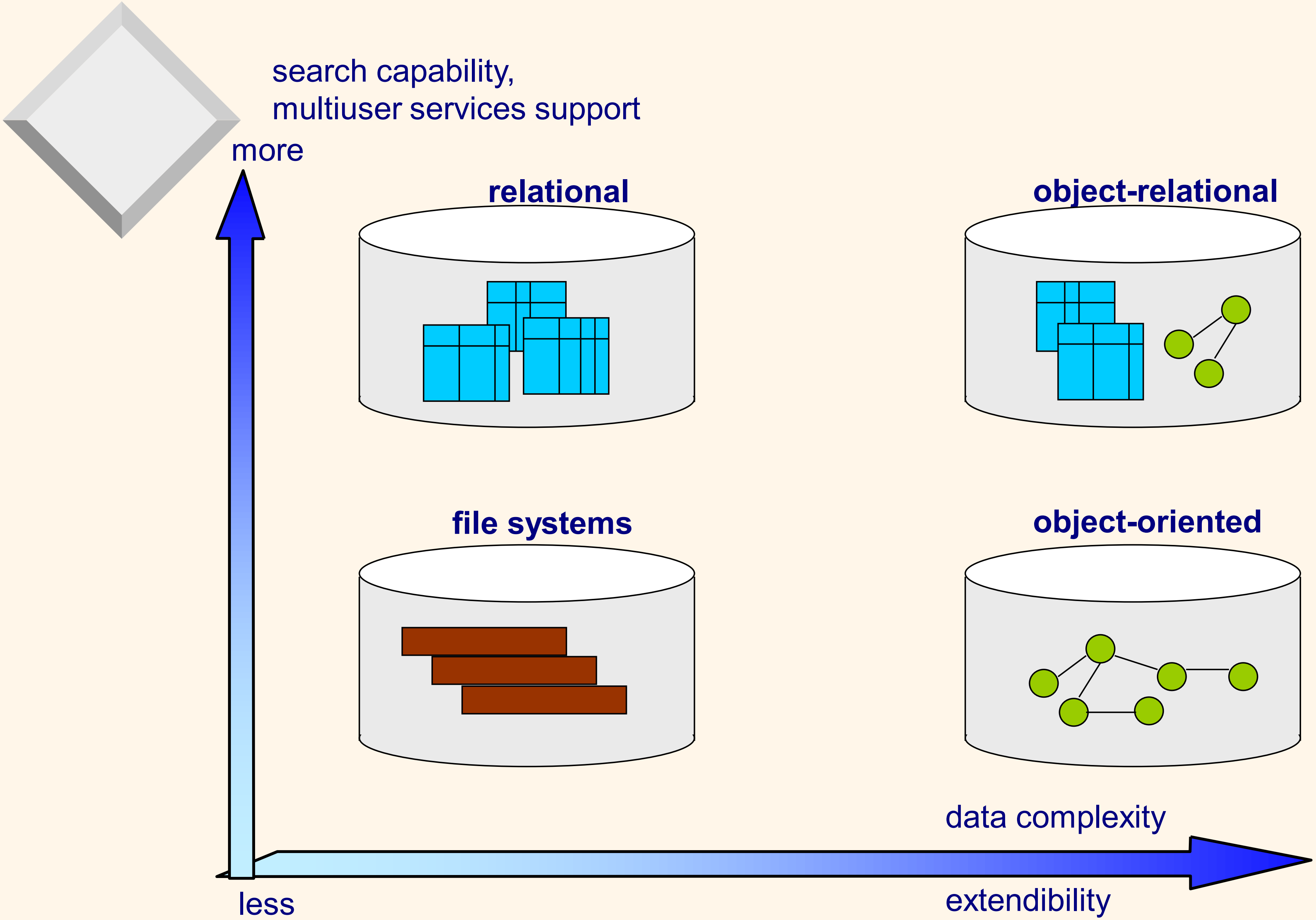
- Actual implementations of ORDBMS:
  - complaints:

    OODBMS - not database enough

    ORDBMS - not object-oriented enough

    lack of development tools, new methodologies

    the biggest problem, but also the biggest advantage: universality
- Development goes on: XML DB, NoSQL DB, Web, cloud, NewSQL, …, more generally: non-relational, distributed, open-source and horizontally scalable




## The world of DB technologies at the end of the 1st millennium

# Conclusions

?

| technologies | 70s | 80s | 90s | 2000-10 | 2010+ |
|---|---|---|---|---|---|
| research | relational | OO,OR | XML | NoSQL | NewSQL |
| commerce | hierarchical, network | relational | OO,OR | XML | NoSQL |
| inherited | | hierarchical, network | relational | OO,OR | XML |

Lessons learned from history