CHAPTER 1 FUNDAMENTAL CONCEPTS

Database: collection of interrelated date which represents some aspects of the UoD, is logically coherent and has an intended group of users and applications

Database Management System (DBMS): a collection of programs that enables us to create and maintain a database. General purpose software system that facilitates the process of defining, constructing and manipulating databases for various applications

Database system: combination of a DBMS and a database

FILE BASED APPROACH TO DATAMANGEMENT

- Duplicate storage → waste of memory space
- Redundant data
- Inconsistent data (data changes in only one data source)
- Dependency between applications and data (changes in data definitions → changes in all apps)
- Difficult to integrate with various applications (EAI)

DATABASE-ORIENTED APPROACH TO DATA MANAGEMENT

- Self-describing nature of the DB system (catalog)
- Insulation between programs and data, data independence
- Support for multiple views of the data
- Sharing data and multi-user transaction processing (→ concurrency control to prevent inconsistencies)

ELEMENTS OF A DATABASE SYSTEM

- Data model
    - Collection of concepts that can be used to describe the structure of a DB (data types, relationships, constraints, …)
    - Conceptual data model (high-level concepts, EER and UML)
    - Implementation data model (relational model
    - Physical data model (low-level concepts that describe data storage details, query's)
- Schemas and instances
    - **Database schema**: description of a DB, which is specified during DB design and is not expected to change too frequently = model
    - **Database state**: the data in the DB at a particular moment, current set of instances
- Data dictionary (catalog)
    - Contains definitions of: conceptual schema, external views, physical schema
- DBMS languages
    - **DDL**: used by DBA to define DB's conceptual, internal and external schemas
    - **DML**: used to retrieve, insert, delete and modify data; can be entered interactively (terminal) or embedded (general-purpose programming language)
    - Relational DBS: SQL is DDL & DML and interactive SQL & embedded SQL

ADVANTAGES OF USING THE DBMS APPROACH

- Data and functional independence
- DB modeling
    - Should provide a formal and perfect mapping of the real world (e.g. EER, relational, etc.)
- Managing data redundancy
    - Compared to file base approach
    - Data redundancy may be desired (performance)
    - → DBMS guarantees synchronization and consistency of redundant data
- Specifying integrity rules
    - Determine syntactical (not numeric) and semantical (not unique) correctness of data
    - Specified as part of the conceptual schema (in catalog)
    - Integrity rules are checked during data loading and data manipulation
    - Also concurrency control
- Data security
    - Read/write access
    - User accounts and passwords
    - Account authorizations are stored in catalog
    - E-business and CRM stress the importance of data security
- Backup and recovery facilities
    - Backups perform full or incremental backups
    - Recovery facilities allow to restore data after loss or damage
- Performance utilities
    - Part of the job of the DBA
    - Examples: optimizing buffer management, index tuning to optimize indices and queries, detecting and solving I/O problems, etc.

WHEN NOT TO USE A DMBS

There are situations in which a DBMS may involve unnecessary overhead costs that would not be incurred in traditional file processing

- High initial investment in hardware, software and training
- The generality that a DBMS provides for defining and processing data
- Overhead for providing security, concurrency control, recovery and integrity functions

It may be more desirable to use regular files under the following circumstances:

- Simple, well-defined DB applications that are not expected to change at all
- Stringent, real-time requirements for some application programs that may not be met because of DBMS overhead
- Embedded systems with limited storage capacity, where a general-purpose DBMS would not fit
- No multiple-user access to data

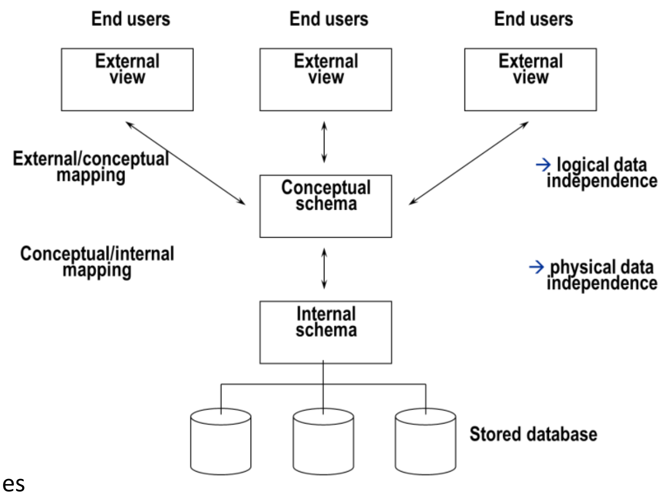
THREE-SCHEMA ARCHITECTURE

Goal: separate the user applications from the physical DB.

1) The internal level has an **internal schema**
→ describes physical storage of the DB, details of data storage and access paths

2) The conceptual level has a **conceptual schema**
→ describes the structure of the whole DB, hides the details of physical storage structures and concentrates on describing entities, data types, relationships, user operations and constraints

3) The external view level has **external schemas / views**
→ describes part of the DB that a user is interested in and hides the rest of the DB



The 3 schemas are only *descriptions* of data; the stored data that *actually* exists is at the physical level only.

DATA INDEPENDENCE

The capacity to change the schema at one level of a DB without having to change the schema at the next higher level.

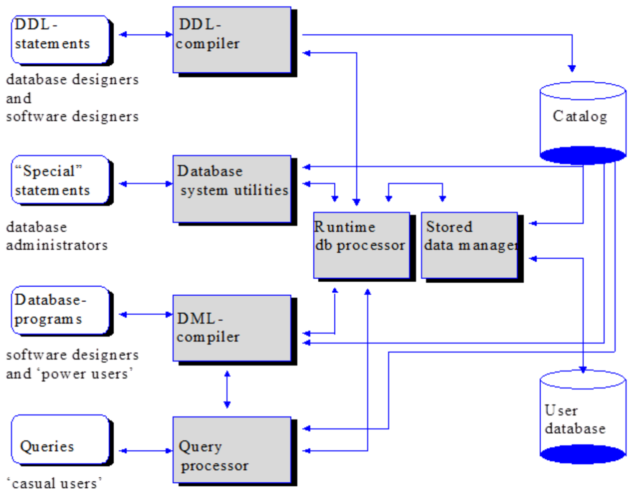
Logical data independence: capacity to change the conceptual schema without having to change external schemas or application programs. After the conceptual schema undergoes a logical reorganization, application programs that reference the external schema must work as before.
Physical data independence: capacity to change the internal schema without having to change the conceptual schema and thus neither the external schema.

Generally, physical data independence exist is most DBs and file environments. Logical data independence is harder to achieve because it allows structural and constraint changes without affecting application programs, a much stricter environment.
The three-schema architecture can make it easier to achieve true data independence, both physical and logical. But the 2 levels of mappings can create an overhead during compilation or execution of a query or program, leading to inefficiencies in the DBMS → few DBMSs have implemented the full three-architecture schema arch.

Functional independence: implementation (method) can change without impact on software applications
E.g. calculate salary → changes in the method won't affect other programs.

CHAPTER 2 ARCHITECTURE AND CLASSIFICATION OF DBMSS

INTERNAL ARCHITECTURE OF A DBMS



- DDL compiler
    - Ideally 3 DDLs
    - Only 1 with 3 independent set of instructions
    - Translates DDL definitions, checks syntax, generates errors and when successful register data definitions as meta data in the catalog
    - Loading utility: data in user DB
- DML compiler
    - Sublanguage needed to access and manipulate the dada (eg embedded SQL)
    - DB programs are offered 1st to DML precompiler
    - DML precompiler extract DML statements and gives them to DML compiler to compile them to objectcode
    - Catalog is inspected to see whether data are available in the DB
    - Data is retrieved depending on type of DML
    - **Procedural DML**: record-at-a-time DML, DML statements specify how to navigate in DB to locate and find the data
    - **Declarative DML**: set-at-a-time DML (eg SQL), DML statements determine which data should be retrieved and DBMS autonomically determines access path and navigational strategy itself
- Query processor
    - Query language is high-abstraction DML to interactively consult data
    - Checks if data are available in DB via catalog, rearranges and optimizes query, consults the catalog for data statistics and indices, determines the "best" access path to data which will be offered as executable code to the runtime DB processor
- Runtime DB processor
    - Receives DB assignments and supervised their execution
    - Guarantees data integrity
    - Coordinates communication of results to users and applications, generate error message
- Stored data manager
    - Controls access to data in catalog and user DB
    - Communicates with transaction manager, buffer manager and recovery manager
- DB system utilities
    - Loading utility, Back-up and recovery utilities, transaction manager, reorganization utilities, performance monitoring, sorting, user monitoring, data compression

Impedance mismatch: data structures of DBMS and data sublanguage may be different than data structures of host language → eg relations DBMS vs OO host language → solution: OODMBS (persistent language) or object relational mapping frameworks (middleware)

CLASSIFICATION BASED ON DATA MODEL

- Hierarchical DBMS
  - Procedural DML (record-at-a-time)
  - Definitions of conceptual and physical schema intertwined
  - IMS (IBM)
- Network DBMS
  - Network data model, CODASYL DBMS
  - Procedural DML (record-at-a-time)
  - Definitions of conceptual and physical schema intertwined
  - CA-IDMS (Computer Associates)
- Relational DBMS
  - Relational data model, usually based on SQL (DDL +DML)
  - Declarative DML (set-at-a-time)
  - Data independence (logical and physical)
  - Universal DB2 v10 (IBM), Oracle 11g r2 (Oracle), SQLServer 2008 r2 (MS)
- Object oriented DBMS
  - Object oriented data model, objects with states and behavior
  - No separate Object Manipulation Language (operations are imbedded in object)
  - No impedance mismatch
  - ODMG defined standard OO model with ODL, OQL and bindings
  - Difficult to use, not so popular
  - Gemstone (Gemstone Corporation)
- Object relational DBMS
  - Extended relational model with OO concepts
  - SQL3 (SQL 99)
  - User-defined types and functions, collections, inheritance, behavior, etc.
- Mainframe DB computing
  - Host based computing, all processing (UI, applications, DB) occurs on mainframe
  - Terminals receive data from end-users and show results
  - Monolithic architecture, no architecturally separate components but all interwoven
- PC/Fileserver DB computing
  - DBMS is installed on PC, all processing on PC (UI, applications, DB)
  - DB is stored on a fileserver
  - High network load, many replications, high maintenance and possible low performance
- Client/Server DB computing
  - Clients are active and request services, servers are passive and respond to client requests
  - Multiple clients per server
  - Fat-client variant: UI logic and application logic is stored on client, DB logic and DBMS is stored on server → transparent communication using middleware
  - Fat-server variant: application logic, DB logic and DBMS stored on server, usage of stored procedures
  - Hybrid variants

CLASSIFICATION BASED ON ARCHITECTURE

- N-tier DB computing
    - Application logic on application server, middleware takes care of communication between different components
    - Possible multiple application and DB servers

CLASSIFICATION BASED ON SIMULTANEOUS ACCESS

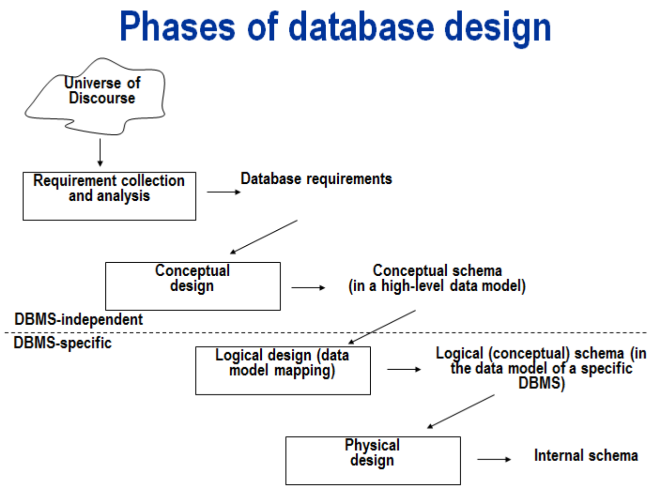
- Single versus multi user systems (needed in a distributed environment)
- DBMS should support multi-threading and/or multiprocessing

CLASSIFICATION BASED ON USAGE

- **OLTP** (OnLine Transaction Protocal) vs **OLAP** (OnLine Analytical Processing)
    - OLTP: manage operational data, DB must be able to process many simple transactions per unit of time, the transactions are initiated in real-time, simultaneously and by many users and applications
      → detailed, current data in normalized data model
    - OLAP: use operational data for tactical and strategical decision making, limited users, complex queries, huge amount of data
      → aggregated, historical data in star schema
- **Native XML**, **enabled XML**, **multimedia DBMS**
    - Native XML DBMS: uses logical, intrinsic structure of XML document and maps its hierarchical structure to a physical storage structure
    - Enabled XML DBMS: existing DBMS with facilities to store semi-structured data (XML) and structured data (relational data) in an integrated and transparent way
    - Multimedia DBMS: 2D or 3D data, images, video, audio, RFID, etc. (YT, Flickr, GMaps)
- **Open source DBMS** (MySQL)
- **Distributed**, **federated** and **mobile DBMS**
    - Distributed DBMS: data distributed across multiple computer in a network
    - Federated DBMS: uniform interface for retrieving data from various sources: DBMS, file system, document management system (IBM DB2 Information Integrator)
    - Mobile DBMS: replicating data to mobile devices from a central source, synchronization is important
- **DBMS for grid computing and embedded applications**
    - Grid computing: sharing geographically dispersed resources in a transparent way and create a big virtual computer
    - Embedded applications: in eg phones and PDAs, “light DB” with fast performance, no black out, no maintenance, carefree, specific interfaces, etc.

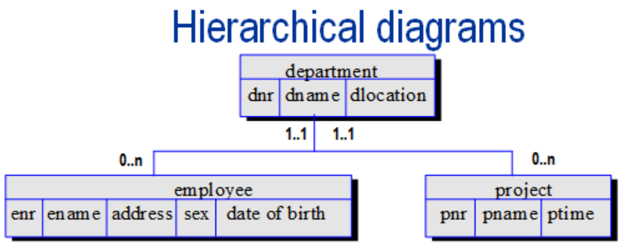
Concepts of data modeling:

- Conceptual schema to capture the specifications of the data and constraints that have to be represented in the DB
- Conceptual data modeling: capture the semantics of the UoD as accurately as possible
- → requires a high-level model that is not implantation specific (eg EER)



THE HIERARCHICAL MODEL

- Parent record type and child record type
- Relationship type can only be 1:N (i.e. 1…1 to 0…N)
- Parents can be multiple parents
- A child only has 1 parent
- A child can be also be a parent (→ hierarchy)

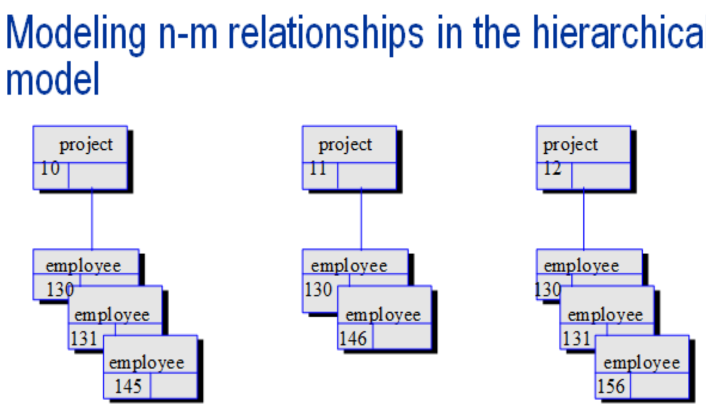


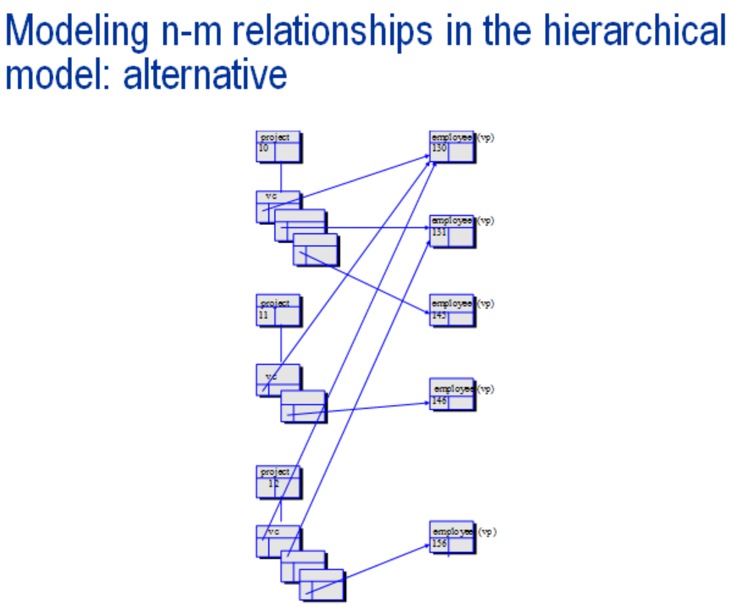
Structural limitations:

- Procedural DML: record data needs to be retrieved by navigating from the rood node
- No straightforward way to model N:M and 1:1 relationships
- Only relationships of degree 2, recursive relationships (=degree 1) are created via VCs
- Maximum and minimum cardinality from child to parent is 1 → cascading effect upon deletion

Modeling N:M relationships:

- Transforms a network structure to tree structure
- Creates redundancy
- Puts relationship type attributes in child record
- Alternative: create 2 hierarchical structure and connect them with a VC
  → no more redundancy and relationship attributes are in VC





THE RELATIONAL MODEL

FUNCTIONAL DEPENDENCY X → Y

- For any two tuples t1 and t2 in *r* that have t1[X] = t2[X], we must also have t1[Y] = t2[Y]
- The values of the Y components of a tuple in *r* depend on and are determined by the values of the X component
- The values of the X component of a tuple uniquely (or functionally) determine the values of the Y component
- If X → Y, this does not mean that Y → X
- If X is a candidate key of R this implies that X → Y for any subset of attributes Y in R
- Example: SSN → ENAME
    - ENAME → SSN does not hold since multiple employees can have the same name
- Example: PNUMBER → {PNAME, PLOCATION}
- Example: {SSN, PNUMBER} → HOURS

Full functional dependency: removal of any attribute from X means that dependency does not hold anymore
<u>SSN, PNUMBER</u> → HOURS
Partial dependency: attributes of X can be removed and the dependency still holds
<u>SSN, PNUMBER</u> → PNAME
Transitive dependency: there is a set of attributes (Z) that is neither a candidate key nor a subset of any key and bot X → Z and Z → Y holds
<u>SSN</u>, ENAME, DNUMBER, DNAME, DMGRSSN: SSN → DNUMBER and DNUMBER → DNAME, DMGRSSN

THE NORMALISATION PROCESS

- Process of analysing the given relation schemas based on their FDs and candidate keys to achieve the desirable properties of
    - (1) minimising redundancy
    - (2) minimising the insertion, deletion and update anomalies
- Relation schemas are decomposed into smaller relation schemas
- Sometimes controlled denormalisation is acceptable for performance purposes

FIRST NORMAL FORM (1NF)

- Attributes must be
    - Atomic (no composite)
    - Single-value (no multi-values)
- Remove multi-value attributes and place it in a separate relation together with the primary key of the original relation, the primary key of the new relation is the combination of the attribute and primary key of the original relation
- Remove nested, composite relation attributes into a new relation and propagate the primary key into it, the primary key of the new relation is the combination of the partial key of the nested relation with the primary key of the original relation

(<u>DNUMBER</u>, DLOCATION, DMGRSSN) → (<u>DNUMBER</u>, DMGRSSN) and (<u>DNUMBER, DLOCATION</u>)

(<u>SSN</u>, ENAME, DNUMBER, DNAME, PROJECT(<u>PNUMBER</u>, PNAME, HOURS)
→ (<u>SSN</u>, ENAME, DNUMBER, DNAME) and (<u>SSN, PNUMBER</u>, PNAME, HOURS)

SECOND NORMAL FORM (2NF)

- Satisfies 1NF and every nonprime attribute A in R is fully functional dependent on any key of R
- Decompose and set up a new relation for each partial key with its dependent attribute(s)

(SSN, PNUMBER, PNAME, HOURS) → (SSN, PNUMBER, HOURS) and (PNUMBER, PNAME)

THIRD NORMAL FORM (3NF)

- Satisfies 2NF and no nonprime attribute of R is transitively dependent on the primary key
- Decompose and set up a relation that includes the nonprime attribute(s) that functionally determines other nonprime attributes

(SSN, ENAME, DNUMBER, DNAME, DMGRSSN)
→ (SSN, ENAME, DNUMBER) and (DNUMBER, DNAME, DMGRSSN)

BOYCE-CODD NORMAL FORM (BCNF)

- Stricter than 3NF (every BCNF is 3NF but not every 3NF is BCNF)
- *Trivial functional dependency*: X → Y and Y is a subset of X
- For every non-trivial functional dependency X → Y, X is a superkey

Supplier (SNR, SNAME, PRODNR, QUANTITY)
- superkey {SNR, PRODNR}: SNR → SNAME
  → (SNR, SNAME) and (SNR, PRODNR, QUANTITY)
- superkey {SNAME, PRODNR}: SNAME → SNR
  → (SNAME, SNR) and (SNAME,PRODNR, QUANTITY)

FOURTH NORMAL FORM (4NF)

- *Multi-valued dependency*: X→→Y if each X value exactly determines a set of Y values, independently of the other attributes
- Satisfies BCNF and for every one of its non-trivial multivalued dependencies X→→Y, X is a superkey

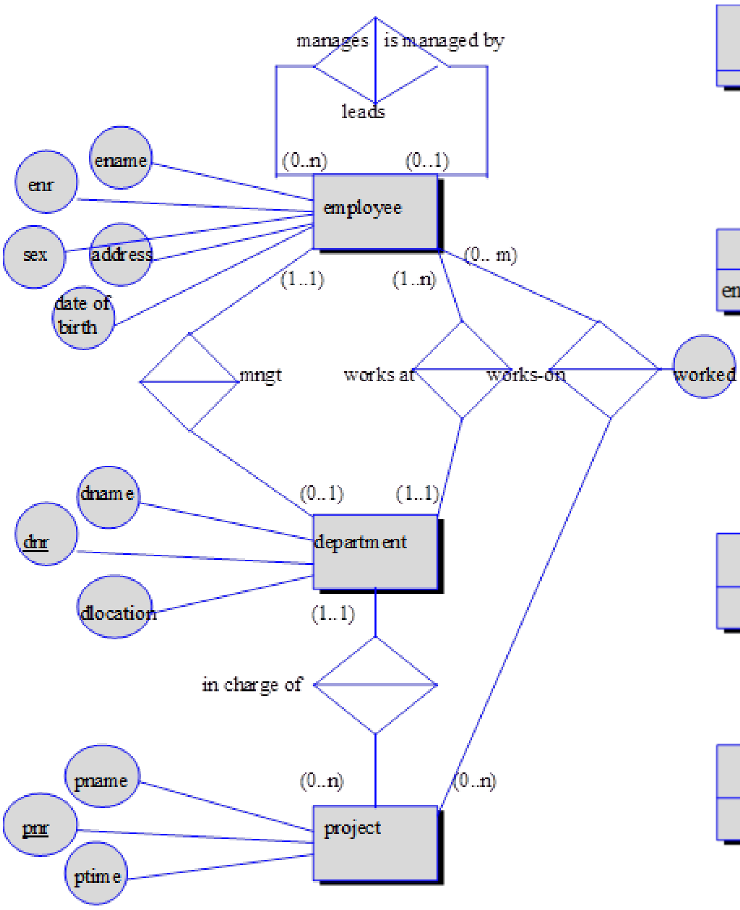
(COURSE, INSTRUCTOR, TEXTBOOK) → (COURSE, TEXTBOOK) and (COURSE, INSTRUCTOR)

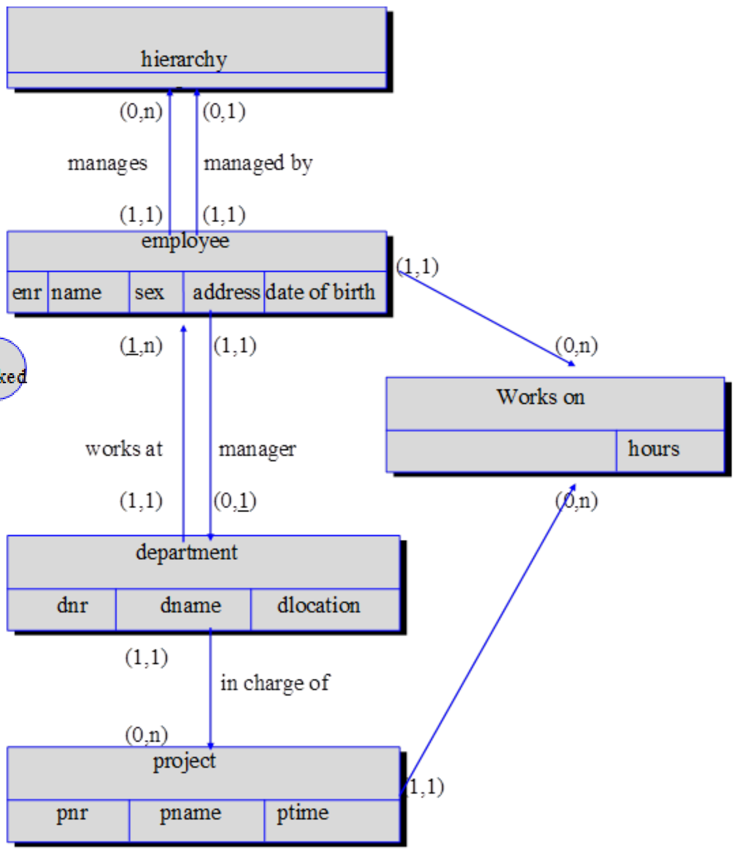
CHAPTER 4 DATABASE DESIGN

- Conceptual design: (E)ER or object-oriented modelling (UML)
- Logical design:
  - Mapping (E)ER conceptual scheme to a CODASYL or relational DB scheme
  - Mapping object-oriented conceptual scheme (UML) to a relational DB scheme
  - Mapping object-oriented conceptual scheme to an object-oriented DB scheme
- Physical design: actual implementation

EER TO CODASYL

- Create record type for every entity type (composite and multivalued attributes supported)
- Create separate record for weak entity types as a member record of the owner record on which it is existence dependent
- Create a set type for every 1:N binary relationship type
- Create a set type for every 1:1 binary relationship type
  - Owner and member defined arbitrarily or via ED
  - → Cannot enforce maximum cardinality of 1 → loss of semantics → application code
- Create dummy record type for every binary N:M relationship type
  - Dummy record type defined as member in 2 set types
  - Dummy record type contains attributes of relationship type
- Create dummy record type for every recursive relationship type
  - Dummy record type becomes member in 3 set types
- Superclass/subclass relationship difficult
  - Create record type for superclass as owner in set types with subclasses as members
    → Cannot guarantee that each set contains exactly 1 member
    → Cannot indicate type of specialization (partial/complete, overlap/disjoint)
  - One record type that contains data from superclass and all the subclasses
    → Lots of empty data fields





ER TO RELATIONAL

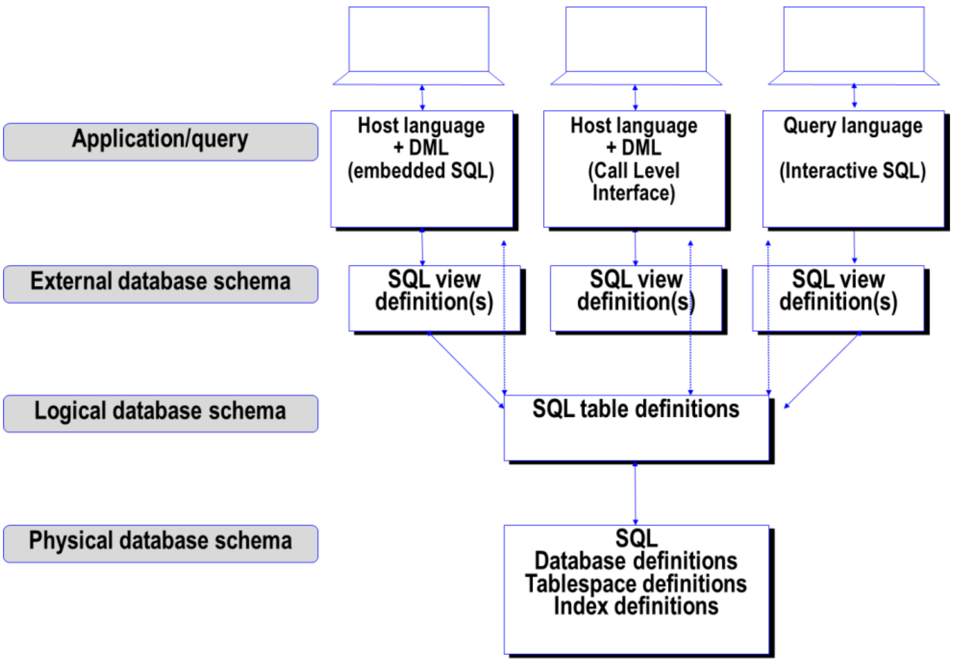
Example in slides (heel duidelijk)

ER Model	**Relational Model**
Entity type	"Entity" relation
1:1 or 1:N relationship type	Foreign key
M:N relationship type	"Relationship" relation and two foreign keys
n-ary relationship type	"Relationship" relation and n foreign keys
Simple attribute	Attribute
Composite attribute	Set of simple component attributes
Multivalued attribute	Relation and foreign key
Value set	Domain
Key attribute	Primary (or secondary) key

CHAPTER 5 DATA LANGUAGES IN A RELATIONAL ENVIRONMENT

RELATIONAL DATABASE SYSTEMS

- RDBMSs are databases which implement the relational model
- SQL is used for both data definition, data retrieval and data updating (DDL + DML)
    - SQL is *set-oriented*: retrieve many records at a time
    - SQL is *declarative*: only needs to specify *which* data to retrieve
      ←→ procedural: declare *how* to retrieve the data (access paths)
- SQL versions
    - SQL 1 (1986, "ANS! SQL")
    - SQL 2 (1992)
    - SQL 3 (1999, object-relational extensions)
- Use of SQL
    - Standalone → interactive SQL (Access)
    - Embedded in a host language → embedded SQL (JAVA)
- SQL as DDL
    - Logical schema: "create table"
    - Physical schema: "create database", "create tablespace" and "create index"
    - External schema: "create view"
- SQL as DML
    - Select … from … where …
    - Insert … into …
    - Update … where …
    - Delete where …
- SQL can also be used to specify security etc.



CREATING DATABASE OBJECTS: SQL DATA DEFINITION STATEMENTS

→ Creating schemas, tables, views, indexes
→ Dropping schemas and tables, altering tables
→ Referential triggered action clauses

SQL SCHEMA

- = a grouping of tables and other constructs (constraints, views, …) that logically belong together
- Identified by a *schema name* and includes an *authorization identifier* to indicate the user or account who owns the schema (full access, add, modify, …)

CREATE SCHEMA COMPANY **AUTHORIZATION** JSMITH;

TABLE

CREATE TABLE EMPLOYEE …   or   **CREATE TABLE** COMPANY.EMPLOYEE…

- Data types:
    - Numeric: INT, SMALLINT, FLOAT, REAL
    - Character-string: CHAR(n), VARCHAR(n)
    - DATE (format: YYYY-MM-DD), TIME (format: HH:MM:SS)
- Constraints:
    - NOT NULL
    - DEFAULT <value>
    - PRIMARY KEY
    - UNIQUE
    - FOREIGN KEY
    - CHECK
- Primary key by default unique

```
(a)
CREATE TABLE EMPLOYEE
     ( FNAME          VARCHAR(15)      NOT NULL ,
       MINIT          CHAR ,
       LNAME          VARCHAR(15)      NOT NULL ,
       SSN            CHAR(9)          NOT NULL ,
       BDATE          DATE ,
       ADDRESS        VARCHAR(30) ,
       SEX            CHAR ,
       SALARY         DECIMAL(10,2) ,
       SUPERSSN       CHAR(9) ,
       DNO            INT              NOT NULL ,
   PRIMARY KEY (SSN) ,
   FOREIGN KEY (SUPERSSN) REFERENCES EMPLOYEE(SSN) ,
   FOREIGN KEY (DNO) REFERENCES DEPARTMENT(DNUMBER) ) ;
CREATE TABLE DEPARTMENT
     ( DNAME          VARCHAR(15)      NOT NULL ,
       DNUMBER        INT              NOT NULL ,
       MGRSSN         CHAR(9)          NOT NULL ,
       MGRSTARTDATE   DATE ,
     PRIMARY KEY (DNUMBER) ,
     UNIQUE (DNAME) ,
     FOREIGN KEY (MGRSSN) REFERENCES EMPLOYEE(SSN) ) ;
CREATE TABLE DEPT_LOCATIONS
     ( DNUMBER        INT              NOT NULL ,
       DLOCATION      VARCHAR(15)      NOT NULL ,
     PRIMARY KEY (DNUMBER, DLOCATION) ,
     FOREIGN KEY (DNUMBER) REFERENCES DEPARTMENT(DNUMBER) ) ;
CREATE TABLE PROJECT
     ( PNAME          VARCHAR(15)      NOT NULL ,
       PNUMBER        INT              NOT NULL ,
       PLOCATION      VARCHAR(15) ,
       DNUM           INT              NOT NULL ,
     PRIMARY KEY (PNUMBER) ,
     UNIQUE (PNAME) ,
     FOREIGN KEY (DNUM) REFERENCES DEPARTMENT(DNUMBER) ) ;
CREATE TABLE WORKS_ON
     ( ESSN           CHAR(9)          NOT NULL ,
       PNO            INT              NOT NULL ,
       HOURS          DECIMAL(3,1)     NOT NULL ,
     PRIMARY KEY (ESSN, PNO) ,
     FOREIGN KEY (ESSN) REFERENCES EMPLOYEE(SSN) ,
     FOREIGN KEY (PNO) REFERENCES PROJECT(PNUMBER) ) ;
CREATE TABLE DEPENDENT
     ( ESSN             CHAR(9)        NOT NULL ,
       DEPENDENT_NAME   VARCHAR(15)    NOT NULL ,
       SEX              CHAR ,
       BDATE            DATE ,
       RELATIONSHIP     VARCHAR(8) ,
         PRIMARY KEY (ESSN, DEPENDENT_NAME) ,
         FOREIGN KEY (ESSN) REFERENCES EMPLOYEE(SSN) ) ;
```

DROP SCHEMA AND DROP TABLE COMMANDS

DROP SCHEMA COMPANY **CASCADE**
→ automatically drop objects (tables, functions, etc.) that are contained in the schema

DROP SCHEMA COMPANY **RESTRICT**
→ refuse to drop the schema if it contains any objects → this is the *default*

DROP TABLE EMPLOYEE **CASCADE**
→ automatically drop objects that depend on the table (such as views, other tables)

DROP TABLE EMPLOYEE **RESTRICT**
→ refuse to drop the table if any objects depend on it → this is the *default*

ALTER TABLE COMMAND

Purpose: adding or dropping a column, changing a column definition or adding/dropping table constraints

ALTER TABLE EMPLOYEE **ADD** JOB VARCHAR(12)
ALTER TABLE EMPLOYEE **DROP** ADRESS **CASCADE**
ALTER TABLE DEPARTMENT **ALTER** MGRSSN **DROP DEFAULT**
ALTER TABLE DEPARTMENT **ALTER** MGRSSN **SET DEFAULT** "333444555"
ALTER TABLE EMPLOYEE **DROP CONSTRAINT** EMPSUPERFK **CASCADE**

REFERENTIAL TRIGGERED ACTION CLAUSES

Attaching referential triggered action clause (*set null*, *cascade*, *set default*, *restrict*) to a foreign key constraint:
→ Specifies actions to be taken if a referential integrity constraint is violated upon deletion of a referenced tuple (*on delete*) or upon modification of a referenced primary key value (*on update*)

ON UPDATE CASCADE: changes in the primary key of DEPARTMENT will automatically change the foreign key
ON UPDATE DELETE: if DEPARTMENT is deleted → all employees working there will also be deleted

```
CREATE TABLE EMPLOYEE
    ( . . . ,
      DNO            INT    NOT NULL    DEFAULT 1,
    CONSTRAINT EMPPK
      PRIMARY KEY (SSN) ,
    CONSTRAINT EMPSUPERFK
      FOREIGN KEY (SUPERSSN) REFERENCES EMPLOYEE(SSN)
                  ON DELETE SET NULL    ON UPDATE CASCADE ,
    CONSTRAINT EMPDEPTFK
      FOREIGN KEY (DNO) REFERENCES DEPARTMENT(DNUMBER)
                  ON DELETE SET DEFAULT    ON UPDATE CASCADE );

CREATE TABLE DEPARTMENT
    ( . . . ,
      MGRSSN   CHAR(9)  NOT NULL DEFAULT '888665555',
      . . . ,
      CONSTRAINT DEPTPK
        PRIMARY KEY (DNUMBER) ,
      CONSTRAINT DEPTSK
        UNIQUE (DNAME),
      CONSTRAINT DEPTMGRFK
        FOREIGN KEY (MGRSSN) REFERENCES EMPLOYEE(SSN)
            ON DELETE SET DEFAULT    ON UPDATE CASCADE );

CREATE TABLE DEPT_LOCATIONS
    ( . . . ,
      PRIMARY KEY (DNUMBER, DLOCATION),
      FOREIGN KEY (DNUMBER) REFERENCES DEPARTMENT(DNUMBER)
        ON DELETE CASCADE    ON UPDATE CASCADE );
```

CONSULTING AND UPDATING DAT WITH SQL: INTERACTIVE SQL

SELECT-FROM-WHERE syntax, joined tables, prefixing and aliasing

- → DISTINCT keyword
- → Substring comparison, arithmetic operators
- → Nested queries
- → EXISTS and NOT EXISTS functions
- → Aggregate functions
- → HAVING clause
- → Set operations: UNION, EXCEPT, INTERSECT
- → ORDER BY clause
- → IN, ANY, ALL operators
- → Checking for NULL values
- → GROUP BY clause
- → INSERT, DELETE and UPDATE statements

Sample schema that will be used for explaining these concepts:

EMPLOYEE

FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO

DEPARTMENT

DNAME	DNUMBER	MGRSSN	MGRSTARTDATE

DEPT_LOCATIONS

DNUMBER	DLOCATION

PROJECT

PNAME	PNUMBER	PLOCATION	DNUM

WORKS_ON

ESSN	PNO	HOURS

DEPENDENT

ESSN	DEPENDENT_NAME	SEX	BDATE	RELATIONSHIP

EMPLOYEE	FNAME	MINIT	LNAME	SSN	BDATE	ADDRESS	SEX	SALARY	SUPERSSN	DNO
	John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
	Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
	Alicia	J	Zelaya	999887777	1968-07-19	3321 Castle, Spring, TX	F	25000	987654321	4
	Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
	Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
	Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
	Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
	James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	null	1

DEPT_LOCATIONS	DNUMBER	DLOCATION
	1	Houston
	4	Stafford
	5	Bellaire
	5	Sugarland
	5	Houston

DEPARTMENT	DNAME	DNUMBER	MGRSSN	MGRSTARTDATE
	Research	5	333445555	1988-05-22
	Administration	4	987654321	1995-01-01
	Headquarters	1	888665555	1981-06-19

WORKS_ON	ESSN	PNO	HOURS
	123456789	1	32.5
	123456789	2	7.5
	666884444	3	40.0
	453453453	1	20.0
	453453453	2	20.0
	333445555	2	10.0
	333445555	3	10.0
	333445555	10	10.0
	333445555	20	10.0
	999887777	30	30.0
	999887777	10	10.0
	987987987	10	35.0
	987987987	30	5.0
	987654321	30	20.0
	987654321	20	15.0
	888665555	20	null

PROJECT	PNAME	PNUMBER	PLOCATION	DNUM
	ProductX	1	Bellaire	5
	ProductY	2	Sugarland	5
	ProductZ	3	Houston	5
	Computerization	10	Stafford	4
	Reorganization	20	Houston	1
	Newbenefits	30	Stafford	4

DEPENDENT	ESSN	DEPENDENT_NAME	SEX	BDATE	RELATIONSHIP
	333445555	Alice	F	1986-04-05	DAUGHTER
	333445555	Theodore	M	1983-10-25	SON
	333445555	Joy	F	1958-05-03	SPOUSE
	987654321	Abner	M	1942-02-28	SPOUSE
	123456789	Michael	M	1988-01-04	SON
	123456789	Alice	F	1988-12-30	DAUGHTER
	123456789	Elizabeth	F	1967-05-05	SPOUSE

THE SELECT-FROM-WHERE STRUCTURE

SELECT <attribute list>
FROM <table list>
WHERE <condition>;

Retrieve the birthdate and address of the employee whose name is "John B. Smith".
SELECT BDATE, ADDRESS
FROM EMPLOYEE
WHERE FNAME = 'John'
AND MINIT = 'B'
AND LNAME = 'Smith';

Retrieve the name and address of all employees who work for the "Research" department

SELECT FNAME, LNAME, ADDRESS
FROM EMPLOYEE, DEPARTMENT
WHERE DNAME = 'Research'
AND DNUMBER = DNO;

SELECT FNAME, LNAME, ADDRESS
FROM (EMPLOYEE **JOIN** DEPARTMENT **ON** DNUMBER = DNO)
WHERE DNAME = 'Research';

Retrieve every project located in "Stafford", list project number, department number and manager's last name, address and birthdate → 2 join conditions
SELECT PNUMBER, DNUM, LNAME, ADDRESS, BDATE
FROM PROJECT, DEPARTMENT, EMPLOYEE
WHERE DNUM = DNUMBER
AND MGRSSN = SSN
AND PLOCATION = 'Stafford';

Prefixing and aliasing (avoids ambiguity)
SELECT FNAME, EMPLOYEE.NAME, ADDRESS
FROM EMPLOYEE, DEPARTMENT
WHERE DEPARTMENT.NAME = 'Research'
AND DEPARTMENT.DNUMBER = EMPLOYEE.DNUMBER;

SELECT E.FNAME, E.NAME, E.ADDRESS
FROM EMPLOYEE E, DEPARTMENT D
WHERE D.NAME = 'Research' **AND** D.DNUMBER = E.DNUMBER;

SELECT E.FNAME, E.LNAME, S.FNAME, S.LNAME
FROM EMPLOYEE E, EMPLOYEE S
WHERE E.SUPERSSN = S.SSN;

SELECT E.LNAME **AS** EMPLOYEE_NAME, S.LNAME **AS** SUPERVISOR_NAME
FROM EMPLOYEE **AS** E, EMPLOYEE **AS** S
WHERE E.SUPERSSN = S.SSN;

Unspecified WHERE-clause

SELECT SSN
FROM EMPLOYEE
→ retrieves all of employees SSN

SELECT SSN, NAME
FROM EMPLOYEE, DEPARTMENT
→ selects all combinations EMPLOYEE SSN & DEPARTMENT DNAME

Use of asterisk (*)

SELECT *
FROM EMPLOYEE
WHERE DNO = 5;
→ selects all attributes of employees with dno=5

SELECT *
FROM EMPLOYEE, DEPARTMENT
WHERE DNAME = 'Research' **AND** DNO = DNUMBER;
→ selects all attributes of emps and dep of research dep

THE DISTINCT KEYWORD

SQL usually treats tables as a *multiset* rather than as a set
→ SQL doesn't automatically eliminate duplicate tuples → tuples can appear more than once in a query result

- Duplicate elimination is an expensive operation
- The user may want to see duplicate tuples in a query result
- If we use aggregate functions (eg AVG, MAX, MIN) we usually do not want to eliminate duplicates

→ eliminate duplicates by using the DISTINCT keyword in the SELECT-clause

SELECT SALARY
FROM EMPLOYEE

VS

SELECT DISTINCT SALARY
FROM EMPLOYEE;

SET OPERATIONS: UNION (OR), EXCEPT, INTERSECT (AND)

Set operations only aply to union-compatible relations: same attributes in the same order!

Make a list of project numbers for projects that involve an employee whose last name is "Smith", either as a worker or as a manager of the department that controls the project

(**SELECT DISTINCT** PNUMBER
FROM PROJECT, DEPARTMENT, EMPLOYEE
WHERE DNUM = DNUMBER
AND MGRSSN = SSN
AND LNAME = 'Smith')
UNION
(**SELECT DISTINCT** PNUMBER
FROM PROJECT, WORKS_ON, EMPLOYEE
WHERE PNUMBER = PNO
AND ESSN = SSN
AND LNAME = 'Smith');

→ Notice that duplicates in the union are possible (from the 1st and the 2nd part)

SUBSTRING COMPARISON AND ARITHMETIC OPERATORS

Retrieve all employees whose address in in Houston, Texas

SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE ADRESS **LIKE** '%HOUSTON,TX%'

Retrieve all employees who were born during the 1950s
SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE BDATE **LIKE** ‘195 _ - _ _ - _ _’

Note: ‘AB_CD\%EF’ **ESCAPE** ‘\’
→ literal string of ‘AB_CD%EF’
→ using ’ in a string: ’’

Arithmetic operators in queries:
+, -, *, /, BETWEEN, <, >, <=, >=, =, <>

ORDER BY-CLAUSE

The default order is in ascending (ASC) order of values

Retrieve list of employees and the projects they are working on, ordered by department name and within each department ordered by last name, first name
SELECT DNAME, LNAME, FNAME, PNAME
FROM DEPARTMENT, EMPLOYEE, WORKS_ON, PROJECT
WHERE DNUMBER = DNO
AND SSN = ESSN
AND PNO = PNUMBER
ORDER BY DNAME DESC, LNAME ASC, FNAME ASC;

NESTED QUERIES

SCALAR SUBQUERY

Retrieve the first name and last name of all employees working in the department “Research”
SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE DNO =
(**SELECT** DNUMBER
FROM DEPARTMENT
WHERE DNAME = 'Research')

IN OPERATOR

Retrieve project numbers of the projects where either Smith is involved as manager or as worker
SELECT DISTINCT PNUMBER
FROM PROJECT
WHERE PNUMBER **IN**
(**SELECT** PNUMBER
FROM PROJECT, DEPARTMENT, EMPLOYEE
WHERE DNUM = DNUMBER
AND MGRSSN = SSN
AND LNAME = 'Smith')
OR PNUMBER **IN**
(**SELECT** PNO
FROM WORKS_ON, EMPLOYEE
WHERE ESSN = SSN
AND LNAME = 'Smith');

Select SSNs of all employees who work the same (project, hours) combination on some project that employee John Smith (SSN = 123456789) work on

```
SELECT DISTINCT ESSN
FROM WORKS_ON
WHERE (PNO, HOURS) IN
        (SELECT PNO, HOURS
         FROM WORKS_ON
         WHERE ESSN = '123456789');
```

Retrieve SSNs of all employees who work on project numbers 1, 2 or 3

```
SELECT DISTINCT ESSN
FROM WORKS_ON
WHERE PNO IN (1, 2, 3);
```

ANY AND ALL OPERATORS (COMBINED WITH <, <=, >, >=, <>)

Give the names of employees whose salary is greater than the salary of all employees in department 5

```
SELECT LNAME, FNAME
FROM EMPLOYEE
WHERE SALARY > ALL (SELECT SALARY
                    FROM EMPLOYEE
                    WHERE DNO = 5);
```

CORRELATED NESTED QUERIES

→ a condition in the WHERE-clause of a nested query references some attribute of a relation declared in the outer query → the inner query is evaluated once for each tuple or combination of tuples in the outer query

Retrieve first name and last name of all employees with a higher wage than the manager of their department

```
SELECT E1.FNAME, E1.LNAME
FROM EMPLOYEE E1
WHERE E1.SALARY >=
        (SELECT E2.SALARY
         FROM EMPLOYEE E2, DEPARTMENT D
         WHERE E1.DNO = D.DNUMBER
         AND D.MGRSSN = E2.SSN)
```

→ Note: no E1 in the second query → for each tuple in E1 the inner query will be executed → correlated query

EXISTS AND NOT EXISTS FUNCTIONS

Retrieve name of each employee who has a dependent with the same first name and sex as the employee

```
SELECT E.FNAME, E.LNAME
FROM EMPLOYEE E
WHERE EXISTS   (SELECT *
                FROM DEPENDENT
                WHERE E.SSN = ESSN
                AND E.SEX = SEX
                AND E.FNAME = DEPENDENT_NAME);
```

```
SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE NOT EXISTS (SELECT *
                  FROM DEPENDENT
                  WHERE SSN = ESSN) ;
```

→ Employee names with no dependents

CHECKING FOR NULL VALUES

Retrieve names of all employees who do not have supervisors
SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE SUPERSSN **IS NULL**

Retrieve names of all employees who do have a supervisor
SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE SUPERSSN **IS NOT NULL**

TYPES OF JOINS

The default JOIN is the INNER JOIN, where a tuple is included in the result only if a matching tuple exists in the other relation. NULL values are exlcuded

- LEFT OUTER JOIN: all tuples of the first table are included
- RIGHT OUTER JOIN: all tuples of the second table are included
- FULL OUTER JOIN: all tuples of both tables are included

Retrieve names of ***all*** *departments and the employees working in them, also departments without employees*
SELECT DNAME, FNAME, LNAME
FROM (DEPARTMENT **LEFT OUTER JOIN** EMPLOYEE
    ON DNUMBER = DNO)
ORDER BY DNAME;

AGGREGATE FUNCTIONS

The following aggregate functions can be used in a SELECT-clause or HAVING-clause :

- COUNT: returns number of tuples/values as specified in the query
- SUM: returns the sum of a set of numeric values as specified in the query
- MAX: returns the maximum of a set of numeric values, as specified in the query
- MIN: returns the minimum
- AVG: returns the mean
- MIN and MAX also used for attributes with nonnumeric domains if the domain values have a total ordering (eg names A-Z)

SELECT SUM(SALARY), **MAX**(SALARY), **MIN**(SALARY), **AVG**(SALARY)
FROM EMPLOYEE, DEPARTMENT
WHERE DNO = DNUMBER **AND** DNAME = 'Research';

SELECT COUNT(*) → number of employees in the company
FROM EMPLOYEE

SELECT COUNT(**DISTINCT** SALARY) → number of distinct salaries in the DB
FROM EMPLOYEE

AGGREGATE FUNCTIONS IN THE WHERE-CLAUSE

Retrieve names of all employees who have two or more dependents

```
SELECT LNAME, FNAME
FROM EMPLOYEE
WHERE (SELECT COUNT(*)
            FROM DEPENDENT
            WHERE SSN = ESSN) >= 2;
```

THE GROUP BY-CLAUSE

- Allows to apply aggregate functions to subgroups of tuples in a relation, based on some attribute
- → grouping attribute
- The function is applied to each group independently
- The grouping attributes have to appear in the SELECT-clause
- GROUP BY has nothing to do with ORDER BY

For each employee, retrieve the department number, the number of employees in the department and their average salary

```
SELECT DNO, COUNT(*), AVG(SALARY)        → these 3 are reported separately
FROM EMPLOYEE
GROUP BY DNO ;
```

COMBINATION OF A JOIN AND THE GROUP BY-CLAUSE

For each project, retrieve the project number, the project name and the #employees working on that project

```
SELECT PNUMBER, PNAME, COUNT(*)
FROM PROJECT, WORKS_ON
WHERE PNUMBER = PNO
GROUP BY PNUMBER, PNAME;
```

THE HAVING-CLAUSE

When GROUP BY-clause is used, the HAVING-clause allows to select only groups that satisfy certain conditions

On each project on which more than two employees work, retrieve the project number, project name and the number of employees working on that project

```
SELECT PNUMBER, PNAME, COUNT(*)
FROM PROJECT, WORKS_ON
WHERE PNUMBER = PNO
GROUP BY PNUMBER, PNAME
HAVING COUNT(*) > 2;
```

SUMMARY OF THE SQL SELECT SYNTAX

SELECT <attribute and function list>	*attributes or functions to be retrieved*
FROM <table list>	*all tables needed + joined relations but not those in nested queries*
[**WHERE** <condition>]	*conditions for selection of tuples, including join conditions*
[**GROUP BY** <grouping attribute(s)>]	*grouping attributes*
[**HAVING** <group by condition>]	*conditions on the groups being selected*
[**ORDER BY** <attribute list>];	*order in which to display the query result*

Select project numbers of projects that have "Smith" involved as manager

```
SELECT DISTINCT PNUMBER
FROM PROJECT, DEPARTMENT, EMPLOYEE
WHERE DNUM = DNUMBER
AND MGRSSN = SSN
AND LNAME = 'Smith';
```

→ join

```
FROM PROJECT
WHERE EXISTS
  (SELECT *
    FROM DEPARTMENT, EMPLOYEE
    WHERE DNUM = DNUMBER
    AND MGRSSN = SSN
    AND LNAME = 'Smith');
```

→ exists operator

```
SELECT DISTINCT PNUMBER
FROM PROJECT
WHERE PNUMBER IN
          (SELECT PNUMBER
           FROM PROJECT, DEPARTMENT, EMPLOYEE
           WHERE DNUM = DNUMBER
           AND MGRSSN = SSN
           AND LNAME = 'Smith');
```

→ nested query

INSERT, DELETE AND UPDATE STATEMENTS IN SQL

```
INSERT INTO EMPLOYEE(FNAME, LNAME, DNO, SSN)
VALUES ('Richard', 'Marini', 4, '111222333') ;
```

→ null value for other attributes

```
DELETE FROM EMPLOYEE
WHERE SSN = '111222333'          WHERE SALARY > 4000;
```

```
UPDATE PROJECT
SET PLOCATION = 'Bellaire', DNUM = 5
WHERE PNUMBER = 10
```

OTHER SQL ISSUES

VIEWS

= virtual tables, without physical tuples
= a formula that determines which attributes from the base tables are to be shown upon invocation
→ the view's content is generated upon this invocation

Advantages of views:

- Ease of use: can represent complex queries (eg joinviews)
- Data protection (you don't have to give all data)
- (Logical) data independence
- Can be materiaslised: temporary physical table is created when the view is 1st queried
  → speed up and duplication
  → DBMS must implement an efficient strategy for automatically updating view table

CREATING AND DROPPING VIEWS

CREATE VIEW WORKS_ON1
AS SELECT FNAME, LNAME, PNAME, HOURS
FROM EMPLOYEE, PROJECT, WORKS_ON
WHERE SSN = ESSN
AND PNO = PNUMBER;

CREATE VIEW DEPT_INFO (DEPT_NAME, NO_OF_EMPS, TOTAL_SAL)
AS SELECT DNAME, **COUNT**(*), **SUM**(SALARY)
FROM DEPARTMENT, EMPLOYEE
WHERE DNUMBER = DNO
GROUP BY DNAME;

DROP VIEW WORKS_ON1 **RESTRICT**;

DROP VIEW DEPT_INFO **CASCADE**;

SQL SELECT QUERIES ON VIEWS

SELECT FNAME, LNAME
FROM WORKS_ON1
WHERE PNAME = 'ProjectX' ;

UPDATABLE VIEWS

Some views can be updated → view serves as a 'window' through wich updates are propagated to base tables
Updatable views require that INSERT, UPDATE and DELETE on a view can be mapped unambiguously to INSERT, UPDATE and DELETE on the base tables → otherwise : the view is read only

Requirements for views to be updatable :

- no DISTINCT option in the SELECT-clause
- no aggregate functions in the SELECT-clause
- only one table name in the FROM-clause (→ no joins)
- no correlated subqueries in the WHERE-clause
- no GROUP BY in the WHERE-clause
- no UNION, INTERSECT or EXCEPT in the WHERE-clause

THE WITH CHECK OPTION

If rows are inserted or updated through an updatable view, there is the chance that such row does not satsify the view definition after the update, i.e. the row cannot be retrieved through the view.

→ WITH CHECK option allows to avoid such 'unexpected' effects : UPDATE and INSERT statements are checked for conformity with the view definition
→ If changes are made to tuples of a view, the tuple must still be part of the view, otherwise change rejected

CREATE VIEW LOW_SALARY_EMPLOYEES
AS SELECT FNAME, LNAME, SSN, SALARY
FROM EMPLOYEE
WHERE SALARY < 30000
WITH CHECK OPTION;

UPDATE LOW_SALARY_EMPLOYEES
SET SALARY = 45000
WHERE SSN = 453453453;
→*Update is rejected by the DBMS*

UPDATE LOW_SALARY_EMPLOYEES
SET SALARY = 29000
WHERE SSN = 453453453;
→ *Update is accepted by the DBMS*

INDEXES

- Belong in the physical DB schema
  → they were specified in the initial SQL standard but removed in SQL2 because not conceptual
- Can be defined over one or more columns
- They don't influence the data but allow for faster retrieval
- Their implementation (and syntax) is DBMS specific, although a few basic concepts are fairly common

CREATE INDEX EMPLOYEE_NAME_INDEX
ON EMPLOYEE(FNAME **ASC**, LNAME **ASC**);

CREATE INDEX EMPLOYEE_SALARY_INDEX
ON EMPLOYEE(SALARY **DESC**);

DROP INDEX EMPLOYEE_SALARY_INDEX;

CREATE UNIQUE INDEX EMPLOYEE_UNIQUE_NAME_INDEX
ON EMPLOYEE(FNAME **ASC**, LNAME **ASC**, MINIT **ASC**);

CREATE INDEX EMPLOYEE_NAME_CLUSTERING_INDEX
ON EMPLOYEE(FNAME **ASC**, LNAME **ASC**) **CLUSTER**;

PRIVILEGES

- SQL has a language construct for specifying the granting and revoking of privileges to users
- *Authorisation identifier*: refers to user accounts or groups of user accounts
- DBMS provides selective access to each relation in the DB, based on accounts
- Each relation is assigned an *owner* and either the owner or DBA can grant privileges to use an SQL statement (eg SELECT, INSERT, DELETE, UPDATE) to access the relation
- The DBA can grant privileges to create schemas, tables or views to user accounts
- Privileges are granted on *account level* and on *table level*

Retrieval privilege: SELECT privilege, MODIFY privilege (update,insert,delete), REFERENCES privilege: for referential integrity constraints, GRANT OPTION: propagation of privileges
→ to create a view, the account must have SELECT privilege on *all* relations involved in the view definition

DBA: **CREATE SCHEMA** EXAMPLE **AUTHORIZATION** A1;
A1: **CREATE TABLE EMPLOYEE** (NAME, SSN, BDATE, ADDRESS, SEX, SALARY, DNO);
A1: **CREATE TABLE DEPARTMENT** (DNUMBER, DNAME, MGRSSN);
A1: **GRANT INSERT**, **DELETE ON** EMPLOYEE, DEPARTMENT **TO** A2;
A1: **GRANT SELECT ON** EMPLOYEE, DEPARTMENT **TO** A3 **WITH GRANT OPTION**;
A3: **GRANT SELECT ON** EMPLOYEE **TO** A4;
A1: **REVOKE SELECT ON** EMPLOYEE **FROM** A3;
A1: **CREATE VIEW** A3EMPLOYEE **AS**
SELECT NAME, BDATE, ADDRESS **FROM** EMPLOYEE **WHERE** DNO = 5;
A1: **GRANT SELECT ON** A3EMPLOYEE **TO** A3 **WITH GRANT OPTION**;
A1: **GRANT UPDATE ON** EMPLOYEE (SALARY) **TO** A4;

TRANSACTION

- = atomic unit of work that is either completed in its entirety or not done at all
- For recovery purposes the system needs to keep track of when transaction starts, terminates and commits or aborts
  - BEGIN_TRANSACTION : marks beginning of transaction execution
  - Read from / write to the DB
  - END_TRANSACTION : read and write operations have ended
  - COMMIT_TRANSACTION : sucessful end of the transaction
  - ROLLBACK (or ABORT) : unsucessful end of the transaction

Desired properties of transaction : ACID

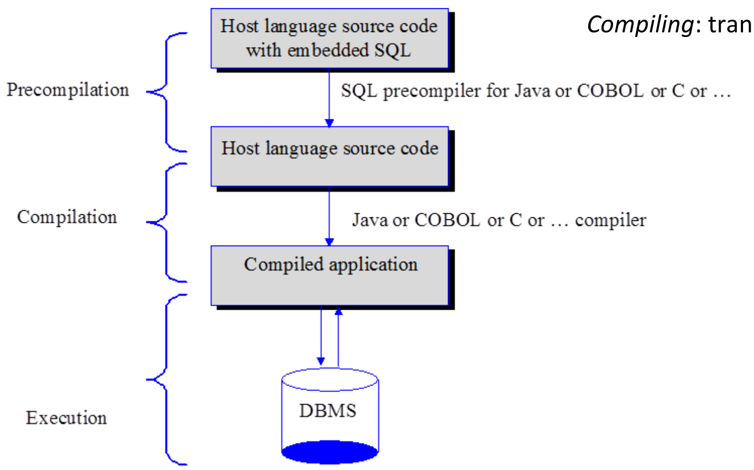
- Atomicity
- Consistency : transaction execution brings the DB from one consistent state to another
- Isolation : parallel still possible
- Durability : updates in buffer that are committed must be moved to HD

SQL does not specify an explicit BEGIN_TRANSACTION statement.
But, every transaction must have an explicit end statement : COMMIT or ROLLBACK

CONSULTING AND UPDATING DATA WITH SQL : EMBEDDED SQL

- Many RDBMS users are never confronted directly with SQL language constructs
  → interactions is with applications (often with GUI)
  → hides complexity of SQL
- These applications are written in general-purpose programming languages (C, COBOL, Java) combined with SQL statements for DB access
- Two broad options for using SQL statements in general-purpose programming languages:
  - *Call level interface* (CLI): SQL statements as parameters to procedure calls
  - *Embedded SQL*: SQL statements are embedded in a host language
- Embedded SQL resembles interactive SQL but specifies additional language constructs for the interaction between SQL statements and host language

EXECUTION OF EMBEDDED SQL STATEMENTS



Compiling: translates text to executable code

SPECIFIC LANGUAGE CONSTRUCTS FOR EMBEDDED SQL

SQL DELIMITERS

Seperate the SQL instructions (to be processed by the precompiler) from the native host language instructions
→ Java: #SQL {<sql instructions>};

HOST LANGUAGE VARIABLES

- A variable that is declared in the host language
- → can be accessed in embedded SQL instructions to pass data from SQL to host language & vice versa
- *Output host variable*: pass DB data to app; *input host variable*: value in app is used in SQL statement
- Embedded SQL allows host variable in any position whereas interactive SQL would allow for a constant
- Preceded by ":" in embedded SQL → differentiate from eg column names
- C and COBOL require host variables to be explicitly declared (SQL DECLARE SECTION), Java does not

SELECT STATEMENT FOR A SINGLE TUPLE (SINGLETON SELECT)

If only a single tuple is expected as the query result (singleton select), this result can be read directly “into” the host variable.

<begin delimiter > → entering SQL mode
SELECT BDATE, ADDRESS
INTO :BIRTHDATE, :ADDRESS → output host language
FROM EMPLOYEE
WHERE FNAME = :FIRSTNAME → input host language
AND LNAME = :LASTNAME → input host language
< end delimiter > → exiting SQL mode and entering host language mode

Note: when precompiling there will be a “type check” eg BDATE vs :BIRTHDATE (check for same format)

CURSORS

- Way of scrolling/running through your SQL result one by one
- SQL is *set oriented* → generally result = many multiple tuples
- Host language (C, COBOL, Java) is *record oriented* → cannot handle more than 1 record/tuple at a time
  ➔ *impedance mismatch*
- Solution: cursor mechanism → tuples from SQL query are presented to the application code 1 by 1
- A cursor has to be declared, i.e. associated with a query
- Cursors can be used in embedded SQL SELECT instructions and (positioned) UPDATE and DELETE instr.

< begin delimiter >
DECLARE MYEMPLOYEES **CURSOR FOR** → “MYEMPLOYEES” = name cursor
SELECT FNAME, LNAME
FROM EMPLOYEE
WHERE DEPNO = :MYDEPARTMENT → input host variable
< end delimiter >

< begin delimiter >
OPEN MYEMPLOYEES **CURSOR**
< end delimiter >

< begin delimiter >
FETCH MYEMPLOYEES **INTO** :FIRSTNAME, :LASTNAME → the 1st row is fetched (only 1 at a time!)
while <no more rows condition = false> FETCH default = the next row
display :FIRSTNAME, :LASTNAME
FETCH MYEMPLOYEES **INTO** :FIRSTNAME, :LASTNAME → scrolling through result
endwhile
< end delimiter >

< begin delimiter >
CLOSE CURSOR MYEMPLOYEES
< end delimiter >

POSITIONED UPDATE AND POSITIONED DELETE

- Positioned UPDATE instruction: affects the *current tuple* in the cursor
  → contains a CURRENT OF <cursor name> statement (instead of WHERE-clause)
- Positioned DELETE instruction: deletes the cursor’s current tuple from the corresponding table
  → contains a CURRENT OF <cursor name> statement

POSITIONED UPDATE: EXAMPLE

```
< begin delimiter >
DECLARE MYEMPLOYEES2 CURSOR FOR
   SELECT SSN, FNAME, LNAME, SALARY
   FROM EMPLOYEE
   WHERE DEPNO = :MYDEPARTMENT
< end delimiter >
```

```
< begin delimiter >
OPEN MYEMPLOYEES2 CURSOR
< end delimiter >
```

```
< begin delimiter >
FETCH MYEMPLOYEES2 INTO :SSN, :FIRSTNAME, :LASTNAME, :SALARY
while <no more rows condition = false>
   < application program code determines the salary raise of current employee. This value is attributed to the input host
variable SALARY_RAISE.>        → outside delimiter : this is host language
   UPDATE EMPLOYEE
      SET SALARY = SALARY * :SALARY_RAISE WHERE CURRENT OF MYEMPLOYEES2
   FETCH MYEMPLOYEES2 INTO :SSN, :FIRSTNAME, :LASTNAME, :SALARY
endwhile
< end delimiter >
```

```
< begin delimiter >
CLOSE CURSOR MYEMPLOYEES2
< end delimiter >
```

SEARCHED UPDATE AND SEARCHED DELETE

```
< begin delimiter >
UPDATE EMPLOYEE
SET SALARY = SALARY * :SALARY_RAISE
WHERE SSN = :SSN
< end delimiter >
```

```
< begin delimiter >
DELETE FROM EMPLOYEE
WHERE SALARY > 40000
< end delimiter >
```

THE INSERT STATEMENT

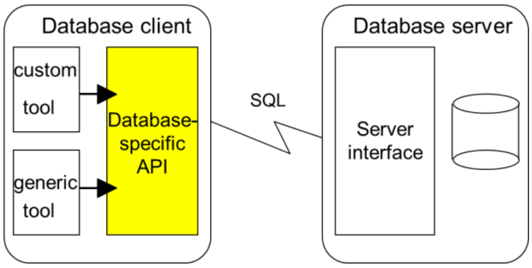
A *positioned* INSERT statement would not make sense: it is useless to insert a tuple at a given cursor postion
→ the rows in a table are not logically ordered

< begin delimiter >
INSERT INTO EMPLOYEE(FNAME, LNAME, DNO, SSN)
VALUES ('Richard', 'Marini', :DEPNUMBER, '653298653');
< end delimiter >

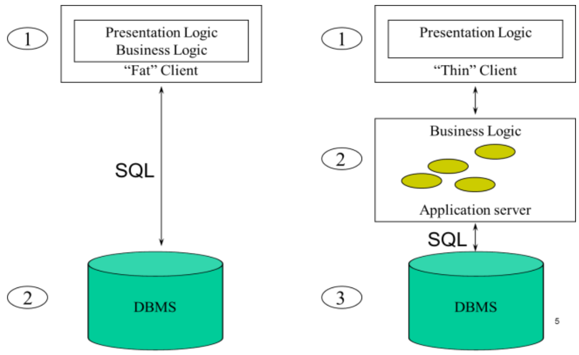
CHAPTER 6 UNIVERSAL INTERFACES TO RELATIONAL DATABASE SYSTEMS

EMBEDDED DB API VERSUS CALL-LEVEL DB API

Client/Server interaction



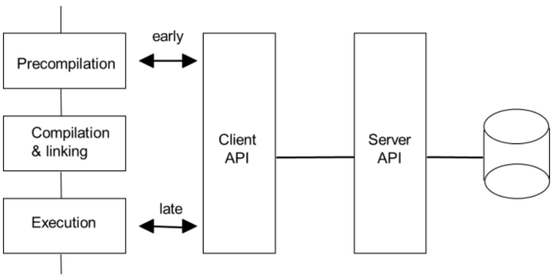
2 tiers versus 3 tiers



DATABASE API

- Acts as a mediator between application and DB, the application "talks" to DB through the API
- Call-level API: provides *methods* that can be called to perform the desired DB operations
  → Establishing a DB connection, buffering and executing SQL instructions, processing query results and returning status information
- Embedded API: the SQL instructions are *embedded* in a *host language*
  → The SQL code is processed separately during *precompilation* phase

SQL BINDING TIME (COMPILATION TIME)



- Conversion of SQL code to an internal format that can be executed by the DB engine
  - validation table & column names
  - authorisation checks
  - generation, optimisation access path
  - generation machine code
  - binding access path to DB
- *Static SQL*: early binding (cannot be changed at execution time)
- *Dynamic SQL*: late binding (binding happens at runtime)

SQL BINDING TIME AND API TYPE

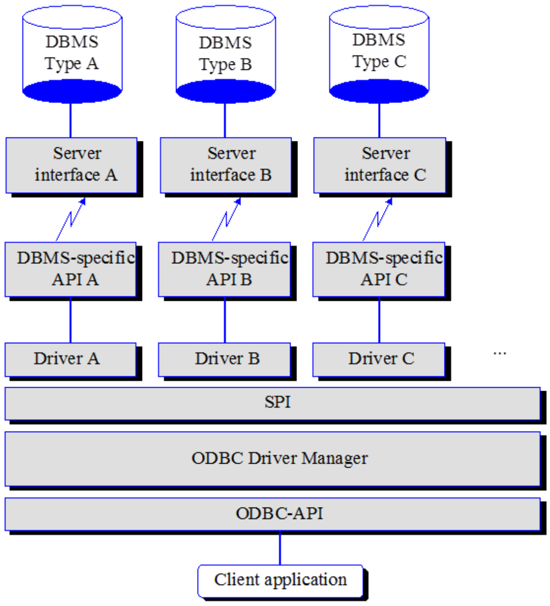
	Static	Dynamic
Embedded	SQLJ	X
Call-level	Stored procedure calls through ODBC or JDBC	ODBC JDBC

STORED PROCEDURES

- Piece of precompiled executable code (may consist of SQL and program language instructions) which is stored in the DBMSs *catalog*
- Code is activated by an explicit *call* from an application program
- Advantages: store behavioural specifications into DB, grouping of logically related operations, host language independence and increased data independence

OPEN DATABASE CONNECTIVITY CALL-LEVEL API (ODBC)

- Developed by Microsoft
- Open standard to provide applications with a uniform interface to relational DBMSs
- The ODBC API hides underlying DBMS specific API
- Components
  - **ODBC API**: call-level interface, early and late binding → DB independent API
  - **Database drivers**: routine libraries made to interact with a particular DBMS
  - **ODBC Driver Manager**: selects appropriate driver to access a particular DBMS type
  - **Service Provider Interface**: interface between the driver manager and the DB drivers

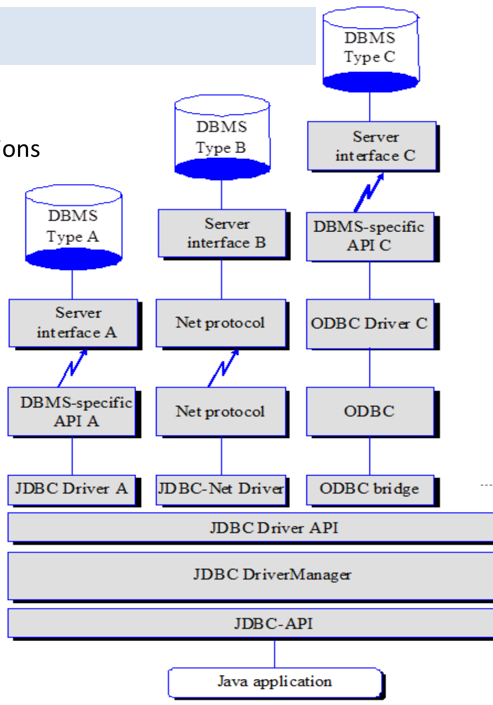


ODBC FUNCTIONS

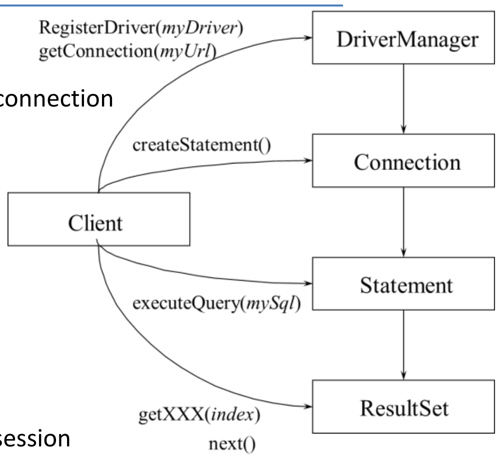
- Connect to a data source, close the connection
- "Prepare" (i.e. bind) an SQL statement
- Execute an SQL statement, close a statement
- Call a stored procedure
- Retrieve query results and status
- Retrieve information from the catalog
- Retrieve information about a driver or data source

JAVA DATABASE CONNECTIVITY CALL-LEVEL API (JDBC)

- Implements a call-level DB API that is independent of the underlying DBMS
- Java based and exclusively targeted at providing DB access to Java applications
- Features typical Java advantages: OO constructs, platform independence dynamic code loading, etc.



JDBC OVERVIEW



- **DriverManager interface**: provides uniform interface to establish a DB connection
  - Register an appropriate driver for the DB system
  - Call the getConnection method
    → DB identified by URL and possibly uname and pw
- **Driver interface**: mediates between DriverManager and DB
  → a driver object is never accessed directly by an application
  - Driver to access DBMC through its native interface
  - DBMS-neutral “net protocol” driver
  - JDBC-ODBC “bridge” driver
- **Connection interface**: a connection object represents an individual DB session
  - Maintains the DB connection
  - Generates statements to execute SQL queries
  - *Transaction control*: defines commit and rollback methods and supports locking
- **Statement interface**: a statement object is the Java abstraction of an SQL query
  - Generates ResultSet object that will contain the query result
  - Methods for executing SELECT and UPDATE queries and stored procedures
  - *PreparedStatement*: separates binding and execution in a query
  - *CallableStatement*: calls a stored procedure
- **ResultSet interface**: a ResultSet object contains the results of a SELECT query that was executed through a Statement query
  - Structured as rows and columns
  - A *cursor* indicates the current row of the result → calling next() method moves the cursor
  - getXXX() method reads the current row in the result → XXX = data type desired column
  - Possible to inquire for metadata (e.g. data types and column names of the ResultSet)
- **Other classes and interfaces**
  - **ResultSetMetaData interface**: used to retrieve metadata regarding query result
  - **DataBaseMetaData interface**: used to retrieve metadata regarding the DB
  - **SQLException class**: used for error handling

```
// ----> Initialisation
 int supplierNr;
 String supplierName;
 int minimumRating;

// ----> Setup database connection
 DriverManager.registerDriver(new oracle.jdbc.driver.OracleDriver());
 Connection myConnection
   = DriverManager.getConnection(myUrl, myUid, myPassw);

// ----> Specify and bind query
 PreparedStatement myStatement = myConnection.prepareStatement(
   “select suppliernumber, suppliername
    from suppliers where supplierrating > ?”);

// ----> Set parameter and execute query
 minimumRating = 30;
 myStatement.setInt(1, minimumRating);
 ResultSet myResultSet = myStatement.executeQuery();

// ----> Show results
 while myResultSet.next()  {
   supplierNr = myResultSet.getInt(“suppliernumber”);
   supplierName = myResultSet.getString(“suppliername”);
   System.out.println(supplierNr + “: ” + supplierName);
 };

// ----> Disconnect
 myStatement.close();
 myConnection.close();
```

Transaction management in JDBC (SLIDES!!)

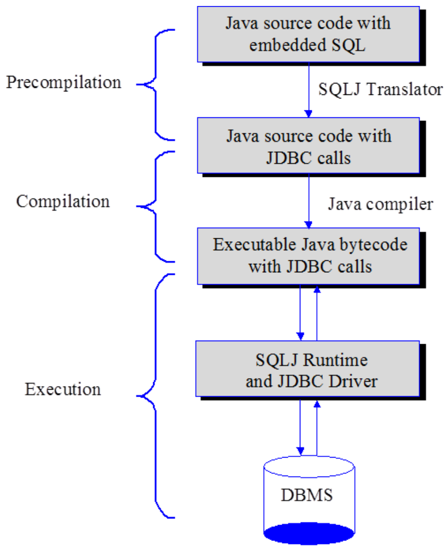
```
myConnection.setTransactionIsolation(
  Connection.TRANSACTION_SERIALIZABLE);
myConnection.setAutoCommit(false);

Statement myStatement1 = myConnection.createStatement();
Statement myStatement2 = myConnection.createStatement();
Statement myStatement3 = myConnection.createStatement();
Statement myStatement4 = myConnection.createStatement();

myStatement1.executeUpdate(myQuery1);
myStatement2.executeUpdate(myQuery2);
Savepoint mySavepoint = myConnection.setSavepoint();

myStatement3.executeUpdate(myQuery3);
myConnection.rollback(mySavepoint);

myStatement4.executeUpdate(myQuery4);
myConnection.commit();
```

SQLJ EMBEDDED API

- Implements embedded SQL standards for Java
  → only static SQL (because dynamic SQL was already established with JDBC)
- The static code is precompiled into standard Java instructions, which access the DB through an underlying call-level interface (e.g. JDBC), the Java code is then compiled in its entirety
- At compilation time, the SQL code can be check for syntactical correctness, type computability and conformance to the corresponding DB schema

SQL CONCEPTS

- **SQLJ-clauses**: delimit the SQLJ code (i.e. code that is to be subject to precompilation
- Each SQLJ clause defines a **connection-context**, like with JDBC
- **Host variables**: Java objects can be used as parameters in SQLJ instructions → pass information between Java and SQL
- **Iterator**: object that contains the result rows of an SQL query which can be accessed one by one (cursor)
- **CALL statement**: used to invoke a stored procedure



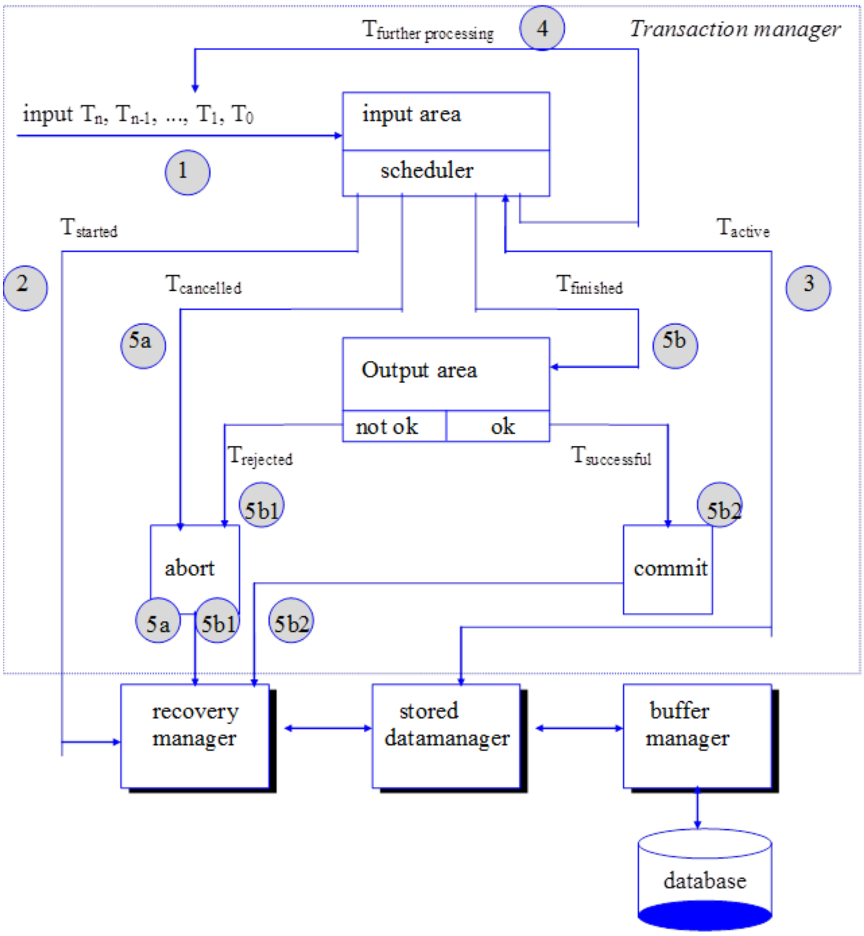
SQLJ	**JDBC**
Static invocation	Dynamic invocation
Syntax, type and schema checking	No checking
Optimisation	No optimisation

```
// ----> Initialisation
int supplierNr;
String supplierName;
int minimumRating;

// ----> Define iterator in SQLJ
#sql iterator SupplierIterator(int, String);

// ----> Setup database connection
DriverManager.registerDriver(new oracle.jdbc.driver.OracleDriver());
Connection myConnection = DriverManager.getConnection(myUrl, myUid, myPassw);
DefaultContext.setDefaultContext(new DefaultContext(myConnection));

// ----> Define iterator in Java
SupplierIterator mySupplierIterator;

// ----> Specify query and relate to iterator
#sql mySupplierIterator = {select suppliernumber, suppliername
                           from suppliers where supplier rating > :minimumrating};

// ----> Set parameter
minimumRating = 30;

// ----> Show results
#sql {fetch :mySupplierIterator into :supplierNr, :supplierName};
while (!mySupplierIterator.endFetch()) {
  System.out.println(supplierNr + ": " + supplierName);
  #sql {fetch :mySupplierIterator into :supplierNr, :supplierName};
  }

// ----> Disconnect
myStatement.close();
myConnection.close();
```

CHAPTER 7 TRANSACTIONS, RECOVERY AND CONCURRENCY CONTROL

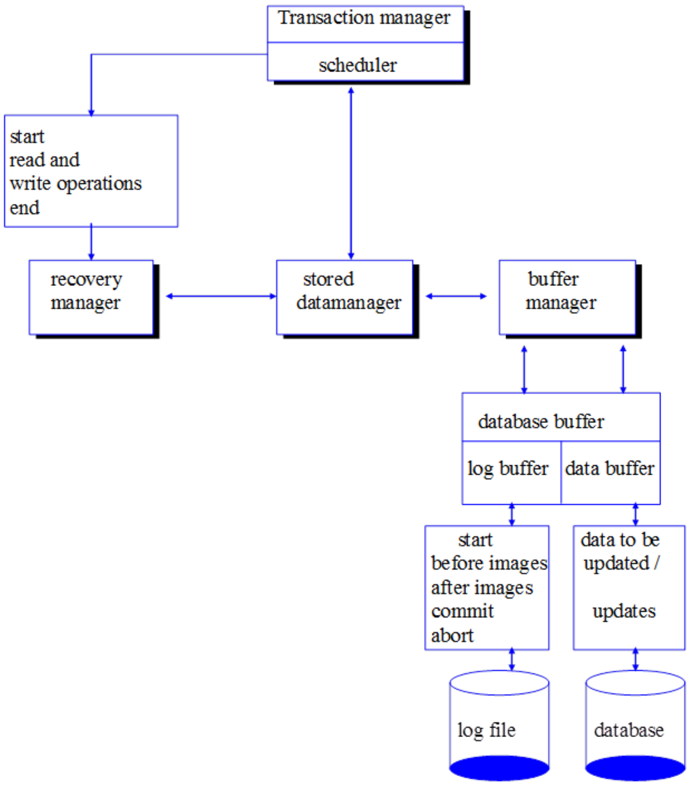
TRANSACTION

- Series of DB operations that are to be executed as one, undividable whole
    - Users should never be able to see inconsistent data
    - It should be impossible to complete a set of operations in such a way that the DB is left in an inconsistent state
- Series of DB operations that are guaranteed to bring the DB from one consistent state to another
- *Beginning of a transaction*
    - Implicit or through BEGIN TRANSACTION instruction
    - The transaction is fed to a transaction manager and put into a schedule
    - The transaction is started
- *End of a transaction*
    - Implicit or through END TRANSACTION instruction
    - Successful end → COMMIT
    - No successful end → ABORT or ROLLBACK
- Example: see picture of transaction management in JDBC previous chapter



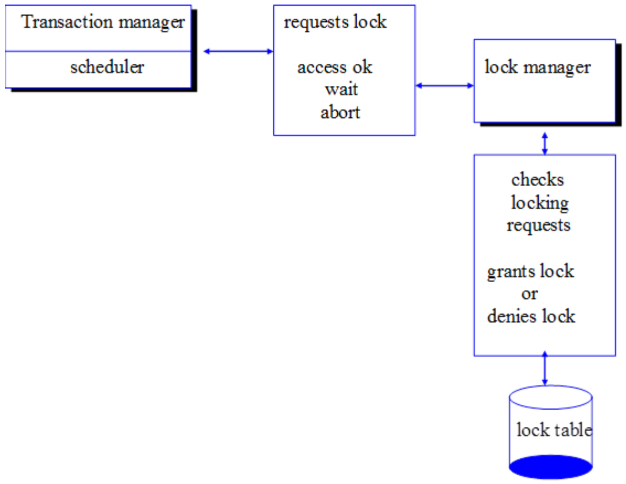
RECOVERY

- Several kind of errors or calamities may occur during the execution of a transaction
- Activity of ensuring that data can always be recuperated
- Coordinated by *recovery manager*: only effects of successful transactions are persisted into the DB and all (partial) effects of unsuccessful transactions are undone



CONCURRENCY CONTROL

- Multiuser environment → transaction interfere → unwanted side effects
- Activity of coordinating the operations of simultaneous transactions which the affect same data → Data cannot become inconsistent
- Schedule should be *serialisable* → it produces the same output as a *serial* schedule
- → Locking
  - Lock = access privilege that can be granted over an object
  - Locking protocol → specifies rules that determine when transactions obtain/release locks



TRANSACTIONS AND TRANSACTION MANAGEMENT

REGISTRATIONS ON THE LOGFILE

- File with redundant information that is necessary to recuperate or restore the data
- *Logrecords*: contain data about individual transactions
    - Transaction ID (shows beginning transaction & type of transaction: read-only write-only)
    - Record ID of the records that are used
    - Operation ID of operations that execute on the records (select, update, insert, delete)
    - Before images: undo part of the logfile
    - After images: redo part of the logfile
    - The current state of the transaction: *active*, *committed* or *aborted*
    - Checkpoint records: synchronization points to allow rollback (JDBC: savepoint)
- *Write ahead log strategy*: updates on the logfile always precede the corresponding updates in the DB
  → Transaction only executed if before images are registered on logfile
  → Transaction only committed if after images of corresponding data are registered on the logfile
- *Force writing the logfile strategy*: the logfile should be written to disk before a transaction can be committed
- *Transaction table*: contains one row for each active transaction, the row contains:
    - Transaction identifier
    - Current state of the transaction
    - Log sequence number of the most recent log record for this transaction

TRANSACTION PROPERTIES (“ACID” PROPERTIES)

- Atomicity: a transaction is atomic whole → everything or nothing (recovery & transaction manager)
- Consistency: states before and after a transaction have to be consistent (programmer)
- Isolation: to avoid interference (locking & recovery manager)
- Durability: when transaction commit → persistent in data (recovery manager)

RECOVERY TECHNIQUES

TYPES OF FAILURE

- *Transaction failure*: a transaction “aborts” by application or DB system → system recovery
- *System failure*: the content of the main memory is lost, content DB buffer lost → system recovery
- *Medium failure*: some data in the DB and/or logfile are damaged or destroyed → medium recovery

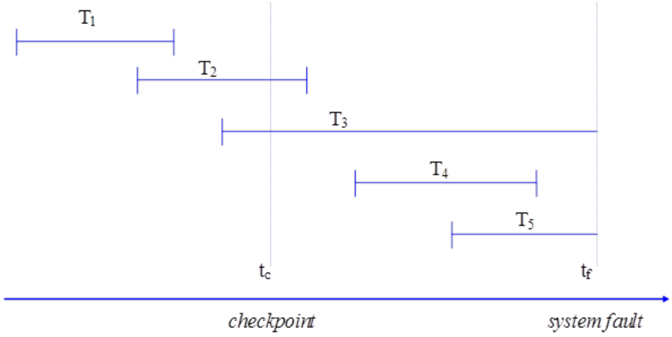
MEDIUM RECOVERY

- Solution: redundancy
    - *Disk mirroring*: data written in real-team to two or more disks
    - *Archiving*: the DB (and logfile) are duplicated periodically
      → if log is not damaged: committed transactions are reconstructed by rollforward utility that used the REDO part of the logfile, uncommitted transactions have disappeared

SYSTEM RECOVERY

- DB buffer is lost
- Transaction that have written data to this buffer belong to either of two categories:
  - reached committed state at the moment of the fault → REDI
  - were still active at the moment of the fault → UNDO
- Assumption: the recovery manager periodically commands buffer manager to write the DB buffer to disk → checkpoint → denotes which transaction were finished and which ones were active

T_1: nothing
T_2: REDO
T_3: UNDO
T_4: REDO
T_5: nothing



CONCURRENCY CONTROL TECHNIQUES

When multiple transactions are executed simultaneously, and no preventive measures are taken, problems may occur because of interference between the transactions' actions

LOST UPDATE PROBLEM

Time	*T_1*	*T_2*	*$account_x$*
t_1		begin transaction	100
t_2	begin transaction	read($account_x$)	100
t_3	read($account_x$)	$account_x = account_x + 120$	100
t_4	$account_x = account_x - 50$	write($account_x$)	220
t_5	write($account_x$)	commit	50
t_6	commit		50

UNCOMMITTED DEPENDENCY PROBLEM ("DIRTY READ PROBLEM")

Time	*T_1*	*T_2*	*$Account_x$*
t_1		begin transaction	100
t_2		read($account_x$)	100
t_3		$account_x = account_x + 120$	100
t_4	begin transaction	write($account_x$)	220
t_5	read($account_x$)		220
t_6	$account_x = account_x - 50$	rollback	100
t_7	write($account_x$)		170
t_8	commit		170

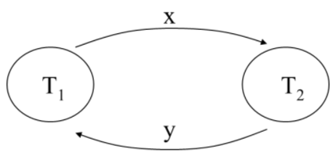
INCONSISTENT ANALYSIS PROBLEM

Time	T_1	T_2	$Account_x$	y	z	*sum*
t_1		begin transaction	100	75	60	
t_2	begin transaction	sum = 0	100	75	60	0
t_3	read($account_x$)	read($account_x$)	100	75	60	0
t_4	$account_x = account_x - 50$	$sum = sum + account_x$	100	75	60	100
t_5	write($account_x$)	read($account_y$)	50	75	60	100
t_6	read($account_z$)	$sum = sum + account_y$	50	75	60	175
t_7	$account_z = account_z + 50$		50	75	60	175
t_8	write($account_z$)		50	75	110	175
t_9	commit	read($account_z$)	50	75	110	175
t_{10}		$sum = sum + account_z$	50	75	110	285
t_{11}		commit	50	75	110	285

SERIAL SCHEDULES

- A schedule *S* is a sequential ordering of the operations of *n* transactions in such a way that for each transaction *T* in *S* the following holds:
  "if operation I precedes operation j in *T*, then operation I precedes operation j in *S*"
- Ordering of operations within a transaction should always be respected, ordering of operations between transactions can be scheduled randomly
  → each alternative ordering results in a different schedule
- *Serial schedule*: all operations of each transaction in the schedule are processed consecutively
  → n! different schedules
  → puts a heavy burden on throughput
- Assumption: a transaction is correct if it executed in isolation and transaction are independent
  → serial schedule is always correct

SERIALISABLE SCHEDULES



- Are the equivalent of serial schedules in terms of output
- Check for serialisability → *precedence graph*
- Schedule is serialisable if the precedence graph has no cycles
- Arrow T_1 → T_2 if:
  - T_2 reads a value that was last written by T_1
  - T_2 writes a value after it was read by T_1
- You can put constraints on schedules to ensure there are no cycles
- Checking every schedule for serialisability causes overhead
  - *Optimistic protocols*: assumes conflicts between simultaneously transactions occur rarely; at the moment a transaction is completed and is about to be committed, the scheduler checks if conflict occurred → rollback → too optimistic → throughput is worse
  - *Pessimistic protocols*: assumes conflict is likely; operations are delayed until the scheduler overviews the situation and enforces a schedule that minimizes risk for conflict
    → extreme case: serial scheduler

LOCKING AND LOCKING PROTOCOLS

- *Conflicting transactions*: two operations from different transactions conflict if
    - they are to be executed on the same DB object
    - (at least) one of them is “write” operation
- *Locking protocol*: a set of rules enforcing that if two conflicting operations try to access the same object, the access to this object is granted to only a single operation at a time
- *Lock*: a variable associated with a DB object, for which the value determines which operations are allowed (at this time) on the object
- *Locking manager*: grants/releases locks on the basis of a “lock table” and a locking protocol
- *Exclusive lock*: write lock, exclusive right to access an object → no other transaction can read or write to this object until the lock is released (write operation)
- *Shared lock*: read lock, guarantee that no other transaction can *write* to that object (read operation)

State of a lock on an object

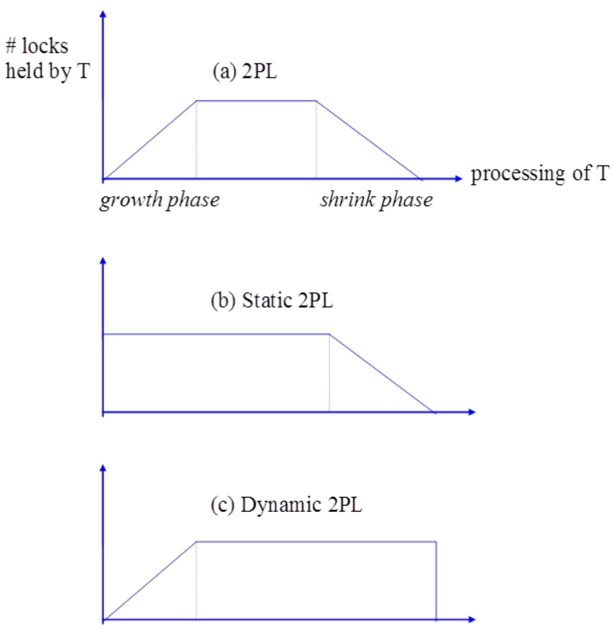
type of the requested lock on the object	*unlocked*	*shared*	*exclusive*
unlocked	-	yes	yes
shared	yes	yes	no
exclusive	yes	no	no

- Exclusive lock released: any of the waiting transactions is a candidate to acquire a lock → scheduling strategy
- Shared lock released: it is possible other shared locks remain, the lock manager has to use a priority schema to determine whether
    - New shared locks are granted
    - The shared locks are gradually removed for an exclusive lock
- Unfair priority schemas may result in “livelocks” (transaction in an endless waiting state)

THE TWO-PHASE LOCKING PROTOCOL (2PL-PROTOCOL)

- (1) When a transaction wants to “read” resp. “write” from/to an object, it will first have to request and acquire a read lock resp. write lock with the lock manager
- (2) Lock manager determines (based on compatibility matrix) whether some operations are conflicting or not and grants the lock right away or determines to postpone it
- (3) Requesting and releasing lock occurs in two phases:
    - A *growth phase*: transactions acquire new locks without releasing any locks
    - A *shrink phase*: transaction release locks without acquiring new locks

→ A transaction satisfies rule (3) when all its locking instructions proceed the first unlock instruction



- 2PL-protocol is the solution to the lost update and uncommitted dependency problem
- But: risk of deadlocks (two transactions keep waiting on each other

Time	T_1	T_2
t_1	begin transaction	
t_2	x-lock($Account_x$)	begin transaction
t_3	read($Account_x$)	x-lock($Account_y$)
t_4	$Account_x = Account_x - 50$	read($Account_y$)
t_5	write($Account_x$)	$Account_y = Account_y$ - 30
t_6	x-lock($Account_y$)	write($Account_y$)
t_7	wait	x-lock($Account_x$)
t_8	wait	wait

- Deadlock prevention: static 2PL → if a transaction fails in acquiring all necessary lock at the start time, it is put in a wait state → possible decrease of throughput
- → Better to not take measures to avoid deadlocks but to detect and resolve them
- Deadlock detection: wait-for-graph → each transaction is a node and arrows indicate a lock → deadlock = cycle in wait-for-graph
    - Deadlock detection algorithm that investigates wait-for-graph periodically
    - Interval too short → much overhead
    - Interval too long → detections takes a while
- Deadlock resolving: victim selecting and aborting and rollback → avoid aborting transaction that made a lot of changes to the DB

CASCADING ROLLBACK

- Rollback of a transaction may cause a cascade of rollbacks of transactions that used the data that were updated by the initial transaction that was rolled back
- Avoid: transaction holds all its lock until it commits → dynamic 2PL

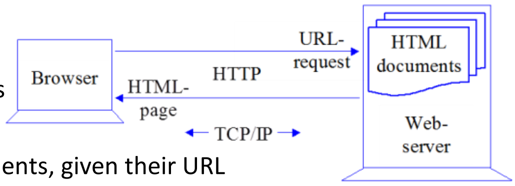
VARIATION POINTS

- Transaction isolation levels
    - In practice, *multiple isolation levels* are applied, so as to increase the throughput
    - A *short-term lock* on an object is a lock that is only held during the execution of the operation associated with the lock. If short term locks are used, rule 3 of the 2PL-protocol is violated, i.e. serialisability can no longer be guaranteed
    - Dependending on the requirements of the transaction, several isolation levels can be distinguished:
        - *Uncommitted Read (UC):* no concurrency control
        - *Committed Read (CR):* long-term write locks + short-term read locks (problem: inconsistent analysis)
        - *Serializable:* cf. 2PL

- Locking granularity levels
    - The 'object' of a lock can be a row, a table, a physical block, a tablespace, ...
    - Tradeoff:
        - Lock on fine grained objects: more throughput
        - Lock on coarse grained objects: less overhead
    - *Multiple-Granularity Locking- Protocol* (*MGL-protocol*): extends 2PL to allow for locking at multiple granularity levels (row, table, ...)
        - → consistency required between different levels of hierarchy, e.g. a lock on a table and a lock on a row in that table
        - → More complex compatibility matrix

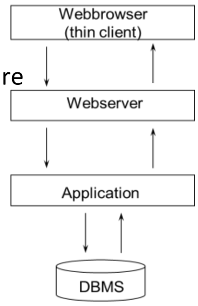
CHAPTER 8 WEB-DB CONNECTIVITY AND DB SYSTEMS IN AN N-TIER ENVIRONMENT

- *HTML*: HyperText Markup Language
    - Specifies the document format used to write web documents
    - Features limited constructs for user input (eg buttons, checkboxes, etc.) in so-called HTML forms
- *URL*: Uniform Resource Locator
    - Uniquely and unambiguously identifies Web documents
- *HTTP*: HyperText Transfer Protocol
    - High-level protocol for requesting/fetching Web documents, given their URL
    - Build upon underlying TCP/IP network protocol stack



THE WEB AS CLIENT/SERVER MEDIUM

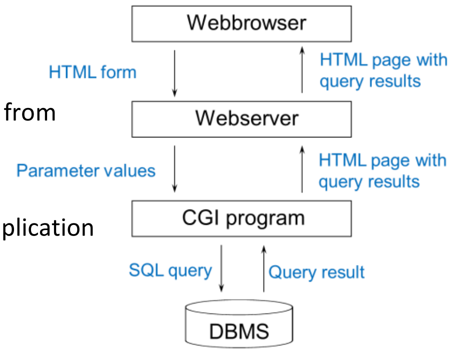
- Architecture where end users (with a web browser) can transparently access DB data
  → No attention to underlying connection details and no need for installing specific client software
  → Thin client principle, all core business logic is implemented server-side
- Shortcomings:
    - HTML are static text pages, no execution
    - Limited GUI capabilities of HTML
    - HTTP protocol is not connection oriented and stateless



EXECUTABLE CODE IN A WEB ENVIRONMENT

COMMON GATEWAY INTERFACE (CGI)

- First technology in WWW with executable code
- API that allows for executable code (stored at webserver) to be activated from a web browser
- Request is similar to a call to a static HML page
- Mechanism to pass parameter values by means of a HTML form to the application
- Application queries the DB, results are packaged as a HTML page
- Problems:
    - Complex parameter binding
    - Each request = new server process (a new instance of CGI program)
    - Bad performance and no difficult scalability
    - Security issues (easy hackable)



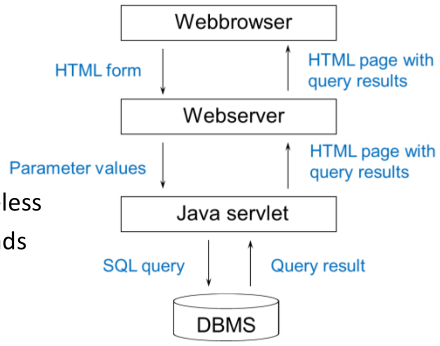
JAVA

- OO programming language and a real computing platform
- Portability: write once, run anywhere where JVM is installed
- Mobility: dynamic code loading
- Security: untrusted code in run in a "sandbox" → shield resources from executable code
- DB access: JDBC, SQLJ
- Web integration: applets, servlets
- Distributed object computing and components: RMI and EJB (Enterprise JavaBeans)
- Worldwide deployment: JVM exists in any web browser, webserver, DB server or application server

JAVA APPLETS

- Pieces of Java code that can be downloaded and executed in JVM of a web browser (client side)
- Applet invocations are embedded in code HTML page → applet runs in HTML page
- Applets can use Java GUI objects
- It is possible to directly access DBMS from applets
    - Goes against think client principle
    - Interaction/Connection with DB is not available locally for security reasons
- Applets can improve client functionality:
    - Better GUI features than HTML forms
    - Receive and validate user input
    - Cutting short web server → communicate with server side applications via non-HTTP based interaction mechanism

JAVA SERVLETS



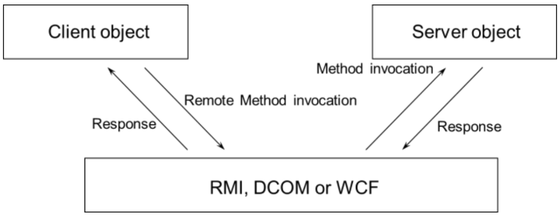
- Special Java application that run on a webserver with a servlet engine
- Platform independent server-side programs, accessible through universal API
- Interaction mechanism resembles CGI based approach
- Remain active after handling a request, able to contain session info ←→ stateless
- Multiple requests can be dealt with by same servlet instance in separate threads
- Performance and security improvements in comparison to CGI programs

Servlets	**Applets**
• Run on webservers.	• Run on webbrowsers.
• Allow for only an HTML based GUI.	• Can offer a very rich GUI.
• Can handle very complex tasks.	• Can only handle fairly simple tasks.

CLIENT-SIDE AND SERVER-SIDE SCRIPTING

- Scripting code = code that is interpret rather than compiled
- Can be embedded in a static HTML page → dynamic features for HTML page
- *Server-side scripts*: pieces of code that are executed when the document is accessed on the server
→ Comparable to servlet (behavioral)
- *Client-side script*: executed when the document is received by the web browser
    - Certain degree of dynamism at client side
    - Comparable to applets (behavioral)
    - Mainly used for UI enhancements
- Server-side scripting technologies:
    - JSP (Java Server Pages): server side system Java, compiled into servlet for performance
    - ASP (Active Server Pages): server side system MS, embedded in HTML or separate file
    → More recent: ASP.NET (for MS .NET framework)
    - PHP (PHP HyperText Preprocessor): strong integration with open source technologies

DISTRIBUTED OBJECT ARCHITECTURES



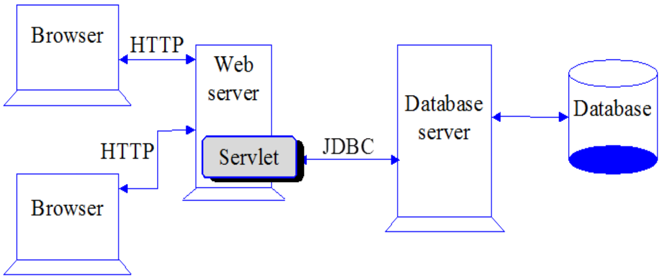
- Support method based interaction between objects on different hosts
- Objects interact by remotely calling one another's methods
- Not necessarily web based
- Java environment: RMI
  - Part of Java EE
  - Interaction between Java components (enterprise beans)
- MS environment
  - DCOM (Distributed Common Object Model): earlier pre-web approach
  - WCF (Windows Communication Foundation): more recent, part of .NET framework

CLIENT/SERVER INTERACTION ON THE WEB

- Only executable code on server:
  - Interaction through HTTP and servlets
  - Interaction through HTTP and server-side scripts
- Executable code on server and in the web browser:
  - Interaction through TCP/IP and socket-to-socket communication
  - Interaction through distributed objects (e.g. RMI)

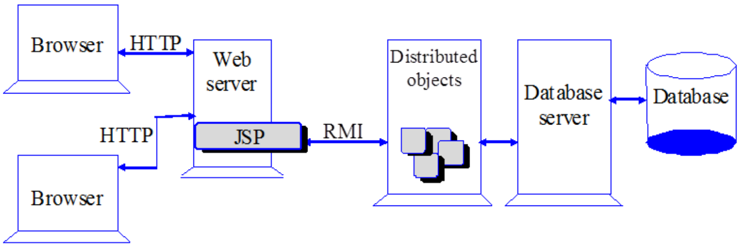
CLIENT/SERVER INTERACTION THROUGH SERVLETS

- Servlet invoked like a static page
- DB access and query results in generated static HTML page
- Interaction is entirely HTTP based
- Client requirements minimal → only web browser
- No client-side intelligence, input validation server-side
- GUI is entirely HTML based
- Very simple, no firewall problems



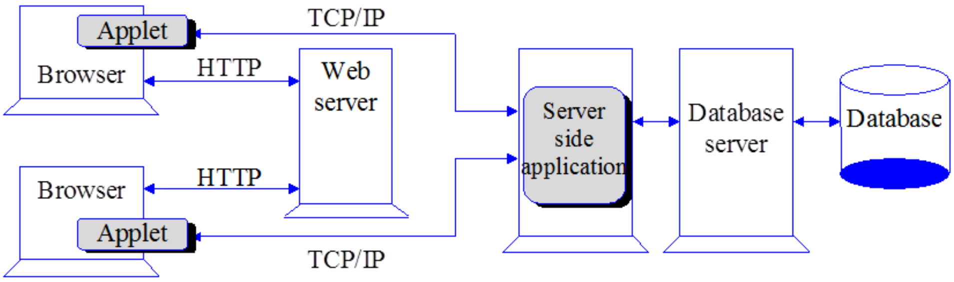
CLIENT/SERVER INTERACTION THROUGH SERVER-SIDE SCRIPTS

- Similar to servlet-based interaction
- Communication between browser and script HTTP based
- Server-side code consists of a script, embedded in HTML page
- Script calls upon DO that implement actual business logic
- DO executes queries and result is incorporated in HTML page by the script
- Advantage: separation of business logic and HTML layout ←→ servlets



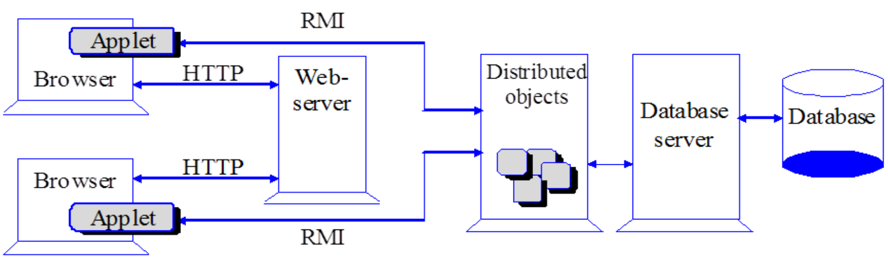
CLIENT/SERVER INTERACTION THROUGH SOCKET-TO-SOCKET COMMUNICATION

- Sockets define low-level TCP/IP connections
- Client-side and server-side code interact through sockets
- Webserver downloads initial HTML page with an applet → browser can't "talk" TCP/IP
- Applet directly interacts with server-side application → no webserver as intermediary
  - Applet validates input variables
  - TCP/IP communicates input and query results, no need to package in HTML
  - Business logic in server-side application
- Server-side application executes queries
- Interaction by means of variables instead of entire HTML pages
  → Much faster than HTTP and it is session based
- Very low-level → considerate amount of "plumbing" code required
- Possible firewall problems → don't approve the TCP/IP connection



CLIENT/SERVER INTERACTION THROUGH DISTRIBUTED OBJECT ARCHITECTURE

- Objects in applets and on application server interact by remotely calling one another's method (RMI)
- Webserver downloads initial HTML page with an applet
- Applet directly interacts with server-side application → no webserver as intermediary
  - Applet validates input variables
  - Much higher-level and less "plumbing" than socket-to-socket communication
- RMI is used as high-level protocol instead of HTTP
- RMI is a layer above TCP/IP and is more programmer friendly
- Possible firewall problems with RMI → only suitable on an intranet

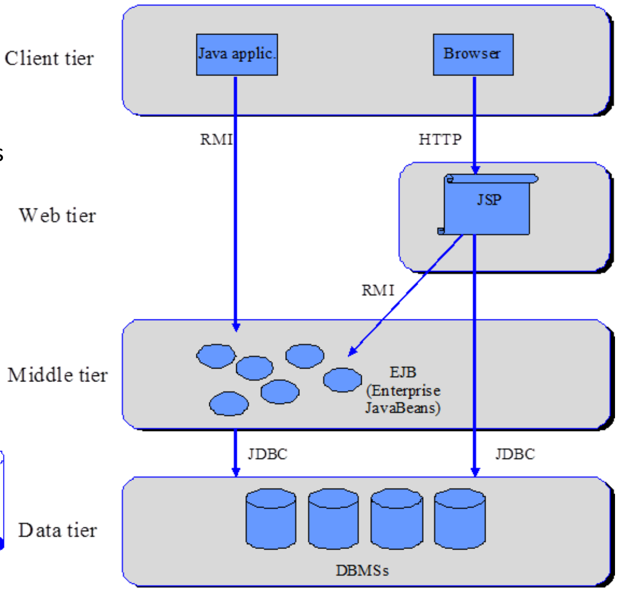


→ Security enhancement:

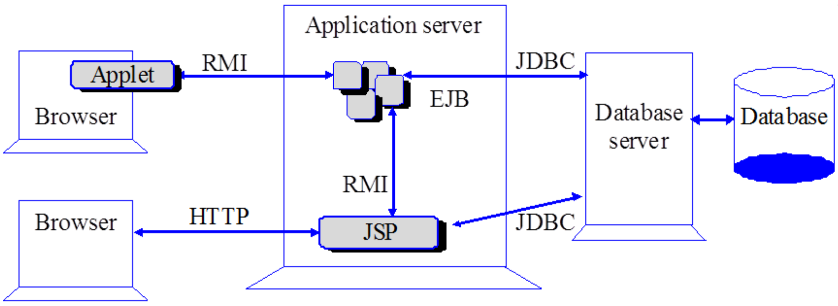
- Intranet: distributed object architecture
- Extranet: server side scripts

A GLOBAL ARCHITECTURE FOR WEB-BASED DATABASE ACCESS

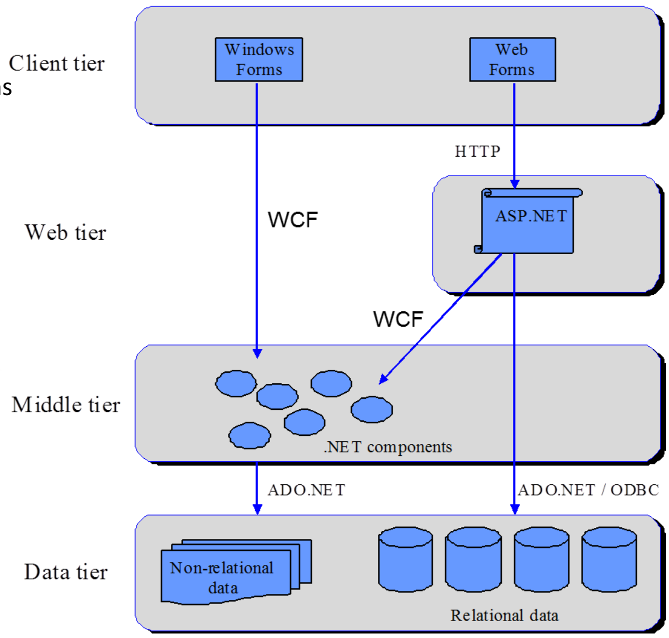
JAVA EE: OVERVIEW



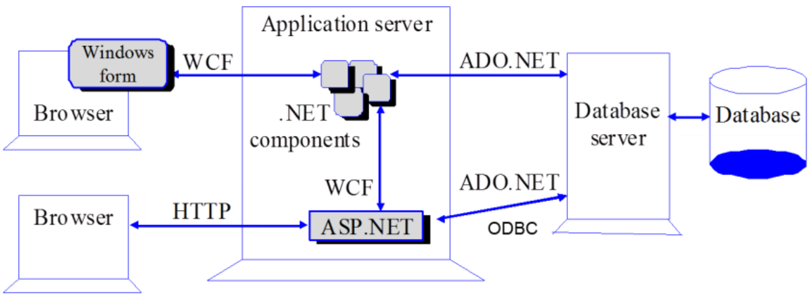
- Java applic = applet, standalone client
- JSP: server side script
- Straight from JSP to DMBS through JDBC when no business logic is needed
- RMI: firewall difficulties ←→ HTTP
- Actual business logic: components of Java (beans)
- The applet provides better performance + UI
- There are possibilities to enhance UI in browser



MICROSOFT .NET: OVERVIEW

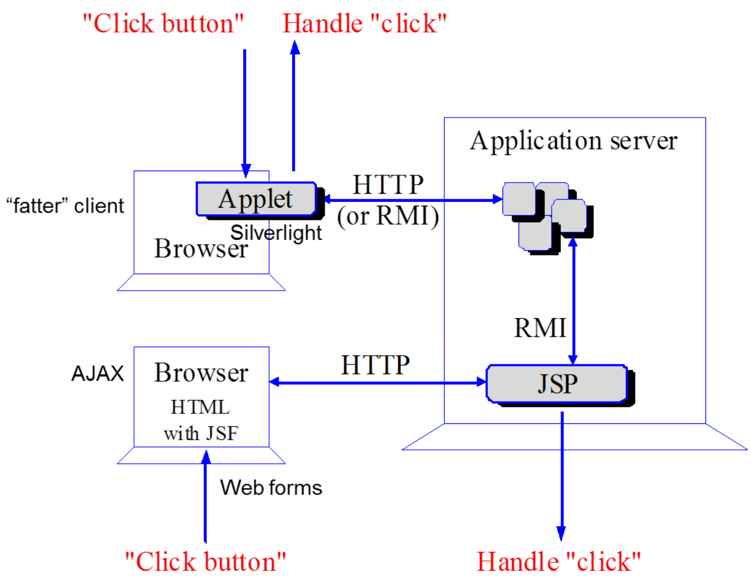


- Browser UI enhancements possible through web forms
- Windows forms only works on Windows
  (not that much used)



FROM THIN CLIENTS TOWARDS RICH INTERNET APPLICATIONS

- RIA: web based applications with "rich" look and feel, similar to desktop applications
- Two lines of technologies:
    - Browser-based (AJAX, Asynchronous JavaScript and XML)
        - GUI functionality is split over browser and web server
        - No refresh of entire HTML page but rather individual page fragments
        - Client side scripting combined with server side technology
        - XML based data exchange
        - Often used by GUI technologies that allow for handling GUI event server side (JavaServer Faces, Microsoft Web Forms)
    - Plugin based
        - Executable code downloaded and run in web browser
        - Rich, non-HTML based GUI objects
        - Communication with server side business logic
        - Flash, Java applets, Microsoft Silverlight



CONCLUSIONS

- Access DB data through web browser without installation of client-side software
- Download of plugins into browser → thin client, only UI and performance improvements
- Different technologies with different distribution of GUI functionality over browser and server: not all thin clients are equally thin
- Business logic remains server-side → different technologies for server side executable code
- Importance of separating page layout and GUI design from developing business logic

CHAPTER 9 DATA WAREHOUSING

- *Business intelligence*: process of collecting, processing, communicating and interpreting information in order to support an organization's tactical and strategical decision making
- Business intelligence systems often rely on data warehouses to support these activities

TPS database	Data warehouse
Supports operational processes	Supports tactical and strategic decision-making
Kept up-to-date in real-time	Certain time lag is allowed
Application-oriented design	Subject-oriented design
Detailed data	Also aggregated and enriched data
Volatile, continually updated data	Only data added
No systematic history kept of data	History of data
Read and modify existing data	Only read existing data
Repetitive usage patterns	Ad-hoc usage
Many simple transactions on a few records	Complex queries that have to scan large parts of DB
"Online Transaction Processing" (OLTP)	*"Online Analytical Processing" (OLAP)*

DATA WAREHOUSE

- Subject-oriented, integrated, time-variant and non-volatile collection of data
- *Subject-oriented*: organized around the major subjects (customer) of an enterprise rather than the major application areas (customer invoicing)
- *Integrated*: integrates application-oriented data from different sources (Transaction processing systems, legacy systems or external sources)
    - Data may be stored in different formats
    - Same entity with different identifiers
    - Web extraction (external source): can be part of competitive intelligence
- *Time-variant*: all data in warehouse is associated with time → series of historical snapshots
- *Non*-volatile: new data is always added as supplement rather than as replacement
- **Data mart**: designed to support decision-making of particular user group; subset of company data that is relevant for this user group

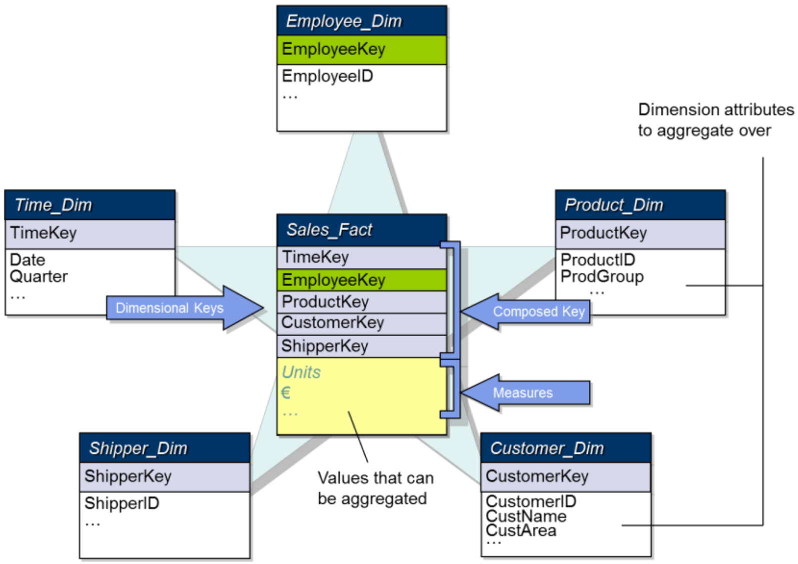
ADVANTAGES OF SEPARATE DATA WAREHOUSE

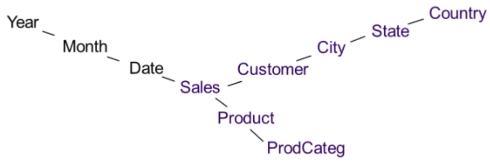
- Performance
    - Off-load complex analytical processing from the OLTP
    - Concurrency control and recovery modes of OLTP are not compatible with OLAP analysis → not so much an issue when you're only consulting data
- Function
    - Integrated with company-wide view of high-quality data
    - Tailored to meet information needs of decision making
    - Management of historic data resources

DATA WAREHOUSE DESIGN

- Method: star schema (or snowflake)
- Relation design with a fact table
  - Data that describes transactions or events from a business process
  - Attributes (eg customerID, sales, etc.)
  - Contains numeric measures that can ben aggregated over attributes of dimension tables
  - Design decisions (granularity and surrogate keys)

1. And dimension tables
   - Determine dimensions along which analyses will occur
   - Attributes (also key that relates dimension to fact table)
   - Design decisions (denormalise → snowflake)
2. Fact constellations: multiple fact tables share dimension tables





PHASES IN DATA WAREHOUSE DESIGN

1. Global data warehouse design
   - Develop knowledge strategy and identify processes that generate knowledge
   - Decisions about fact tables (granularity, meaning of 1 row, identify attributes
   - Decisions about dimension tables (determined by fact tables, attributes)
2. Designing data marts
   - Determine scope and time frame of data mart
   - Determine development priorities
   - Detailed logical design + adapt for physical implementation
     - Denormalise
     - Identify mini dimensions and use surrogate keys
     - Generate aggregated data
   - Physical design
     - Cluster tables
     - Apply special index types and other storage methods
     - Partitioning and parallelism
3. Building an enterprise data warehouse: integration of data marts into global data warehouse

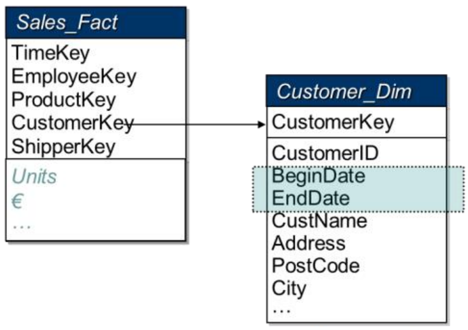
CHOOSING THE GRAIN

- Grain of a fact table = the meaning of one fact table row
- Determines the maximum level of detail of the warehouse
- Finer-grained fact tables are more expensive and have more rows
- Trade-off between performance and expressiveness
  - Rule of thumb: err in favor of expressiveness
  - Pre-computed aggregates can solve performance problems

TRACKING SLOWLY CHANGING DIMENSIONS

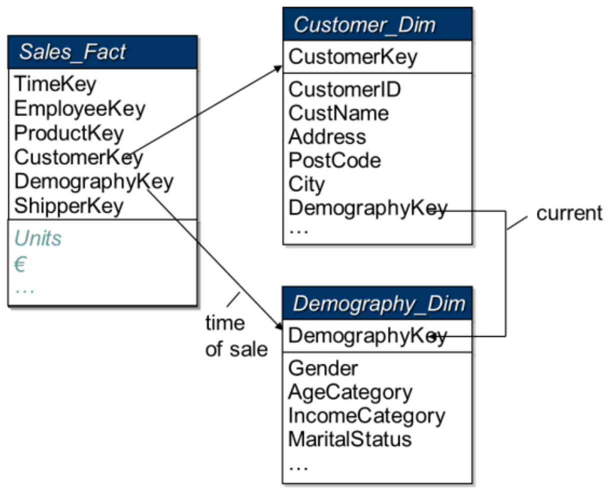
- Overwrite records in dimensions tables (loss of historic information)
- Introduce validity range (use surrogate keys)
- Use minidimensions

Validity range



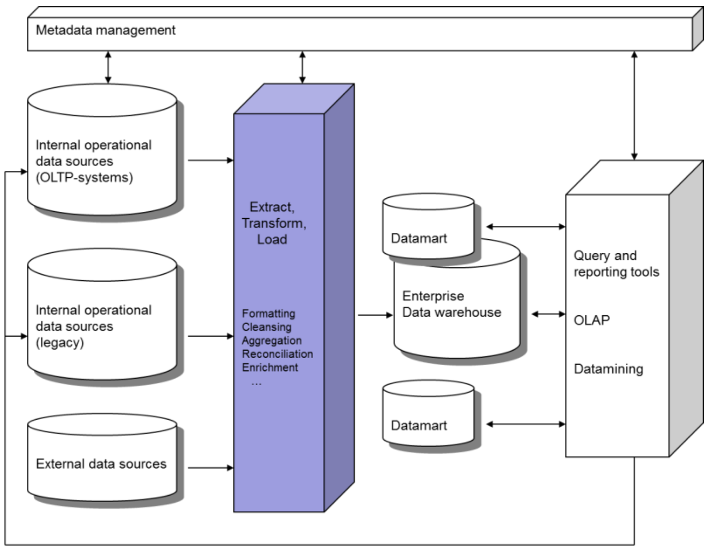
Customer Key	Customer ID	BeginDate	EndDate	Cust Name	Address	Postcode	City
53059	K100567	01/01/1998	21/07/2003	Smith , John	123 Hill Lane	SO15 5AD	Southampto n
66990	K100567	22/07/2003	31/12/2999	Smith , John	144 Fratton Road	PO1 5HD	Portsmouth

Minidimensions



THE ETL PROCESS

- **Extract** data from source systems (operational, legacy, external)
  - Full copy or only "changed data capture"
  - Latency (daily/weekly/monthly)
    → trend analysis: longer is ok
    → corporate performance management: 0
- **Transform** data
  - Can be done on source or target system
  - Format → cleanse → aggregate & merge → enrich
- **Load** data into target system (DW, DM)
  - Fill fact and dimension table, generate key values, etc
- Post-processing
  - Derived data, aggregated tables, etc.



DATA INTEGRATION PROBLEMS

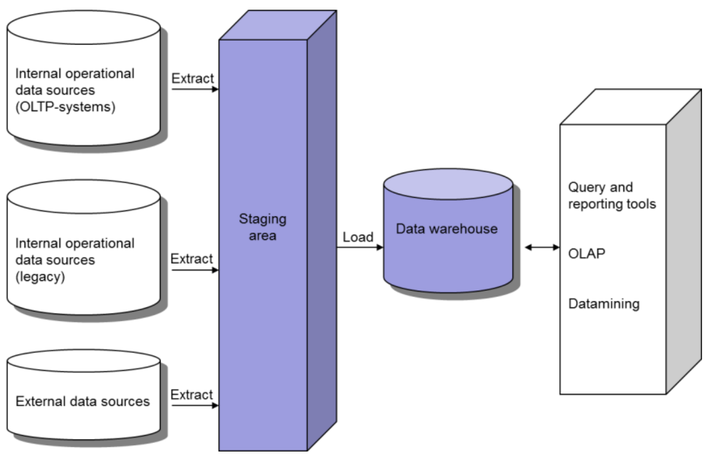
- **Attribute naming**: can be differently across different data sources
- **Measurement basis**: the same attribute can be measured in different units

DATA WAREHOUSING: CRITICAL SUCCESS FACTORS

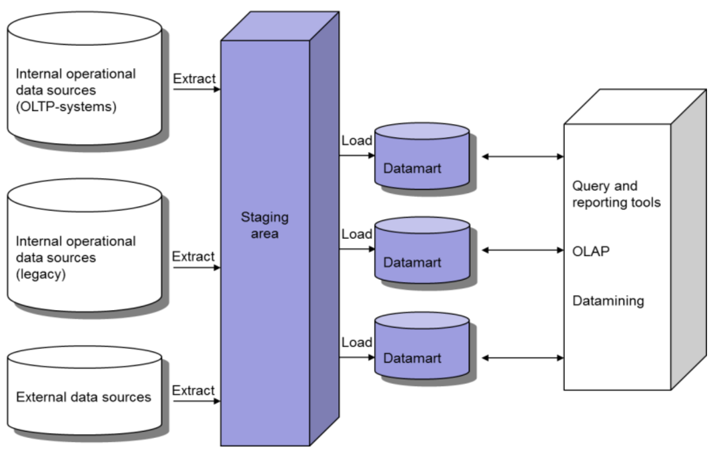
- Top management involvement
- Think big, start small: focus on high-impact processes first
- Project management
  - In-house BI: “competence center” → combines IT & business workers
  - Iterative, incremental process
  - External consultancy (outsourcing) is also an option
- Data quality: discover – understand – improve – enrich – deliver
  - DW driven by what is there, not by what should be there in an ideal world (+outliers)
  - Do you have enough quality data to do something useful with?
  - Don’t wait for the quality of the source data collection to improve
- Right methodology (=good model), technical architecture and tools
- Deliver the right information to the right people at the right time

DATA WAREHOUSE ARCHITECTURES

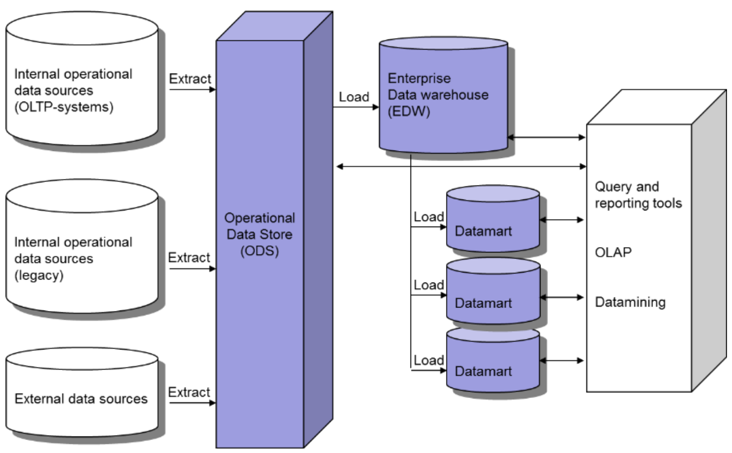
Two-level architecture



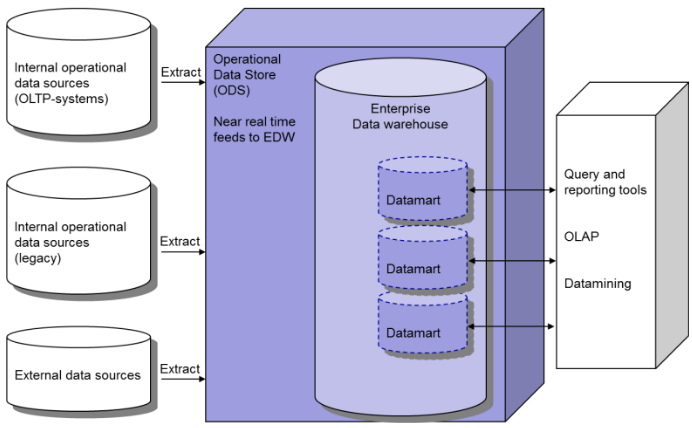
Independent data marts



Dependent data marts + operational data store

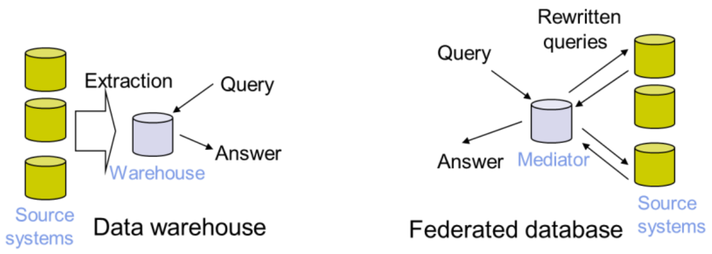


Logical data marts + real time data warehouse



FEDERATED DBS

- = alternative to data warehouses
- DW: create a copy of all the data; execute queries against the copy
- FDB: pull data from source systems as needed to answer queries



WH VS FDB

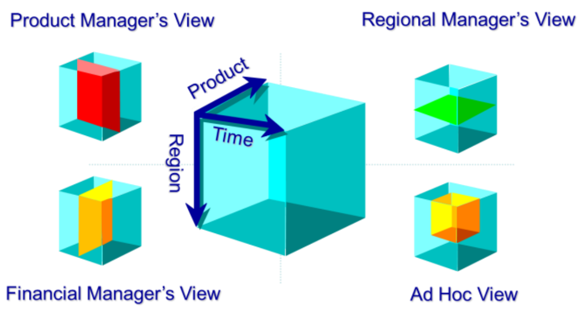
- Advantages FDBs:
    - No redundant copying of data
    - Queries see real-time view of evolving data
    - More flexible security policy
- Disadvantages FDBs:
    - Analysis queries place extra load on transactional systems
    - Query optimization is hard to do well
    - Historical data may not be available
    - Complex "wrappers" needed to mediate between analysis server and source systems
- DWs are much more common in practice:
    - Better performance
    - Lower complexity
    - Slightly out-of-date data is acceptable

OLAP AND DATA MINING

- *Verification based* analysis techniques: testing of hypotheses as formulated by user
  → SQL based querying and reporting
  → On-Line Analytical Processing (OLAP)
- *Discovery based* analysis techniques: generation of new hypotheses
  → Data mining and text mining

OLAP

- Interactive analysis of large chunks of multidimensional data from a DW or DM
- Advanced graphical representation of the data
- *Rollup*: aggregate data along one or more dimensions (daily to monthly)
- *Drill-down*: disaggregate data along one or more dimensions
- *Slicing* and *dicing*: analyze data from different angles
- Basic way of doing OLAP: pivot tables
  → interactively re-arrange and manipulate aggregated data using a two dimensional table



OLAP queries in SQL: sample data

Salary distribution

Name	*City*	*Province*	*Cntry*	*Sex*	*YOB*	*Salary*
Dooms	Meise	Vlaams-Brabant	B	M	1975	50200
Michel	Meise	Vlaams-Brabant	B	M	1973	63100
Verhelst	Leuven	Vlaams-Brabant	B	M	1942	65600
Kerkhofs	Leuven	Vlaams-Brabant	B	V	1942	53000
Siraut	null	Vlaams-Brabant	B	M	1980	44000
Adam	null	Vlaams-Brabant	B	V	1975	49000
Grommen	Bornem	Antwerpen	B	M	1942	67500
Belmans	Bornem	Antwerpen	B	V	1973	54000
Lettany	Mortsel	Antwerpen	B	V	1978	45300
Thys	Mortsel	Antwerpen	B	V	1978	42800
Kroon	Nieuwegein	Utrecht	NL	V	1978	61000
Belt	Nieuwegein	Utrecht	NL	M	1975	45000
Hendriks	Breda	Noord-Brabant	NL	M	null	45600
De Schepper	Breda	Noord-Brabant	NL	V	1978	null
Dewilde	Breda	Noord-Brabant	NL	M	1973	56000
Kok	Leeuwaarden	Friesland	NL	M	1951	62200
Veenhuis	Leeuwaarden	Friesland	NL	M	1973	61800
Duyverman	null	Friesland	NL	M	1980	59700

GROUP BY ROLLUP construct

```
SELECT COUNTRY, PROVINCE, CITY, COUNT(*) AS NUMBER,
   AVG(SALARY) AS AVERAGE-SALARY
FROM SALARY-DISTRIBUTION
GROUP BY ROLLUP(COUNTRY, PROVINCE, CITY);
```

GROUP BY ROLLUP construct with CASE GROUPING

```
SELECT CASE GROUPING(COUNTRY)
  WHEN 1 THEN 'ALL' ELSE COUNTRY END AS COUNTRY,
        CASE GROUPING(PROVINCE)
  WHEN 1 THEN 'ALL' ELSE PROVINCE END AS PROVINCE,
        CASE GROUPING(CITY)
  WHEN 1 THEN 'ALL' ELSE CITY END AS CITY,
        COUNT (*) AS NUMBER, AVG(SALARY) AS
        AVERAGE-SALARY
FROM SALARY-DISTRIBUTION
GROUP BY ROLLUP(COUNTRY, PROVINCE, CITY);
```

GROUP BY ROLLUP construct (contd)

Country	*Province*	*City*	*Number*	*Average-salary*
B	Vlaams -Brabant	Meise	2	56650
B	Vlaams -Brabant	Leuven	2	59300
B	Vlaams -Brabant	null	2	46500
B	Antwerpen	Bornem	2	60750
B	Antwerpen	Mortsel	2	44050
NL	Utrecht	Nieuwegein	2	53000
NL	Noord-Brabant	Breda	2	50800
NL	Friesland	Leeuwaarden	2	62000
NL	Friesland	null	1	59700
B	Vlaams-Brabant	null	6	54150
B	Antwerpen	null	4	52400
NL	Utrecht	null	2	53000
NL	Noord-Brabant	null	2	50800
NL	Friesland	null	3	61233
B	null	null	10	53450
NL	null	null	7	55900
null	null	null	17	54459

GROUP BY ROLLUP construct with CASE GROUPING (contd)

Country	*Province*	*City*	*Number*	*Average-salary*
B	Vlaams -Brabant	Meise	2	56650
B	Vlaams -Brabant	Leuven	2	59300
B	Vlaams -Brabant	null	2	46500
B	Antwerpen	Bornem	2	60750
B	Antwerpen	Mortsel	2	44050
NL	Utrecht	Nieuwegein	2	53000
NL	Noord-Brabant	Breda	2	50800
NL	Friesland	Leeuwaarden	2	62000
NL	Friesland	null	1	59700
B	Vlaams-Brabant	all	6	54150
B	Antwerpen	all	4	52400
NL	Utrecht	all	2	53000
NL	Noord-Brabant	all	2	50800
NL	Friesland	all	3	61233
B	all	all	10	53450
NL	all	all	7	55900
all	all	all	17	54459

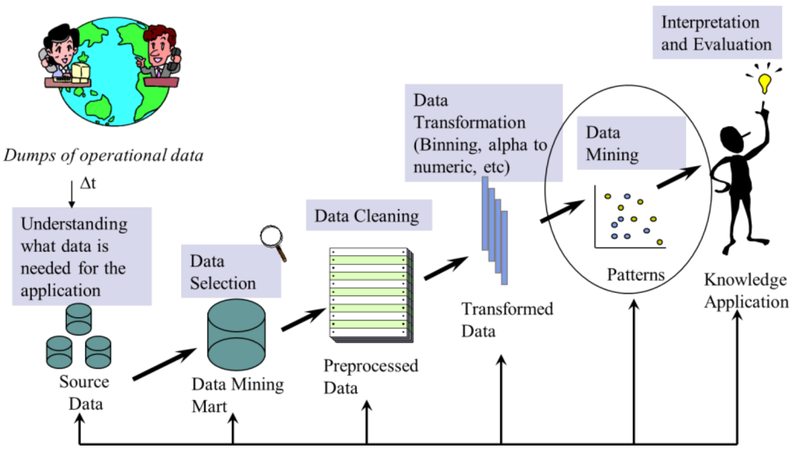
GROUP BY ROLLUP construct with CASE GROUPING (contd)

Country	*Province*	*City*	*Number*	*Average-salary*
B	Vlaams -Brabant	Meise	2	56650
B	Vlaams -Brabant	Leuven	2	59300
B	Vlaams -Brabant	null	2	46500
B	Antwerpen	Bornem	2	60750
B	Antwerpen	Mortsel	2	44050
NL	Utrecht	Nieuwegein	2	53000
NL	Noord-Brabant	Breda	2	50800
NL	Friesland	Leeuwaarden	2	62000
NL	Friesland	null	1	59700
B	Vlaams-Brabant	all	6	54150
B	Antwerpen	all	4	52400
NL	Utrecht	all	2	53000
NL	Noord-Brabant	all	2	50800
NL	Friesland	all	3	61233
B	all	all	10	53450
NL	all	all	7	55900
all	all	all	17	54459

KNOWLEDGE DISOVERY IN DATA (KDD)

- = “the non-trivial process of identifying valid, novel, potentially useful and ultimately understandable patterns in data”
- Iterative and multi-disciplinary process
- Retail (response modelling, retention modelling), Credit card+Ebay+Phone company (fraud detection), Amazon (customized recommendations), Email (spam detection), Financial institutions (credit risk prediction), etc.

Typical KDD process

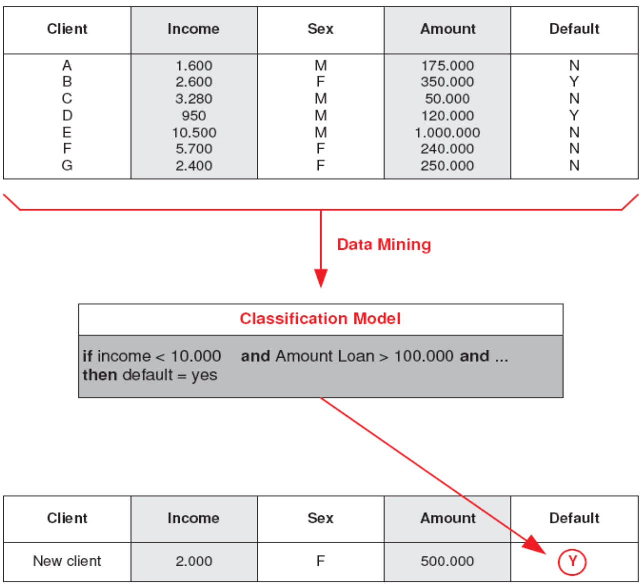


DATA MINING

- = discovery of new patterns in a collection of structured data
  - descriptive analysis: discover patterns in past events (association, sequencing, clustering)
  - *predictive analysis*: discover patterns to predict future events (classification, regression)
- Text mining: identify new patterns in a collection of unstructured data

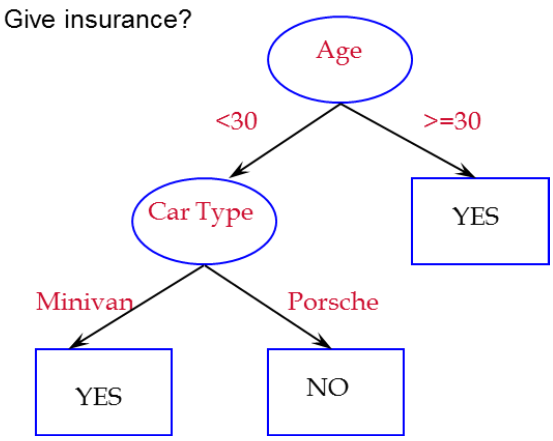
CLASSIFICATION (PREDICTIVE ANALYSIS)

The target variable is discrete. Used in financials (credit scoring), marketing (response model, churn) and counter-terrorism.



Client	Income	Sex	Amount	Default
A	1.600	M	175.000	N
B	2.600	F	350.000	Y
C	3.280	M	50.000	N
D	950	M	120.000	Y
E	10.500	M	1.000.000	N
F	5.700	F	240.000	N
G	2.400	F	250.000	N

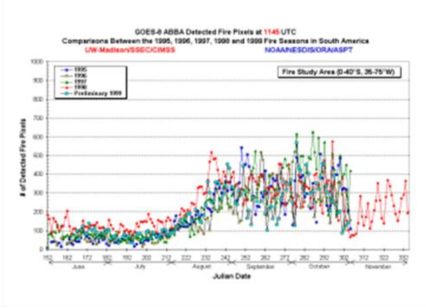
Client	Income	Sex	Amount	Default
New client	2.000	F	500.000	Y



REGRESSION (DESCRIPTIVE ANALYSIS)

The target variable is continuous (forecasting loss, stock prices, customer lifetime value, etc.)

House price = 0.125 squared_foot
+ 0.305 location + …
+ 3.1 proximity_park



ASSOCIATIONS (DESCRIPTIVE ANALYSIS

Detects frequently occurring patterns between items and are represented as association rules.
Eg: market basket analysis → which products are bought together?

SEQUENCES (DESCRIPTIVE ANALYSIS)

These are associations with a time aspect and they detect temporal patterns between items.
Eg: web mining → if web page A then webpage B and then webpage C
Eg: medical → if operation X then 30% chance of infection in 1 week

CLUSTERING (DESCRIPTIVE ANALYSIS)

Divides data in groups: maximal similarity within group, maximal dissimilarity between groups
Eg: segmentation → innovators, early adopters, …, late majority ➔ often pre-processing to other techniques