DATABASDESIGN FÖR INGENJÖRER - 1DL124

Sommar 2005

En introduktionskurs i databassystem

http://user.it.uu.se/~udbl/dbt-sommar05/
alt. http://www.it.uu.se/edu/course/homepage/dbdesign/st05/

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Introduction to Object-Oriented and Object-Relational Databases

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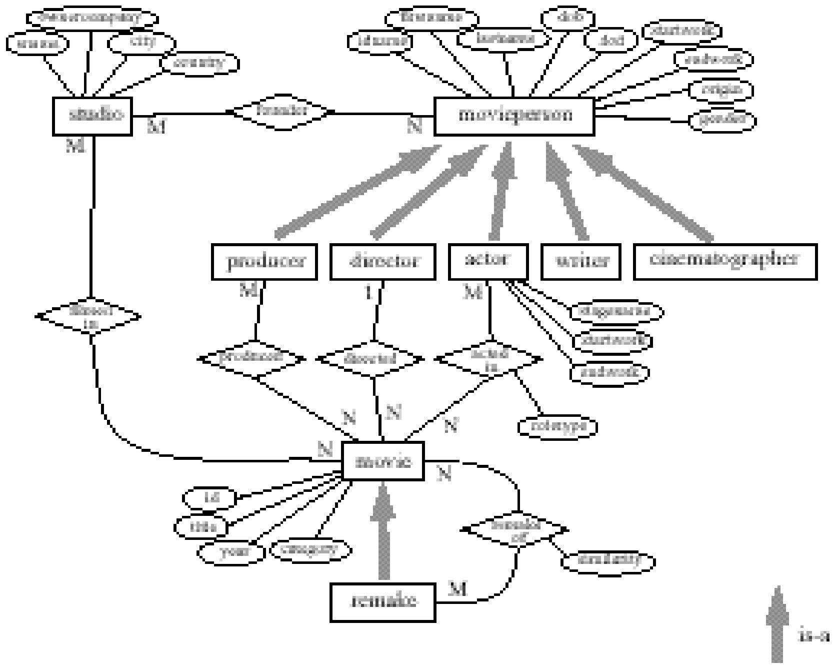
Outline of presentation

- Some General DBMS Concepts
  - limitations of traditional DBMSs
- History of DBMSs
- Object-Oriented Databases
- Object-Relational Databases
- Differences
- Standards

Database Design

- Database Design:
  - How to translate subset of reality into data representations in the database.
- Schema:
  - A description of properties of data in a database (i.e. a meta-database)
- Data Model:
  - A set of building blocks (data abstractions) to represent reality.
    Each DBMS supports one Data Model.
    The most common one is the Relational Data Model where data is represented in tables.
    NOTICE: E.g. CAD people use the word ‘Data Model’ instead of ‘Schema’
- Conceptual Data Model:
  - A very high level and user-oriented data model (often graphical).
    CDM not necessarily representable in DBMS or computer!
    Most common CDM is Entity-Relationship (ER) data model.
    But also Extended ER models are common
- Conceptual Schema Design
  - Produce a DBMS independent Conceptual Schema in the Conceptual Data Model

Extended Entity-Relationship Diagram



Logical Database Design

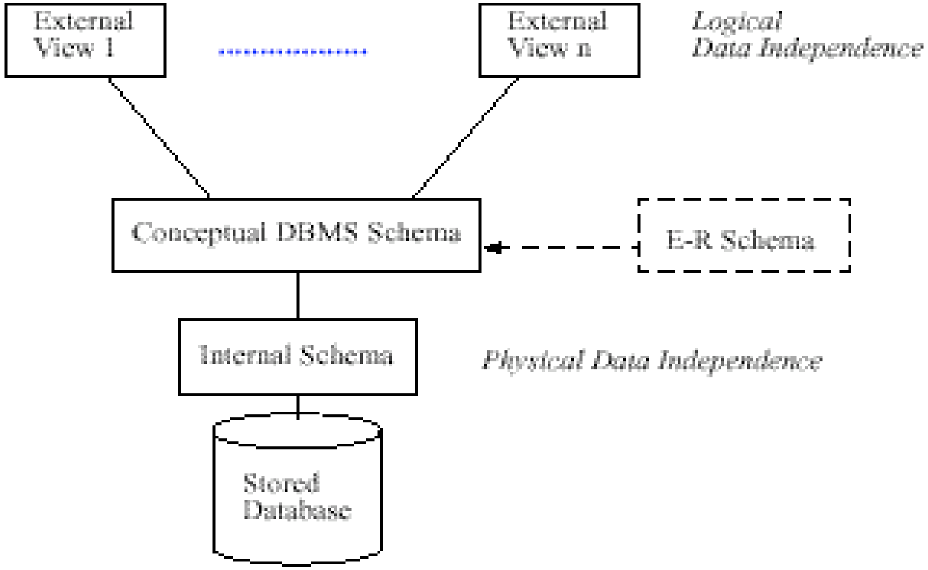
- Logical Database Design:
  – How to translate Conceptual Schemas in the conceptual data model (e.g. ER-schemas)
    to a Conceptual Schema in the DBMS data model (e.g relational tables)
- Logical Database Design for the Relational Data Model includes:
  – Key Identification: What attributes are used to identify rows in a table?
  – Normalization: Table decomposition to solve update problems, normal forms
- PROBLEM: Semantics may disappear or be blurred when data is translated to less expressive data model and normalized

Physical Database Design

- Physical Database Design:
  - Physical representation of the database schema optimized with respect to the access patterns of critical applications.
- Indexes:
  - permit fast matching of records in table satisfying certain search conditions.
  - The index structures are closely related to the internal physical representations of the DBMS.
  - Indexes can speed up execution considerably, as well as storing data usually accessed together in the same table.
  - Indexes permit the database to scale, i.e. the access times grow much slower than the database size.
- PROBLEM: New applications may require data and index structures that are not supported by the DBMS. (e.g. calendars, numerical data, geographical data, data exchange formats, etc.)

The ANSI/SPARC three-schema Architecture

- Achieves Data Independence



Data Independence

- External View:
  - Mapping Conceptual Schema --> subset of the database for a particular (group of) users.
- Data Independence:
  - The capability to change the database schema without having to change applications.
    NOTE: Data Independence is very important since databases continuously change!
- Logical Data Independence:
  - The capability to change conceptual schema without having to change applications and interfaces to views.
    E.g.: create a new table, add a column to a table, or split a table into two tables
- Physical Data Independence:
  - The capability to change the physical schema without having to change applications and logical schema (E.g. add/drop indexes, change data formats, etc.)
- PROBLEM: Application programs still often have data dependencies, e.g. to map relational database tables to application object structures.

Database Manipulation

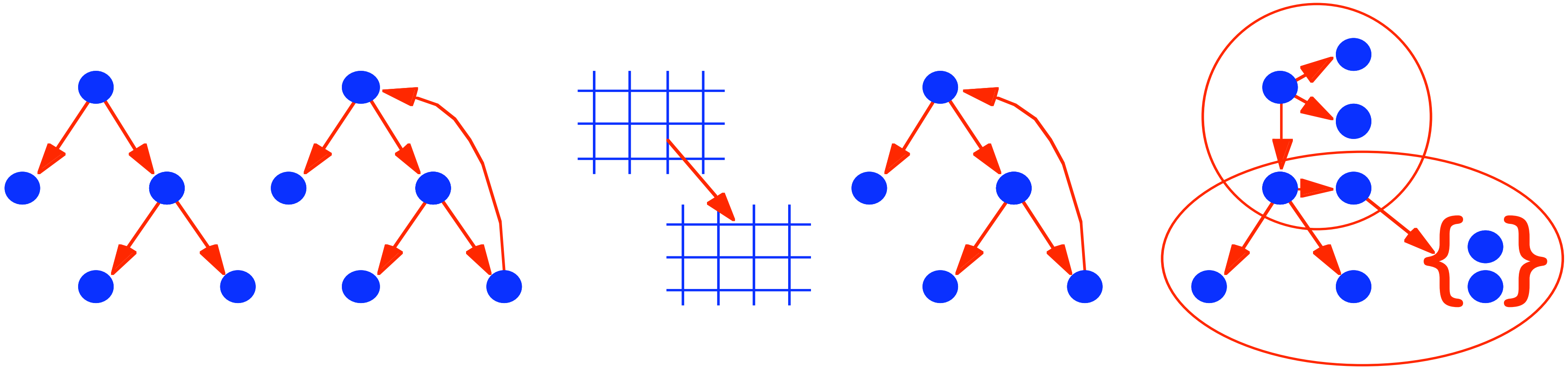
- Query Language:
  - Originally a QL could only specify more or less complex database searches.
    Now the query language (SQL) is a general language for interactions with the database.
- Typical query language operations are:
  - Searching for records fulfilling certain selection conditions
  - Iterating over entire tables applying update operations
  - Schema definition and evolution operators
  - Object-Oriented Databases have other operations such as create and delete objects
- The user directly or indirectly calls SQL in the following ways:
  - By running an interpreter that interactively executes SQL commands
  - By running an application program that contains calls to Embedded SQL
  - By running a graphical Database Browser to navigate through the database. (The browser internally calls embedded SQL)
- PROBLEM: Would like to be able to customize and extend query language for different application areas.

Views

- View:
  - A view is a mapping from the Conceptual Schema to a subset of the database as seen by a particular (group of) users.
    - SQL is a closed query language that maps tables into tables => SQL allows very general views (derived tables) to be defined as single queries
- Views provide:
  - External schema
    - Each user is given a set of views that map to relevant parts of the database
  - Logical data independence
    - When schema is modified views mapping new to old schema can be defined
  - Encapsulation
    - Views hide details of physical table structure
  - Authorization
    - The DBA can assign different authorization privileges to views of different users
- NOTICE: Views provide logical data independence.

Evolution of Database Technology

1960	1970	1980	1990	1997
Hierarchical (IMS)	Network model (CODASYL)	Relational model (e.g. ORACLE)	1st Generation OODB (e.g. Objectivity)	Object Realtional DBMS (e.g. SQL99)
Trees	Complex data structures	Tables	OO data structures	Object model



New DBMS Applications (for OODBMSs)

- Classical DBMS:
  - Administrative applications, e.g. Banking (ATMs)
- Properties:
  - Very large structured data volumes
  - Very many small Transactions On-line (High transaction rates)
  - Occasional batch programs
  - High Security/Consistency
- New Needs for Engineering, Scientific databases, etc.:
  - Extensibility (on all levels)
  - Better performance
  - Expressability (e.g. Object-Orientation needed)
  - Tight PL Interfaces
  - Long transactions (work in 'sand box')

New DBMS Applications (cont. ...)

Problem areas:

- CASE Computer Aided Software Engineering
- CAD Computer Aided Design
- CAM Computer Aided Manufacturing
- OIS Office Information Systems
- Multi-media databases
- Scientific Applications
- Hypertext databases (WWW)

Object-Oriented Databases

Problems with using RDBMSs for OO applications

- Complex mapping from OO conceptual model to relations
- Complex mapping => complex programs and queries
- Complex programs => maintenance problems
- Complex programs => reliability problems
- Complex queries => database query optimizer may be very slow
- Application vulnerable to schema changes
- Performance

Object-Oriented Databases

- First generation ODBs
- Extend OO programming language with DBMS primitives
  - E.g. C++, SmallTalk, Java
  - Allow persistent data structures in C++ programs
  - Navigate through database using C++ primitives (as CODASYL)
  - An object store for C++, SmallTalk, Java, etc.
- Several products out, e.g.:
  - Objectivity, Versant, ObjectStore, Gemstone, Poet , PJama, O_2

Object-Oriented Databases

- Pros and cons:
  +Long transactions with checkin/checkout model (sand box)
  +Always same language (C++)
  +High efficiency (but only for checked-out data)
  - Primitive ‘query languages’ (now OQL standard proposed)
  - No methods in database (all code executes in client, no stored procedures)
  - Rudimentary data independence (no views)
  - Limited concurrency
  - Unsafe, database may crash
  - Slow for many small transactions (e.g. ATM applications)
  - May require extensive C++ or Java knowledge

Object-Oriented Databases

Persistence

- Integrated with programming language:
  - E.g. C++ with persistent objects
    class PERSON { ... };
    ....
    {PERSON P; // Local within block... }
    static PERSON p; // Local for execution
    persistent PERSON p; // Exists between program executions
- Pointer *swizzling*:
  - Automatic conversion from disk addresses to MM addresses
  - References to data structures on disk (OIDs) look like regular C++ pointers!
  - Navigational access style.
  - Fast when database cached in main-memory of client!
  - Preprocessed by OODBMS for convenient extension of C++

Object-Relational Databases

- Object-Relational DBMSs
- Idea:
  - Extend on RDBMS functionality
  - Customized (abstract) data types
  - Customized index structures
  - Customized query optimizers
  - Use declarative query languages, SQL extension (SQL99)
- Extensible DBMS
  - Object-orientation for abstract data types
  - Data blades (data cartridges, data extenders) are database server ‘plug-ins’ that provide:
    - User definable index structures
    - Cost hints and re-write rules for the query optimizer

Object-Relational Databases

- Pros and cons:
  +Migration path to SQL
  +Views, logical data independence possible
  +Programming language independence
  +Full DBMS functionality
  +Stored procedures, triggers, constraints
  +High transaction performance by avoiding data shipping
  +Easy to use declarative queries
  - Overkill for application needing just a C++ object store
  - Performance may suffer compared to OODBs for applications needing just an object store
  - May be very difficult to extend index structures and query optimizers
- Research prototypes: Iris (HP), Postgres (Berkeley), Starburst (IBM)
- Products: Informix, OpenODB (Odapter), DB2
  NOTE: On-going evolution of 1st gen. products to become more Object-Relational

Object-Oriented Databases

- Literature:
  - M.Stonebraker: *Object-relational DBMSs - The next great wave*, Morgan-Kaufmann 1996
- Object-Oriented Manifestos
  - First generation ODB Manifesto: *State-of-the-*art OODBs anno 1990
    - Atkinsson et al: *The OO Database System Manifesto* in W.Kim, J-M. Nicolas, S.Nishio (eds): *1st Intl. Conf. on Deductive and OO Databases*
      Early O_2
  - Object-relational DB Manifesto: *Requirements for next generation DBMSs* anno 1990
    - Stonebraker et. al.: *Third-generation Data Base System Manifesto*
      SIGMOD Record, Vol. 20, No. 4, Dec.1991.

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Object-Oriented Databases

The Manifestos:

- Object identity
  - E.g. for structure sharing:
    Unique OIDs maintained by DBMS
    E.g. Parent(:tore) = :ulla, Parent(:kalle)=:ulla
- Complex objects
  - Not only tables, numbers, strings but
    sets, bags, lists, and arrays, i.e. *non-1NF relations*
  - E.g. Courses(:tore) = {:c1,:c2,:c3}
- Encapsulation
  - Simplicity
    Modularity
    Security

Object-Oriented Databases (manifesto cont. ...)

- Extensibility
  1. User-defined data types and operations on these new datatypes
     - e.g. datatypes: create type Person, create type Timepoint
     - e.g. operations. name(:tore), :t2 - :t1, :t2 > :t1, etc.
     - Both OO and OR allow abstract datatypes through object-orientation
  2. Extensions of physical representations (including indexes) and corresponding operations
     - OO/OR databases allow extensions of physical representations
     - OR databases allow definition of new indexes
  3. Extensions of query processor with optimization algorithms and cost models
     - OR databases allow extensions of query processing
- Class Hierarchies as modelling tool (both OO/OR)
  - Classification
    - e.g. Student subtype of Person
  - Shared properties
  - Specialization
    - Student subtype of Person with extra attributes University, Classes, …

Object-Oriented Databases (manifesto cont. ...)

- Computational completeness
  - OR databases: Turing complete ‘query’ language: SQL99 code executes on server
  - OO databases: C++/Java code with embedded OQL statements executes in client (web server)
- Persistence
  - OO databases: transparent access to persistent object by swizzling
  - OR databases: embedded queries to access persistent objects
- Secondary storage management
  - OR databases: indexes can be implemented by user (difficult!)
- Concurrency
  - OO databases: good support for long transactions
  - OR database: good support for short transactions
- Ad hoc query facility
  - OO Databases: weak
  - OR Databases: very strong

Object-Oriented Databases (manifesto cont. ...)

- Data independence
  - OO Databases: weak
  - OR Databases: strong
- Views
  - Important for data independence
  - Query language required
  - Only in OR databases!
- Schema evolution
  - Relational DBs have it!
  - Fully supported in OR databases, primitive in OO databases

Object Database Standards

- Object-Oriented DBMS Standard
  - The ODMG standard proposal:
    - R. Cattell, Ed.: *The ODMG-93 Standard for Object Databases*, Morgan-Kaufmann Publishers, San Mateo, California, 1993.
  - Includes an Object Data Model
  - Object Query Language: OQL (different model than SQL99)

- Object-Relational DBMS Standards
  - The SQL99 (SQL3) standard proposal:
    - *ISO-Final Draft International Standard (FDIS):*
      ISO/IEC FDIS 9075-2 Database Language SQL
  - Very large (>1000 pages)
  - SQL-92 is subset
  - Much more than object-orientation included
  - Triggers, procedural language, OO, error handling, etc.
  - Certain parts, e.g. standards for procedures, error handling, triggers, already being included in the new SQL-99 standard.

Data Exchange Formats

Purpose:

- Standardized formats for sending data between systems
  - examples: STEP/EXPRESS, PDF, HTML, XML, VRML, MIDI, MP3, etc.
- Engineering domain standard: STEP (standard for exchange of product data)
  - STEP is an industry wide ISO standard for exchange of mainly engineering (CAx etc.) data
  - separates meta-data (schema) and data as for databases
  - EXPRESS is data model in database terms: i.e. it is the language in which to define the schema.
  - STEP models are standardized schemas for different engineering application areas, e.g. AP209
  - The exchanged data follows specialized STEP schemas,
    e.g. PART 21 most common (XML based too, PART 29)
  - CAx vendors normally not able to handle EXPRESS schemas
  - Only PART 29 files following a specific schema, e.g. AP 209

Data Exchange Formats

- The STEP/EXPRESS and database community sometimes use the same terminology with different meanings:
- Data model:
  – database world: schema *language* (i.e. EXPRESS is a data model)
  – STEP/EXPRESS world: here a particular schema *definition* written in EXPRESS
  – We therefore avoid the word data model to minimize confusion
- Multi-level schema architecture:
  – database world: *external* - *conceptual* - *internal* schemas
  – STEP/EXPRESS world:
    - *Application protocol*, AP (c.f. external schema)
    - *Integrated resources*, IR (c.f. conceptual schema)

Data Exchange Formats

- The XML language
- Extension of HTML to be able to define *own tags* in web documents,
  - for example:

```
<polygon>
<line><start>1.2 1.3</start>
</end>2.1 3.4</end>
</line>
<line><start>2.1 3.4</start>
</end>4.6 4.2</end>
</line>
</polygon>
```

- Can also define DTD which is grammar for allowed tags in the documents *referencing* it
- DTDs are more or less well specified schemas
- On-going work to define real schema language for XML: SMLSchema
- XML not object-oriented - only nested structures