Programmerade system
TDA143
Lecture on Databases

Graham Kemp
kemp@chalmers.se
Room 6475, EDIT Building
http://www.cse.chalmers.se/~kemp/

Material in course textbook

"Computer Science: An Overview"
9th /10th /11th Edition, J. Glenn Brookshear

Chapter 9

Why study databases?

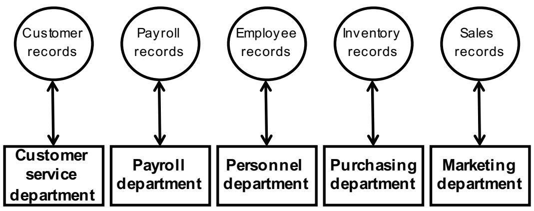
Banking, ticket reservations, customer records, sales records, product records, inventories, employee records, address [illegible] records, student records, course plans, schedules, surveys, test suites, research data, genome bank, [illegible] records, time tables, news archives, sports results, e-commerce, user authentication systems, web forums, www.imdb.com, the world wide web, …

Databases are everywhere!

Examples

- Banking
  - Drove the development of DBMS
- Industry
  - Inventories, personnel records, sales …
  - Production Control
  - Test data
- Research
  - Sensor data
  - Geographical data
  - Laboratory information management systems
  - Biological data (e.g. genome data)

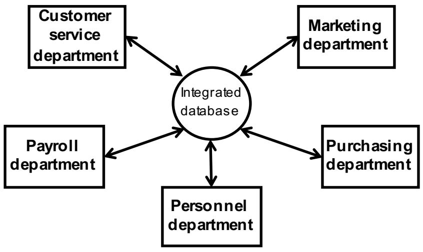
File-oriented information system



Problems with working with files

- Redundancy
  - Updates
  - Wasted space
- Changing a data format will require all application programs that read/write these files to be changed.
- Sharing information between departments can be difficult.

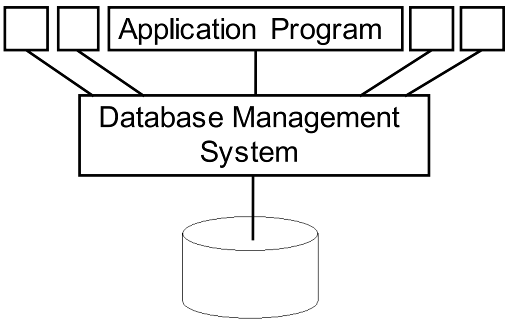
Database-oriented information system



A database is …

- a collection of data
- managed by specialised software called a **database management system** (DBMS) (or, informally, a “database system”)
- needed for large amounts of persistent, structured, reliable and shared data

Using a DBMS: an overview



Centralised control of data

- amount of redundancy can be reduced
  - less inconsistency in the stored data
- stored data can be shared
- standards can be enforced
- security restrictions can be applied
- data integrity can be maintained
  - validation done in one place
- conflicting requirements can be balanced
- provides **data independence**
  - can change storage structure without affecting applications

Motivation for database systems

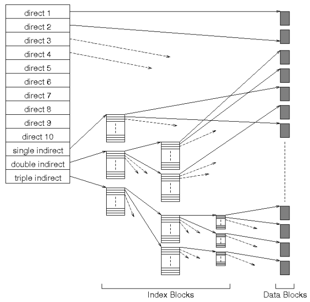
Needed for large amounts of persistent, structured, reliable and shared data (Ted Codd, 1973)

- Large amounts:
  - needs indexing for fast access
  - needs a load utility
- Persistent:
  - needs schema definition of types which evolves
- Structured:
  - storage schema held with data
  - query language (e.g. SQL) independent of storage
- Shared:
  - locking mechanism for concurrent update
  - access control via DBMS
  - centralised integrity checking
- Reliable:
  - changes to disc pages are logged
  - commit protects against program of disc crash
  - can undo (rollback) uncommitted updates

Traditional File Structures

A short digression …

UNIX file management



Actual organisation is hidden

- Just as the file management system in an operating system gives the users the illusion that a text file is stored on disc as a long consecutive sequence of characters …
- … a database management system gives the users the illusion that their data are stored on disc in accordance with a **data model**.

Data models

- Storing data in a computer system requires describing the data according to some **data model**, in a form which can be represented directly within the computer.
- A **data model** specifies the rules according to which data are structured and also the associated operations that are permitted.

Data models: brief overview

- "No data model"
  - Flat files
- "Classical" data models
  - Hierarchical (tree)
  - Network (e.g. CODASYL) (graph)
  - **Relational** (Codd, 1970) (tables)
- Semantic data models, e.g.
  - Entity-Relationship model (Chen, 1976)
  - Functional Data Model (Shipman, 1981)
  - SDM (Hammer and McLeod, 1981)

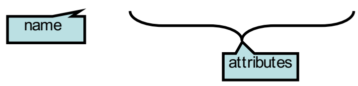
Relational DBMSs

- Very simple model
- Familiar tabular structure
- Has a good theoretical foundation from mathematics (set theory)
- Industrial strength implementations, e.g.
  - Oracle, Sybase, MySQL, PostgreSQL, Microsoft SQL Server, DB2 (IBM mainframes)
- Large user community

Relation Schemas

- In the relational data model, a design consists of a set of **relation schemas**.
- A relation schema has
  - a name, and
  - a set of attributes (+ types):

```
Courses(code, name, teacher)
```



Schema vs Instance

- ***Schema*** (or ***intension*** or a relation)
  - name and attributes of a relation

```
Courses(code, name, teacher)
```

- ***Instances*** (or ***extension*** of a relation)
  - the actual data
  - a set of **tuples**:

```
{ ('TDA357', 'Databases', 'Niklas Broberg'),
  ('TIN090', 'Algorithms', 'Devdatt Dubhashi') }
```

tuples

From schema to database

- The relations of the database schema become the tables when we implement the database in a DBMS. The tuples become the rows:

```
Courses(code, name, teacher)
```

relation schema

table instance

code	*name*	*teacher*
'TDA357'	'Databases'	'Niklas Broberg'
'TIN090'	'Algorithms'	'Devatt Dubhashi'

Keys

- Relations have **keys** – attributes whose values uniquely determine the values of all other attributes in the relation.

Courses(<u>code</u>, name, teacher)

key

```
{('TDA357', 'Databases', 'Niklas Broberg'),
```
~~('TDA357', 'Algorithms', 'Devdatt Dubhashi')~~ }

Composite keys

- Keys can consist of several attributes

Courses(<u>code</u>, <u>period</u>, name, teacher)

```
{('TDA357', 2, 'Databases', 'Graham Kemp'),
 ('TDA357', 3, 'Databases', 'Niklas Broberg')}
```

Schemas and subschemas

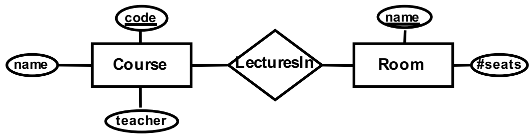
- A <u>schema</u> is a description of the entire database structure.
- A <u>subschema</u> is a description of only a part of the database structure.
  - Tailored to the needs of a user group
  - Controls access to data

Database design

- We design the conceptual model for our database using a high-level data model like the Enitity-Relationship model …
- … then we translate this design to the relational model (for implementation in an RDBMS).

Enitity-Relationship Diagram

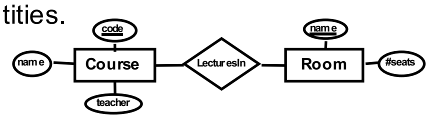
Example:



- A course has lectures in a room.
- A course is related to a room by the fact that the course has lectures in that room.
- A relationship is often named with a verb (e.g. HasLecturesIn)

Translation to relations

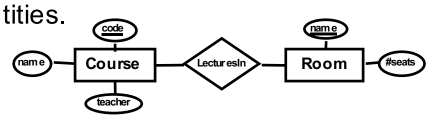
- A relationship between two entities is translated into a relation, where the attributes are the *keys* of the related entities.



⇨ **What?**

Translation to relations

- A relationship between two entities is translated into a relation, where the attributes are the *keys* of the related entities.



⇨

```
Courses(code, name, teacher)
Rooms(name, #seats)
LecturesIn(code, name)
```

Relational operators (1)

- Selection
  - Choose rows from a relation
  - State condition that rows must satisfy

$\sigma_{condition}(T)$

Examples:

$\sigma_{seats>100}(Rooms)$

$\sigma_{(code="TDA143" \text{ AND } day="Friday")}(Lectures)$

Relational operators (2)

- Projection
  - Choose columns from a relation
  - State which columns (attributes)

$\pi_A(T)$

Examples:

$\pi_{code}(Courses)$

$\pi_{name,seats}(Rooms)$

Relational operators (3)

$R_1 \times R_2$
- Cartesian product
- Combine each row of R_1 with each row of R_2

$R_1 \bowtie_{condition} R_2$
- join operator
- Combine row of R_1 with each row of R_2 if the condition is true

$R_1 \bowtie_{condition} R_2 = \sigma_{condition}(R_1 \times R_2)$

SQL

- SQL = Structured Query Language
- A very high-level *declarative* language.
  - Specify *what* information you want, not *how* to get that information (like you would in e.g. Java).
- Based on Relational Algebra

SELECT-FROM-WHERE

- Basic structure of an SQL query:

```
SELECT  attributes
FROM    tables
WHERE   tests over rows
```

```
SELECT  A
FROM    T
WHERE   C
```

⟺ $\pi_A(\sigma_C(T))$

Example:

GivenCourses =

course	per	teacher
TDA357	2	Niklas Broberg
TDA357	4	Rogardt Heldal
TIN090	1	Devdatt Dubhashi

```
SELECT *
FROM   GivenCourses
WHERE  course = 'TDA357';
```

Result =

What?

Example:

GivenCourses =

course	per	teacher
TDA357	2	Niklas Broberg
TDA357	4	Rogardt Heldal
TIN090	1	Devdatt Dubhashi

```
SELECT *
FROM   GivenCourses
WHERE  course = 'TDA357';
```

Result =

course	per	teacher
TDA357	2	Niklas Broberg
TDA357	4	Rogardt Heldal

Example:

GivenCourses =

course	per	teacher
TDA357	2	Niklas Broberg
TDA357	4	Rogardt Heldal
TIN090	1	Devdatt Dubhashi

```
SELECT course, teacher
FROM   GivenCourses
WHERE  course = 'TDA357';
```

Result =

What?

Example:

GivenCourses =

course	per	teacher
TDA357	2	Niklas Broberg
TDA357	4	Rogardt Heldal
TIN090	1	Devdatt Dubhashi

```
SELECT course, teacher
FROM   GivenCourses
WHERE  course = 'TDA357';
```

Result =

course	teacher
TDA357	Niklas Broberg
TDA357	Rogardt Heldal

Example:

```
SELECT  code, name, period
FROM    Courses, GivenCourses
WHERE   teacher = 'Niklas Broberg'
        AND code = course;
```

Courses

code	name
TDA357	Databases
TIN090	Algorithms

GivenCourses

course	per	teacher
TDA357	2	Niklas Broberg
TDA357	4	RogardtHeldal
TIN090	1	DevdattDubhashi

$\pi_{code,name,period}(\sigma_{teacher='Niklas\ Broberg'\ \&\ code\ =\ course}(Courses \times GivenCourses))$

Example:

```
SELECT code, name, period
FROM Courses, GivenCourses
WHERE  teacher = 'Niklas Broberg'
       AND code = course;
```

code	name	course	per	teacher
TDA357	Databases	TDA357	2	Niklas Broberg
TDA357	Databases	TDA357	4	RogardtHeldal
TDA357	Databases	TIN090	1	DevdattDubhashi
TIN090	Algorithms	TDA357	2	Niklas Broberg
TIN090	Algorithms	TDA357	4	RogardtHeldal
TIN090	Algorithms	TIN090	1	DevdattDubhashi

$\pi_{code,name,period}(\sigma_{teacher='Niklas\ Broberg'\ \&\ code\ =\ course}(Courses \times GivenCourses))$

Example:

```
SELECT code, name, period
FROM   Courses, GivenCourses
WHERE teacher = 'Niklas Broberg'
      AND code = course;
```

code	name	course	per	Teacher
TDA357	Databases	TDA357	2	Niklas Broberg
TDA357	Databases	TDA357	4	RogardtHeldal
TDA357	Databases	TIN090	1	DevdattDubhashi
TIN090	Algorit[illegible]	[illegible]	[illegible]	[illegible]
TIN090	Algorit[illegible]	[illegible]	[illegible]	[illegible]
TIN090	Algorit[illegible]	[illegible]	[illegible]	[illegible]

code	name	course	per	teacher
TDA357	Databases	TDA357	2	Niklas Broberg

$\pi_{code,name,period}(\sigma_{teacher='Niklas\ Broberg'\ \&\ code\ =\ course}(Courses \times GivenCourses))$

Example:

```
SELECT code, name, period
FROM   Courses, GivenCourses
WHERE  teacher = 'Niklas Broberg'
       AND code = course;
```

code	name	course	per	teacher
TDA357	Databases	TDA357	2	Niklas Broberg

code	name	per
TDA357	Databases	2

$\pi_{code,name,period}(\sigma_{teacher='Niklas\ Broberg'\ \&\ code\ =\ course}(Courses \times GivenCourses))$

Inserting data

```
INSERT INTO tablename
  VALUES (values for attributes);

INSERT INTO Courses
  VALUES ('TDA357', 'Databases');
```

code	name
TDA357	Databases

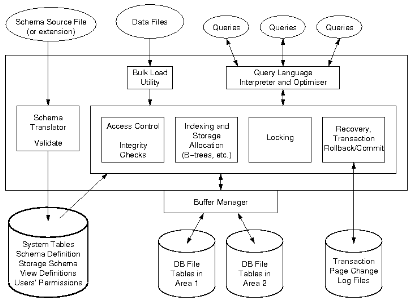
Deletions

```
DELETE FROM tablename
  WHERE test over rows;

DELETE FROM Courses
  WHERE code = 'TDA357';

DELETE FROM Courses;
```

Updates

```
UPDATE tablename
SET    attribute = ...
WHERE  test over rows

UPDATE GivenCourses
SET    teacher = ’Rogardt Heldal’
WHERE  code = ’TDA357’
  AND  period = 4;
```

Database system architecture



More about Databases

TDA357 - Databases

- 7,5 Higher education credits
- Runs twice each year, periods 2 and 3