Database Systems I
Week 1: Introduction

SFU SIMON FRASER UNIVERSITY

- Tuesday

SFU SIMON FRASER UNIVERSITY

Syllabus

- **Class Time and Location:**
  - Tue 14:30-16:20 AQ3005
  - Thu 14:30-15:20 AQ3003
- **Course Website:**
- http://www.cs.sfu.ca/CC/354/rfrank/

- **Instructor:** Richard Frank, PhD
- **Email:** rfrank@sfu.ca
- **Burnaby Campus Office:** TBD
- **Phone:** TBD

- **TA:** Ankit Gupta
- **Email:** aga53@sfu.ca
- **Burnaby Campus Office:** TBD
- **Phone:** TBD

Required Text

- Database Management Systems, third edition.
- By Raghu Ramakrishnan, Johannes Gehrke, McGraw Hill, 2002 (9780072465631)
- 60$ used at www.amazon.ca
- The book has a complimentary website with lecture slides, solutions to odd numbered exercises.
- The website is: http://pages.cfs.wisc.edu/~dbbook/

Syllabus

- there will be theory/conceptual questions on the assignments
- we will also apply the course material in a practical setting, and thus some assignment questions will require programming.
- Programs must be written in VB.NET, C#, C++ as part of Visual Studio (VS) 2010, or below
- The database component must be SQL Server 2008 R2, or below.
- Express [free] editions of both these software are available via CS@SFU and http://www.microsoft.com/express/downloads/

Syllabus

- Some assignments will require programming
  - stand-alone application
  - web-based application
  - (both can be done via VS)
- The entire VS Project, and the corresponding database, must be submitted as part of the assignment.
- Code must be documented to a level sufficient to easily understand the code.
  - This means document what the INPUT and OUTPUT are, along with any sections of code that are not obvious.
  - Err on the side of "too much"
  - Do not write a book.

SYLLABUS

	Week of	Lecture Topic	Due
1	Sept 7, 9	Introduction to Course - Overview of DBS [Ch 1]	
2	Sept 14, 16	Database Design [Ch 2]	Assignment #1
3	Sept 21, 23	Relational Model [Ch 3]	Assignment #2
4	Sept 28, 30	Algebra [Ch 4]	Assignment #3
5	Oct 5, 7	Queries [Ch 5]	Assignment #4
6	Oct 12, 14	Review of Ch3.1 & Transactions [Ch 16.1-16.4] Exam Review	Assignment #5
7	Oct 19, 21	Midterm Exam	
8	Oct 26, 28	Server Architecture [Ch 7.5] Standalone Application Development [Ch 6]	Assignment #6
9	Nov 2, 4	Standalone Application Development [Ch 6] Security [Ch 21.1-21.3]	Assignment #7
10	Nov 9	Internet Application Development [Ch 7]	Assignment #8
11	Nov 16, 18	XML Query Language [Ch 27.5-27.8]	Assignment #9
12	Nov 23, 25	Data Warehousing [Ch 25]	Assignment #10
13	Nov 30, Dec 2	Various Topics: - Parallel Databases [Ch 22.2] - Distributed Databases [Ch 22.6-22.8] - Deductive Databases [Ch 24.1-24.2] - Data Mining [quick overview of Ch 26] - Spatial Data [Ch 28.1-28.2]	Assignment #11
14		Final Exam	

SYLLABUS

Individual Assignments	50%
Midterm Exam	20%
Final Exam	30%

SYLLABUS

- All assignments are due immediately before class on the Thursday of the week indicated on the assignment.
  - For example, Assignment #1 is due on September 16 at 14:30.
  - For electronic submissions, submit your solution to the online submission server.
  - For paper assignments, hand in hard copies of your assignments before lecture.
- There are in total 11 assignments, all worth 5%.
- At the end of the course, the best 10 of 11 assignments will make up the Individual Assignment portion of your course grade.
- All paper-based submissions should be 1.5-spaced, 1" margins, size 10 font. Page requirements include all references, images/diagrams, but not cover pages.

Chapter 1: Overview of Database Systems

SFU SIMON FRASER UNIVERSITY

This course is important for...

- End users of DBS
- DB application programmers
- Database administrators (*DBA*)
- DBMS vendors
  - *Must understand how a DBMS works!*

SFU SIMON FRASER UNIVERSITY

The Inreasing Flood of Data

Customer Transactions

- As of 2004, Walmart data-warehouse was 500terabytes in size.
- In 2007, it was over 1petabyte (1m gigabytes)
- Sources:
- http://www.eweek.com/c/a/Enterprise-Applications/At-WalMart-Worlds-Largest-Retail-Data-Warehouse-Gets-Even-Larger/
- http://www.informationweek.com/news/storage/showArticle.jhtml?articleID=201203024

Human Genome

- The human genome contains 3.2 billion chemical nucleotide base pairs (A, C, T, and G).
- Largest known human gene is dystrophin at 2.4 million base pairs.
- Functions are unknown for more than 50% of discovered genes.
- Source: http://www.ornl.gov/sci/techresources/Human_Genome/project/journals/insights.shtml

Online Bookstore

- Amazon has roughly a bazillion products, give or take a couple zillion.

- Amazon: Website, database or application?

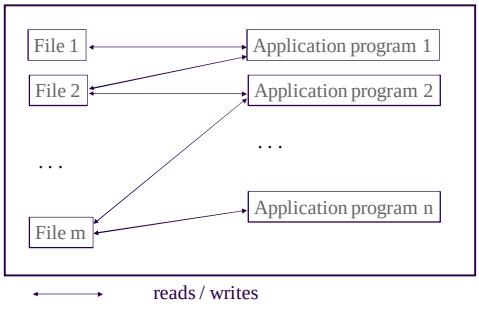
WHAT IS A DATABASE?

- A *database* (*DB*) is a very large, integrated, permanent collection of data.
- Models real-world
  - Entities (e.g., students, courses)
  - Relationships (e.g., Madonna is taking CMPT354).
- Example databases:
  - Customer Transactions
  - Human Genome
  - Online Bookstore
  - . . .

What is a DB(M)S?

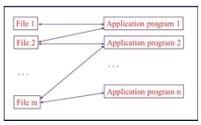
- A *Database Management System (DBMS)* is a software package designed to store, manage and retrieve databases.
- A *Database System (DBS)* consists of two components:
  - the DBMS
  - the DB.
- A DBMS can manage databases for any application as long as they are in the proper format (data model).

Data Storage Without DBMS

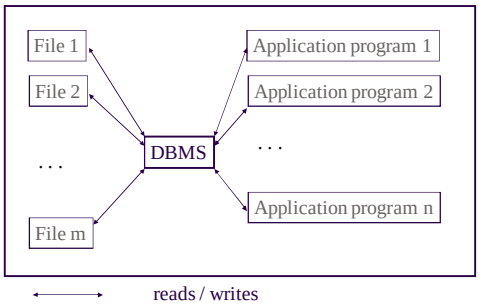


Data Storage Without DBMS

- Working directly with the file system creates major problems:
  - What if one attribute is added to the records in file 1?
  - How to efficiently access only one out of one million records?
  - What if several programs simultaneously want to access and modify the same record?
  - How to restore a meaningful database state after a system crash during the run of an application program?
    - How to fix a corrupted file?



Data Storage With DBMS



Data Storage With DBMS

- All data access is centralized and managed by the DBMS.
- The DBMS provides:
  - Logical data independence.
  - Physical data independence.
  - Reduced application development time.
  - Efficient access.
  - Data administration.
  - Data integrity and security.
  - Concurrent access / concurrency control.
  - Recovery from crashes.

Data Independence

- The layered DBMS architecture insulates applications from how data is structured and stored.
- A DBMS can be programmed at a much higher level of abstraction than the file system.
- Application programs need not be modified on change of database structure and / or storage.
- Reduced application development and maintainence time

Data Independence

- Applications are insulated from data and how data is structured and stored.
- *Logical data independence*: Protection from changes in *logical* structure of data.
  Ex.: adding another attribute to a relation
- *Physical data independence*: Protection from changes in *physical* structure of data.
  Ex.: adding / removing index structure
  or moving file to another disk

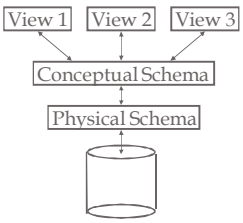
* *One of the most important benefits of using a DBMS!*

Data Models

- A *data model* is a collection of concepts for describing data (a formal language!).
- A *schema* is a description of a particular collection of data (database), using the given data model.
- The *relational data model* is the most widely used model today.
  - Main concept: *relation*, basically a table with rows and columns.
  - Every relation has a schema, which describes the columns, or fields.

Levels of Abstraction

- The *conceptual schema* defines the logical structure of the whole database.
- An *external schema* (*view*) describes how some user sees the data (restricted access, derived data).
- The *physical schema* describes the storage and index structures of the database.



EXAMPLE: UNIVERSITY DATABASE

- Conceptual schema
- Physical schema
- External schema (view)

EXAMPLE: UNIVERSITY DATABASE

- Conceptual schema:

Students(sid: string, name: string, login: string, age: integer, gpa:real)
Courses(cid: string, cname:string, credits:integer)
Enrolled(sid:string, cid:string, grade:string)

EXAMPLE: UNIVERSITY DATABASE

- Physical schema:
  - Relations stored as unordered tuples.
  - Index on first column of Students.

- Conceptual schema:
Students(sid: string, name: string, login: string, age: integer, gpa:real)
Courses(cid: string, cname:string, credits:integer)
Enrolled(sid:string, cid:string, grade:string)

EXAMPLE: UNIVERSITY DATABASE

- External schema (view):
  - *Course_info(cid:string, enrollment:integer)*

- Conceptual schema:
  Students(sid: string, name: string, login: string, age: integer, gpa:real)
  Courses(cid: string, cname:string, credits:integer)
  Enrolled(sid:string, cid:string, grade:string)

EXAMPLE: UNIVERSITY DATABASE

- Updates:
  - insert new student *(XXXid, XXX, XXX, 21, 3.5)*
  - delete course *CMPT-YYY*
  - enroll student *XXXid* in course *CMPT-ZZZ*
- Queries:
  - retrieve all students having a gpa of < 3.0
  - retrieve the average gpa of all students enrolled in course *CMPT-ZZZ*
  - retrieve the names of all courses having at least one student with a grade of 4.0

- Thursday

SYLLABUS

- **Class Time and Location:**
  - Tue 14:30-16:20 AQ3005
  - Thu 14:30-15:20 AQ3003
- **Course Website:**
- http://www.cs.sfu.ca/CC/354/rfrank/
- **Instructor:** Richard Frank, PhD
- **Email:** rfrank@sfu.ca
- **Burnaby Campus Office:** TBD
- **Phone:** TBD
- **TA:** Ankit Gupta
- **Email:** aga53@sfu.ca
- **Burnaby Campus Office:** TBD
- **Phone:** TBD

SYLLABUS

	Week of	Lecture Topic	Due
1	Sept 7, 9	Introduction to Course - Overview of DBS [Ch 1]	
2	Sept 14, 16	Database Design [Ch 2]	Assignment #1
3	Sept 21, 23	Relational Model [Ch 3]	Assignment #2
4	Sept 28, 30	Algebra [Ch 4]	Assignment #3
5	Oct 5, 7	Queries [Ch 5]	Assignment #4
6	Oct 12, 14	Review of Ch3.1 & Transactions [Ch 16.1-16.4] Exam Review	Assignment #5
7	Oct 19, 21	Midterm Exam	
8	Oct 26, 28	Server Architecture [Ch 7.5] Standalone Application Development [Ch 6]	Assignment #6
9	Nov 2, 4	Standalone Application Development [Ch 6] Security [Ch 21.1-21.3]	Assignment #7
10	Nov 9	Internet Application Development [Ch 7]	Assignment #8
11	Nov 16, 18	XML Query Language [Ch 27.5-27.8]	Assignment #9
12	Nov 23, 25	Data Warehousing [Ch 25]	Assignment #10
13	Nov 30, Dec 2	Various Topics: - Parallel Databases [Ch 22.2] - Distributed Databases [Ch 22.6-22.8] - Deductive Databases [Ch 24.1-24.2] - Data Mining [quick overview of Ch 26] - Spatial Data [Ch 28.1-28.2]	Assignment #11
14		Final Exam	

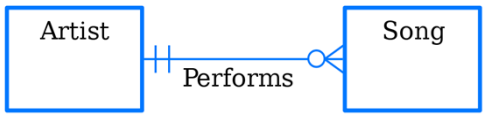
ASSIGNMENT 1

- References
  - What I had in mind was simply to quote any sources that you used. If you found a fact from http://www.xyz.com, say so in the paper.

> blah blah blah [1] blah blah.
>
> References/Bibliography
> [1] http://www.xyz.com accessed at DATE

- Make reasonable and believable assumptions
- Due Sept 16, 2:30.

Crow's Feet

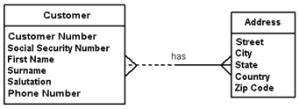


View vs. Conceptual vs. Physical

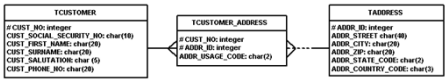
- View (external schema)

John Smith	123 Main St.
Sally Smith	123 Main St.
Sally Smith	456 Elm St.
-	789 Oak St.
Bob Jones	333 Birch St.

- Conceptual Schema

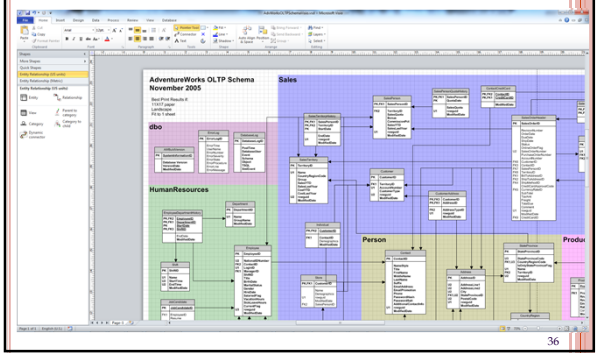


- Physical Schema

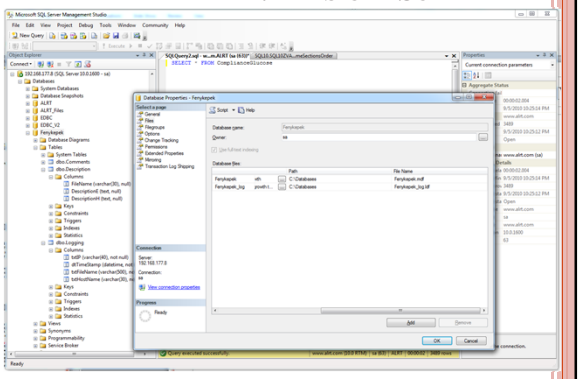


- http://www.agiledata.org/essays/dataModeling101.html

Ex: Conceptual Schema



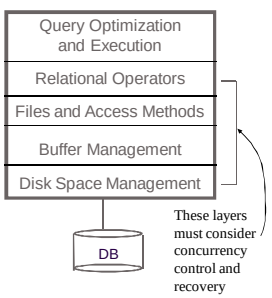
EX: PHYSICAL SCHEMA



- Onto the Lecture

STRUCTURE OF A DBMS

- A typical DBMS has a layered architecture.
- The figure does not show the concurrency control and recovery components.
- This is one of several possible architectures; each system has its own variations.



Efficient Access

- When the user wants to access only a small portion of a large relation, the DBMS does not scan the entire relation.
  - Ex.: retrieve *sid* of all students enrolled in course *CMPT-ZZZ*
- An *index structure* maps (logical) attribute values to (physical) storage addresses.
  - Ex.: need index on attribute *sid* of relation Enrolled
- Index lookup returns the storage addresses of all matching tuples that can be directly accessed without scanning the whole relation.
  - Much more efficient query processing

Concurrency Control

- Concurrent execution of several user programs
  - Many users want to work on the same database concurrently, cannot wait for other users to finish.
  - Because disk accesses are frequent, and relatively slow, it is important to keep the cpu humming by working on several user programs concurrently.
- Interleaving actions of different user programs can lead to inconsistency: e.g., check is cleared while account balance is being computed.
- DBMS ensures such problems don't arise: users can pretend they are using a single-user system.

Transaction

- Key concept is *transaction*, which is an *atomic* sequence of database actions (reads/writes).
- Each transaction, executed completely, must leave the DB in a *consistent state* if DB is consistent when the transaction begins.
  - Users can specify some simple *integrity constraints* on the data, and the DBMS will enforce these constraints.
  - Beyond this, the DBMS does not really understand the semantics of the data. (e.g., it does not understand how the interest on a bank account is computed).
  - Thus, ensuring that a transaction (run alone) preserves consistency is ultimately the user's responsibility!

TRANSACTIONS

- A *transaction* has the following properties:
  - Atomicity: all-or-nothing property
  - Consistency: must leave the DB in a *consistent state* if DB is consistent when the transaction begins
  - Isolation: transaction is performed as if only one transaction at a time (serial processing)
  - Durability: effects of completed transactions are permanent

!!ACID principle!!

ENSURING CONSISTENCY

- Users can specify *integrity constraints* on the data, and the DBMS will enforce these constraints upon all database updates.
  - Ex: Insert *Student X* into *Course*, only if *Student X* is enrolled.
- Beyond this, the DBMS does not really *understand* the semantics of the data.
  - e.g., it does not understand how the interest on a bank account is computed.
    - Application level logic.
- Thus, ensuring that a transaction (run alone) preserves consistency is ultimately the user's responsibility!

ENSURING ISOLATION

- DBMS ensures that concurrent (interleaved) execution of *{T1, … , Tn}* is equivalent to some *serial* execution of *{T1, … , Tn}*.
- Before reading/writing an object, a transaction requests a *lock* on the object, and waits till the DBMS gives it the lock.
- Read locks are compatible with each other, but there can be only one write lock on an object at a given point of time.
  - Many reads can occur on a record
  - As soon as one write occurs on a record, no reads can take place at that time.
- All locks are released at the end of the transaction.

Ensuring Isolation

- If an action of *Ti* (say, writing *X*) affects *Tj* (which perhaps reads *X*), one of them, say *Ti*, will obtain the lock on *X* first and *Tj* is forced to wait until *Ti* completes.
- This effectively orders the transactions.

Ensuring Atomicity / Durability

- DBMS ensures *atomicity* even if system crashes in the middle of a transaction.
  - a series of database operations either *all* occur, or *nothing* occurs
- DBMS ensures *durability* also if system crashes after the commit of a transaction.
  - transactions that have committed will survive permanently
- Idea: Keep a *log* (history) of all relevant actions carried out by the DBMS while executing a set of transactions, i.e. log all updates and "transaction events" (commit, abort).

The Log

- The following actions are recorded in the log:
  - *Ti writes an object*: the old value and the new value.
    - Log record must go to disk *before* the changed page!
  - *Ti commits/aborts*: a log record indicating this action.
- Log records chained together by Xact id, so it's easy to undo a specific Xact (e.g., to resolve a deadlock).
- Log is often *duplexed* and *archived* on "stable" storage.
- All log related activities (and in fact, all activities such as lock/unlock, dealing with deadlocks etc.) are handled transparently by the DBMS.

Crash Recovery

- A system crash may lead to the loss of information, that has not yet been flushed to the hard disk.
- A system crash can lead to partially executed transactions and inconsistent (disk-resident) databases.
- After a crash,
  - the effects of partially executed transactions are *undone* using the log, and
  - the effects of completely executed transactions are *redone* using the log.

Summary

- Datasets increasing in diversity and volume.
- DBMS used to manage and query large datasets.
- Benefits include recovery from system crashes, concurrent access, quick application development, data integrity and security.
- Levels of abstraction give data independence.
- A DBMS typically has a layered architecture.
- DBS is one of the broadest, most exciting areas in CS.