LBSC 690 Session #7

Structured Information: Databases

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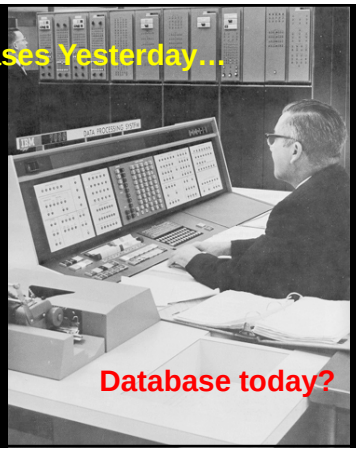
Take-Away Messages

- Databases are suitable for storing structured information
- Databases are important tools to organize, manipulate, and access structured information
- Databases are integral components of modern Web applications

Databases Yesterday…



Database today?

What's structured information?

It's what you put in a database

What's a database?

It's what you store structured information in

So what's a database?

An integrated collection of data organized according to some model…

So what's a relational database?

An integrated collection of data organized according to a relational model

Database Management System (DBMS)

Software system designed to store, manage, and facilitate access to databases

Databases (try to) model reality…

- Entities: things in the world
  - Example: airlines, tickets, passengers
- Relationships: how different things are related
  - Example: the tickets each passenger bought
- "Business Logic": rules about the world
  - Example: fare rules

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So what's the Web?

Relational Databases

Source: Microsoft Office Clip Art

Components of a Relational Database

- **Field:** an "atomic" unit of data
- **Record:** a collection of related fields
- **Table:** a collection of related records
  - Each record is a row in the table
  - Each field is a column in the table
- **Database:** a collection of tables

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A Simple Example

Table

Field Name

Name	DOB	SSN
John Doe	04/15/1970	153-78-9082
Jane Smith	08/31/1985	768-91-2376
Mary Adams	11/05/1972	891-13-3057

Record

Field

Primary Key

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Why "Relational"?

- View of the world in terms of entities and relations between them:
  - Tables represent "relations"
  - Each row in the table is sometimes called a "tuple"
  - Each tuple is "about" an entity
  - Fields can be interpreted as "attributes" or "properties" of the entity
- Data is manipulated by "relational algebra":
  - Defines things you can do with tuples
  - Expressed in SQL

The Registrar Example

- What do we need to know?
  - Something about the students (e.g., first name, last name, email, department)
  - Something about the courses (e.g., course ID, description, enrolled students, grades)
  - Which students are in which courses
- How do we capture these things?

A First Try

Put everything in a big table…

Student ID	Last Name	First Name	Dept ID	Dept	Course ID	Course name	Grade	email
1	Arrows	John	EE	EE	lbsc690	Information Technology	90	jarrows@wam
1	Arrows	John	EE	Elec Engin	ee750	Communication	95	ja_2002@yahoo
2	Peters	Kathy	HIST	HIST	lbsc690	Informatino Technology	95	kpeters2@wam
2	Peters	Kathy	HIST	history	hist405	American History	80	kpeters2@wma
3	Smith	Chris	HIST	history	hist405	American History	90	smith2002@glue
4	Smith	John	CLIS	Info Sci	lbsc690	Information Technology	98	js03@wam

Why is this a bad idea?

Goals of "Normalization"

- Save space
  - Save each fact only once
- More rapid updates
  - Every fact only needs to be updated once
- More rapid search
  - Finding something once is good enough
- Avoid inconsistency
  - Changing data once changes it everywhere

Another Try…

Student Table

Student ID	Last Name	First Name	Department ID	email
1	Arrows	John	EE	jarrows@wam
2	Peters	Kathy	HIST	kpeters2@wam
3	Smith	Chris	HIST	smith2002@glue
4	Smith	John	CLIS	js03@wam

Department Table

Department ID	Department
EE	Electrical Engineering
HIST	History
CLIS	Information Studies

Course Table

Course ID	Course Name
lbsc690	Information Technology
ee750	Communication
hist405	American History

Enrollment Table

Student ID	Course ID	Grade
1	lbsc690	90
1	ee750	95
2	lbsc690	95
2	hist405	80
3	hist405	90
4	lbsc690	98

Keys

- "Primary Key" uniquely identifies a record
  - e.g., student ID in the student table
- "Foreign Key" is primary key in the other table
  - It need not be unique in this table

Approaches to Normalization

- For simple problems (like the homework):
  - Start with the entities you're trying to model
  - Group together fields that "belong together"
  - Add keys where necessary to connect entities in different tables
- For more complicated problems:
  - Entity-relationship modeling (LBSC 670)

The Data Model

Student Table

Student ID	Last Name	First Name	Department ID	email
1	Arrows	John	EE	jarrows@wam
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4	Smith	John	CLIS	js03@wam

Department Table

Department ID	Department
EE	Electrical Engineering
HIST	History
CLIS	Information Studies

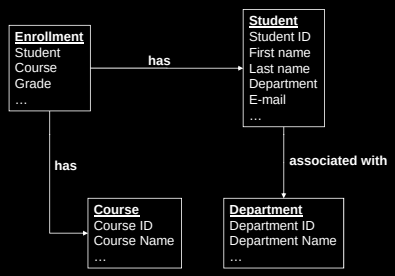
Course Table

Course ID	Course Name
lbsc690	Information Technology
ee750	Communication
hist405	American History

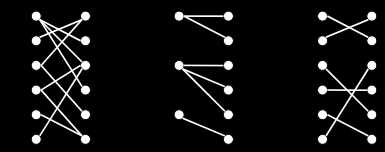
Enrollment Table

Student ID	Course ID	Grade
1	lbsc690	90
1	ee750	95
2	lbsc690	95
2	hist405	80
3	hist405	90
4	lbsc690	98

Registrar ER Diagram



Types of Relationships



Many-to-Many One-to-Many One-to-One

Database Integrity

- Registrar database must be internally consistent
  - All enrolled students must have an entry in the student table
  - All courses must have a name
  - …
- What happens:
  - When a student withdraws from the university?
  - When a course is taken off the books?

Integrity Constraints

- Conditions that must be true of the database at any time
  - Specified when the database is designed
  - Checked when the database is modified
- RDBMS ensures that integrity constraints are always kept
  - So that database contents remain faithful to the real world
  - Helps avoid data entry errors
- Where do integrity constraints come from?

Relational Algebra
(Don't Panic!)

Join

Student Table

Student ID	Last Name	First Name	Department ID	email
1	Arrows	John	EE	jarrows@wam
2	Peters	Kathy	HIST	kpeters2@wam
3	Smith	Chris	HIST	smith2002@glue
4	Smith	John	CLIS	js03@wam

Department Table

Department ID	Department
EE	Electrical Engineering
HIST	History
CLIS	Information Studies

"Joined" Table

Student ID	Last Name	First Name	Dept ID	Department	email
1	Arrows	John	EE	Electrical Engineering	jarrows@wam
2	Peters	Kathy	HIST	History	kpeters2@wam
3	Smith	Chris	HIST	History	smith2002@glue
4	Smith	John	CLIS	Information Stuides	js03@wam

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Project

Student ID	Last Name	First Name	Dept ID	Department	email
1	Arrows	John	EE	Electrical Engineering	jarrows@wam
2	Peters	Kathy	HIST	History	kpeters2@wam
3	Smith	Chris	HIST	History	smith2002@glue
4	Smith	John	CLIS	Information Stuides	js03@wam

SELECT Student ID, Department

Student ID	Department
1	Electrical Engineering
2	History
3	History
4	Information Stuides

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Restrict

Student ID	Last Name	First Name	Dept ID	Department	email
1	Arrows	John	EE	Electrical Engineering	jarrows@wam
2	Peters	Kathy	HIST	History	kpeters2@wam
3	Smith	Chris	HIST	History	smith2002@glue
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WHERE Department ID = "HIST"

Student ID	Last Name	First Name	Department ID	Department	email
2	Peters	Kathy	HIST	History	kpeters2@wam
3	Smith	Chris	HIST	History	smith2002@glue

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Relational Operations

- Joining tables: JOIN
- Choosing columns: SELECT
  - Based on their labels (field names)
- Choosing rows: WHERE
  - Based on their contents

  department ID = "HIST"
- These can be specified together

  SELECT Student ID, Dept WHERE Dept = "History"

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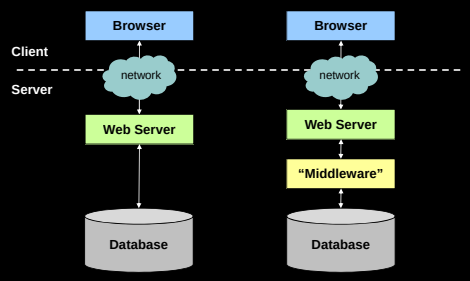
So how's a database more than a spreadsheet?

Databases in Web Applications



Database in the "Real World"

- Typical database applications:
  - Banking (e.g., saving/checking accounts)
  - Trading (e.g., stocks)
  - Traveling (e.g., airline reservations)
  - Networking (e.g., Facebook)
  - …
- Characteristics:
  - Lots of data
  - Lots of concurrent operations
  - Must be fast
  - "Mission critical" (well… sometimes)

Operational Requirements

- Must hold a lot of data
- Must be reliable
- Must be fast
- Must support concurrent operations

Must hold a lot of data

Solution: Use lots of machines
(Each machine holds a small slice)

So which machine has your copy?

Must be reliable

Solution: Use lots of machines
(Store multiple copies)

But which copy is the right one?
How do you keep the copies in sync?

Must be fast

Solution: Use lots of machines
(Share the load)

How do you spread the load?

Must support concurrent operations

Solution: this is hard!

(But fortunately doesn't matter for many applications)

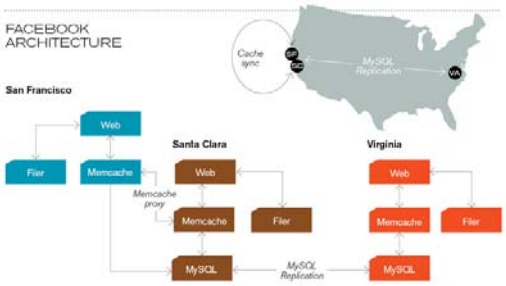
Database Transactions

- Transaction = sequence of database actions grouped together
  - e.g., transfer $500 from checking to savings
- ACID properties:
  - **Atomicity:** all-or-nothing
  - **Consistency:** each transaction must take the DB between consistent states
  - **Isolation:** concurrent transactions must appear to run in isolation
  - **Durability:** results of transactions must survive even if systems crash

Making Transactions

- Idea: keep a log (history) of all actions carried out while executing transactions
  - Before a change is made to the database, the corresponding log entry is forced to a safe location

- Recovering from a crash:
  - Effects of partially executed transactions are undone
  - Effects of committed transactions are redone
  - Trickier than it sounds!



Caching servers: 15 million requests per second, 95% handled by memcache (15 TB of RAM)

Database layer: 800 eight-core Linux servers running MySQL (40 TB user data)

Source: Technology Review (July/August, 2008)

RideFinder Exercise

- Design a database to match drivers with passengers (e.g., for road trips):
  - Drivers post available seats; they want to know about interested passengers
  - Passengers call up looking for rides: they want to know about available rides (they don't get to post "rides wanted" ads)
  - These things happen in no particular order

Exercise Goals

- Design the tables you will need
  - First decide what information you need to keep track of
  - Then design tables to capture this information
- Design queries (using join, project, and restrict)
  - What happens when a passenger comes looking for a ride?
  - What happens when a driver comes to find out who his passengers are?
- Role play!