CPSC 534P – Background

(aka, all you need to know about databases for this course in two lectures)

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Administrative notes

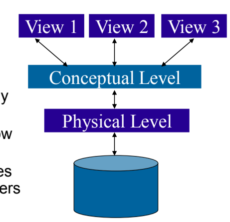
- Don't forget to sign up for a presentation day and one discussion day (we'll decide about other slots after enrollment has settled down)
- Anyone having topics they'd like for student request days should send those to me today
- Sign up for the mailing list – mail majordomo@cs.ubc.ca with "subscribe cpsc534p" in the *body*
- HW 1 is on the web, due beginning of class a week from today
  - General theory – trying to make sure you understand basics and have thought about it – not looking for one, true, answer.
  - State any assumptions you make
  - If you can't figure out a detail, write an explanation as to what you did and why.
- Office hours?

Overview of the next two classes

- Entity Relationship (ER) diagrams
- Relational databases
- Object Oriented Databases (OODBs)
- XML
- Other data types
- Database internals (Briefly)
- Potpourri

Levels of Abstraction

- A major purpose of a DB management system is to provide an abstract view of the data.
- Three abstraction levels:
  - **Physical level**: how data is actually stored
  - **Conceptual (or Logical) level**: how data is perceived by the users
  - **External (or View) level**: describes part of the database to different users
    - Convenience, security, etc.
  - E.g., views of student, registrar, & database admin.



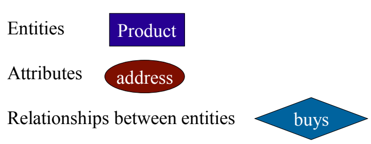
Schema and Instances

- We'll start with the **schema** – the logical structure of the database (e.g., students take courses)
  - **Conceptual (or logical) schema**: db design at the logical level
  - **Physical schema**: db design at the physical level; indexes, etc
- Later we'll populate **instances** – content of the database at a particular point in time
  - E.g., currently there are no grades for CPSC 534P
- **Physical Data Independence** – ability to modify physical schema without changing logical schema
  - Applications depend on the conceptual schema
- **Logical Data Independence** – Ability to change conceptual scheme without changing applications
  - Provided by views

Conceptual Database Design

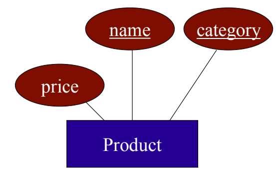
- What are the entities and relationships involved?
  - Entities are usually nouns, e.g., "course" "prof"
  - Relationships are statements about 2 or more objects. Often, verbs., e.g., "a prof teaches a course"
- What information about these entities and relationships should we store in the database?
- What integrity constraints or other rules hold?
- In relational databases, this is generally created in an **Entity-Relationship (ER) Diagram**

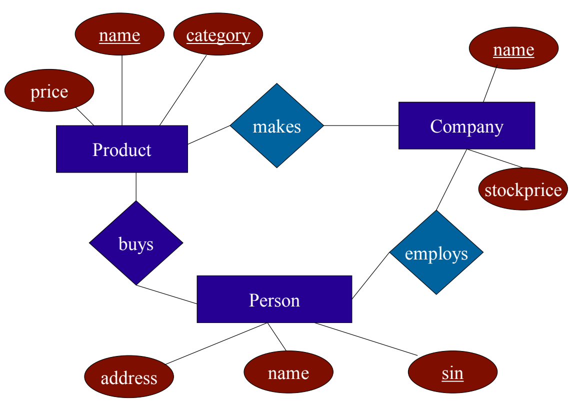
Entity / Relationship Diagrams



Keys in E/R Diagrams

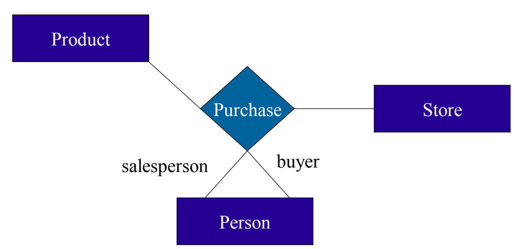
- Every entity set must have a key which is identified by an underline



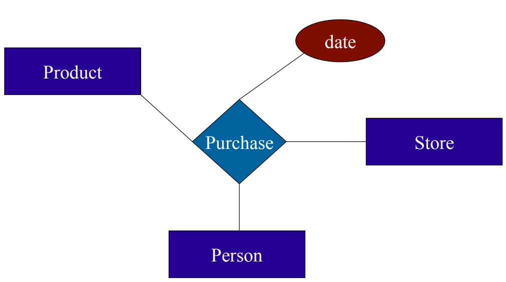


Roles in Relationships

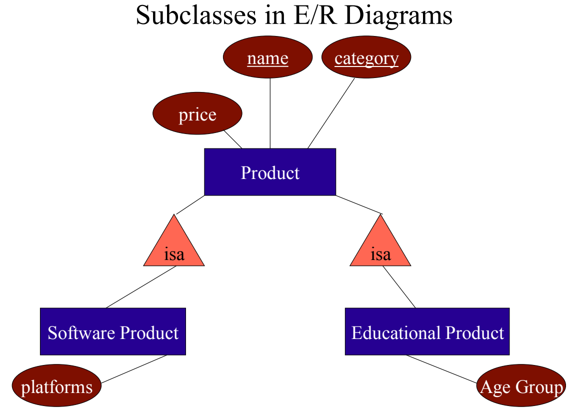
What if we need an entity set twice in one relationship?



Attributes on Relationships



Subclasses in E/R Diagrams



Summarizing ER diagrams

- Basics: entities, relationships, and attributes
- Also showed inheritance
- Has things other things like cardinality
- Used to design databases...

But how do you store data in them?

Overview of the next two classes

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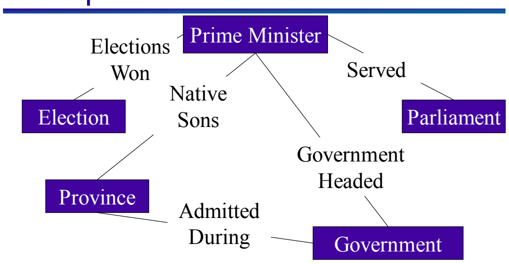
- Relational databases
  - How did we get here?
  - What's in a relational schema?
  - From ER to relational
  - Query Languages
- Object Oriented Databases (OODBs)
- XML
- Other data types
- Database internals (Briefly)
- Potpourri

How did we get the relational model?

- Before the relational model, there were two main contenders
  - Network databases
  - Hierarchical databases
- Network databases had a complex data model
- Hierarchical databases integrated the application in the data model

Example Hierarchical Model



Example IMS (Hierarchical) query: Print the names of all the provinces admitted during a Liberal Government

```
DLITPLI:PROCEDURE (QUERY_PCB) OPTIONS (MAIN);

 DECLARE QUERY_PCB POINTER;
 /*Communication Buffer*/
 DECLARE 1 PCB BASED(QUERY_PCB),
  2 DATA_BASE_NAME CHAR(8),
  2 SEGMENT_LEVEL CHAR(2),
  2 STATUS_CODE CHAR(2),
  2 PROCESSING_OPTIONS CHAR(4),
  2 RESERVED_FOR_DLI FIXED BIRARY(31,0),
  2 SEGMENT_NAME_FEEDBACK CHAR(8)
  2 LENGTH_OF_KEY_FEEDBACK_AREA FIXED BINARY(31,0),
  2 NUMBER_OF_SENSITIVE_SEGMENTS FIXED BINARY(31,0),
  2 KEY_FEEDBACK_AREA CHAR(28);
 /* I/O Buffers*/
 DECLARE PRES_IO_AREA CHAR(65),
  1 PRESIDENT DEFINED PRES_IO_AREA,
  2 PRES_NUMBER CHAR(4),
  2 PRES_NAME CHAR(20),
  2 BIRTHDATE CHAR(8)
  2 DEATH_DATE CHAR(8),
  2 PARTY CHAR(10),
  2 SPOUSE CHAR(15);
 DECLARE SADMIT_IO_AREA CHAR(20),
  1 province_ADMITTED DEFINED SADMIT_IO_AREA,
  2 province_NAME CHAR(20);
 /* Segment Search Arguments */
 DECLARE 1 PRESIDENT_SSA STATIC UNALIGNED,
  2 SEGMENT_NAME CHAR(8) INIT('PRES '),
  2 LEFT_PARENTHESIS CHAR (1) INIT('('),
  2 FIELD_NAME CHAR(8) INIT ('PARTY '),
  2 CONDITIONAL_OPERATOR CHAR (2) INIT('='),
  2 SEARCH_VALUE CHAR(10) INIT ('Liberal '),
2 RIGHT_PARENTHESIS CHAR(1) INIT(')');
 DECLARE 1 province_ADMITTED_SSA STATIC UNALIGNED,
  2 SEGMENT_NAME CHAR(8) INIT('SADMIT ');
 /* Some necessary variables */
 DECLARE GU CHAR(4) INIT('GU '),
  GN CHAR(4) INIT('GN '),
  GNP CHAR(4) INIT('GNP '),
  FOUR FIXED BINARY (31) INIT (4),
  SUCCESSFUL CHAR(2) INIT(' '),
  RECORD_NOT_FOUND CHAR(2) INIT('GE');
 /*This procedure handles IMS error conditions */
 ERROR;PROCEDURE(ERROR_CODE);
  *
  *
  *
 END ERROR;
 /*Main Procedure */
 CALL PLITDLI(FOUR,GU,QUERY_PCB,PRES_IO_AREA,PRESIDENT_SSA);
 DO WHILE(PCB.STATUS_CODE=SUCCESSFUL);
  CALL PLITDLI(FOUR,GNP,QUERY_PCB,SADMIT_IO_AREA,province_ADMITTED_SSA);
  DO WHILE(PCB.STATUS_CODE=SUCCESSFUL);
   PUT EDIT(province_NAME)(A);
  CALL PLITDLI(FOUR,GNP,QUERY_PCB,SADMIT_IO_AREA,province_ADMITTED_SSA);
   END;
  IF PCB.STATUS_CODE NOT = RECORD_NOT_FOUND
   THEN DO;
    CALL ERROR(PCB.STATUS_CODE);
    RETURN;
    END;
   CALL PLITDLI(FOUR,GN,QUERY_PCB,PRES_IO_AREA,PRESDIENT_SSA);
  END;
  IF PCB.STATUS_CODE NOT = RECORD_NOT_FOUND
   THEN DO;
    CALL ERROR(PCB.STATUS_CODE);
    RETURN;
    END;
END DLITPLI;
```

Relational model to the rescue!

- Introduced by Edgar Codd (IBM) in 1970
- Most widely used model today.
  - Vendors: IBM, Informix, Microsoft, Oracle, Sybase, etc.
- Former Competitor: object-oriented model
  - ObjectStore, Versant, Ontos
  - A synthesis emerged: *object-relational model*
    - Informix Universal Server, UniSQL, O2, Oracle, DB2
- Recent competitor: XML data model

Key points of the relational model

- Exceedingly simple to understand – main abstraction is a table
- Query language separate from application language
  - General form is simple
  - Many bells and whistles

Structure of Relational Databases

- ***Relational database:*** a set of ***relations***
- ***Relation:*** made up of 2 parts:
  - ***Schema*** : specifies name of relation, plus name and **domain** (type) of each **field** (or **column** or **attribute**).
    - e.g., Student (*sid*: string, *name*: string, *major*: string).
  - ***Instance*** : a ***table***, with rows and columns. ***#Rows = cardinality, #fields = dimension / arity***
- ***Relational Database Schema:*** collection of schemas in the database
- ***Database Instance:*** a collection of instances of its relations (e.g., currently no grades in CPSC 534P)

Example of a Relation Instance

Product — Attribute names or columns

Name	Price	Category	Manufacturer
gizmo	$19.99	gadgets	GizmoWorks
Power gizmo	$29.99	gadgets	GizmoWorks
SingleTouch	$149.99	photography	Canon
MultiTouch	$203.99	household	Hitachi

Tuples or rows — Relation or table

Order of rows isn't important

Formal Definition:

Product(Name: string, Price: double, Category: string, Manufacturer: string)

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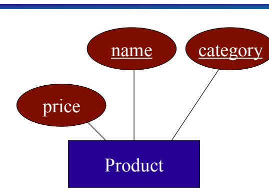
From E/R Diagrams to Relational Schema

- Entity set → relation
- Relationship → relation

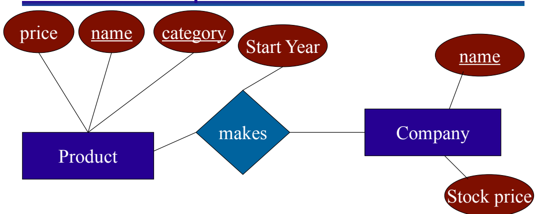
Entity Set to Relation



Product(<u>name, category</u>, price)

name	category	price
gizmo	gadgets	$19.99

Relationships to Relations



Makes(product-name, product-category, company-name, year)

Product-name	Product-Category	Company-name	Starting-year
gizmo	gadgets	gizmoWorks	1963

(watch out for attribute name conflicts)

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Relational Query Languages

- A major strength of the relational model: simple, powerful *querying* of data.
- Queries can be written intuitively; DBMS is responsible for efficient evaluation.
  - Precise semantics for relational queries.
  - Optimizer can re-order operations, and still ensure that the answer does not change.
- We'll look at 3: relational algebra, SQL, and Datalog

Querying – Relational Algebra

- *Select* (σ)- chose tuples from a relation
- *Project* (π)- chose attributes from relation
- *Join* ($\bowtie$) - allows combining of 2 relations
- *Set-difference* (—) Tuples in relation 1, but not in relation 2.
- *Union* ($\cup$)
- *Cartesian Product* ($\times$) Each tuple of R1 with each tuple in R2

Find products where the manufacturer is GizmoWorks

Product

Name	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

Selection:

$\sigma_{\text{Manufacturer = GizmoWorks}}\text{Product}$

Name	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks

Find the Name, Price, and Manufacturers of products whose price is greater than 100

Product

Name	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

Selection + Projection:

$\pi_{\text{Name, Price, Manufacturer}}(\sigma_{\text{Price > 100}}\text{Product})$

Name	Price	Manufacturer
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

Find names and prices of products that cost less than $200 and have Japanese manufacturers

Product

Name	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
MultiTouch	$203.99	Household	Hitachi

Company

Cname	StockPrice	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

$$\pi_{Name,\ Price}((\sigma_{Price < 200}Product) \bowtie_{Manufacturer = Cname} (\sigma_{Country = 'Japan'}Company))$$

Name	Price
SingleTouch	$149.99

When are two relations related?

- You guess they are
- I tell you so
- Constraints say so
  - A *key* is a set of attributes whose values are unique; we underline a key
    Product(<u>Name</u>, Price, Category, <u>Manfacturer</u>)
  - Foreign keys are a method for schema designers to tell you so
    - A foreign key states that an attribute is a reference to the key of another relation
      ex: Product.Manufacturer is foreign key of Company
    - Gives information and enforces constraint

The SQL Query Language

- Structured Query Language
- The standard relational query language
- Developed by IBM (System R) in the 1970s
- Standards:
  - SQL-86
  - SQL-89 (minor revision)
  - SQL-92 (major revision, current standard)
  - SQL-99 (major extensions)

SQL

- Data Manipulation Language (DML)
  - Query one or more tables
  - Insert/delete/modify tuples in tables
- Data Definition Language (DDL)
  - Create/alter/delete tables and their attributes
- Transact-SQL
  - Idea: package a sequence of SQL statements → server

SQL basics

- Basic form: (many many more bells and whistles in addition)

  Select attributes
  From relations (possibly multiple, joined)
  Where conditions (selections)

SQL – Selections

```
SELECT   *
FROM     Company
WHERE    country="Canada" AND stockPrice > 50
```

Some things allowed in the WHERE clause:

- attribute names of the relation(s) used in the FROM.
- comparison operators: =, <>, <, >, <=, >=
- apply arithmetic operations: stockPrice*2
- operations on strings (e.g., "||" for concatenation).
- Lexicographic order on strings.
- Pattern matching: s LIKE p
- Special stuff for comparing dates and times.

SQL – Projections

Select only a subset of the attributes

```
SELECT   name, stock price
FROM     Company
WHERE    country="Canada" AND stockPrice > 50
```

Rename the attributes in the resulting table

```
SELECT   name AS company, stockPrice AS price
FROM     Company
WHERE    country="Canada" AND stockPrice > 50
```

SQL – Joins

```
SELECT   name, store
FROM     Person, Purchase
WHERE    name=buyer AND city="Vancouver"
                 AND product="gizmo"
```

Product (name, price, category, maker)
Purchase (buyer, seller, store, product)
Company (name, stock price, country)
Person(name, phone number, city)

Selection:

$\sigma_{Manufacturer\ =\ GizmoWorks}(Product)$

Product

Name	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
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What's the SQL?

Name	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks

Selection + Projection:

$\pi_{Name,\ Price,\ Manufacturer}\ (\sigma_{Price\ >\ 100} Product)$

Product

Name	Price	Category	Manufacturer
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What's the SQL?

Name	Price	Manufacturer
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$\pi_{Name,\ Price}((\sigma_{Price\ <=\ 200} Product) \bowtie_{Manufacturer\ =\ Cname} (\sigma_{Country\ =\ 'Japan'} Company))$

Product

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Company

Cname	StockPrice	Country
GizmoWorks	25	USA
Canon	65	Japan
Hitachi	15	Japan

What's the SQL?

Name	Price
SingleTouch	$149.99

Administrative notes

- Remember: the 1st homework is due beginning of class Monday
- Remember: the first paper responses are due on Sunday at 8pm
  - The goal is NOT to only have a summary. Having a good summary will get you a 2 (85%). To get a 3 (100%) you have to show that you're thinking critically about the paper.
  - I will not grade this one, but I'll tell you what I'd give you if I were to grade it
  - Look at course website for samples
- DB-talks: Fridays, 2-3pm, ICICS/CS 238

Querying – Datalog (Our final query language)

- Enables recursive queries
- More convenient for analysis
- Some people find it easier to understand
- Without recursion but with negation it is equivalent in power to relational algebra and SQL
- Limited version of Prolog (no functions)

Datalog Rules and Queries

A Datalog rule has the following form:
head :- atom1, atom2, …, atom,…
You can read this as then :- if ...

Arithmetic comparison or interpreted predicate

ExpensiveProduct(N) :- Product(N,P,C,M), P > $10
CanadianProduct(N) :- Product(N,P,C,M), Company(M, SP, "Canada")
IntlProd(N) :- Product(N,M,P), NOT Company(M, SP, "Canada"),
Company(M1,SP,C)

Negated subgoal

Relations:
Product (name, price, category, maker)
Purchase (buyer, seller, store, product)
Company (name, stock price, country)
Person(name, phone number, city)

Conjunctive Queries

- A subset of Datalog
- Only relations appear in the right hand side of rules
- No negation
- Functionally equivalent to Select, Project, Join queries
- Very popular in modeling relationships between databases

Selection: $\sigma_{Manufacturer = GizmoWorks}(Product)$

Product

Name	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks
SingleTouch	$149.99	Photography	Canon
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What's the Datalog?

Name	Price	Category	Manufacturer
Gizmo	$19.99	Gadgets	GizmoWorks
Powergizmo	$29.99	Gadgets	GizmoWorks

Selection + Projection: $\pi_{Name, Price, Manufacturer}(\sigma_{Price > 100}Product)$

Product

Name	Price	Category	Manufacturer
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What's the Datalog?

Name	Price	Manufacturer
SingleTouch	$149.99	Canon
MultiTouch	$203.99	Hitachi

$\pi_{Name,Price}((\sigma_{Price <= 200}Product) \bowtie_{Manufacturer = Cname} (\sigma_{Country = 'Japan'}Company))$

Product

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Company

Cname	StockPrice	Country
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Canon	65	Japan
Hitachi	15	Japan

What's the Datalog?

Name	Price
SingleTouch	$149.99

Bonus Relational Goodness: Views

Views are stored queries treated as relations, Virtual views are not physically stored. Materialized views are stored

They are used (1) to define conceptually different views of the database and (2) to write complex queries simply.

View: purchases of telephony products:

```
CREATE VIEW telephony-purchases AS
  SELECT product, buyer, seller, store
  FROM Purchase, Product
  WHERE Purchase.product = Product.name
        AND Product.category = "telephony"
```

Summarizing/Rehashing Relational DBs

- Relational perspective: Data is stored in relations. Relations have attributes. Data instances are tuples.
- SQL perspective: Data is stored in tables. Tables have columns. Data instances are rows.
- Query languages
  - Relational algebra – mathematical base for understanding query languages
  - SQL – most commonly used
  - Datalog – based on Prolog, very popular with theoreticians
- Bonus! Views allow complex queries to be written simply

Outline

- Entity Relationship (ER) diagrams
- Relational databases
- Object Oriented Databases (OODBs)
- XML
- Other data types
- Database internals (Briefly)
- Potpourri

Object-Oriented DBMS's

- Started late 80's
- Main idea:
  - Toss the relational model!
  - Use the OO model – e.g., C++ classes
- Standards group: ODMG = Object Data Management Group.
- OQL = Object Query Language, tries to imitate SQL in an OO framework.

The OO Plan

ODMG imagines OO-DBMS vendors implementing an OO language like C++ with extensions (OQL) that allow the programmer to transfer data between the database and "host language" seamlessly.

A brief diversion: the impedance mismatch

OO Implementation Options

- Build a new database from scratch (O_2)
  - Elegant extension of SQL
  - Later adopted by ODMG in the OQL language
  - Used to help build XML query languages
- Make a programming language persistent (ObjectStore)
  - No query language
  - Niche market
- We'll see a few others

ODL

- ODL defines *persistent* classes, whose objects may be stored permanently in the database.
  - ODL classes look like Entity sets with binary relationships, plus methods.
  - ODL class definitions are part of the extended, OO host language.

ODL – remind you of anything?

```
interface Person
  (extent People key sin)
{  attribute string  sin;
   attribute string  dept;
   attribute string  name;}
```

```
interface Course
  (extent Crs key cid)
{  attribute string cid;
   attribute string cname;
   relationship Person instructor;
   relationship Set<Student> stds
       inverse takes;}
```

```
interface Student extends Person
  (extent Students)
{  attribute string major;
   relationship Set<Course> takes inverse stds;}
```

Why did OO Fail?

- Why are relational databases so popular?
  - Very simple abstraction; don't have to think about programming when storing data.
  - Very well optimized
- Relational db are very well entrenched – OODBs had not enough advantages, and no good exit strategy

Merging Relational and OODBs

- Object-oriented models support interesting data types – not just flat files.
  - Maps, multimedia, etc.
- The relational model supports very-high-level queries.
- Object-relational databases are an attempt to get the best of both.
- All major commercial DBs today have OR versions – full spec in SQL99, but your mileage may vary.

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XML

- eXtensible Markup Language
- XML 1.0 – a recommendation from W3C, 1998
- Roots: SGML (from document community - works great for them; from db perspective, very nasty).
- After the roots: a format for sharing *data*

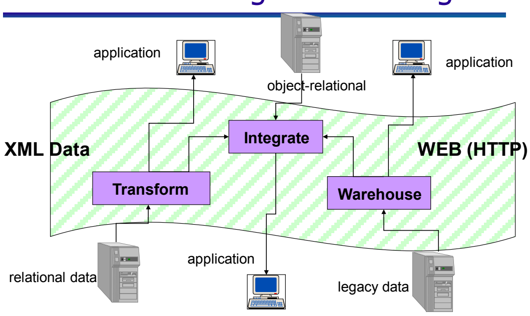
XML is self-describing

- Schema elements become part of the data
  - In XML <persons>, <name>, <phone> are part of the data, and are repeated many times
  - Relational schema: persons(name,phone) defined separately for the data and is fixed
- Consequence: XML is very flexible

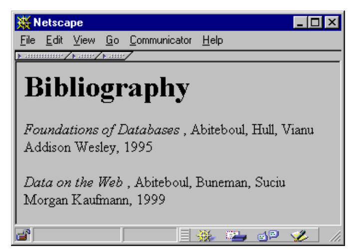
Why XML is of Interest to Us

- XML is *semistructured* and *hierarchical*
- XML is just syntax for data
  - Note: we have no syntax for relational data
- This is exciting because:
  - Can translate *any* data to XML
  - Can ship XML over the Web (HTTP)
  - Can input XML into any application
  - Thus: data sharing and exchange on the Web

XML Data Sharing and Exchange



From HTML to XML



HTML describes the presentation

HTML

<h1> Bibliography </h1>
<p> <i> Foundations of Databases </i>
Abiteboul, Hull, Vianu

 Addison Wesley, 1995
<p> <i> Data on the Web </i>
Abiteoul, Buneman, Suciu

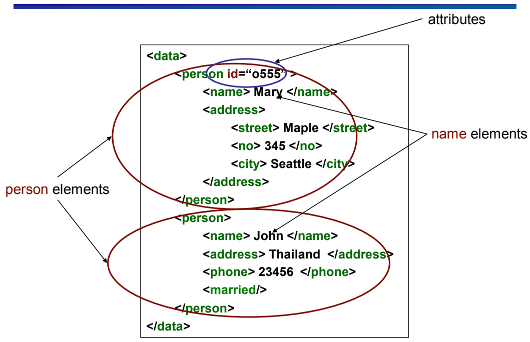
 Morgan Kaufmann, 1999

XML

<bibliography>
<book> <title> Foundations… </title>
<author> Abiteboul </author>
<author> Hull </author>
<author> Vianu </author>
<publisher> Addison Wesley </publisher>
<year> 1995 </year>
</book>
…
</bibliography>

XML describes the content

XML Document

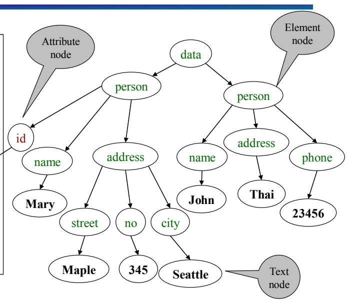


XML Terminology

- Elements
  - enclosed within tags:
    - <person> … </person>
  - nested within other elements:
    - <person> <address> … </address> </person>
  - can be empty
    - <married></married> abbreviated as <married/>
  - can have Attributes
    - <person id="0005"> … </person>
- XML document has as single ROOT element

XML as a Tree !!

```
<data>
    <person id="o555" >
        <name> Mary </name>
        <address>
            <street> Maple </street>
            <no> 345 </no>
            <city> Seattle </city>
        </address>
    </person>
    <person>
        <name> John </name>
        <address> Thailand </address>
        <phone> 23456 </phone>
    </person>
</data>
```



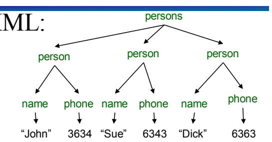
Minor Detail: Order matters !!!

Relational Data as XML

person

name	phone
John	3634
Sue	6343
Dick	6363

XML:




```
<persons>
    <person> <name>John</name>
             <phone> 3634</phone>
    </person>
    <person> <name>Sue</name>
             <phone> 6343</phone>
    </person>
    <person> <name>Dick</name>
             <phone> 6363</phone>
    </person>
</persons>
```

XML is semi-structured

- Missing elements:

```
<person>  <name> John</name>
          <phone>1234</phone>
</person>

<person>  <name>Joe</name>
</person>
```

← no phone !

- Could represent in a table with nulls

name	phone
John	1234
Joe	-

XML is semi-structured

- Repeated elements

```
<person> <name> Mary</name>
         <phone>2345</phone>
         <phone>3456</phone>
</person>
```

← two phones !

- Impossible in tables:

name	phone	
Mary	2345	3456

???

XML is semi-structured

- Elements with different types in different objects

```
<person> <name>  <first> John </first>
                 <last> Smith </last>
         </name>
         <phone>1234</phone>
</person>
```

← structured name !

- Heterogeneous collections:
  - <persons> can contain both <person>s and <customer>s

Summarizing XML

- XML has first class elements and second class attributes
- XML is semi-structured
- XML is nested
- XML is a tree
- XML is a huge buzzword

Will XML replace relational databases?

Outline

- Entity Relationship (ER) diagrams
- Relational databases
- Object Oriented Databases (OODBs)
- XML
- Other data types
- Database internals (Briefly)
- Potpourri

Other data formats

- Makefiles
- Forms
- Application code

What format is your data in?

Outline

- Entity Relationship (ER) diagrams
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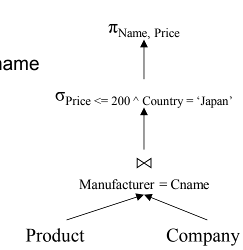
  - Query Optimization & Execution
- Potpourri

How SQL Gets Executed: Query Execution Plans

Select Name, Price
From Product, Company
Where Manufacturer = Cname
AND Price <= 200
AND Country = 'Japan'



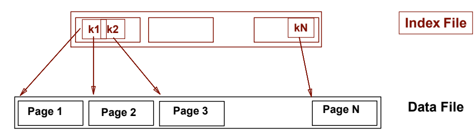
Query optimization also specifies the algorithms for each operator; then queries can be executed

Overview of Query Optimization

- *Plan*: *Tree of ordered Relational Algebra operators and choice of algorithm for each operator*
- Two main issues:
  - For a given query, what plans are considered?
    - Algorithm to search plan space for cheapest (estimated) plan.
  - How is the cost of a plan estimated?
- Ideally: Want to find best plan. Practically: Avoid worst plans.
- Some tactics
  - Do selections early
  - Use materialized views
  - Use Indexes

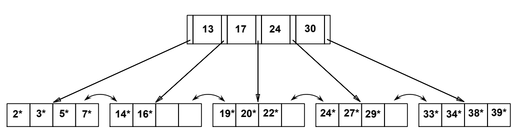
Tree-Based Indexes

- *``Find all students with gpa > 3.0''*
  - If data is sorted, do binary search to find first such student, then scan to find others.
  - Cost of binary search can be quite high.
- Simple idea: Create an `index' file.



Example B+ Tree

- Search begins at root, and key comparisons direct it to a leaf.
- Search for 5*, 15*, all data entries >= 24* ...



Query Execution

- Now that we have the plan, what do we do with it?
  - How do joins work?
  - How do deal with paging in data, etc.
- New research covers new paradigms where interleaved with optimization

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Outline

- Entity Relationship (ER) diagrams
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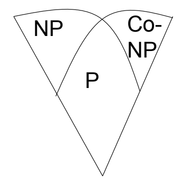
- Potpourri
  - Complexity

Complexity

- Characterize algorithms by how much time they take
- The first major distinction: Polynomial (P) vs. Non-deterministic Polynomial (NP)
- Agorithms in P can be solved in P. time in size of input
  - E.g., merge sort is O(n log n) (where n = # of items)
- NP algorithms can be solved in NP time; equivalently, they can be *verified* in in polynomial time
- NP-complete = a set of algorithms that is as hard as possible but still in NP
  - E.g., Traveling Salesperson Problem
- Co-NP refers to algorithms whose converses are NP complete

Complexity Ice Cream Cone



How to read a research paper

- Here's how I do it:
  - Read the intro
  - Read as much as I can stand/process
  - Read the related work
  - Read the experiments
  - Read the conclusions
  - Try to write up a summary
  - Go back through and see if it makes sense
- http://cseweb.ucsd.edu/~wgg/CSE210/howtoread.html

Plagiarism: the worst part of teaching

- Your work is to be *your* work.
- If you take *ideas* from somewhere, you must cite it (e.g., if this slide is citation [1], you could say Rachel thinks plagiarism is bad [1])
- If you take *words* from somewhere else, they have to be quoted and cited (e.g., Rachel says that plagiarism is "the worst part of teaching." [1])
- It's wrong, and usually makes crappy results anyway. So don't do it.

Now what?

- Time to read papers
- Prepare paper responses – it'll help you focus on the paper, and allow for the discussion leader to prepare better discussion
- You all have different backgrounds, interests, and insights. Bring them into class!