Database Models

Parke's database

I have a database! Oh? What's it about?

Well, here it is:

$$[42]$$

That's it? *Yes.*

42. *Yes.*

But 42 what?! Kangaroos? Number of cousins? Just the number itself?!

Needs *context*

A *datum* — a piece of *data* — by itself means nothing.

A datum with *context* means something.

- The context might be a *question*, and the datum an *answer* to the question.

  E.g., *How many cats does Parke have?* 42.

- The context might be provided by *where* that data is "within" a *schema* (*wrt* a database model).

Need to *model* context

- **data(base) model**
  - This provides a logical framework for *how*
    - data can be organized, and
    - can be inter-related among themselves.
  - In other words, it provides a model for context.
- **schema**
  - A schema is an *instance* of the data model that specifies how
    - data *is* organized, and
    - is inter-related.
- **query language**
  - This provides a way to retrieve / query data by context.
  - And it may provide powerful means to query for data that are inter-related in ways we had not anticipated beforehand.

Outline

- **data models**
  a. the *relational model*
  b. a *semi-structured model*
     e.g., `XML`
- **schema** (*wrt* the data model)
  a. *relational schema*
  b. e.g., `DTD` (*Document Type Definition*)
- **query languages** / ”programming” languages
  a. e.g., `SQL`
  b. e.g., `XQuery` (& `XPath`)

What is a data(base) model?

It is a mathematical representation for data.

1. **relational model**:
   - data organized in *tables*
   - the tables can be *related* in specific ways
   - the data can be *constrained* in specific ways
2. **semi-structured models**:
   - data organized as labeled *trees*, or
   - as labeled *graphs*

Logical vs physical representation

- Data models & schema are about how the data is *logically* organized.
- How a *database system — a database management system* — for a given database model is
  - implemented, and
  - how the data is *physically* organized

  are different matters.

This “separation of concerns” is called *data independence*.

A relation is just a table

Beers	
name	**manf**
Winterbrew	Pete's
Bud Lite	Anheuser-busch

- **relation name**: name of the table. E.g., **Beers**
- **attributes**: the column headers. E.g., **name** & **manf**
- **tuples**: the rows.
- **cells**: individual values (given attribute, given tuple).

That's it?!

Well, yes. (Almost.)

- Kind of like a spreadsheet, eh?
  But without all the cool functions!
- This extreme *simplicity* of representation will let us
  - design a powerful, *declarative* query language,
  - support the features we want — e.g., *integrity* & *transactions*, — and
  - build quite efficient database systems.
- Even while really simple, lots of data is *tabular* — that is, can be fit into tables — in nature.

Relational databases

- *Used* to be about boring stuff. E.g.,
  - employee records, bank records
- Today, the field covers all the largest sources of data, spanning many new ideas. E.g.,
  - web search
  - data mining
  - social networking
  - scientific & medical databases
  - integrating information

Databases everywhere

Databases are hidden behind almost everything you do on the Web or in an app.

- web searches (Google, Bing)
- searching at Amazon, eBay
- e-commerce
  - buying concert tickets on-line
- scrolling your favourite social-network feed
  - Instagram, Snapchat, Twitter, Facebook

Database systems everywhere

The functionality of database systems *solve* many complications for complex applications behind the scenes “for free”.

- Supports complex information procressing. (**the query language**)
- Juggles many activities simultaneously. (**concurrency**)
- Ensures correctness of the results of the activities. (**transaction management**)
    - E.g., two withdrawals from the same account must *each* debit the account.

Relational schema terminology

- **relation schema**: relation name and attribute list (*set*).
  - And optionally, the *types* of the attributes.
  - E.g., `Beers(name, manf)` or `Beers(name: string, manf: string)`
- **database**: collection of relations.
- **database schema**: set of all relation schemas in the database.

Our running example schema

- **Beers**(**name**, manf)
- **Pubs**(**name**, addr, license)
- **Drinkers**(**name**, *addr*, *phone*)
- **Likes**(**drinker**, **beer**)
- **Sells**(**pub**, **beer**, price)
- **Frequents**(**drinker**, **pub**)

- **bolded** attribute means it is (part of) the key

Database schemas in SQL

- SQL is primarily a *query language* for getting information from a database.
- But SQL also includes a *data-definition* component for describing database schemas.

Creating / declaring a relation / table

The simplest form is

```
create table <name> (
    <list of elements>
);
```

To *delete* a relation:

```
DROP TABLE <name>;
```

Elements of table declarations

The most common types are

- `int` or `integer` (synonyms)
- `real` or `float` (synonyms)
- `char(n)`: fixed-length string of `n` characters
- `varchar(n)`: variable-length string of up to `n` characters

Example: create table

```
create table Sells (
        pub     char(20),
        beer    varchar(20),
        price   real
);
```

SQL values

Integers and reals are represented as you would expect.

Strings are too, except they require single quotes.

- Two single quotes = real quote, e.g., 'Joe''s Bar'.

Any value can be *null*.

Dates and times

`date` and `time` are types in SQL. The form of a `date` value is:

- `'yyyy-mm-dd'`
- E.g., `'2007-09-30'` for September 30, 2007.

Times as values

The form of a `time` value is

- `'hh:mm:ss'`

with an optional decimal point and fractions of a second following.

- E.g., `'15:30:02.5'`
  meaning two and a half seconds after 3:30pm.

Declaring keys

An attribute, or list (set) of attributes, may be declared as `primary key` or `unique`.

This says that no two tuples in the relation (table) may agree on *all* the attributes's values in the key's list.

There are a few distinctions to be mentioned later.

Declaring single-attribute keys

Place `primary key` or `unique` after the type in the declaration of the attribute.

E.g.,

```
create table Beers (
    name    CHAR(20) UNIQUE,
    manf    CHAR(20)
);
```

Declaring multi-attribute keys

- A key declaration can also be another element in the list of elements of a `create table` statement.
- This form is necessary if the key consists of more than one attribute.
- But this form may be used too for one-attribute keys.

Example: multiattribute key

The *pub* and *beer* together are the key for **Sells**.

```
create table Sells (
    pub       char(20),
    beer      varchar(20),
    price     real,
    primary key (pub, beer)
);
```

Primary key vs Unique

1. There can be only one `primary key` for a relation, but any number of `unique` declarations.

2. No value of an attribute in the `primary key` can ever be `null` in any tuple.

   But values of attributes declared in `unique` may have `null`'s! And there may be several tuples with `null`.

Caveat: `null` is a messy concept

- *DB2* (IBM): any attribute used in a `unique` declaration must also be declared `not null`.
- *SQL Server* (Microsoft): at most *one* tuple may appear in the table with a given `null` pattern *wrt* s `unique` declaration.
- *PostgresQL*: there may be any number of tuples appearing in the table with `null` values for attributes participating in a `unique` declaration.

A semi-structured data model

Let's present another data model, this one based on trees.

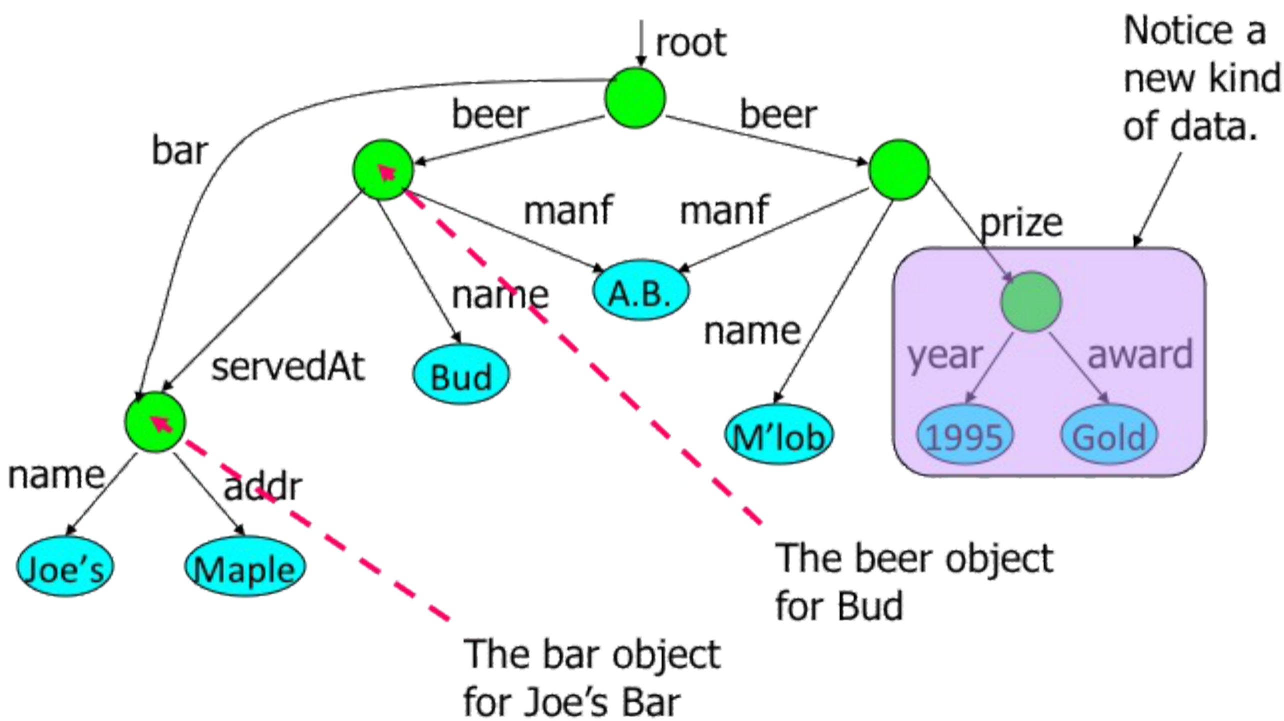
Motivation

1. a more flexible (?) representation of data
2. able to go “schema-less”, or have as little or as much “schema” as needed
3. sharing of “documents” among systems and databases

Graphs of semi-structured data

- *Nodes* = objects.
- *Labels* on arcs (like attribute names).
- *Atomic values* at leaf nodes (nodes with no arcs out).
- Flexibility. No restriction on
  - labels out of a node
  - number of successors with a given label

Example: Data Graph



XML

XML = Extensible Markup Language.

While HTML uses tags for *formatting* (e.g., “italic”), XML uses tags for *semantics* (e.g., “this is an address”).

Key idea. Create tag sets for a domain (e.g., genomics), and translate all data into properly tagged XML documents.

XML documents

Start the document with a declaration, surrounded by `<?xml … ?>`. E.g.,

```
<?xml version = “1.0” encoding = “utf-8” ?>
```

The balance of document is a *root* tag surrounding nested tags.

Tags

- Tags, as in HTML, are matched pairs, as `<foo>...</foo>`.
- Optional single tag `<foo/>`, which is shorthand for `<foo></foo>`.
- Tags may be nested arbitrarily.
- XML tags are case sensitive.

Example: an XML document

```xml
<pubs>
    <pub>
        <name>Joe's Bar</name>
        <beer>
            <mark><name>Bud</name></mark>
            <price>2.50</price>
        </beer>
        <beer>
            <name>Molsons</name>
            <price>3.50</price>
        </beer>
    </pub>
    <pub>...</pub>
    ...
</pubs>
```

The difference between XML and HTML

- XML is not a replacement for HTML.
- XML and HTML were designed with different goals:
  - XML was designed to describe data, with focus on what data is
  - HTML was designed to display data, with focus on how data looks
- HTML is about displaying information, while XML is about carrying information.

Attributes

Like HTML, the opening tag in XML can have `attribute = value` pairs.

Attributes also allow linking among elements (discussed later).

DTD

A grammatical notation for describing allowed use of tags.

Definition form:

```
<!DOCTYPE <root tag> [
    <!ELEMENT <name>(<components>)>
    . . . more elements . . .
]>
```

DTD: Attributes

Opening tags in XML can have *attributes*.

In a `DTD`, `<!ATTLIST E . . . >` declares an attribute for element E, along with its datatype.

Example: DTD

```
<!DOCTYPE BARS [
    <!ELEMENT BARS (BAR*)>
    <!ELEMENT BAR (NAME, BEER+)>
    <!ELEMENT NAME (#PCDATA)>
    <!ELEMENT BEER (NAME, PRICE)>
    <!ELEMENT PRICE (#PCDATA)>
]>
```