Plan

1. Information integration: important new application that motivates what follows.
2. Semistructured data: a new data model designed to cope with problems of information integration.
3. XML: a new Web standard that is essentially semistructured data.
4. XQUERY: an emerging standard query language for XML data.

Information Integration

Problem: related data exists in many places. They talk about the same things, but differ in model, schema, conventions (e.g., terminology).

Example

In the real world, every bar has its own database.

- Some may have relations like beer-price; others have an MS-word file from which the menu is printed.
- Some keep phones of manufacturers but not addresses.
- Some distinguish beers and ales; others do not.

Two approaches

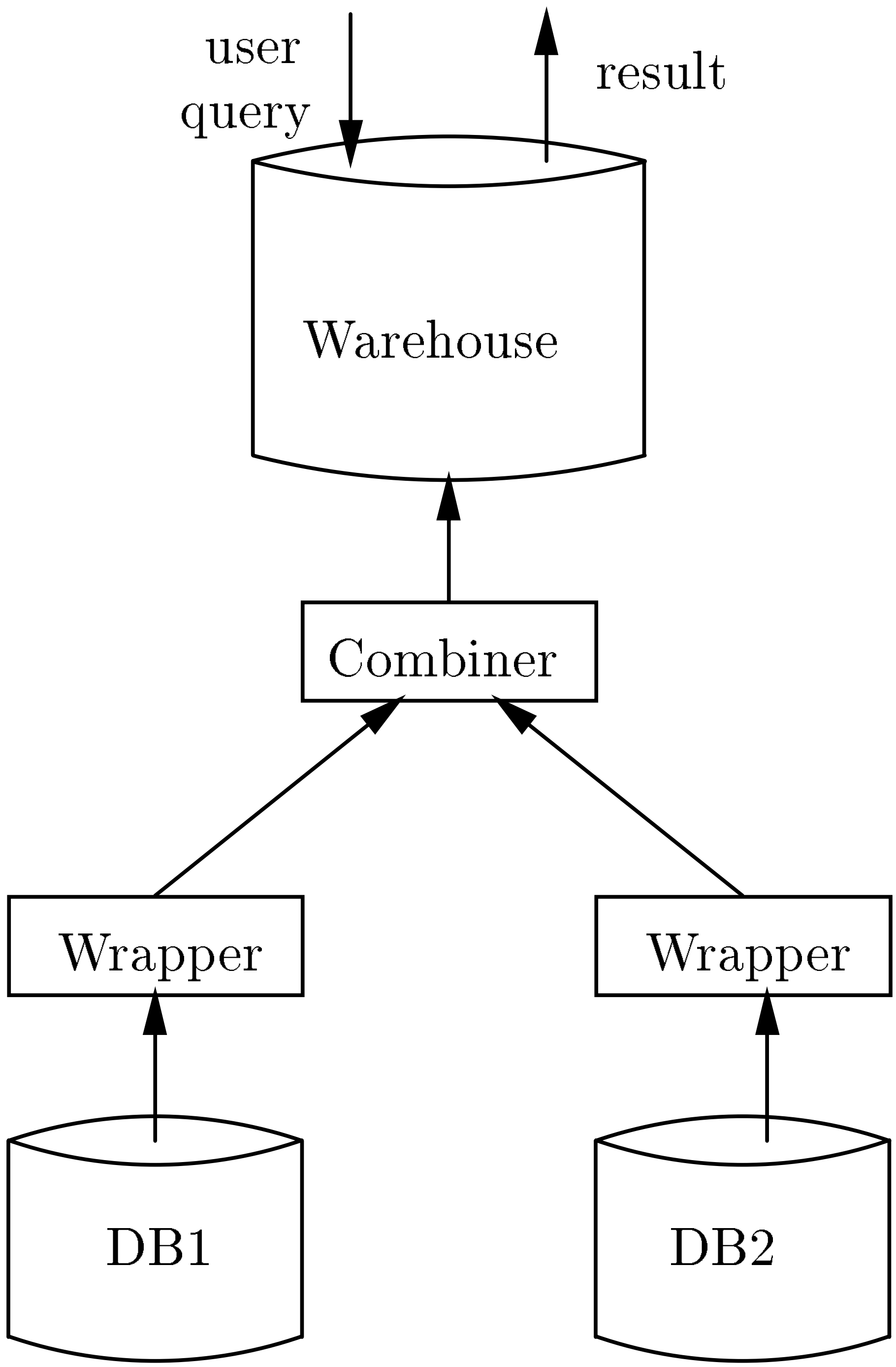
1. *Warehousing*: Make copies of information at each data source centrally.

   - Reconstruct data daily/weekly/monthly, but do not try to keep it up-to-date.

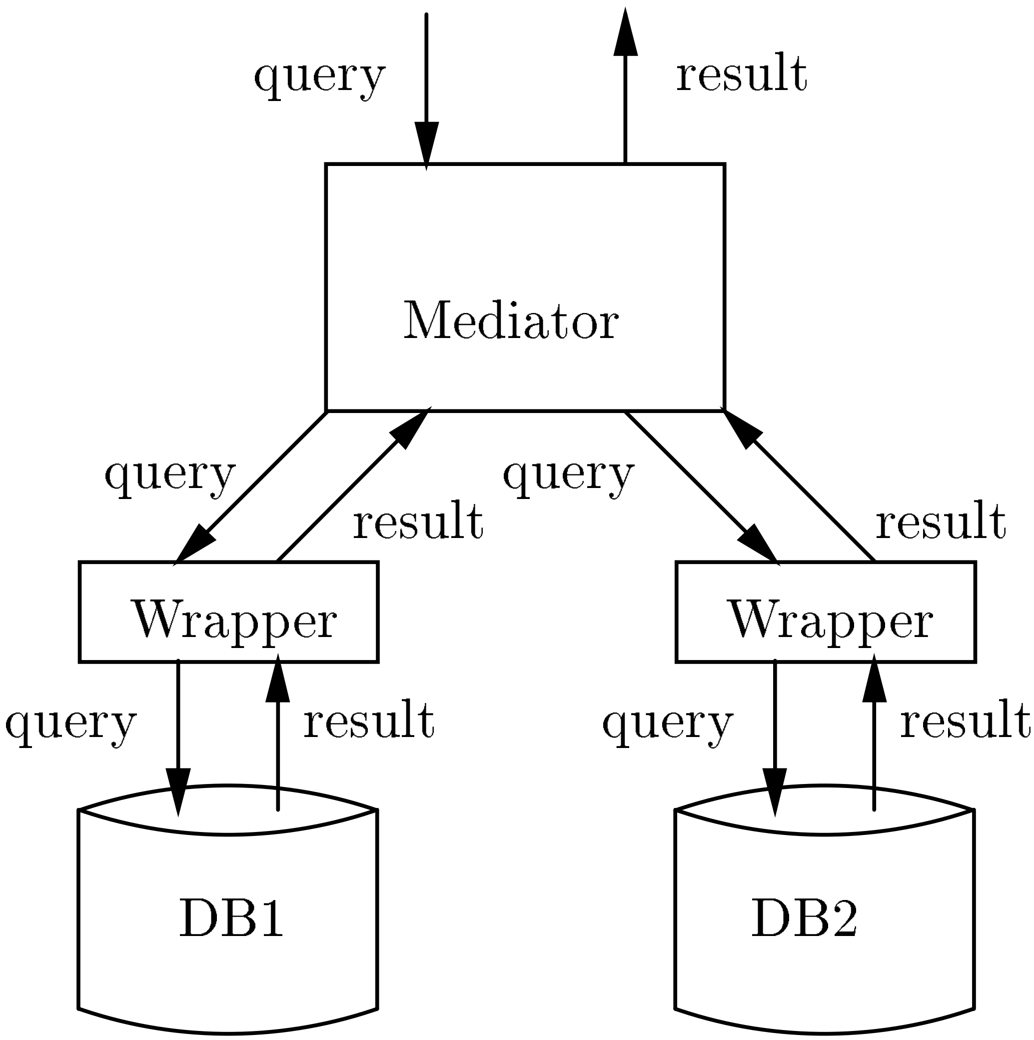
2. *Mediation*: Create a view of all information, but do not make copies.

   - Answer queries by sending appropriate queries to sources.

Warehousing



Mediation



query
result
Mediator
query
result
query
result
Wrapper
Wrapper
query
result
query
result
DB1
DB2

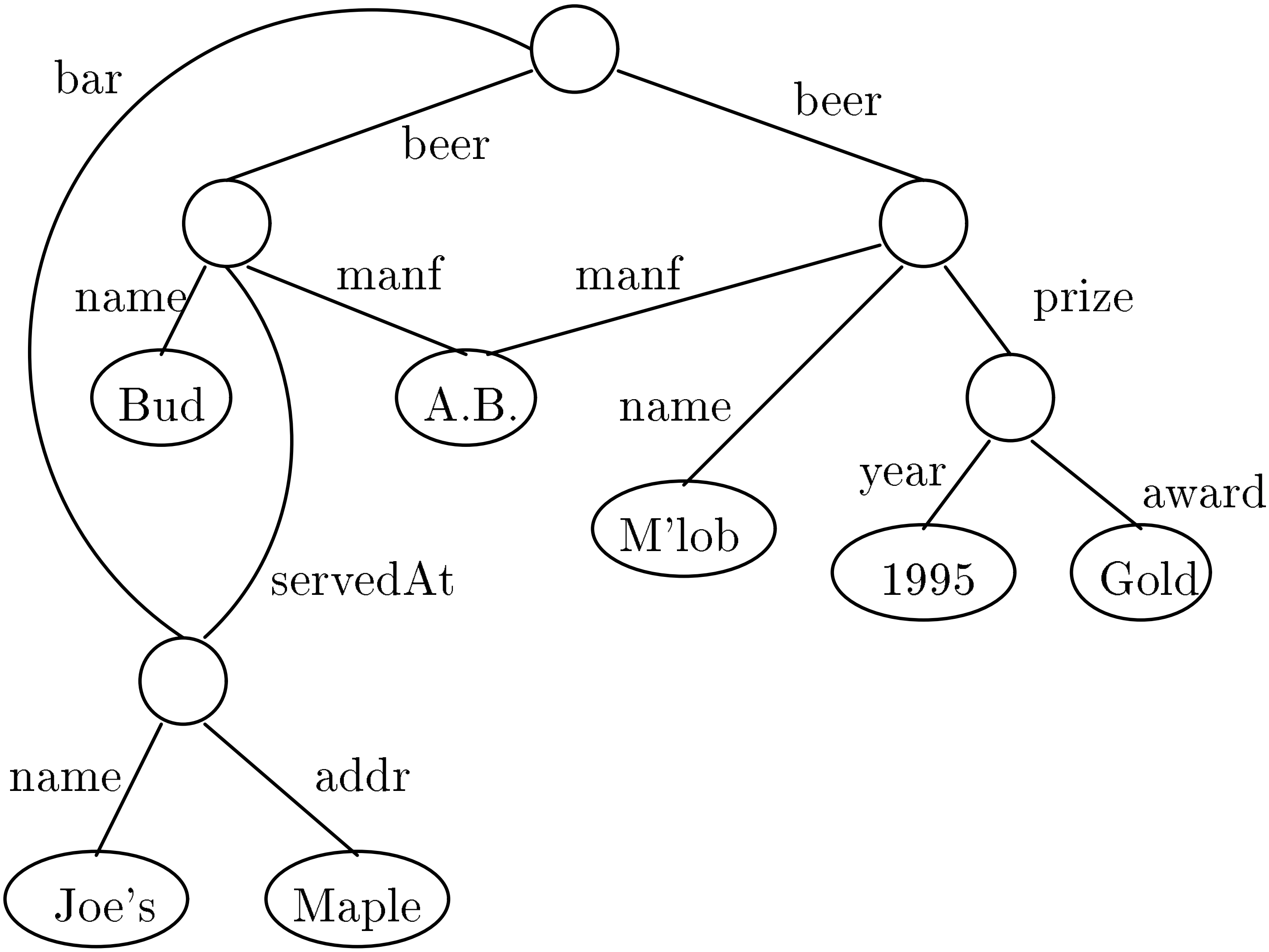
Semistructured Data

- A different kind of data model, more suited to information-integration applications than either relational or OO.
  - Think of "objects," but with the type of an object its own business rather than the business of the class to which it belongs.
  - Allows information from several sources, with related but different properties, to be fit together in one whole.
- Major application: XML documents.

Graph Representation of Semistructured Data

- Nodes = objects.
- Nodes connected in a general rooted graph structure.
- Labels on arcs.
- Atomic values on leaf nodes.
- Big deal: no restriction on labels (roughly = attributes).
    - Zero, one, or many children of a given label type are all OK.

Example


bar
beer
beer
name
manf
manf
prize
Bud
A.B.
name
year
award
M'lob
1995
Gold
servedAt
name
addr
Joe's
Maple

XML (Extensible Markup Language)

HTML uses tags for formatting (e.g., "italic"). XML uses tags for semantics (e.g., "this is an address").

- Two modes:
    1. *Well-formed* XML allows you to invent your own tags, much like labels in semistructured data.
    2. *Valid* XML involves a DTD (Document Type Definition) that tells the labels and gives a grammar for how they may be nested.

Well-Formed XML

1. Declaration = `<? ... ?>`.

   - Normal declaration is `<? XML VERSION = "1.0" STANDALONE = "yes" ?>`

   - "Standalone" means that there is no DTD specified.

2. *Root* tag surrounds the entire balance of the document.

   - `<FOO>` is balanced by `</FOO>`, as in HTML.

3. Any balanced structure of tags OK.

   - Option of tags that don't *require* balance, like `<P>` in HTML.

Example

```
<?XML VERSION = "1.0" STANDALONE = "yes"?>
<BARS>
    <BAR><NAME>Joe's Bar</NAME>
        <BEER><NAME>Bud</NAME>
            <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME>
            <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> ...
</BARS>
```

Document Type Definitions (DTD)

Essentially a grammar describing the legal nesting of tags.

- Intention is that DTD's will be standards for a domain, used by everyone preparing or using data in that domain.
    - Example: a DTD for describing protein structure; a DTD for describing bar menus, etc.

Gross Structure of a DTD

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

Elements of a DTD

An *element* is a name (its tag) and a parenthesized description of tags within an element.

- Special case: `(#PCDATA)` after an element name means it is text.

Example

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

Components

- Each element name is a tag.
- Its components are the tags that appear nested within, in the order specified.
- Multiplicity of a tag is controlled by:

  a) `*` = zero or more of.

  b) `+` = one or more of.

  c) `?` = zero or one of.
- In addition, `|` = "or."

Using a DTD

1. Set `STANDALONE` = `"no"`.
2. Either
   a) Include the DTD as a preamble, or
   b) Follow the `XML` tag by a `DOCTYPE` declaration with the root tag, the keyword `SYSTEM`, and a file where the DTD can be found.

Example of (a)

```
<?XML VERSION = "1.0" STANDALONE = "no"?>

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

<BARS>
    <BAR><NAME>Joe's Bar</NAME>
        <BEER><NAME>Bud</NAME>
            <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME>
            <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> ...
</BARS>
```

Example of (b)

Suppose our bars DTD is in file `bar.dtd` .

```
<?XML VERSION = "1.0" STANDALONE = "no"?>

<!DOCTYPE Bars SYSTEM "bar.dtd">

<BARS>
    <BAR><NAME>Joe's Bar</NAME>
        <BEER><NAME>Bud</NAME>
            <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME>
            <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR> ...
</BARS>
```

Attribute Lists

Opening tags can have "arguments" that appear within the tag, in analogy to constructs like `<A HREF = ...>` in HTML.

- Keyword `!ATTLIST` introduces a list of attributes and their data types.

Example

```
<!ELEMENT BAR (NAME BEER*)>
<!ATTLIST BAR
    type = "sushi"|"sports"|"other"
>
```

- Bar objects can have a (bar) type, and the value of that type is limited to the three strings shown.
- Example of use:

```
<BAR type = "sushi">
    . . .
</BAR>
```

ID's and IDREF's

These are pointers from one object to another, analogous to `NAME = "foo"` and `HREF = "#foo"` in HTML.

- Allows the structure of an XML document to be a general graph, rather than just a tree.
- An attribute of type `ID` can be used to give the object (string between opening and closing tags) a unique string identifier.
- An attribute of type `IDREF` refers to some object by its identifier.
  - Also `IDREFS` to allow multiple object references within one tag.

Example

Let us include in our `Bars` document type elements that are the manufacturers of beers, and have each beer object link, with an IDREF, to the proper manufacturer object.

```
<!DOCTYPE Bars [
    <!ELEMENT BARS (BAR*, MANF*)>
    <!ELEMENT BAR (NAME, BEER+)>
    <!ELEMENT NAME (#PCDATA)>
    <!ELEMENT MANF (ADDR)>
        <!ATTLIST MANF (name ID)>
    <!ELEMENT ADDR (#PCDATA)>
    <!ELEMENT BEER (NAME, PRICE)>
        <!ATTLIST BEER (manf = IDREF)>
    <!ELEMENT PRICE (#PCDATA)>
]>
```

XQUERY

Emerging standard for querying XML documents. Basic form:

```
FOR <variables ranging over
    sets of elements>
WHERE <condition>
RETURN <set of elements>;
```

- Sets of elements described by *paths*, consisting of:
  1. URL, if necessary.
  2. Element names forming a path in the semistructured data graph, e.g., `//BAR/NAME` = "start at any `BAR` node and go to a `NAME` child."
  3. Ending condition of the form `[<condition about subelements, attributes (preceded by @), and values>]`.

Example

The file `http://www.stanford.edu/bars.xml`:

```
<?XML VERSION = "1.0" STANDALONE = "no"?>

<!DOCTYPE Bars SYSTEM "bar.dtd">

<BARS>
    <BAR type = "sports">
        <NAME>Joe's Bar</NAME>
        <BEER><NAME>Bud</NAME>
            <PRICE>2.50</PRICE></BEER>
        <BEER><NAME>Miller</NAME>
            <PRICE>3.00</PRICE></BEER>
    </BAR>
    <BAR type = "sushi">
        <NAME>Homma's</NAME>
        <BEER><NAME>Sapporo</NAME>
            <PRICE>4.00</PRICE></BEER>
    </BAR> ...
</BARS>
```

XQUERY Query

Find the prices charged for Bud by sports bars that serve Miller.

```
FOR $ba IN document("http://www.stan-
    ford.edu/bars.html")
    //BAR[@type = "sports"],
    $be IN $ba/BEER[NAME = "Bud"]
WHERE $ba/BEER/[NAME = "Miller"]
RETURN $be/PRICE;
```