Object-Relational Databases

User-Defined Types

Object ID's

Nested Tables

Merging Relational and Object Models

- 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.

Evolution of DBMS's

- Object-oriented DBMS's failed because they did not offer the efficiencies of well-entrenched relational DBMS's.
- Object-relational extensions to relational DBMS's capture much of the advantages of OO, yet retain the relation as the fundamental abstraction.

SQL-99 and Oracle Features

- SQL-99 includes many of the object-relational features to be described.
- However, different DBMS's use different approaches.
  - We'll sometimes use features and syntax from Oracle.

User Defined Types

- A *user-defined type*, or UDT, is essentially a class definition, with a structure and methods.
- Two uses:
  1. As a *rowtype*, that is, the type of a relation.
  2. As the type of an attribute of a relation.

UDT Definition

```
CREATE TYPE <typename> AS (
    <list of attribute-type pairs>
);
```

- Oracle syntax:
  1. Add "OBJECT" as in CREATE … AS OBJECT.
  2. Follow with / to have the type stored.

Example: UDT Definition

```
CREATE TYPE BarType AS (
  name    CHAR(20),
  addr    CHAR(20)
);
CREATE TYPE BeerType AS (
  name    CHAR(20),
  manf    CHAR(20)
);
```

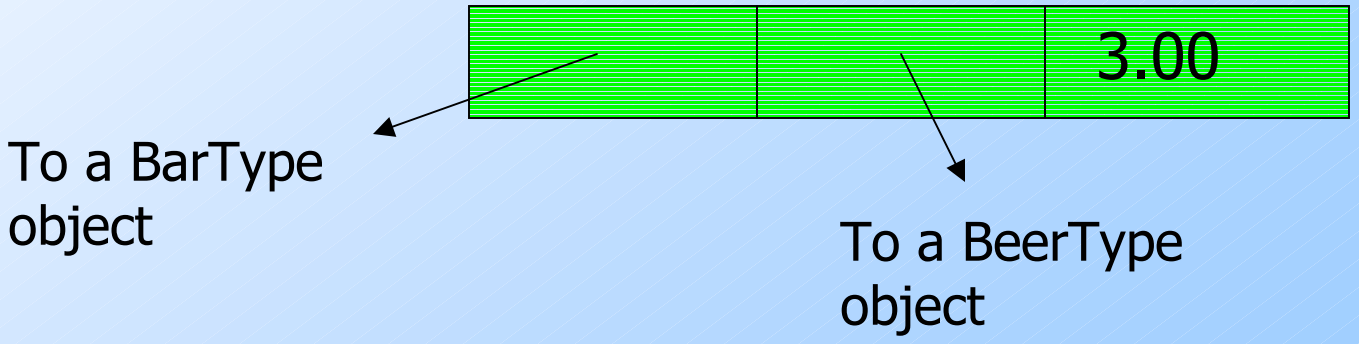
References

- If *T* is a type, then REF *T* is the type of a reference to *T*, that is, a pointer to an object of type *T*.
- Often called an "object ID" in OO systems.
- Unlike object ID's, a REF is visible, although it is gibberish.

Example: REF

```
CREATE TYPE MenuType AS (
  bar      REF BarType,
  beer     REF BeerType,
  price    FLOAT
);
```

- MenuType objects look like:



UDT's as Rowtypes

- A table may be defined to have a schema that is a rowtype, rather than by listing its elements.
- Syntax:

```
CREATE TABLE <table name> OF
  <type name>;
```

Example: Creating a Relation

```
CREATE TABLE Bars OF BarType {
  PRIMARY KEY (name)};
CREATE TABLE Beers OF BeerType {
  PRIMARY KEY (name)};
CREATE TABLE Sells OF MenuType {
  PRIMARY KEY (bar, beer),
  FOREIGN KEY ( . . . );
```

Constraints are a function of tables, not types.

Values of Relations with a Rowtype

- Technically, a relation like Bars, declared to have a rowtype BarType, is not a set of pairs --- it is a unary relation, whose tuples are objects with two components: name and addr.
- Each UDT has a *type constructor* of the same name, which wraps objects of that type.

Example: Type Constructor

- The query

```
SELECT * FROM Bars;
```

- Produces "tuples" such as:

  BarType('Joe''s Bar', 'Maple St.')

Accessing Values From a Rowtype

- In Oracle, the dot works as expected.
  - But it is a good idea, in Oracle, to use an alias for every relation, when O-R features are used.
- Example:

```
SELECT bb.name, bb.addr
FROM Bars bb;
```

Accessing Values: SQL-99 Approach

- In SQL-99, each attribute of a UDT has *generator* (get the value) and *mutator* (change the value) methods of the same name as the attribute.
  - The generator for *A* takes no argument, as A().
  - The mutator for *A* takes a new value as argument, as A(v).

Example: SQL-99 Value Access

- The same query in SQL-99 is

```
SELECT bb.name(), bb.addr()
FROM Bars bb;
```

Inserting Rowtype Values

- In Oracle, we use a standard INSERT statement.
  - But remember that a relation with a rowtype is really unary and needs that type constructor.
- Example:

```
INSERT INTO Bars VALUES(
BarType('Joe''s Bar', 'Maple St.')
);
```

Inserting Values: SQL-99 Style

1. Create a variable *X* of the suitable type, using the constructor method for that type.
2. Use the mutator methods for the attributes to set the values of the fields of *X*.
3. Insert *X* into the relation.

Example: SQL-99 Insert

- The following must be part of a procedure, e.g., PSM, so we have a variable newBar.

```
SET newBar = BarType();
newBar.name('Joe's Bar');
newBar.addr('Maple St.');
INSERT INTO Bars VALUES(newBar);
```

Mutator methods change newBar's name and addr components.

UDT's as Column Types

- A UDT can be the type of an attribute.
- In either another UDT declaration, or in a CREATE TABLE statement, use the name of the UDT as the type of the attribute.

Example: Column Type

```
CREATE TYPE AddrType AS (
   street     CHAR(30),
   city       CHAR(20),
   zip        INT
);
CREATE TABLE Drinkers (
   name       CHAR(30),
   addr       AddrType,
   favBeer    BeerType
);
```

Values of addr and favBeer components are objects with 3 and 2 fields, respectively.

Oracle Problem With Field Access

- You can access a field *F* of an object that is the value of an attribute *A* by *A.F*.
- However, you must use an alias, say *rr*, for the relation *R* with attribute *A*, as *rr.A.F*.

Example: Field Access in Oracle

- Wrong:

```
SELECT favBeer.name
FROM Drinkers;
```

- Wrong:

```
SELECT Drinkers.favBeer.name
FROM Drinkers;
```

- Right:

```
SELECT dd.favBeer.name
FROM Drinkers dd;
```

Following REF's: SQL-99 Style

- *A* -> *B* makes sense if:
  1. *A* is of type REF *T*.
  2. *B* is an attribute (component) of objects of type *T*.
- Denotes the value of the *B* component of the object pointed to by *A*.

Example: Following REF's

- Remember: Sells is a relation with rowtype MenuType(bar, beer, price), where bar and beer are REF's to objects of types BarType and BeerType.
- Find the beers served by Joe:

```
SELECT ss.beer()->name
FROM Sells ss
WHERE ss.bar()->name = 'Joe''s Bar';
```

Then use the arrow to get the names of the bar and beer referenced

First, use generator methods to access the bar and beer components

Following REF's: Oracle Style

- REF-following is implicit in the dot.
- Use a REF-value, a dot and a field of the object referred to.
- Example:

```
SELECT ss.beer.name
FROM Sells ss
WHERE ss.bar.name = 'Joe''s Bar';
```

Oracle's DEREF Operator -- Motivation

- If we want the set of beer objects for the beers sold by Joe, we might try:

```
SELECT ss.beer
FROM Sells ss
WHERE ss.bar.name = 'Joe''s Bar';
```

- Legal, but ss.beer is a REF, hence gibberish.

Using DEREF

- To see the BeerType objects, use:

```
SELECT DEREF(ss.beer)
FROM Sells ss
WHERE ss.bar.name = 'Joe''s Bar';
```

- Produces values like:

  BeerType('Bud', 'Anheuser-Busch')

Methods --- Oracle Syntax

- Classes are more than structures; they may have methods.
- We'll study the Oracle syntax.

Method Definitions (Oracle)

- Declare methods in CREATE TYPE.
- Define methods in a CREATE TYPE BODY statement.
  - Use PL/SQL syntax for methods.
  - Variable SELF refers to the object to which the method is applied.

Example: Method Declaration

- Let's add method priceInYen to MenuType.

```
CREATE TYPE MenuType AS OBJECT (
   bar          REF BarType,
   beer         REF BeerType,
   price        FLOAT,
   MEMBER FUNCTION priceInYen(rate IN FLOAT)
        RETURN FLOAT,
   PRAGMA RESTRICT_REFERENCES(priceInYen, WNDS)
);
/
```

What Oracle calls methods.

"Write no database state."
That is, whatever priceInYen does it won't modify the database.

Method Definition -- Oracle Style

- Form of create-body statement:

```
CREATE TYPE BODY <type name> AS
   <method definitions = PL/SQL
      procedure definitions, using
      "MEMBER FUNCTION" in place of
      "PROCEDURE">
END;
/
```

Example: Method Definition

```
CREATE TYPE BODY MenuType AS
   MEMBER FUNCTION
      priceInYen(rate FLOAT) RETURN FLOAT IS
         BEGIN
            RETURN rate * SELF.price;
         END;
END;
/
```

No mode (IN) in body, just in declaration

Use parentheses *only* when there is at least one argument

The MenuType object to which the method is applied

Method Use

- Follow a name for an object by a dot and the name of the method, with arguments if any.
- Example:

```
SELECT ss.beer.name,
       ss.priceInYen(110.0)
FROM Sells ss
WHERE ss.bar.name = 'Joe''s Bar';
```

Order Methods: SQL-99

- Each UDT *T* may define two methods called EQUAL and LESSTHAN.
  - Each takes an argument of type *T* and is applied to another object of type *T*.
  - Returns TRUE if and only if the target object is = (resp. <) the argument object.
- Allows objects of type *T* to be compared by =, <, >=, etc. in WHERE clauses and for sorting (ORDER BY).

Order Methods: Oracle

- We may declare any one method for a UDT to be an *order method*.
- The order method returns a value <0, =0, or >0, as the value of object SELF is <, =, or > the argument object.

Example: Order Method Declaration

- Order BarType objects by name:

```
CREATE TYPE BarType AS OBJECT (
   name      CHAR(20),
   addr      CHAR(20),
   ORDER MEMBER FUNCTION before(
        bar2 IN BarType) RETURN INT,
   PRAGMA RESTRICT_REFERENCES(before,
                WNDS, RNDS, WNPS, RNPS)
);
/
```

Read/write no database state/package state. A "package" is a collection of procedures and variables that can communicate values among them.

Example: Order Method Definition

```
CREATE TYPE BODY BarType AS
   ORDER MEMBER FUNCTION
        before(bar2 BarType) RETURN INT IS
   BEGIN
        IF SELF.name < bar2.name THEN RETURN –1;
        ELSIF SELF.name = bar2.name THEN RETURN 0;
        ELSE RETURN 1;
        END IF;
   END;
END;
/
```

Oracle Nested Tables

- Allows values of tuple components to be whole relations.
- If *T* is a UDT, we can create a type *S* whose values are relations with rowtype *T*, by:

  CREATE TYPE *S* AS TABLE OF *T*;

Example: Nested Table Type

```
CREATE TYPE BeerType AS OBJECT (
  name    CHAR(20),
  kind    CHAR(10),
  color   CHAR(10)
);
/
CREATE TYPE BeerTableType AS
  TABLE OF BeerType;
/
```

Example --- Continued

- Use BeerTableType in a Manfs relation that stores the set of beers by each manufacturer in one tuple for that manufacturer.

```
CREATE TABLE Manfs (
    name      CHAR(30),
    addr      CHAR(50),
    beers     beerTableType
);
```

Storing Nested Relations

- Oracle doesn't really store each nested table as a separate relation --- it just makes it look that way.
- Rather, there is one relation *R* in which all the tuples of all the nested tables for one attribute *A* are stored.
- Declare in CREATE TABLE by:

  NESTED TABLE *A* STORE AS *R*

Example: Storing Nested Tables

```
CREATE TABLE Manfs (
        name        CHAR(30),
        addr        CHAR(50),
        beers       beerTableType
)
NESTED TABLE beers STORE AS BeerTable;
```

Note where the semicolon goes and doesn't go.

Querying a Nested Table

- We can print the value of a nested table like any other value.
- But these values have two type constructors:
  1. For the table.
  2. For the type of tuples in the table.

Example: Query a Nested Table

- Find the beers by Anheuser-Busch:

```
SELECT beers FROM Manfs
WHERE name = 'Anheuser-Busch';
```

- Produces one value like:

BeerTableType(
  BeerType('Bud', 'lager', 'yellow'),
  BeerType('Lite', 'malt', 'pale'),...
)

Querying Within a Nested Table

- A nested table can be converted to an ordinary relation by applying THE(…).
- This relation can be used in FROM clauses like any other relation.

Example: Use of THE

- Find the ales made by Anheuser-Busch:

```
SELECT bb.name
FROM THE(
    SELECT beers
    FROM Manfs
    WHERE name = 'Anheuser-Busch'
) bb
WHERE bb.kind = 'ale';
```

The one nested table for the Anheuser-Busch beers

An alias for the nested table, which has no name

Turning Relations Into Nested Tables

- Any relation with the proper number and types of attributes can become the value of a nested table.
- Use CAST(MULTISET(…) AS <type>) on the relation to turn it into the value with the proper type for a nested table.

Example: CAST – (1)

- Suppose we have a relation Beers(beer, manf), where beer is a BeerType object and manf a string --- the manufacturer of the beer.
- We want to insert into Manfs a new tuple, with Pete's Brewing Co. as the name and a set of beers that are whatever Beers has for Pete's.

Example: CAST – (2)

```
INSERT INTO Manfs VALUES (
    'Pete''s', 'Palo Alto',
    CAST(
        MULTISET(
            SELECT bb.beer
            FROM Beers bb
            WHERE bb.manf = 'Pete''s'
        ) AS BeerTableType
    )
);
```

The set of BeerType objects for Pete's

Turn the set of objects into a nested relation