

Schedule

- Today: Feb. 19 (T)
 - ◆ Object-Relational Systems.
 - ◆ Read Sections 4.5, 9.4-9.5. Assignment 5 due.
- Feb. 21 (TH)
 - ◆ Transactions, Authorization.
 - ◆ Read Sections 8.6-8.7. Project Part 5 due.
- Feb. 26 (T)
 - ◆ Datalog.
 - ◆ Read Sections 10.1-10.2. Assignment 6 due.
- Feb. 28 (TH)
 - ◆ Datalog and SQL Recursion, ODL.
 - ◆ Read Sections 10.3-10.4, 4.1-4.4. Project Part 6 due.

Object-Relational Systems

- Object-oriented ideas enter the relational world.
 - ◆ Keep relation as the fundamental abstraction.
- Compare with “object-oriented DBMS,” which uses the class as the fundamental abstraction and tacks on relations as one of many types.

Motivations

- Allow DBMS’s to deal with specialized types – maps, signals, images, etc. – with their own specialized methods.
- Supports specialized methods even on conventional relational data.
- Supports structure more complex than “flat files.”

Plan

1. Basic ideas from SQL standards documents.
2. Use Oracle 8i/9i notation when similar.
3. Introduce some new concepts from Oracle.

User-Defined Types

SQL allows *UDT*'s that play a dual role:

1. They can be the types of relations; i.e., the type of their tuple.
 - ◆ Sometimes called a *row type*.
2. They can be the type of an attribute in a relation.

Defining UDT's – Example in Oracle Syntax

```
CREATE TYPE BarType AS OBJECT (  
    name CHAR(20) UNIQUE,  
    addr CHAR(20)  
);  
/  
  
CREATE TYPE BeerType AS OBJECT (  
    name CHAR(20) UNIQUE,  
    manf CHAR(20)  
);  
/  
  
CREATE TYPE MenuType AS OBJECT (  
    bar REF BarType,  
    beer REF BeerType,  
    price FLOAT  
);  
/
```

Notes

- In Oracle, type definitions must be followed by a slash (/) in order to get them to compile.
- The SQL standard is similar, but “OBJECT” is not used after “AS.”

Creating Tables

Type declarations do not create tables.

- They are used in place of element lists in `CREATE TABLE` statements.

Example

```
CREATE TABLE Bars OF BarType;  
  
CREATE TABLE Beers OF BeerType;  
  
CREATE TABLE Sells OF MenuType;
```

Values of User-Defined Types – Oracle Approach

- Each UDT has a type constructor of the same name.
- Values of that type are the values of its fields wrapped in the constructor.

Example

```
SELECT * FROM Bars;
```

produces values such as

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


Accessing Fields of an Object – Oracle Approach

The dot operator works as expected.

- Thus, if we want the bar name and address without the constructor:

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

- The alias `bb` is not technically necessary, but there are other places where we must use an alias in order to access objects, and it is a good habit to use an alias always.
- SQL standard: Same idea, but the attribute is treated as a *generator* method, with parentheses, e.g., `bb.name ( )`.

Inserting Values – Oracle Approach

We can use the standard `INSERT` in Oracle, but we must wrap the inserted object in its type-constructor.

Example

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

- SQL standard involves generator and mutator methods; see text.

Types for Columns

A UDT can also be the type of a column.

Example – Oracle Syntax

Let’s create an address type for use with bars and drinkers.

```
CREATE TYPE AddrType AS OBJECT (  
    street CHAR(30),  
    city CHAR(20),  
    zip INT  
);
```

We can then create a table of drinkers that includes their name, address, and favorite beer.

- The beer is included as a beer object, which “unnormalizes” the relation but is legal.

```
CREATE TABLE Drinker (  
    name CHAR(30),  
    addr AddrType,  
    favBeer BeerType  
);
```

Need to Use Aliases

If you access an attribute whose type is an object type, you *must* use an alias for the relation. *E.g.*,

```
SELECT favBeer.name  
FROM Drinker;
```

will not work in Oracle; neither will:

```
SELECT Drinker.favBeer.name  
FROM Drinker;
```

You have to say:

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

References

UDT's can have *references*.

- If T is a UDT, then $\text{REF}(T)$ is the type of a reference to a T object.
- Unlike OO systems, refs are values that can be seen by queries.

Dereferencing in SQL

$A \rightarrow B$ = the B attribute of the object referred to by reference A .

Example

Find the beers served by Joe.

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

Dereferencing in Oracle

- Dereferencing automatic, using dot operator.

Example

Same query in Oracle syntax:

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

Oracle's Deref Operator

If we wanted the entire BeerType object, we might try to write

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

That is legal, but `ss.beer` is a reference, and we'd get a gibberish value.

- To see the whole beer object, use:

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


Methods

Real reason object-relational isn't just nested structures in relations.

- We'll follow Oracle syntax.
- Declared in a `CREATE TYPE` statement, defined in a `CREATE TYPE BODY` statement.
- Methods are functions or procedures; in Oracle they are defined like any PL/SQL procedure or function.
- ◆ But, there is a special tuple variable `SELF` that refers to that object to which the method is applied.

Example

Let's add a method `priceInYen` to the `MenuType` and thus to the `Sells` relation.

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

Some Points to Remember

- The pragma is needed to allow `priceInYen` to be used in queries.
 - ◆ `WNDS` = “write no database state.”
- In the declaration, function/procedure arguments need a mode, `IN`, `OUT`, or `IN OUT`, just like PL/SQL procedures.
 - ◆ But the mode does not appear in the definition.
- Many methods will take no arguments (relying on the built-in “self”).
 - ◆ In that case, do not use parentheses after the function name.
- The body can have any number of function declarations, separated by semicolons.

Example of Method Use

Follow a designator for the object to which you want to apply the method by a dot, the name of the method, and argument(s).

```
SELECT ss.beer.name,  
       ss.priceInYen(120.0)  
FROM Sells ss  
WHERE ss.bar.name = 'Joe's Bar';
```

Built-In Comparison Functions (SQL)

We can define for each ADT two functions EQUAL and LESSTHAN.

- Allow values of this ADT to participate in WHERE clauses involving =, <=, etc. and in ORDER-BY sorting.

Order Methods in Oracle

We can declare one method for a type to be an ORDER method.

- Definition of this method must return <0, 0, >0, if “self” is less than, equal to, or greater than the argument object.
- Also used in comparisons for WHERE and ORDER BY.

Example

Order BarType objects by name.

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

```

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;

```

- The extra codes in the pragma guarantee no reading or writing of the database state or the “package state.”