Object-Oriented Database Approaches:

ODMG → JDO and beyond

Slides from Jeff Ullman, with modifications for JDO, etc. by Bob Keller, who borrowed liberally from other presentations on the web.

Object-Oriented DBMS’s

- Standards group: ODMG = Object Data Management Group.
- ODL = Object Description Language, like CREATE TABLE part of SQL.
- OQL = Object Query Language, tries to replace SQL in an OO framework.

ODMG Framework - 1

- ODMG imagined OO-DBMS vendors implementing an OO host language such as C++ being extended with a DB language (OQL) that allows the programmer to transfer data seamlessly between the database and the host language.

ODMG Framework - 2

- ODL was used to define persistent classes, those 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 language.

ODMG Obsolescence

- Despite its apparent virtues, the ODMG has not seemed to catch on to the extent it was hoped.
- However, it is still worthwhile, from an academic viewpoint, to review some of the ideas.
- Then we will look at JDO (Java Data Objects), which seems to be catching on, at least in the Java world.
- Microsoft has announced ObjectSpaces, which may play a similar role in its world.

ODL Overview

- A class declaration includes:
  1. A name for the class.
  2. Optional key declaration(s).
  3. Extent declaration = name for the set of currently existing objects of the class.
  4. Element declarations. An element is either an attribute, a relationship, or a method.
Class Definitions in ODL

```java
class <name>
{
<list of element declarations, separated by semicolons>
}
```

Attribute and Relationship Declarations

- Attributes are (usually) elements with a type that does not involve classes.
  ```java
  attribute <type> <name>;
  ```

- Relationships connect an object to one or more other objects of one class.
  ```java
  relationship <type> <name>
  inverse <relationship>;
  ```

Inverse Relationships

- Suppose class C has a relationship R to class D.
- Then class D must have some relationship S to class C.
- R and S must be true inverses.
- If object d is related to object c by R, then c must be related to d by S.

Example: Attributes and Relationships

```java
class Bar {
attribute string name;
attribute string addr;
relationship Set<Beer> serves inverse Beer::servedAt;
}
class Beer {
attribute string name;
attribute string manf;
relationship Set<Bar> servedAt inverse Bar::serves;
}
```

Types of Relationships

- The type of a relationship is either
  1. A class, like Bar. If so, an object with this relationship can be connected to only one Bar object.
  2. Set<Bar>: the object is connected to a set of Bar objects.
  3. Bag<Bar>, List<Bar>, Array<Bar>: the object is connected to a bag, list, or array of Bar objects.

Multiplicity of Relationships

- All ODL relationships are **binary**.
- Many-many relationships have Set<...> for the type of the relationship and its inverse.
- Many-one relationships have Set<...> in the relationship of the "one" and just the class for the relationship of the "many."
- One-one relationships have classes as the type in both directions.
Example: Multiplicity

class Drinker {
  ... 
  relationship Set<Beer> likes inverse Beer::fans;
  relationship Beer favBeer inverse Beer::superfans;
}

class Beer {
  ... 
  relationship Set<Drinker> fans inverse Drinker::likes;
  relationship Set<Drinker> superfans inverse Drinker::favBeer;
}

Many-many uses Set<...> in both directions.

Another Multiplicity Example

class Drinker {
  attribute ... ;
  relationship Drinker husband inverse wife;
  relationship Drinker wife inverse husband;
  relationship Set<Drinker> buddies inverse buddies;
}

husband and wife are one-one and inverses of each other.

Connecting Classes

- Suppose we want to connect classes X, Y, and Z by a relationship R.
- Devise a class C, whose objects represent a triple of objects (x, y, z) from classes X, Y, and Z, respectively.
- We need three many-one relationships from (x, y, z) to each of x, y, and z.

Example: Connecting Class

- Suppose we have Bar and Beer classes, and we want to represent the price at which each Bar sells each beer.
  - A many-many relationship between Bar and Beer cannot have a price attribute as it did in the E/R model.
- One solution: create class Price and a connecting class BBP to represent a related bar, beer, and price.

Example, Continued

- Since Price objects are just numbers, a better solution is to:
  1. Give BBP objects an attribute price.
  2. Use two many-one relationships between a BBP object and the Bar and Beer objects it represents.
Example, Concluded

Here is the definition of BBP:

```cpp
class BBP {
    attribute price: real;
    relationship Bar theBar inverse Bar::toBBP;
    relationship Beer theBeer inverse Beer::toBBP;
}
```

Bar and Beer must be modified to include relationships, both called toBBP, and both of type Set<BBP>.

Example: Struct and Enum

Attributes can have be a **structure** (as in C) or be an **enumeration**.

Declare with:

```cpp
attribute [Struct or Enum] <name of struct or enum> {
    <details>
    <name of attribute>
}
```

Details are field names and types for a Struct, a list of constants for an Enum.

Example: Struct and Enum

```cpp
class Bar {
    attribute string name;
    attribute Struct Addr {
        string street, string city, int zip
    } address;
    attribute Enum Lic {
        FULL, BEER, NONE
    } license;
    relationship ...
}
```

Names for the structure and enumeration

Names of the attributes

Example: Methods

```cpp
real gpa(in string) raises(noGrades);
```

1. The method gpa returns a real number (presumably a student’s GPA).
2. gpa takes one argument, a string (presumably the name of the student) and does not modify its argument.
3. gpa may raise the exception noGrades.

Reuse of Structs and Enums

We can refer to the name of a Struct or Enum in another class definition.

Use the :: operator to indicate source class.

Example:

```cpp
class Drinker {
    attribute string name;
    attribute Struct Bar::Addr address; ...
}
```

Use the same street-city-zip structure here.
The ODL Type System

- Basic types: int, real/float, string, enumerated types, and classes.
- Type constructors:
  - Struct for structures.
  - Collection types: Set, Bag, List, Array, and Dictionary (= mapping from a domain type to a range type).
- Relationship types can only be a class or a single collection type applied to a class.

ODL Subclasses

- Usual object-oriented subclasses.
- Indicate superclass with a colon and its name.
- Subclass lists only the properties unique to it.
  - Also inherits its superclass’ properties.

Example: Subclasses

- Ales are a subclass of beers:
  class Ale:Beer {
    attribute string color;
  }

ODL Keys

- You can declare any number of keys for a class.
- After the class name, add:
  (key <list of keys>)
- A key consisting of more than one attribute needs additional parentheses around those attributes.

Example: Keys

class Beer (key name) { ... }  
name is the key for beers.

class Course (key (dept,number),(room, hours)) {
  dept and number form one key; so do
  room and hours.

Extents

- For each class there is an extent, the set of existing objects of that class.
  - Think of the extent as the one relation with that class as its schema.
- Indicate the extent after the class name, along with keys, as:
  (extent <extent name> ... )
Example: Extents

class Beer
  (extent Beers key name) { ... }

Conventionally, we’ll use singular for class names, plural for the corresponding extent.

OQL

- OQL is the object-oriented query standard.
- It uses ODL as its schema definition language.
- Types in OQL are like ODL’s.
- Set(Struct) and Bag(Struct) play the role of relations.

Path Expressions

- Let \( x \) be an object of class \( C \).
  1. If \( a \) is an attribute of \( C \), then \( x.a \) is the value of that attribute.
  2. If \( r \) is a relationship of \( C \), then \( x.r \) is the value to which \( x \) is connected by \( r \).
    - Could be an object or a set of objects, depending on the kind of \( r \).
  3. If \( m \) is a method of \( C \), then \( x.m (...) \) is the result of applying \( m \) to \( x \).

Running Example

class Sell (extent Sells) {
  attribute real price;
  relationship Bar bar inverse Bar::beersSold;
  relationship Beer beer inverse Beers::soldBy;
}
class Bar (extent Bars) {
  attribute string name;
  attribute string addr;
  relationship Set<Sell> beersSold inverse Sell::bar;
}

Running Example, Concluded

class Beer (extent Beers) {
  attribute string name;
  attribute string manf;
  relationship Set<Sell> soldBy inverse Sell::beer;
}

Example: Path Expressions

- Let \( s \) be a variable of type Sell, i.e., a bar-beer-price object.
  1. \( s.price = \) the price in object \( s \).
  2. \( s.bar.addr = \) the address of the bar we reach by following the bar relationship in \( s \).
    - Note the cascade of dots is OK here, because \( s.bar \) is an object, not a collection of objects.
Example: Illegal Use of Dot

- We cannot apply the dot with a `collection` on the left --- only with a single object.
- Example (illegal), with `b` a Bar object:
  ```
  b.beersSold. price
  ```
  This expression is a set of Sell objects. It does not have a price.

OQL Select-From-Where

- We may compute relation-like collections by an OQL statement:
  ```
  SELECT <list of values>
  FROM <list of collections and names for typical members>
  WHERE <condition>
  ```

FROM clauses

- Each term of the FROM clause is:
  ```
  <collection> <member name>
  ```
- A collection can be:
  1. The extent of some class.
  2. An expression that evaluates to a collection, e.g., certain path expressions like `b.beersSold`.

Example

- Get the menu at Joe’s Bar.
  ```
  SELECT s.beer.name, s.price
  FROM Sells s
  WHERE s.bar.name = "Joe’s Bar"
  ```
  Legal expressions. `s.beer` is a beer object and `s.bar` is a Bar object.

Another Example

- This query also gets Joe’s menu:
  ```
  SELECT s.beer.name, s.price
  FROM Bars b, b.beersSold s
  WHERE b.name = “Joe’s Bar”
  ```
  `b.beersSold` is a set of Sell objects, and `s` is now a typical sell object that involves Joe’s Bar.

Trick For Using Path Expressions

- If a path expression denotes an `object`, you can extend it with another dot and a property of that object.
  ```
  Example: s, s.bar, s.bar.name
  ```
- If a path expression denotes a `collection` of objects, you cannot extend it, but you can use it in the FROM clause.
  ```
  Example: b.beersSold
  ```
The Result Type

- As a default, the type of the result of select-from-where is a Bag of Structs.
  - Struct has one field for each term in the SELECT clause. Its name and type are taken from the last name in the path expression.
  - If SELECT has only one term, technically the result is a one-field struct.
    - But a one-field struct is identified with the element itself.

Example: Result Type

```sql
SELECT s.beer.name, s.price
FROM Bars b, b.beersSold s
WHERE b.name = "Joe's Bar"
```

- Has type:
  - Bag(Struct(name: string, price: real))

Renaming Fields

- To change a field name, precede that term by the name and a colon.
- Example:
  ```sql
  SELECT beer: s.beer.name, s.price
  FROM Bars b, b.beersSold s
  WHERE b.name = "Joe’s Bar"
  ```
  - Result type is
    - Bag(Struct(beer: string, price: real)).

Producing a Set of Structs

- Add DISTINCT after SELECT to make the result type a set, and eliminate duplicates.
- Example:
  ```sql
  SELECT DISTINCT s.beer.name, s.price
  FROM Bars b, b.beersSold s
  WHERE b.name = "Joe’s Bar"
  ```
  - Result type is
    - Set(Struct(name: string, price: string))

Producing a List of Structs

- Use an ORDER BY clause, as in SQL to make the result a list of structs, ordered by whichever fields are listed in the ORDER BY clause.
  - Ascending (ASC) is the default; descending (DESC) is an option.
- Access list elements by index [1], [2], ...
- Gives capability similar to SQL cursors.

Example: Lists

- Let joeMenu be a host-language variable of type
  ```javascript
  List(Struct(name: string, price: real))
  ```
  ```javascript
  joeMenu = SELECT s.beer.name, s.price
  FROM Bars b, b.beersSold s
  WHERE b.name = "Joe’s Bar"
  ORDER BY s.price;
  ```
Example, Continued

- Now, `joeMenu` has a value that is a list of structs, with name and price pairs for all the beers Joe sells.
- We can find the first (lowest price) element on the list by `joeMenu[1]`, the next by `joeMenu[2]`, and so on.
- Example: the name of Joe’s cheapest beer:
  ```cpp
cheapest = joeMenu[1].name;
```

Example, Concluded

- After evaluating `joeMenu`, we can print Joe’s menu by code such as:
  ```cpp
cout << "Beer\tPrice\n";
for (i=1; i<=COUNT(joeMenu); i++)
cout << joeMenu[i].name << "\t" << joeMenu[i].price << "\n";
```

COUNT gives the number of members in any collection.

Subqueries

- A select-from-where expression can be surrounded by parentheses and used as a subquery in several ways, such as:
  1. In a FROM clause, as a collection.
  2. In EXISTS and FOR ALL expressions.

Example: Subquery in FROM

- Find the manufacturers of beers sold at Joe’s:
  ```cpp
  SELECT DISTINCT b.manf
  FROM (SELECT s.beer FROM Sells s
         WHERE s.bar.name = "Joe's Bar")
  
  Technically a one-field struct containing a Beer object, but identified with that object itself.
  ```

Quantifiers

- Two boolean-valued expressions for use in WHERE clauses:
  ```cpp
  FOR ALL x IN <collection> : <condition>
  EXISTS x IN <collection> : <condition>
  ```

Example: EXISTS

- Find all names of bars that sell at least one beer for more than $5.
  ```cpp
  SELECT b.name FROM Bars b
  WHERE EXISTS s IN b.beersSold
  s.price > 5.00
  
  At least one Sell object for bar b has a price above $5.
  ```
Another Quantifier Example

◆ Find the names of all bars such that the only beers they sell for more than $5 are manufactured by Pete’s.

```
SELECT b.name FROM Bars b
WHERE FOR ALL be IN (SELECT s.beer FROM b.beersSold s WHERE s.price > 5.00)
    be.manf = "Pete's"
```

Simple Coercions

◆ As we saw, a one-field struct is automatically converted to the value of the one field.

   - Struct(f : x) coerces to x.
   - A collection of one element can be coerced to that element, but we need the operator ELEMENT.
   - E.g., ELEMENT(Bag(x)) = x.

Example: ELEMENT

◆ Assign to variable p of type real, the price Joe charges for Bud:

```
p = ELEMENT(
    SELECT s.price FROM Sells s
    WHERE s.bar.name = "Joe's Bar"
    AND s.beer.name = "Bud"
);
```

Aggregations

◆ AVG, SUM, MIN, MAX, and COUNT apply to any collection where they make sense.

◆ Example: Find and assign to x the average price of beer at Joe’s:

```
x = AVG(
    SELECT s.price FROM Sells s
    WHERE s.bar.name = "Joe's Bar"
);
```

Grouping

◆ Recall SQL grouping:
  1. Groups of tuples based on the values of certain (grouping) attributes.
  2. SELECT clause can extract from a group only items that make sense:
     - Aggregations within a group.
     - Grouping attributes, whose value is a constant within the group.

OQL Grouping

◆ OQL extends the grouping idea in several ways:
  1. Any collection may be partitioned into groups.
  2. Groups may be based on any function(s) of the objects in the initial collection.
  3. Result of the query can be any function of the groups.
Outline of OQL GROUP BY

- **Initial collection**: defined by `FROM`, `WHERE` (Group by values of function(s))
- **Intermediate collection**: with function values and partition (Terms from SELECT clause)
- **Output collection**

Example: GROUP BY

- We'll work through these concepts using an example: "Find the average price of beer at each bar."
  
  ```
  SELECT barName, avgPrice: AVG(
  SELECT p.s.price FROM partition p)
  FROM Sells s
  GROUP BY barName: s.bar.name
  ```

Initial Collection

- Based on `FROM` and `WHERE` (which is missing): `FROM Sells s`
- The initial collection is a Bag of structs with one field for each "typical element" in the `FROM` clause.
- Here, a bag of structs of the form `Struct(s: obj)`, where `obj` is a Sell object.

Example: Typical Member

- A typical member of the intermediate collection in our example is:
  
  ```
  Struct(barName = "Joe's Bar",
  partition = \{s_1, s_2, ..., s_n\})
  ```
- Each member of partition is a Sell object `s_i` for which `s_i.bar.name` is "Joe's Bar".

Example: Intermediate Collection

- In general, bag of structs with one component for each function in the `GROUP BY` clause, plus one component always called `partition`.
- The partition value is the set of all objects in the initial collection that belong to the group represented by this struct.

Example: Intermediate Collection

- SELECT `barName`, `avgPrice`: AVG(
  SELECT `p.s.price` FROM `partition p`)
  FROM `Sells s`
  GROUP BY `barName`: `s.bar.name`

Example: Intermediate Collection

- One grouping function. Name is `barName`, type is string. Intermediate collection is a set of structs with fields `barName`: string and `partition`: Set<Struct(s: Sell)>
The Output Collection

- The output collection is computed by the SELECT clause, as usual.
- Without a GROUP BY clause, the SELECT clause gets the initial collection from which to produce its output.
- With GROUP BY, the SELECT clause is computed from the intermediate collection.

Example: Output Collection

```
SELECT barName, avgPrice: AVG(
    SELECT p.s.price FROM partition p)
```

A Less Typical Example

- Find for each beer, the number of bars that charge a “low” price (< $2) and a “high” price (> $4) for that beer.
- Strategy --- group by three values:
  1. The beer name.
  2. A boolean function that is TRUE if and only if the price is low.
  3. A boolean function that is TRUE if and only if the price is high.

The Query

```
SELECT beerName, low, high, count: COUNT(partition)
FROM Beers b, b.soldBy s
GROUP BY beerName: b.name,
    low: s.price < 2.00, high: s.price > 4.00
```

The Intermediate Collection

- A set of structs with four fields:
  1. beerName: string
  2. low: boolean
  3. high: boolean
  4. partition: Set<Struct(b: Beer, s: Sell)>

Typical Structs in the Intermediate Collection

<table>
<thead>
<tr>
<th>beerName</th>
<th>low</th>
<th>high</th>
<th>partition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bud</td>
<td>TRUE</td>
<td>FALSE</td>
<td>S_low</td>
</tr>
<tr>
<td>Bud</td>
<td>FALSE</td>
<td>TRUE</td>
<td>S_high</td>
</tr>
<tr>
<td>Bud</td>
<td>FALSE</td>
<td>FALSE</td>
<td>S_mid</td>
</tr>
</tbody>
</table>

- $S_{low}$, etc., are sets of Beer-Sell pairs.
- Note low and high cannot both be true; their groups are always empty.
The Output Collection

```
SELECT beerName, low, high, count: COUNT(partition)

+--------+--------+--------+------+
<table>
<thead>
<tr>
<th>beerName</th>
<th>low</th>
<th>high</th>
<th>count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bud</td>
<td>TRUE</td>
<td>FALSE</td>
<td>27</td>
</tr>
</tbody>
</table>
```

JDO
Java Data Objects

What is JDO?

- An API for persistent objects in Java that is becoming the accepted standard (similar to what ODMG intended, except that Java is currently the only host).
- Since the host is Java, all definitions are done in Java without modification.
- A separate file (in XML) defines which classes are persistent.

Who Defines JDO?

- JDO is a result of a community process, known as the Java Community Process (JCP).
- The actual spec is here: http://jcp.org/aboutJava/communityprocess/final/jsr012/index2.html
- The enabling request is here: http://www.jcp.org/en/jsr/detail?id=12#2

JDO DB Applications

déjà vu?

- JDO is similar to the OODB concept demonstrated in previous slides, e.g. using Poet™.
- Poet, Inc. has revised its API to be JDO compliant, and calls it FastObjects™.
- Recently Poet, Inc. announced a .NET version for the Microsoft world. They also have a C++ version.
What about EJB and J2EE?

- **EJB** = "Enterprise Java Beans"
- **J2EE** = "Java 2 Enterprise Edition"

JDO is compatible with the above, but provides a significant set of facilities that they don’t have, thus is complementary.

What about JDBC?

- JDBC is used for connecting Java to SQL relational databases.
- (ODBC is the counterpart to JDBC in the Microsoft world.)
- JDO is independent of JDBD; the two can coexist.
- JDO does not replace JDBC, although some functionality could be accomplished by either.

Partial List of JDO Vendor Products

- FastObjects (Poet) - JDO built on small-footprint ODBMS that provides parallel and nested transactions, multi-thread. Provides XML import and export, built-in failover/failback. Plug-ins for JBuilder, NetBeans, Rational.
- Codigo Xpress - Product creates a complete J2EE application and deployment with a JDO layer.
- OJB (T. Mahler) - ODMG 3.0 facade with dynamic mapping and an XML-based repository.
- FrontierSuite for JDO (Object Frontier) - Frontier Suite is a cross-platform JDO and EJB persistence manager that provides JDO connectivity.
- Open Fusion (PrismTech) - API implements JDO 0.8 - maps Java classes to RDBMS schema. See data sheet and diagram.
- KodoJDO (SolarMetric) - Database access without coding SQL or major source code changes; implements vast majority of JDO final spec - including query filters and maps. Supports JDBC 1.x, 2, JBoss, WebLogic, a number of RDBMSs.
- Rexip JDO (TCCybersoft) - JDO implementation.

Object Categories

- **transient**: Object disappears when application ends (as in conventional applications).
- **persistent**: Object persists after application ends.

JDO Objectives

- **Transparent** persistence
  - class developers "generally unaware" of persistence [7]
- **Data store independence**
  - relational, object, hierarchical databases
  - file systems
- **Range of implementations**
  - embedded (J2ME, Connected Device Configuration)
  - two tier (J2SE)
  - enterprise (J2EE, EJB)

A Consequence of Persistence

- Recall that in Java objects are deleted automatically by garbage collection.
- For persistent objects, **explicit deletion** is required, for it is never known when the object might be subsequently required.
**JDO Object Model**

- Persistence-Capable classes
  - most user-defined classes
  - exceptions: JNI (C code), subclasses of some System classes

- Persistent field types
  - all primitive types
  - interface types treated as java.lang.Object
  - reference types (with some restrictions)

**States of Objects (1 of 2)**

- JDO defines **ten** possible states of an object:
  - **Transient**: Ordinary Java objects; has no JDO identity.
  - **Persistent-New**: A newly-created persistent object.
  - **Persistent-Clean**: A persistent object with no uncommitted changes.
  - **Persistent-Dirty**: A persistent object with uncommitted changes.
  - **Persistent-Deleted**: A persistent object that has been explicitly deleted.

**States of Objects (2 of 2)**

- Object States, continued:
  - **Hollow**: A persistent object, but values have been loaded from the data store (usually transparent to the application).
  - Other optional transactional states

**Life Cycle Views**

- There are several different life cycles for JDO objects. We just present a few of them.

**Life Cycle: Explicit Persistence**

- Persistent-Dirty
  - rollback
  - commit
  - deletePersistent
  - makePersistent

**Transitive Persistence**

- If A is persistent, and A refers to B, then B is automatically persistent.
- So if there is a root object for the application, just making it persistent is enough to make everything persistent.
- Of course, we might not want everything to be persistent.
A Simple Example

```java
PersistenceManagerFactory factory = JDOHelper.getPersistenceManagerFactory();
PersistenceManager pm = JDOFactory.getPersistenceManager();
Transaction trans = pm.currentTransaction();
User user = new User("ron", "Ron Hitchens", "ron@ronsoft.com");
Address addr = new Address("123 Main St.", "Smallville", "CA", "12345");
user.setAddress(addr);
trans.begin();
pm.makePersistent(user); // Makes addr persistent also!
trans.commit();
pm.close();
```

Life Cycle: Data Store

The Other Aspect of Transactions

**Concurrency control:** Objects being read by a transaction will not simultaneously be modified by another transaction.

This can be useful even for objects that are not persistent.

Transactional Persistence

"Transactional persistence" means that

- Old values are cached at the start of the transaction.
- In the event of a **rollback** (an alternative to **commit**) the old values are restored, leaving the object unchanged.

This feature is an option rather than a requirement for a JDO implementation.

JDO Runtime Environment

Compilation Steps

**.java**

**.class**

**Echo Server**

**.class**

**Byte code enhancement**

**.class**

**JDO MetaData**

**XML**
A More Complex Example (1/6)

```
package company;
import java.util.*;
import java.lang.String;
import java.util.Iterator;

public class Company {
  private String name;
  private Vector employees = new Vector();
  private Manager manager;

  public String getName() {
    return name;
  }

  public void setName(String name) {
    this.name = name;
  }

  public Vector getEmployees() {
    return employees;
  }
}
```

A More Complex Example (2/6)

```
package company;
import java.util.*;
import java.lang.String;
import java.util.Iterator;

public class Company {
  private String name;
  private Vector employees = new Vector();
  private Manager manager;

  public String getName() {
    return name;
  }

  public void setName(String name) {
    this.name = name;
  }

  public Vector getEmployees() {
    return employees;
  }
}
```

A More Complex Example (3/6)

```
package company;
import java.util.*;
import java.lang.String;
import javax.jdo.*;

public class Main {
  public static void main(String args[]) {
    PersistenceManagerFactory pmf;
    PersistenceManager pm;
    Transaction tx;
    Properties prop = new Properties();
    try {
      prop.put("javax.jdo.PersistenceManagerFactoryClass", args[0]);
      pmf = JDOHelper.getPersistenceManagerFactory(prop);
      pmf.setConnectionDriverName(args[1]);
      pmf.setConnectionURL(args[2]);
      pm = pmf.getPersistenceManager();
      tx = pm.currentTransaction();

      tx.begin();
      Company company = new Company();
      pm.makePersistent(company);
      company.setName("ACME");
      Employee employee = new Employee();
      employee.setName("John");
      employee.setAge(30);
      employee.setSalary(40000);
      employee.setCompany(company);
      employee = new Employee();
      employee.setName("Joe");
      employee.setAge(25);
      employee.setSalary(30000);
      employee.setCompany(company);
      tx.commit();
    }
    catch(Exception e){
      e.printStackTrace();
    }
    tx.begin();
    Manager manager = new Manager();
    manager.setName("Jack");
    manager.setAge(40);
    manager.setSalary(100000);
    manager.setStocks(1000);
    company.setManager(manager);
    company.addEmployees(manager);
    tx.commit();
    tx.begin();
    company = new Company();
    pm.makePersistent(company);
    company.setName("MacroSoft");
    manager = new Manager();
    manager.setName("Bill");
    manager.setAge(50);
    manager.setSalary(1000000);
    manager.setStocks(1000000);
    company.setManager(manager);
    company.addEmployees(manager);
    company.populate();
    tx.commit();
    pm.close();
  }
}
```

A More Complex Example (4/6)

```
package company;
import java.util.*;
import java.lang.String;
import java.util.Iterator;

public class Main {
  public static void main(String args[]) {
    PersistenceManagerFactory pmf;
    PersistenceManager pm;
    Transaction tx;
    Properties prop = new Properties();
    try {
      prop.put("javax.jdo.PersistenceManagerFactoryClass", args[0]);
      pmf = JDOHelper.getPersistenceManagerFactory(prop);
      pmf.setConnectionDriverName(args[1]);
      pmf.setConnectionURL(args[2]);
      pm = pmf.getPersistenceManager();
      tx = pm.currentTransaction();

      tx.begin();
      Company company = new Company();
      pm.makePersistent(company);
      company.setName("ACME");
      Employee employee = new Employee();
      employee.setName("John");
      employee.setAge(30);
      employee.setSalary(40000);
      employee.setCompany(company);
      employee = new Employee();
      employee.setName("Joe");
      employee.setAge(25);
      employee.setSalary(30000);
      employee.setCompany(company);
      tx.commit();
    }
    catch(Exception e){
      e.printStackTrace();
    }
    tx.begin();
    Manager manager = new Manager();
    manager.setName("Jack");
    manager.setAge(40);
    manager.setSalary(100000);
    manager.setStocks(1000);
    company.setManager(manager);
    company.addEmployees(manager);
    tx.commit();
    tx.begin();
    company = new Company();
    pm.makePersistent(company);
    company.setName("MacroSoft");
    manager = new Manager();
    manager.setName("Bill");
    manager.setAge(50);
    manager.setSalary(1000000);
    manager.setStocks(1000000);
    company.setManager(manager);
    company.addEmployees(manager);
    company.populate();
    tx.commit();
    pm.close();
  }
}
```

A More Complex Example (5/6)

```
package company;
import java.util.*;
import java.lang.String;
import java.util.Iterator;

public class Main {
  public static void main(String args[]) {
    PersistenceManagerFactory pmf;
    PersistenceManager pm;
    Transaction tx;
    Properties prop = new Properties();
    try {
      prop.put("javax.jdo.PersistenceManagerFactoryClass", args[0]);
      pmf = JDOHelper.getPersistenceManagerFactory(prop);
      pmf.setConnectionDriverName(args[1]);
      pmf.setConnectionURL(args[2]);
      pm = pmf.getPersistenceManager();
      tx = pm.currentTransaction();

      tx.begin();
      Company company = new Company();
      pm.makePersistent(company);
      company.setName("ACME");
      Employee employee = new Employee();
      employee.setName("John");
      employee.setAge(30);
      employee.setSalary(40000);
      employee.setCompany(company);
      employee = new Employee();
      employee.setName("Joe");
      employee.setAge(25);
      employee.setSalary(30000);
      employee.setCompany(company);
      tx.commit();
    }
    catch(Exception e){
      e.printStackTrace();
    }
    tx.begin();
    Manager manager = new Manager();
    manager.setName("Jack");
    manager.setAge(40);
    manager.setSalary(100000);
    manager.setStocks(1000);
    company.setManager(manager);
    company.addEmployees(manager);
    tx.commit();
    tx.begin();
    company = new Company();
    pm.makePersistent(company);
    company.setName("MacroSoft");
    manager = new Manager();
    manager.setName("Bill");
    manager.setAge(50);
    manager.setSalary(1000000);
    manager.setStocks(1000000);
    company.setManager(manager);
    company.addEmployees(manager);
    company.populate();
    tx.commit();
    pm.close();
  }
}
```

A More Complex Example (6/6)

```
package company;
import java.util.*;
import java.lang.String;
import java.util.Iterator;

public class Main {
  public static void main(String args[]) {
    PersistenceManagerFactory pmf;
    PersistenceManager pm;
    Transaction tx;
    Properties prop = new Properties();
    try {
      prop.put("javax.jdo.PersistenceManagerFactoryClass", args[0]);
      pmf = JDOHelper.getPersistenceManagerFactory(prop);
      pmf.setConnectionDriverName(args[1]);
      pmf.setConnectionURL(args[2]);
      pm = pmf.getPersistenceManager();
      tx = pm.currentTransaction();

      tx.begin();
      Company company = new Company();
      pm.makePersistent(company);
      company.setName("ACME");
      Employee employee = new Employee();
      employee.setName("John");
      employee.setAge(30);
      employee.setSalary(40000);
      employee.setCompany(company);
      employee = new Employee();
      employee.setName("Joe");
      employee.setAge(25);
      employee.setSalary(30000);
      employee.setCompany(company);
      tx.commit();
    }
    catch(Exception e){
      e.printStackTrace();
    }
    tx.begin();
    Manager manager = new Manager();
    manager.setName("Jack");
    manager.setAge(40);
    manager.setSalary(100000);
    manager.setStocks(1000);
    company.setManager(manager);
    company.addEmployees(manager);
    tx.commit();
    tx.begin();
    company = new Company();
    pm.makePersistent(company);
    company.setName("MacroSoft");
    manager = new Manager();
    manager.setName("Bill");
    manager.setAge(50);
    manager.setSalary(1000000);
    manager.setStocks(1000000);
    company.setManager(manager);
    company.addEmployees(manager);
    company.populate();
    tx.commit();
    pm.close();
  }
}
```

Showing the use of a Query

```
package company;
import java.util.*;
import java.lang.String;
import java.util.Iterator;

public class Main {
  public static void main(String args[]) {
    PersistenceManagerFactory pmf;
    PersistenceManager pm;
    Transaction tx;
    Properties prop = new Properties();
    try {
      prop.put("javax.jdo.PersistenceManagerFactoryClass", args[0]);
      pmf = JDOHelper.getPersistenceManagerFactory(prop);
      pmf.setConnectionDriverName(args[1]);
      pmf.setConnectionURL(args[2]);
      pm = pmf.getPersistenceManager();
      tx = pm.currentTransaction();

      tx.begin();
      javax.jdo.Query q = pm.newQuery(Employee.class,"salary<150000");
      q.setOrdering("salary descending");
      Collection result = (Collection)q.execute();
      Iterator it = result.iterator();
      while (it.hasNext()) {
        Employee employee = (Employee)it.next();
        System.out.println(employee.getName() + employee.getSalary());
      }
    }
    catch(Exception e){
      e.printStackTrace();
    }
    tx.begin();
    Company company = new Company();
    pm.makePersistent(company);
    company.setName("ACME");
    Employee employee = new Employee();
    employee.setName("John");
    employee.setAge(30);
    employee.setSalary(40000);
    employee.setCompany(company);
    employee = new Employee();
    employee.setName("Joe");
    employee.setAge(25);
    employee.setSalary(30000);
    employee.setCompany(company);
    tx.commit();
    pm.close();
  }
}
```
Ways to Retrieve Object

- By query, in JDOQL (pass a string that represents the query)
- By navigation:
  - Direct object reference
  - Iterating over extent for the class

Getting to the First Object

- Application may access a “closure of instances” navigated to from one instance
- 3 ways to get the first instance:
  - PersistenceManager getObjectById()
  - PersistenceManager getExtent()
  - JDOQL

Life Cycle of PersistenceCapable

Another View of Previous

The Corresponding File metadata.jdo

<?xml version="1.0"?>
<metadata jdo jdk="" jvm="" jre="">
  <package name="company">
  <class name="Company">
    <field name="employees">
      <collection element-type="company.Employee"/>
    </field>
  </class>
  <class name="Employee"/>
  <class name="Manager" persistence-capable superclass="company.Employee"/>
  </package>
</metadata>

Summary of Enhancement
Identity, Equality Issues

- Java identity implemented by JVM
  - 1 == 2
- Object equality implemented by class developer
  - o1.equals(o2)
- JDO Identity implemented by JDO vendor
  - o1.jdoGetObjectId().equals(o2.jdoGetObjectId())
  - Primary key (defined by application, enforced in db)
  - Database (managed by db)
  - Non-managed (e.g. tables without primary key)

Object Uniqueness

- JDO instances representing the same data store object exist only once per PersistenceManager, regardless of how the instance is obtained:
  - query
  - navigation
  - getObjectById
  - getTransactionalInstance

Inheritance

- Polymorphism is supported
  - Base type must be PersistenceCapable
  - Persistent super classes must be listed in metadata definition
  - Queries may return subclasses, if requested
- Implementation defines table mapping strategy
  - Single Table, Class Table, Concrete Table
- Interfaces may not be directly persisted

JDO API

- Six interfaces
  1. PersistenceManagerFactory
  2. PersistenceManager
  3. Transaction
  4. Extent
  5. Query
  6. InstanceCallbacks

Instance Callbacks

- Events trigger functions in DBMS
- PersistenceCapable class that provides callback methods implements this interface
- Methods
  - jdoPostLoad()
  - jdoPreStore()
  - jdoPreClear()
  - jdoPreDelete()

JDO Restrictions

- Not all objects are persistable
  - Streams, Sockets, many system classes, etc
- Collections must be homogenous
- Maps may have restrictions on keys
- List ordering may not be preserved
- Objects cannot migrate between PersistenceManager instances
- Persisted objects cannot outlive their owning PersistenceManager
Discussion

- Discuss JDO-style vs. Relational (SQL) style.
- List benefits of each over the other.
- If you had to make a choice of just one for developing a DB application, which capability would you rather have?

JDO in the J2EE Architecture
(replacing Entity Java Beans)

Some JDO References
- Java Specification Request 12 to the Java Community Process
- java.sun.com
- JDO Public Access at sun.com
  - http://access1.sun.com/jdo/
- JDO Central – Developer’s Community for Java Data Objects
  - http://www.jdocentral.com/
- Java Skyline
- Officially : Using Java Data Objects
  - www.opengroup.com/tjg/1379
- Hands-on Java Data Objects - IBM: Java Technology

URLs from which I took stuff
(diagrams, links)
- http://access1.sun.com/jdo/JDO_0_6_Overview_00-04-05.ppt
- http://students.depaul.edu/%7Elahrens/se690/deliver/JDO.ppt
- http://www.javasig.com/Archive/lectures/JavaSIG-JavaDataObjects.ppt

JDO Books

(Amazon customer ratings)