The Object-Oriented Paradigm

- The world consists of objects
- So we use object-oriented languages to write applications
- We want to store some of the application objects (a.k.a. persistent objects)
- So we use an Object Database?

The Reality of DBMS

- Relational DBMS are still predominant
  - Best performance
  - Most reliable
  - Widest support
- Bridge between OO applications and relational databases
  - CLI and embedded SQL
  - Object-Relational Mapping (ORM) tools

Call-Level Interface (CLI)

- Application interacts with database through functions calls

```java
String sql = "select name from items where id = 1";
Connection c = DriverManager.getConnection( url );
Statement stmt = c.createStatement();
ResultSet rs = stmt.executeQuery( sql );
if( rs.next() ) System.out.println( rs.getString("name") );
```

Employee – Application Object

```java
public class Employee {
    Integer id;
    String name;
    Employee supervisor;
}
```
Employee – Database Table

cREATE TABLE employees (  
id integer primary key,  
name varchar(255),  
supervisor integer references employees(id)  
);

From Database to Application

So how do we construct an Employee object based on the data from the database?

public class Employee {  
    Integer id;  
    String name;  
    Employee supervisor;  
    public Employee( Integer id ) {  
        // access database to get name and supervisor  
        ...  
    }  
}

Problems with CLI and Embedded SQL ...

SQL statements are hard-coded in applications

public Employee( Integer id ) {  
    ...  
    PreparedStatement p;  
    p = connection.prepareStatement(  
        "select * from employees where id = ?"  
    );  
    ...  
}  

... Problems with CLI and Embedded SQL ...

Tedious translation between application objects and database tables

public Employee( Integer id ) {  
    ...  
    ResultSet rs = p.executeQuery();  
    if( rs.next() )  
        {  
            name = rs.getString("name");  
            ...  
        }  
}  

... Problems with CLI and Embedded SQL

Application design has to work around the limitations of relational DBMS

public Employee( Integer id ) {  
    ...  
    ResultSet rs = p.executeQuery();  
    if( rs.next() )  
        {  
            supervisor = ??  
            ...  
        }  
}  

The ORM Approach

Application  
ORM tool  
Persistent Data Store

Oracle, MySQL, SQL Server ...  
Flat files, XML ...
Hibernate and JPA

- Java Persistence API (JPA)
  - Annotations for object-relational mapping
  - Data access API
  - An object-oriented query language JPQL
- Hibernate
  - The most popular Java ORM library
  - An implementation of JPA

Hibernate Usage

- Hibernate without JPA
  - API: SessionFactory, Session, Query, Transaction
  - More features
- Hibernate with JPA
  - API: EntityManagerFactory, EntityManager, Query, Transaction
  - Better portability
  - Behaviors are better defined and documented

A Hibernate Example

- Java classes
  - Employee.java
- JPA configuration file
  - persistence.xml
- Code to access the persistent objects
  - EmployeeTest.java
- (Optional) Logging configuration files
  - log4j.properties

Java Classes

- Plain Java classes (POJOs); however, it is recommended that
  - Each persistent class has an identity field
  - Each persistent class implements the Serializable interface
  - Each persistent field has a pair of getter and setter, which don't have to be public

O/R Mapping Annotations

- Describe how Java classes are mapped to relational tables

<table>
<thead>
<tr>
<th>@Entity</th>
<th>Persistent Java Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>@Id</td>
<td>Id field</td>
</tr>
<tr>
<td>@Basic (can be omitted)</td>
<td>Fields of simple types</td>
</tr>
<tr>
<td>@ManyToOne</td>
<td>Fields of class types</td>
</tr>
<tr>
<td>@OneToMany</td>
<td></td>
</tr>
<tr>
<td>@ManyToOne</td>
<td></td>
</tr>
<tr>
<td>@ManyToMany</td>
<td></td>
</tr>
<tr>
<td>@OneToOne</td>
<td></td>
</tr>
</tbody>
</table>

persistence.xml

- `<persistence-unit>`
  - name
- `<properties>`
  - Database information
  - Provider-specific properties
- No need to specify persistent classes
Access Persistent Objects

- EntityManagerFactory
- EntityManager
- Query and TypedQuery
- Transaction
  - A transaction is required for updates

Persist() vs. Merge()

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Persist</th>
<th>Merge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object passed was never persisted</td>
<td>1. Object added to persistence context as new entity</td>
<td>1. State copied to new entity.</td>
</tr>
<tr>
<td></td>
<td>2. New entity inserted into database at flush/commit</td>
<td>2. New entity added to persistence context</td>
</tr>
<tr>
<td></td>
<td>3. New entity inserted into database at flush/commit</td>
<td>3. New entity inserted into database at flush/commit</td>
</tr>
<tr>
<td></td>
<td>4. New entity returned</td>
<td>4. New entity returned</td>
</tr>
<tr>
<td>Object was previously persisted, but not loaded in this persistence context</td>
<td>1. EntityNotFoundException thrown (or a PersistenceException at flush/commit)</td>
<td>1. Entity exists.</td>
</tr>
<tr>
<td></td>
<td>2. Existing entity loaded.</td>
<td>2. State copied from object to loaded entity</td>
</tr>
<tr>
<td></td>
<td>3. Loaded entity updated in database at flush/commit</td>
<td>3. Loaded entity updated in database at flush/commit</td>
</tr>
<tr>
<td></td>
<td>4. Loaded entity returned</td>
<td>4. Loaded entity returned</td>
</tr>
<tr>
<td>Object was previously persisted and already loaded in this persistence context</td>
<td>1. EntityNotFoundException thrown (or a PersistenceException at flush or commit time)</td>
<td>1. State from object copied to loaded entity</td>
</tr>
<tr>
<td></td>
<td>2. Loaded entity updated in database at flush/commit</td>
<td>2. Loaded entity updated in database at flush/commit</td>
</tr>
<tr>
<td></td>
<td>3. Loaded entity returned</td>
<td>3. Loaded entity returned</td>
</tr>
</tbody>
</table>

Some EntityManager Methods

- find( entityClass, primaryKey )
- createQuery( query )
- createQuery( query, resultClass )
- persist( entity )
- merge( entity )
- getTransaction()

Java Persistence Query Language (JPQL)

- A query language that looks like SQL, but for accessing objects
- Automatically translated to DB-specific SQL statements
- select e from Employee e where e.id = :id
  - From all the Employee objects, find the one whose id matches the given value

See Chapter 4 of Java Persistence API, Version 2.0

Hibernate Query Language (HQL)

- A superset of JPQL

Join in HQL ...

```java
class User {
    Integer id;
    String username;
    ...
}...

class Section {
    Integer id;
    User instructor;
    ...
}...

users    sections
<table>
<thead>
<tr>
<th>id</th>
<th>username</th>
<th>instructor.id</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>cysun</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>vcorpi</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>
```
Query: find all the sections taught by the user “cysun”.
- SQL??
- HQL??

Query: find all the sections for which “cysun” is one of the instructors
- SQL??
- HQL??

```
class User {
    Integer id;
    String username;
    Set<User> instructors;
}
```

```
class Section {
    Set<User> instructors;
}
```

Advantages of ORM
- Make RDBMS look like ODBMS
- Data are accessed as objects, not rows and columns
- Simplify many common operations. E.g. `System.out.println(e.supervisor.name)`
- Improve portability
  - Use an object-oriented query language (OQL)
  - Separate DB specific SQL statements from application code
- Object caching

Basic Object-Relational Mapping
- Class-level annotations
  - @Entity and @Table
- Id field
  - @Id and @GeneratedValue
- Fields of simple types
  - @Basic (can be omitted) and @Column
- Fields of class types
  - @ManyToMany and @OneToOne

SchemaExport
- Part of the Hibernate Core library
- Generate DDL from Java classes and annotations
- In Hibernate Examples, run `Hbm2ddl <output_file>`
Advanced ORM

- Embedded class
- Collections
- Inheritance

---

Embedded Class

```java
public class Address {
    String street;
    String city;
    String state;
    String zip;
}
```

```java
public class User {
    Integer id;
    String username;
    String password;
    @Embedded
    Address address;
}
```

---

Mapping Embedded Class

```java
@Embeddable
public class Address {
    String street;
    String city;
    String state;
    String zip;
}
```

```java
@Entity
public class User {
    @Id
    Integer id;
    String username;
    String password;
    @Embedded
    Address address;
}
```

---

Collection of Simple Types

```java
public class Customer {
    Integer id;
    String name;
    String address;
    Set<String> phones;
}
```

```java
public class User {
    Integer id;
    String username;
    String password;
    @Embedded
    Address address;
}
```

---

Mapping Element Collection

```java
@ElementCollection
Set<String> phones;
```

```java
@ElementCollection
@CollectionTable(
    name = "customer_phones",
    joinColumns=@JoinColumn(name = "customer_id")
)
@CollectionTable(
    name = "customer_phones",
    joinColumns=@JoinColumn(name = "customer_id")
)
@CollectionTable(
    name = "customer_phones",
    joinColumns=@JoinColumn(name = "customer_id")
)
@CollectionTable(
    name = "customer_phones",
    joinColumns=@JoinColumn(name = "customer_id")
)
```

---

Customize Collection Table

```java
@ElementCollection
@CollectionTable(  
    name = "customer_phones",  
    joinColumns=@JoinColumn(name = "customer_id")
)  
@ElementCollection
@CollectionTable(  
    name = "customer_phones",  
    joinColumns=@JoinColumn(name = "customer_id")
)  
@ElementCollection
@CollectionTable(  
    name = "customer_phones",  
    joinColumns=@JoinColumn(name = "customer_id")
)  
@ElementCollection
@CollectionTable(  
    name = "customer_phones",  
    joinColumns=@JoinColumn(name = "customer_id")
)
```
List of Simple Types

- Order by property
  - @OrderBy("<property_name> ASC\|DESC")
  - Simple types do not have properties
    @ElementCollection
    @OrderBy("asc")
    List<String> phones;
- Order by a separate column
  @ElementCollection
  @OrderColumn(name = "phone_order")
  List<String> phones;

Issues Related to Collections of Object Types

- Relationships (a.k.a. associations)
  - one-to-many
  - many-to-many
- Unidirectional vs. Bidirectional
- Set and List
- Cascading behaviors

Types of Relationships

- Many-to-Many
- Many-to-One / One-to-Many
- One-to-One

Many-to-One Relationship

- Each entity in $E_1$ can be related to one entity in $E_2$
- Each entity in $E_2$ can be related to many entities in $E_1$

Many-to-Many Relationship

- Each entity in $E_1$ can be related to many entities in $E_2$
- Each entity in $E_2$ can be related to many entities in $E_1$

One-to-One Relationship

- Each entity in $E_1$ can be related to one entity in $E_2$
- Each entity in $E_2$ can be related to one entity in $E_1$
Relationship Type Examples

- Books and authors??
- Books and editors??

One-To-Many Example

- A customer may own multiple accounts
- An account only has one owner

Bidirectional Association – OO Design #1

```java
public class Account {
    Integer id;
    Double balance;
    Date createdOn;
    Customer owner;
    Set<Account> accounts;
}
```

Unidirectional Association – OO Design #2

```java
public class Account {
    Integer id;
    Double balance;
    Date createdOn;
    String name;
    String address;
    Set<String> phones;
    Customer owner;
    Set<Account> accounts;
}
```

Unidirectional Association – OO Design #3

```java
public class Account {
    Integer id;
    Double balance;
    Date createdOn;
    Customer owner;
}
```

Unidirectional vs. Bidirectional

- Do the three OO designs result in different database schemas??
- Does it make any difference on the application side??
- Which one should we use??
Mapping Bidirectional One-To-Many

```java
public class Account {
    Integer id;
    Double balance;
    Date createdOn;
    @ManyToOne
    Customer owner;
}
```

```java
public class Customer {
    Integer id;
    String name;
    String address;
    Set<String> phones;
    @OneToMany(mappedBy="owner")
    Set<Account> accounts;
}
```

Using List

```java
public class Customer {
    Integer id;
    String name;
    String address;
    Set<String> phones;
    @OneToMany(mappedBy="owner")
    @OrderBy( "createdOn asc" )
    List<Account> accounts;
}
```

Many-To-Many Example

- A customer may own multiple accounts
- An account may have multiple owners

Mapping Many-To-Many

```java
public class Account {
    Integer id;
    Double balance;
    Date createdOn;
    @ManyToMany
    Set<Customer> owners;
}
```

```java
public class Customer {
    Integer id;
    String name;
    String address;
    Set<String> phones;
    @ManyToMany(mappedBy="owners")
    Set<Account> accounts;
}
```

Customize Join Table

```java
@ManyToMany
@JoinTable(
    name = "account_owners",
    joinColumns=@JoinColumn(name = "account_id"),
    inverseJoinColumns=@JoinColumn(name="owner_id")
) Set<Customer> owners;
```

Cascading Behavior

- Whether an operation on the parent object (e.g. Customer) should be applied to the children objects in a collection (e.g. List<Account>)

```java
Customer c = new Customer("cysun");
Account a1 = new Account();
Account a2 = new Account();
c.getAccounts().add( a1 );
c.getAccounts().add( a2 );
entityManager.persist(c); // will a1 and a2 be saved as well?
entityManager.remove(c); // will a1 and a2 be deleted from db??
```
Cascading Types in JPA

http://sun.calstatela.edu/~cysun/documentation/jpa-2.0-api/javax/persistence/CascadeType.html

CascadeType Examples

```java
@OneToMany(mappedBy="owner",
    cascade=CascadeType.PERSIST)
List<Account> accounts;

@OneToMany(mappedBy="owner",
    cascade={CascadeType.PERSIST, CascadeType.MERGE})
List<Account> accounts;

@OneToMany(mappedBy="owner",
    cascade=CascadeType.ALL)
List<Account> accounts;
```

Inheritance

```java
public class CDAccount extends Account {
    Integer term;
}
```

Everything in One Table

<table>
<thead>
<tr>
<th>id</th>
<th>account_type</th>
<th>balance</th>
<th>created_on</th>
<th>term</th>
</tr>
</thead>
</table>

Discriminator column

Inheritance Type – SINGLE_TABLE

```java
@Entity
@Table(name="accounts")
@Inheritance(strategy=InheritanceType.SINGLE_TABLE)
@DiscriminatorColumn(name="account_type")
@DiscriminatorValue("CHECKING")
public class Account {
    ...
}

@Entity
@DiscriminatorValue("CD")
public class CDAccount {
    ...
}
```

Table Per Subclass

<table>
<thead>
<tr>
<th>id</th>
<th>balance</th>
<th>created_on</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>account_id</th>
<th>term</th>
</tr>
</thead>
</table>
Inheritance Type – JOINED

```java
@Entity
@Table(name="accounts")
@Inheritance(strategy=InheritanceType.JOINED)
public class Account { ... }

@Entity
@Table(name="cd_accounts")
public class CDAccount { ... }
```

Inheritance Type – TABLE_PER_CLASS

```java
@Entity
@Table(name="accounts")
@Inheritance(strategy=InheritanceType.TABLE_PER_CLASS)
public class Account { ... }

@Entity
@Table(name="cd_accounts")
public class CDAccount { ... }
```

Table Per Concrete Class

```java
accounts
| id | balance | created_on |

cd_accounts
| id | balance | created_on | term |
```

Tips for Hibernate Mapping

- Understand relational design
  - Know what the database schema should look like before doing the mapping
- Understand OO design
  - Make sure the application design is object-oriented

Further Readings

- Pro JPA 2 by Mike Keith and Merrick Schincariol