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 a 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") );
```

Embedded SQL

- SQL statements are embedded in host language

```java
String name;
#sql (select name into :name from items where id = 1);
System.out.println( name );
```

Employee – Application Object

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

```sql
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?

```java
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

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

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

Tedious translation between application objects and database tables

```java
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

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

The ORM Approach
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
- Caching

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
  - EmployeTest.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>Annotation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>@Entity</td>
<td>Persistent Java Class</td>
</tr>
<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>@OneToOne</td>
<td></td>
</tr>
<tr>
<td>@OneToMany</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

Some EntityManager Methods

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

Persist() vs. Merge()

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Persist</th>
<th>Merge</th>
</tr>
</thead>
</table>
| Object passed was never persisted                                        | 1. Object added to persistence context as new entity  
  2. New entity inserted into database at flush/commit  
  3. New entity added to persistence context  
  4. New entity inserted into database at flush/commit  
  5. New entity returned |
| Object was previously persisted, but not loaded in this persistence context | 1. EntityNotFoundException (or RuntimeException at flush/commit)  
  2. Existing entity loaded  
  3. Loaded entity updated in database at flush/commit  
  4. Loaded entity returned |
| Object was previously persisted and already loaded in this persistence context | 1. EntityNotFoundException (or RuntimeException at flush or commit time)  
  2. Existing entity loaded  
  3. Loaded entity updated in database at flush/commit  
  4. Loaded entity returned |

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

Hibernate Query Language (HQL)

- A superset of JPQL
- CSNS Examples
  - `CourseDaoImpl`
  - `QuarterDaoImpl`

See Chapter 4 of Java Persistence API, Version 2.0
Join in HQL ...

class User {
    Integer id;
    String username;
}

class Section {
    Integer id;
    User instructor;
}

users
  id | username
  1  | cysun
  2  | vcrespi

sections
  id | instructor_id
  1  | 1
  2  | 1
  3  | 2

... Join in HQL ...

Query: find all the sections taught by the user “cysun”.
- SQL??
- HQL??

... Join in HQL ...

class User {
    Integer id;
    String username;
}

class Section {
    Integer id;
    Set<User> instructors;
}

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

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
  - @ManyToOne and @OneToOne

Advanced ORM

- Embedded class
- Collections
- Inheritance
Part of the Hibernate Tools package
Generate DDL from Java classes and annotations
In CSNS2 and Hibernate Examples, run
`mvn process-classes`

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

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

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

```java
public class CustomerPhones {
    @Id
    Integer id;
    String customer_id;
    Set<String> phones;
}
```

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

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

```java
@ElementCollection
@CollectionTable(  
    name = "customer_phones",  
    joinColumns=@JoinColumn(name = "customer_id")
)  
@Column(name="phone")
Set<String> phones;
```
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`
  - `@OrderBy("asc")`
  - `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-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 $E_1$

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 $E_1$

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;
}
```

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

Unidirectional Association – OO Design #2

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

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

Unidirectional Association – OO Design #3

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

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

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
    @JoinTable(
        name = "account_owners",
        joinColumns=@JoinColumn(name = "account_id"),
        inverseJoinColumns=@JoinColumn(name="owner_id")
    )
    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

@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

public class CDAccount extends Account {
    Integer term;
}

Inheritance Type – SINGLE_TABLE

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

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

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

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>

<table>
<thead>
<tr>
<th>foreign key</th>
</tr>
</thead>
</table>
Inheritance Type – JOINED

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

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

Table Per Concrete Class

accounts

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

cd_accounts

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

Inheritance Type – TABLE_PER_CLASS

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

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

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