CS 580 Client-Server Programming
Fall Semester, 2012
Doc 23 States, Database Architecture
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References

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Patterns of Enterprise Application Architecture, Martin Folwer, Addison-Wesley, 2003

CS 683 Lecture document 27 Hibernate Example, Fall 2005, http://www.eli.sdsu.edu/courses/fall04/cs683/notes/hibernate/hibernate.html

The Vietnam of Computer Science, Ted Neward, http://blogs.tedneward.com/2006/06/26/The+Vietnam+Of+Computer+Science.aspx

States

Some Servers are stateful or have modes

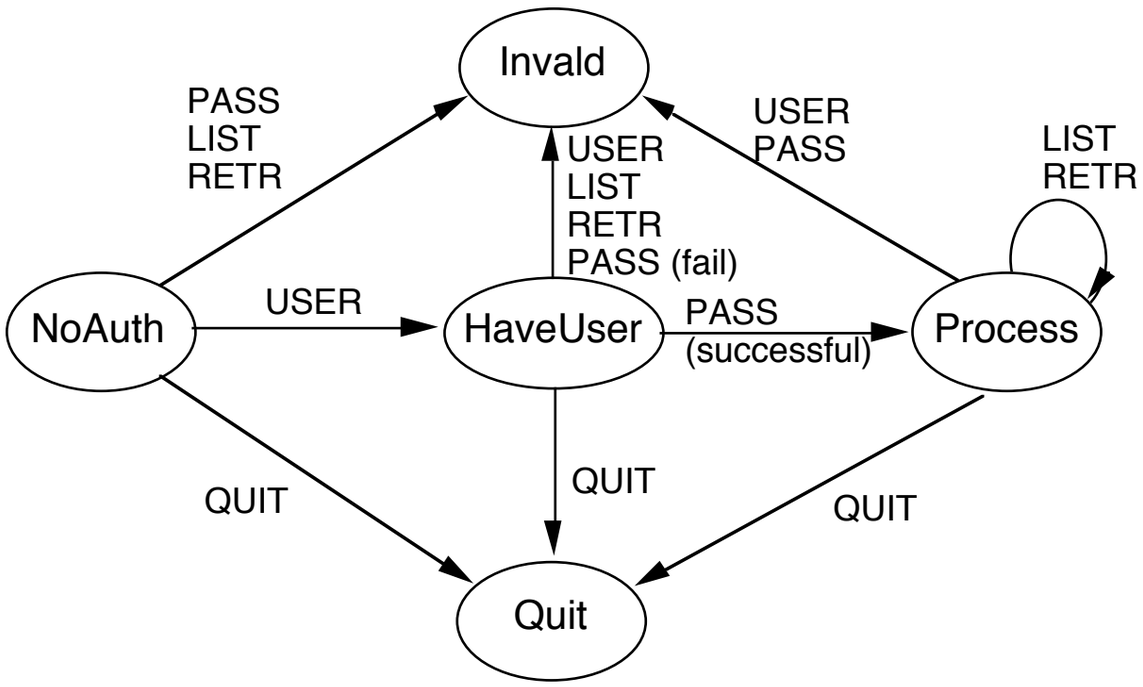
Each connection has different states

Some commands are only legal in some states

How to deal with states?

If (case) statements
Table of function pointers
State Objects (State pattern)

Finite Automata - State Machines



Using Switch Statements

```
int state = 0;
while (true) {
        command = input.read();
        switch (state) {
                case 0:
                        if (command.isUser()) {
                                username = command.argument();
                                state = 1;
                        }
                        else if (command.isQuit())
                                state = 4;
                        else
                                error("Illegal command: " + command);
                        break;
                case 1:
                        if (command.isPassword()) {
                                if (valid(username, command.argument()))
                                        state = 2;
                                else {
                                        error("Unauthorized User");
                                        state = 3;
                                }
                        }
                        else
                                error("Unknown: " + command);
                        break;
```

0	NoAuth
1	HaveUser
2	Process
3	Invalid
4	Quit

More Readable Version

```
int state = NO_AUTH;
while (true) {
        command = input.read();
        switch (state) {
                case NO_AUTH:
                        noAuthorizationStateHandle( command );
                        break;
                case HAVE_USER:
                        haveUserStateHandle( command );
                        break;
                case PROCESS:
                        processStateHandle( command );
                        break;
                case INVALID:
                        invalidStateHandle( command );
                        break;
                case QUIT:
                        quitStateHandle( command );
                        break;
        }
```

```
void noAuthorizationStateHandle(PopCommand a
Command) {
        if (command.isUser()) {
                username = command.argument();
                state = HAVE_USER;
        }
        else if (command.isQuit())
                state = QUIT;
        else
                error("Illegal command: " + command);
}
```

Switch Method Analysis

Disadvantages

Hard to read for large or complex states

Hard to modify

Hard to debug

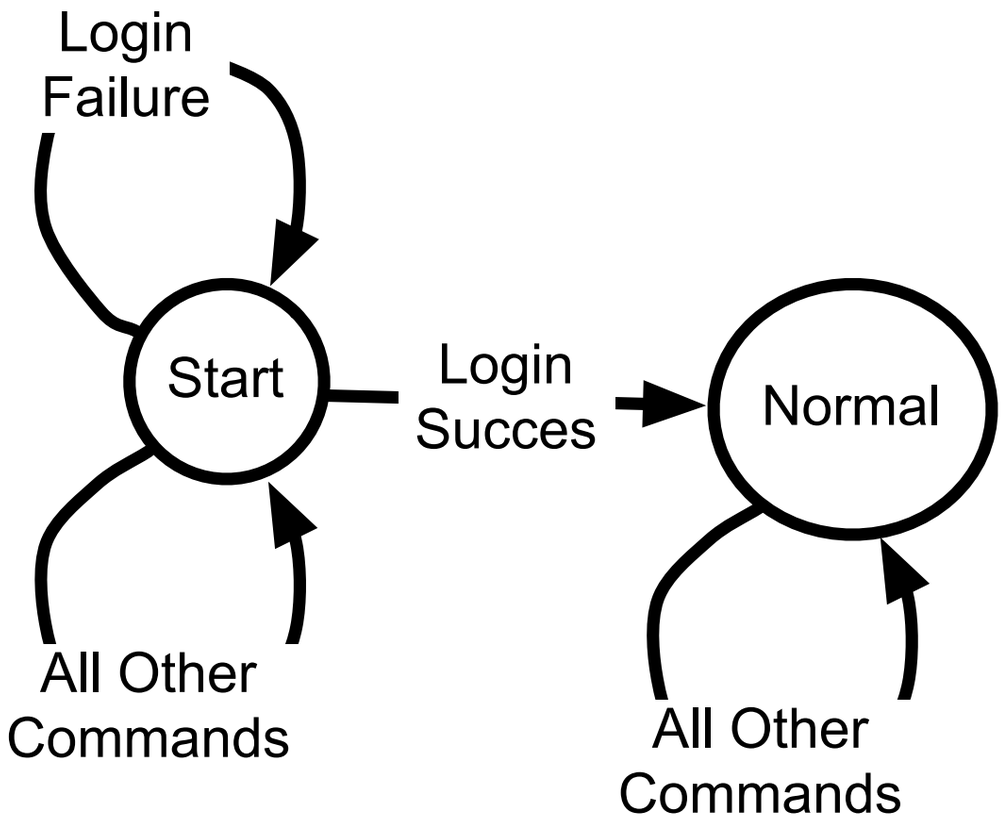
The code will get very long very quickly

Advantages

Everyone understands if statements

Simple for small/simple situations

Special Case




```
command = input.nextCommand()

if command.isLogin()
    process login
else
    handle illegal command
end

while !command.quit?
    command =
input.nextCommand()
    process command
end
```

Special Case Modularized

```
processClientRequest(input, output) {
    try {
        boolean loginSucceeded = processLogin(input,ouput);
        if (!loginSucceeded) return;
        processAuthenticatedRequests(input,output);
    } catch (Exception error) {
        logger.throwing("ClientHandler","processingClientRequest", error);
    } finally {
        input.close();
        output.close();
    }
}
```

Implementing a State Machine with a Table

Commands	States				
	NoAuth	HaveUser	Process	Invalid	Quit
USER					
PASS					
LIST					
RETR					
QUIT					

Each cell needs:

A function to process request
Next state on success
Next state on failure

State Table Details

Commands	States				
	NoAuth	HaveUser	Process	Invalid	Quit
USER	actionUser	actionNull	actionNull		
	HaveUser	Invalid	Invalid	Quit	Quit
	Invalid	*Invalid*	*Invalid*	*Quit*	*Quit*
PASS	actionNull	actionPass	actionNull		
	Invalid	Process	Invalid	Quit	Quit
	Invalid	*Invalid*	*Invalid*	*Quit*	*Quit*
LIST	actionNull	actionNull	actionList		
	Invalid	Invalid	Process	Quit	Quit
	Invalid	*Invalid*	*Invalid?*	*Quit*	*Quit*
RETR	actionNull	actionNull	actionRetr		
	Invalid	Invalid	Process	Quit	Quit
	Invalid	*Invalid*	*Invalid?*	*Quit*	*Quit*
QUIT	actionQuit	actionQuit	actionQuit		
	Quit	Quit	Quit	Quit	Quit
	Quit	*Quit*	*Quit*	*Quit*	*Quit*

Function to process request
Next State on success
Next State on failure

Basic Operation

Get request from user

Use current state and new request to find in table operation to perform

Perform the operation

Change state based on table and result of operation

How to place Operation in a Table

C/C++

Use function pointers

Smalltalk

Use symbols and reflection

Use blocks

Java

Use reflection

Use Inner classes

Ruby

Use function references

Function Pointers in C/C++

```
void quickSort( int* array, int LowBound, int HighBound){
        // source code to sort array from LowBound to HighBound
        // using quicksort has been removed to save room on page
}

void mergeSort(int* array, int LowBound, int HighBound) {  // same here}

void insertionSort(int* array, int LowBound, int HighBound)  {       // ditto }

void main() {
        void (*sort) (int*, int, int);
        int size;
        int data[100];

        // pretend data and Size are initialized

        if (size < 25)
                sort = insertionSort;

        else if (size > 100)
                sort = quickSort;

        else
                sort = mergeSort;

        sort(data, 0, 99);
}
```

SPOP State table in C/C++

```
struct
{
        int             currentState;
        char            *command;
        int             stateIfSucceed;
        int             stateIfFailed;
        int             (*action)(char **);
} actionTable[] =
{
        {0, "USER", 1, 3, actionUser},
        {0, "QUIT", 4, 4, actionQuit},
        {1, "PASS", 2, 3, actionPass},
        {1, "QUIT", 4, 4, actionQuit},
        {2, "LIST", 2, 2, actionList},
        {2, "RETR", 2, 2, actionList},
        {2, "QUIT", 4, 4, actionList},
        {0, 0, 0, 0, 0}
};
```

0	NoAuth
1	HaveUser
2	Process
3	Invalid
4	Quit

Easy to see what is going on.

Easy to add new commands.

Java Reflection

Class.getMethod maps strings to method objects

public Method getMethod(String name,Class parameterTypes[])
    throws NoSuchMethodException, SecurityException

Method.invoke() executes method objects

public Object invoke(Object receiver, Object... args)

A Class for an Example

```
class Example
  {
  public void getLunch()
    {
    System.out.println( "Lunch Time!");
    }

  public void getLunch( String day)
    {
    System.out.println( "Lunch Time for " + day);
    }

  public void eatOut( String where)
    {
    System.out.println( "MacDonalds? ");
    }

  public void eatOut( int where)
    {
    System.out.println( "PizzaHut? " + where );
    }
}
```

Reflection Example

```
import java.lang.reflect.Method;

class Test
   {
   public  static  void  main( String  args[] ) throws Exception
      {
      Example a = new Example();

      Class[] stringType = { Class.forName( "java.lang.String" ) };

      Object[] stringParameter = { "Monday" };

      Method tryMe;

      tryMe = a.getClass().getMethod( "getLunch", stringType );

      tryMe.invoke( a, stringParameter );

      }
}
```

Sample Table Entry

```
class StateTableEntry {
        int         currentState;
        String      command;
        int         stateIfSucceed;
        int         stateIfFailed;
        Method      action;
}
```

```
StateTableEntry sample = new StateTableEntry();
Class[] stringType = { Class.forName( "java.lang.String" ) };
sample.action = Server.getMethod( "username", stringType );
```

State Table Analysis

Advantages

Compact view of states and transitions

Easy to add remove states

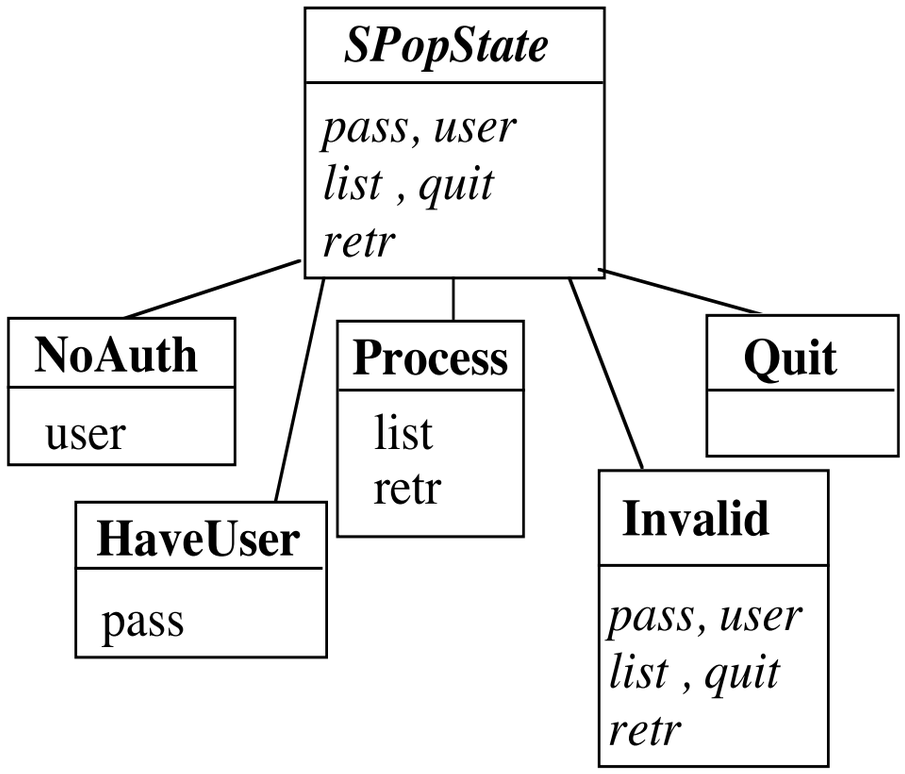
Easy to modify transitions

Disadvantages

Language support varies

Compile time checks are replaced by runtime check

Implementing a State Machine: Objects



Each method (pass, user, etc.) performs the proper action for the given state and returns the next state

SPopState is abstract state with the default behavior for each method

Strawman Driver Program

```
class SPopServer
        {
        public void processRequest(InputStream in, OutputStream out,
                InetAddress clientAddress) throws IOException
                {

                SPopState currentState = new NoAuth();
                do
                        {
                        ProtocolParser requestData = new ProtocolParser( in );
                        String request = requestData.getCommand();
                        if ( request.isPassword() )
                                currentState = currentState.pass( request, this);

                        else if ( request.isUser())
                                currentState = currentState.user(this);
                        etc.

                                send response to client
                        }
                while ( ! currentState instanceof Quit  );
                }
}
```

SPopState Implements Default Behavior

```
public class SPopState {
        public SPopState quit( SPopServer parent) {
                return new Quit();
                }

        public SPopState pass( PopCommand clientRequest, SPopServer parent)
                throws IllegalCommand {
                throw new IllegalCommand();
                }

        public SPopState user( PopCommand clientRequest, SPopServer parent)
                throws IllegalCommand {
                throw new IllegalCommand();
                }

        public SPopState list( PopCommand clientRequest, SPopServer parent)
                throws IllegalCommand {
                throw new IllegalCommand();
                }
```

Subclasses Implement Correct behavior for that State

```
public class NoAuth extends SPopState {
        public SPopState user( PopCommand clientRequest, SPopServer parent) {
                parent.setUser( clientRequest.getArgument() );
                parent.sendOKResponse();
                return new HaveUser();
        }
}

public class HaveUser extends SPopState {
        public SPopState pass( PopCommand clientRequest, SPopServer parent) {
                parent.setPassword( clientRequest.getArgument() );
                if ( parent.user&PasswordValid() ) {
                        parent.sendOKResponse();
                        return new Process();
                }
                else {
                        parent.sendErrorResponse();
                        return new NoAuth();
                }
        }
}
```

State Object Analysis

Problems

Lots of little parts

Algorithm distributed among different classes

Advantages

Easy to add new states

Easy to change state transitions

Each State class deals with one state

Database

Databases & Architecture

How to keep SQL isolated?

How to isolate database connection details?

How to keep dealing with the database under control?

How to structure programs that use databases?

Topics

Organizing Domain Logic

Structuring code that accesses database

Organizing Domain Logic

How to organize an application that uses a database

Fowler provides the following methods

- Transaction Script
- Domain Model
- Table Module
- Service Layer

Transaction Script

Each request from GUI or client can be viewed as a separate transaction

Each request/transaction is handled by a separate method

Consequences

Very simple to implement

As application grows in complexity, becomes overly complex and hard to manage

Domain Model

Implement classes that incorporates both behavior & data

Classes represent objects in the domain

Program becomes collection of interacting objects

Objects map to tables

- A single object may span many tables
- A table row may contain multiple objects

Consequences

Overly complex for simple applications

Scales well to complex applications

Database organizes data differently

Table Module

For each table (or view) implement a class

Each class holds the business logic related to the data in the table

Consequences

Classes are organized around database structure rather than OO principles

Handles more complex situations than Transaction Script

Not as scalable as Domain Model

Structuring code that accesses database

Hiding database connection details

Organizing Access to Database

Issues about Database Connections

Database usernames and passwords should not be scattered in code

How much database connection detail should be scattered in the code

DatabaseConnector

Hide the details

```
public class DatabaseConnector {
        private String databaseUrl;
        private String user;
        private String password;
        private ArrayList connectionPool;

        private static DatabaseConnector instance =
                DatabaseConnector(“filename”);

        public static DatabaseConnector instance() {
                return instance;
        }

        private DatabaseConnector(String filename) {
                read file for database info
                set private fields
        }
```

```
public ResultSet executeQuery( String sql ) {
        return getStatement().executeQuery( sql);
}

public Statement getStatement() {
        return getConnection().createStatement();
}

private Connection getConnection() { return a connection}

etc
```


For CS 635 students - which pattern is this using?

For Future Examples - Office Hours

Common Operations

Find Office hours for instructor X
Find office hours of any graduate advisor
Find office hours of any undergraduate advisor
Find office hours of any TA
Who has office hours at time X
What times are there no office hours
Add office hours
Modify office hours

Tables for Example

Faculty			
Id	Name	Office	Phone
1	Eckberg	GMCS-543	594-6834
2	Donald	GMCS-541	594-7248
3	Carroll	GMCS-537	594-7242

RoleTypes	
ID	Role
1	Undergraduate Advisor
2	Graduate Advisor
3	TA

OfficeHours				
Id	StartTime	EndTime	Day	FacultyId
1	10:00	11:00	Tuesday	1
2	10:00	11:00	Thursday	1

Roles	
FacultyId	TypeId
1	2
2	2
3	1

Organizing Access to Database

Table Data Gateway
Row Data Gateway
Active Record
Data Mapper

Table Data Gateway

A wrapper for the SQL to access the table

One object handles all the rows in a table or view

Each table has one class that knows the table

One object represents the table – all the rows

Gateway hides all the Sql from the rest of the program

Works well with

- Table Module
- Transaction Script

FacultyTableGateway

```
public class FacultyTableGateway {
    public ResultSet findRow(int facultyId) {
        String select = "SELECT * FROM Faculty WHERE id = ?";
        Statement selectStatement =
DatabaseConnector.instance().prepareStatement(select);
        selectStatement.setObject( 1, facultyId);
        return selectStatement.executeQuery();
    }

    public ResultSet findAll() { code here    }

    public ResultSet findWhere(String whereClause) {code here }

    public void update(int facutlyId, String name, String office, String phone) {code here }

    public int insert(String name, String office, String phone) {add insert code here}

    publid void delete(int facutlyId) { code here}
}
```

What to return? Result sets or Objects?

- Result set
  - Handles multiple rows
  - Tied to SQL
- Objects
  - How to deal with multiple rows
  - Use
    - Domain objects
    - Collection

Transaction Script + Table Gateway

```
public class OfficeHoursServer {
        private OfficeHoursTableGateway officeHours;
        private FacultyTableGateway faculty;
        etc.

        public Vector officeHoursFor(String facultyName) {

                int facultyId = faculty.idFor(facultyName,);

                ResultSet officeHoursRows = officeHours.officeHoursFor( facultyId);
                Vector officeHours = new Vector();
                while (officeHoursRows.next() ) {
                        Dictionary officeHour = new Dictionary();
                        officeHour.put( “start”, officeHoursRows.getObject( “start”));
                        officeHour.put( “end”, officeHoursRows.getObject( “end”));
                        officeHour.put( “day”, officeHoursRows.getObject( “day”));
                        officeHours.add( officeHour);
                }
                officeHoursRows.close();
                return officeHours;
        }
```

Row Data Gateway

A Row Data Gateway gives you objects that look exactly like the record in your record structure but can be accessed with the regular mechanisms of your programming language

One object handles or represents a single row in a table or view

Each table has one class that knows the table

Gateway hides all the Sql from the rest of the program

A class provides just accessor methods to data in a row

Works well with Transaction script

FacultyRowGateway - Data Side

```
public class FacultyRowGateway {
    private int id;
    private String name;
    private String office;
    private String phone;

    public void setName(String facultyName) {name = facutlyName;}
    public void setOffice(String facultyOffice) {office = facultyOffice;}
    public void setPhone(String facultyPhone) {phone = facultyPhone;}
    public String getName() {return name;}
    public String getOffice() {return office;}
    public String getPhone() {return phone;}
```

FacultyRowGateway - Database Side

```
public int insert() {
        String insert = "INSERT INTO Faculty VALUES (?, ?, ?)";
        PreparedStatement insertStatement = DB.prepare(insert);
        try {
                insertStatement.setString(1,name);
                insertStatement.setString(2,office);
                insertStatement.setString(3,phone);
                insertStatement.execute();
                return getId();
        } catch (SQLException e) { handle exception}
}
```

FacultyRowGateway - Database Side

```
public void update()  {code to update }

public void delete()  {code to delete }

public static FacultyRowGateway find(int facultyId) {
    code to get data from database and create FacultyRowGateway
}

public static FacultyRowGateway find(String facultyName) {
    code to get data from database and create FacultyRowGateway
}
```

FacultyRowGateway - Database Side

```
private static FacultyRowGateway load(ResultSet facultyData) {
    int id = facultyData.getInt(1);
    String name = facultyData.getString(2);
    String office = facultyData.getString(3);
    String phone = facultyData.getString(4);
    return new FacultyRowGateway(id, name, office, phone);
}
```


In Fowler's text he has a registry of faculty objects, so he first checks the registry for the faculty object before going to the database. Good idea, not done here just to keep the presentation simpler.

Using FacultyRowGateway

```
FacultyRowGateway newFaculty =
     new FacultyRowGateway("Pete", "GMCS 444", "594-2222");
newFaculty.insert();

FacultyRowGateway pete = FacultyRowGateway.find("Pete");
pete.setPhone("594-3333);
pete.update();
```

Active Record

Each domain object know how add/remove/find its state in the database

Class for each table
An object represents one row in the table
Similar to Row Data Gateway with domain logic

Faculty Example

```
public class Facutly {
        String name;
        String phoneNumber;
        int id;
        etc.

        private final static String findByNameSql =
                "SELECT *
                 FROM faculty
                WHERE name = '?'";

        public static Faculty findByName(String name ) {
                Statement find =
                        dabaseConnnector.prepareStatement(findByNameSql);
                find.setObject( 1, name);
                ResultSet facultyRow = find.executeQuery();
                return load(facultyRow);
        }

        private static Faculty load( ResultSet facultyRow) {
                create faculty object.
                get data out of Resultset.
                Put data into faculty object.
```

Faculty Example

```
public boolean hasOfficeHoursAt(Time anHour) {
        Iterator hours = officeHours().iterator();
        while (hours.hasNext() ) {
            OfficeHour officeHour = (OfficeHour) hours.next();
            if (officeHour.contains( anHour) ) return true;
        }
        return false;
    }
```

```
 public ArrayList officeHours() {
        if( officeHours = nil ) {
            officeHours = OfficeHour.findFor( id );
        }
        return officeHours;
 }
```

etc.

Object-Relational Mapping Layers

Data Mapper

Implementing a good object-relational layer is a lot of work

Use existing tools to save a lot of time

Read/Write objects from tables without SQL

Some existing object-relational layers

- JDO – Java Data Object (Java framework)
- TopLink (Commercial - Java)
- Hibernate (Open source - Java)
- Cayenne (Open source - Java)
- GLORP (Open source - Smalltalk)

Hibernate Simple Example

Storing Person objects in table

Database Table

id	first_name	last_name

SQL Used to Create Table

```
CREATE TABLE PEOPLE
    (FIRST_NAME varchar(50) NULL ,
    LAST_NAME varchar(50) NULL ,
    ID int NOT NULL ,
    PRIMARY KEY  (id));
```

Person Class

```
package sample;

public class Person {
        String firstName;
        String lastName;
        long id;

        public People () {super(); }

        public People(String first, String last) {
                firstName = first;
                lastName = last;
        }
        public String getLastName() { return lastName; }
        public String getFirstName() { return firstName; }
        public void setFirstName( String name) { firstName = name; }
        public void setLastName( String name) { lastName = name; }
        public long getId() { return id; }
        public void setId(long l) {id = l; }
        public String toString() {return firstName + " " + lastName + id;}
}
```

Mapping – Person.hbm.xml

Indicates how to map object fields to table columns

```
<?xml version="1.0"?>
<!DOCTYPE hibernate-mapping PUBLIC
        "-//Hibernate/Hibernate Mapping DTD//EN"
        "http://hibernate.sourceforge.net/hibernate-mapping-2.0.dtd" >

<hibernate-mapping package="sample">
        <class
                name="Person"
                table="people" >
                <id
                        name="id"
                        type="java.lang.Long"
                        column="id" >
                        <generator class="assigned"/>
</id>
<property
                        name="lastName"
                        column="last_name"
                        type="string"
                        not-null="false"
                        length="50" />
                                <property
                                        name="firstName"
                                        column="first_name"
                                        type="string"
                                        not-null="false"
                                        length="50" />
        </class>
</hibernate-mapping>
```

Sample Connection

```
public class Main {
    public static void main(String[] args) throws Exception {
        sampleRead();
        sampleWrite();
    }

    static Session getHibernateSession() throws
            MappingException, HibernateException, Exception {
        some code to get HibernateSession
    }

    static void sampleWrite() throws MappingException, HibernateException, Exception {
        Session session = getHibernateSession();
        Transaction save = session.beginTransaction();
        Person newPerson = new Person("Jack", "Frost");
        newPerson.setId(1);
        session.save(newPerson);
        newPerson = new Person("Jack", "Ripper");
        newPerson.setId(2);
        session.save(newPerson);
        save.commit();
        session.close();
    }
```

Sample Connection Continued

```
static void sampleRead() throws
        MappingException, HibernateException, Exception {
    Session session = getHibernateSession();
    Query getByLastName =
        session.createQuery(
            "from People p where p.lastName = :var");
    getByLastName.setString("var", "Frost");
    List result = getByLastName.list();
    System.out.println("Number of Objects: " + result.size());
    Person frost = (Person) result.get( 0);
    System.out.println(frost);
    session.close();
  }
}
```

O-R Mapping - Vietnam of Computer Science

http://blogs.tedneward.com/2006/06/26/The+Vietnam+Of+Computer+Science.aspx

http://www.codinghorror.com/blog/archives/000621.html

Last mile problem & OR mapping Problem

Dual-Schema Problem

Entity Identity Issues

The Data Retrieval Mechanism

- Query-By-Example (QBE)
- Query-By-API (QBA)
- Query-By-Language (QBL)

Some Solutions

Abandon relational databases - store objects

Abandon objects

Abandon OR-layers

Accept OR-Layer limitations

    Use SQL when easier

Add relational concepts to language

Add relational concepts to frameworks