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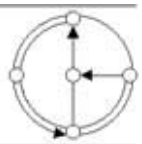

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Vernetzte Systeme
Exercise 9

Ausgabe: 26. Mai 2005
Abgabe: 3. Juni 2005

1. Introduction of RPC / Java RMI

RPC is a common technique for constructing distributed, client-server based application. It enables the intercommunication between two processes - client process and server process, which might be located on a single host or on different hosts. The client process calls the remote procedures which is shared by the server process, and get the return result.

RMI (Remote Method Invocation) is a Java implementation of RPC, which includes a core Java API and class library. It allows Java objects on different hosts to communicate with each other. The server implements a remote interface that specifies which of its methods can be invoked by clients, so that the clients invoke the remote methods as normal local methods.

Java/RMI Setting:
RMI is included in the core Java API and class library. To use RMI, JDK (Java Development Kit) should be installed and Java environment has to be setup.

- Download and install the JDK 1.4.2 from http://java.sun.com
- Setup path **`to $JDK_HOME/bin`**, where $JDK_HOME is the home directory where JDK is installed. In case **`$JDK_HOME=/usr/java`**

```
% setenv PATH=/usr/java/bin:$PATH or,
% export PATH /usr/java/bin:$PATH
```

- Setup environmental argument CLASSPATH for JDK
  as **`.;$JDK_HOME/lib/rt.jar`**

```
% setenv CLASSPATH=.:/usr/java/lib/rt.jar or,
```

```
% export CLASSPATH .:/usr/java/lib/rt.jar
```

- Find the executable files **`java, javac, rmiregistry, rmic`** under the directory **`$JDK_HOME/bin`** .

RMI Example:

Here is a simple example to show how to create a RMI server and client.
A RMI server exposes one remote method `int addOne(int i)` to the clients. With the input arguments `i` from clients, `addOne()` simply returns `i+1`.

Server Side:
First, an interface class declaring the method is created

```
package example;
import java.rmi.*;

public interface Calculator extends Remote{
       public int addOne(int i) throws RemoteException;

}
```

List 1. Interface Calculator

All the remote methods are declared to throw `RemoteException` when failure occurs during the remote invocation. Catching and handling the `RemoteException` is up to the clients which use the remote methods.

The class `CalculatorImpl` implements the interface:

```
package example;
import java.rmi.RemoteException;
import java.rmi.server.UnicastRemoteObject;


public class CalculatorImpl implements Calculator{

       public CalculatorImpl() throws RemoteException  {
              UnicastRemoteObject.exportObject(this);
       }

       public int addOne(int i) throws RemoteException {
              return i+1;
       }
}
```

List 2. Class CalculatorImpl

In the `CalculatorImpl()` constructor, `UnicastRemoteObject.exportObject(this)` exports the object by listening for connections on some port, so that the invocation from clients can be processed.

Now, the way to create a server `CalculatorServer` to handle the client's request is as follows:

```
package example;
import java.net.*;
import java.rmi.*;


public class CalculatorServer {
  public static void main(String[] args){
    try{
      CalculatorImpl c = new CalculatorImpl();
      Naming.rebind("calculator" , c);
      System.out.println("Calculator Server Ready!");
    }
    catch (RemoteException e) {
      System.out.println("Exception in CalculatorImpl.main: " + e);
    }
    catch (MalformedURLException e) {
      System.out.println("MalformedURLException " + e);
    }
  }
}
```

List 3. Class CalculatorServer

`Naming.rebind("calculator", c)` is to bind the calculator object with the name "calculator". The binding name is case-sensitive. Together with the IP address or URL name of the host where the server is running on, a URL address "**rmi://server_ip/calculator**" is used to address the calculator object.

Clients can use the URL "**rmi://server_ip/calculator**" to get the reference to the remote object and invoke the method. Here, **server_ip** is the IP address or URL name of the host where the server is running.

Client Side:
Before a client can call the remote method `addOne(int)`, it needs to retrieve the remote reference to the calculator object. RMI provides a method lookup() in the class **`java.rmi.Naming`** for clients to get the reference to the remote object:

```
Calculator cal = (Calculator) Naming.lookup("rmi://server_ip/calculator");
```

The example of the client is shown below:

```
package example;
import java.rmi.*;
import java.net.*;

public class CalculatorClient {
  public static void main(String args[]) {
    System.out.println("args length =  " + args.length);
    if (args.length == 0 || !args[0].startsWith("rmi:")){
      System.err.println(
        "Usage: java calculatorClient rmi://host.domain/calculator
number");
      return;
    }
```

```
    try {
      Calculator cal = (Calculator ) Naming.lookup(args[0]);
      int input = (new Integer(args[1])).intValue();
      int output = cal.addOne(input);
      System.out.println(
        "The output of addOne(" + input + ")" + " is " + output);
    }
    catch (MalformedURLException e) {
      System.err.println(args[0] + " is not a valid RMI URL");
    }
    catch (RemoteException e) {
      System.err.println("Remote object threw exception " + e);
    }
    catch (NotBoundException e) {
      System.err.println(
        "Cannot find the requested remote object on the server");
    }
  }
}
```

List 4. Class CalculatorClient

Compiling the Stubs:
Compile all the classes of server and client as usual. Additionally, the stubs and skeletons that RMI program required need to be generated as well.

```
% rmic CalculatorImpl
```

`rmic` is the tool included with the JDK. Run **`rmic`** on the remote object's class will generate the stubs and skeletons for the `CalculatorImpl` remote object as `CalculatorImpl_Skel.calss` and `CalculatorImpl_Stub.class`.

Setup:
The server will be started using the following commands:

```
% rmiregistry &
% java example.CalculatorServer
```

On the client side, type:

```
% java example.CalculatorClient rmi://server_ip/calculator 100
The Output of addOne(100) is 101
```

The result is then displayed.

2. Task: Implementation of Server/Client with RMI

This exercise is to implement a server and two clients exchanging messages through a server, as shown in Figure 1.

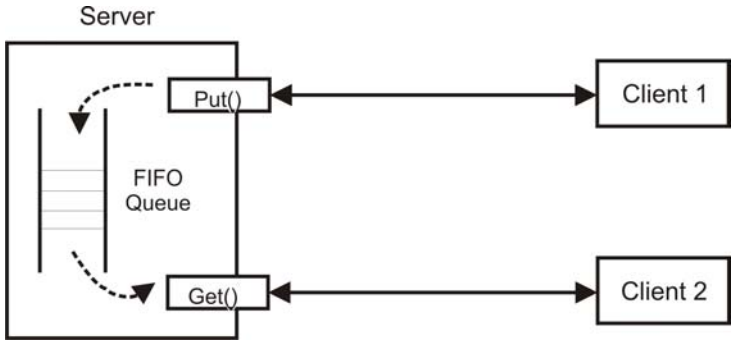

Figure 1: Message Server

- The server **`MessagePoolServer`** implements two remote methods defined in the interface class **`MessagePool`**:

```
import java.rmi.*;

public interface MessagePool extends Remote {
  public void put(String msg) throws RemoteException;
  public String get() throws RemoteException
}
```

List 5. Interface MessagePool

  - **`put()`** method accepts a String message from the client, and stores it into the FIFO queue in the server. In case the queue is full, **`put()`** operation will fail, and a **`QueueFullException`** will be thrown. In case the message from the client is null, the server will throw a **`MessageNullException`**.

  - **`get()`** method retrieves the message out of the queue to the client which invoke it. The retrieved message will be deleted from the queue. In case the queue is empty, **`get()`** operation will fail and a **`QueueEmptyException`** will be thrown.

- The FIFO message queue **`MessageQueue`** should have a size of 100 messages. Messages are strings with at most 500 characters.

- Implement two clients: **`MessagePutClient`** generates messages periodically (1 message per 1 second), and **`MessageGetClient`** retrieve messages periodically (1 message per 2 second). The message could be the timestamp of the client or any random generated string.

- Make sure all cases are handled:
  - Retrieving from an empty queue / Adding message to a full queue
  - Trying to add a message to a full queue

- For this exercise the program should be single threaded.