CS328 Distributed System Assignment 2 Report

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1 Explanation of design

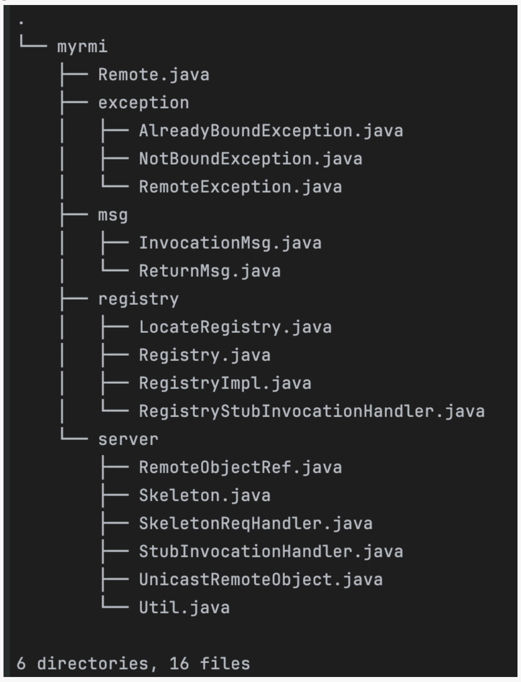
This implement of **RMI (Remote Method Invocation**) is followed by the structure provided by CS328 MyRMI zip file. All *todo* code blocks are finished and a comprehensive testing module can run well.

Following subsections will discuss some details of the implement.

1.1 Overall structure

As figures show:

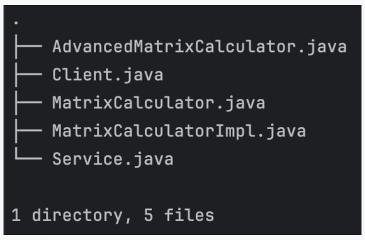
Java:



```
.
└── myrmi
    ├── Remote.java
    ├── exception
    │   ├── AlreadyBoundException.java
    │   ├── NotBoundException.java
    │   └── RemoteException.java
    ├── msg
    │   ├── InvocationMsg.java
    │   └── ReturnMsg.java
    ├── registry
    │   ├── LocateRegistry.java
    │   ├── Registry.java
    │   ├── RegistryImpl.java
    │   └── RegistryStubInvocationHandler.java
    └── server
        ├── RemoteObjectRef.java
        ├── Skeleton.java
        ├── SkeletonReqHandler.java
        ├── StubInvocationHandler.java
        ├── UnicastRemoteObject.java
        └── Util.java

6 directories, 16 files
```

Test:



```
.
├── AdvancedMatrixCalculator.java
├── Client.java
├── MatrixCalculator.java
├── MatrixCalculatorImpl.java
└── Service.java

1 directory, 5 files
```

1.2 Serialization

- Relative files: *./msg/InvocationMsg.java ./msgReturnMsy.java*

These two files implements *Serializable* Interface, which could simplify the serialization process when invocation and return results. The codes are very simple due to the usage of Annotations, as follow shows:

InvocationMsg.java

```
@Getter
@Setter
@AllArgsConstructor
public class InvocationMsg implements Serializable {
    private int objectKey;
    private String methodName;
    private Class<?>[] parameterTypes;
    private Object[] args;
}
```

ReturnMsg.java

```
@Getter
@Setter
@NoArgsConstructor
public class ReturnMsg implements Serializable {
    private int objectKey;
    private int status;
    private Object result;
}
```

1.3 Stub/skeleton generation and communication

- reletive files: *./server/Skeleton.java ./server/SkeletonReqHandler.java ./server/StubInvocationHandler.java ./server/UnicastRemoteObject.java ./server/Util.java*
- (1) *./server/Skeleton.java* is in the server-side, it is a *Thread* class and contains a *ThreadPool* to accept new connection in the client-side. Core codes:

```
            InetAddress bindAddr = InetAddress.getByName(getHost());
            ServerSocket server = new ServerSocket(getPort(), BACKLOG, bindAddr);
            setPort(server.getLocalPort());
            while (true) {
                Socket client = server.accept();
                threadPool.submit(new SkeletonReqHandler(client, getRemoteObj(),
getObjectKey()));
            }
```

- (2) *./server/SkeletonReqHandler.java* is a *Thread* class handle remote call from one client, called by *Skeleton* shows as above codes. Core codes:

```
        ReturnMsg returnMsg = new ReturnMsg();
        returnMsg.setObjectKey(this.objectKey);
        // receive from stub
        try {
            ObjectInputStream in = new ObjectInputStream(socket.getInputStream());
            InvocationMsg invocationMsg = (InvocationMsg) in.readObject();
            objectKey = invocationMsg.getObjectKey();
            methodName = invocationMsg.getMethodName();
            argTypes = invocationMsg.getParameterTypes();
            args = invocationMsg.getArgs();
            Method method = obj.getClass().getDeclaredMethod(methodName, argTypes);
            if (this.objectKey != objectKey) returnMsg.setStatus(-1);  // invocation
error
            else {
                result = method.invoke(obj, args);
                returnMsg.setResult(result);
                if (result == null) returnMsg.setStatus(1);  // void method
                else returnMsg.setStatus(2);  // non-void method
            }
        } catch (...) {...}
        // send to stub
        try (ObjectOutputStream out = new
ObjectOutputStream(socket.getOutputStream())) {
            out.writeObject(returnMsg);
            out.flush();
        } catch (...) {...}
```

- (3) *./server/StubInvocationHandler.java* is similar to *SkeletonReqHandler* but in the client side. Core codes is similar, not show.
- (4) *./server/UnicastRemoteObject.java* has a static method to *export object*, it will create a skeleton for each object in the server-side and wait to registry to bind which could be acquired by clients. Core codes:

```
        int objectKey = obj.hashCode();
        Skeleton skeleton = new Skeleton(obj, host, port, objectKey);
        skeleton.start();
          ...
        String interfaceName = "Remote";
        if (obj.getClass().getInterfaces().length > 0) interfaceName =
obj.getClass().getInterfaces()[0].getName();
        int remotePort = skeleton.getPort();
        RemoteObjectRef ref = new RemoteObjectRef(host, remotePort, objectKey,
interfaceName);
        return Util.createStub(ref);
```

- (5) *./server/Util.java* contains util methods. not shows specific codes.

1.4 Registry

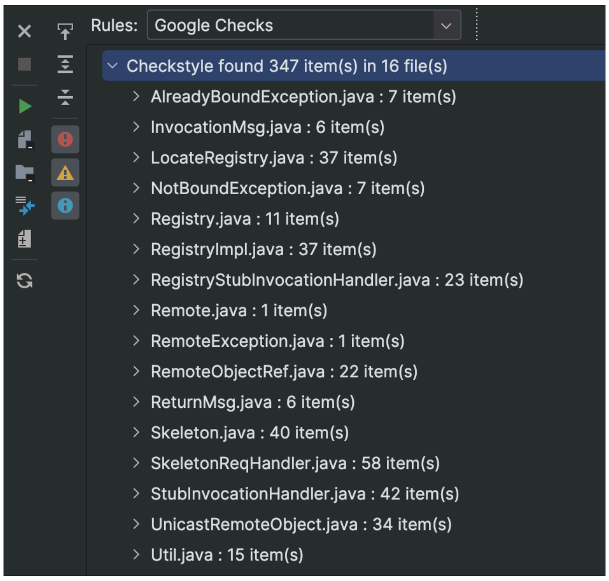
- Relitive files: *./registry/LocateRegistry.java ./registry/Registry.java ./registry/RegistryImpl.java ./registry/RegistryStubInvocationHandler.java*

The goal of *registry* is to let clients to find remote object and call method. These files almost finished by original codes, so core codes will not be shown.

1.5 Quality of code (comments, naming, etc.)

- General **comments** are contained in the files, such as *// send to stub* and *// recieve from stub*
- All the **names** of variables are named by their usage
- Using *CheckStyle* plugin in the *IDEA IntelliJ*

  items changed from 500+ to 347, still has some indentation error (google ask 2 spaces, not 4 spaces in the *IDEA IntelliJ*)

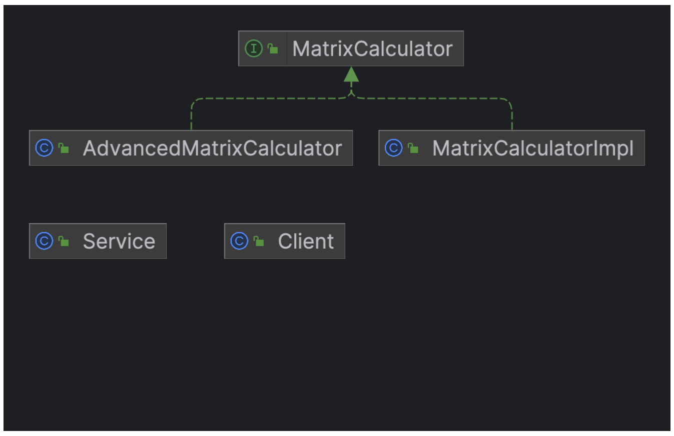


```
Rules: Google Checks
Checkstyle found 347 item(s) in 16 file(s)
  AlreadyBoundException.java : 7 item(s)
  InvocationMsg.java : 6 item(s)
  LocateRegistry.java : 37 item(s)
  NotBoundException.java : 7 item(s)
  Registry.java : 11 item(s)
  RegistryImpl.java : 37 item(s)
  RegistryStubInvocationHandler.java : 23 item(s)
  Remote.java : 1 item(s)
  RemoteException.java : 1 item(s)
  RemoteObjectRef.java : 22 item(s)
  ReturnMsg.java : 6 item(s)
  Skeleton.java : 40 item(s)
  SkeletonReqHandler.java : 58 item(s)
  StubInvocationHandler.java : 42 item(s)
  UnicastRemoteObject.java : 34 item(s)
  Util.java : 15 item(s)
```

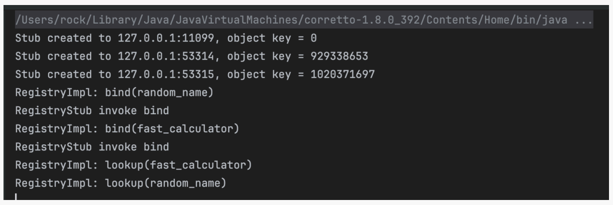
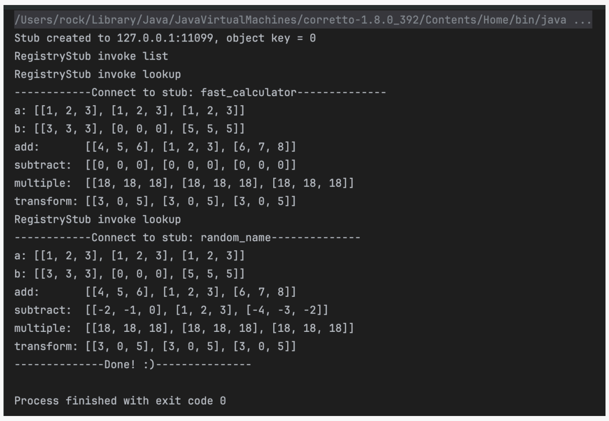
- Manage codes by GitHub: https://github.com/Rock3Yu/CS328_DistributedSys private for now

2 Tests

- Tests of your design (with screenshots): use simple client and server codes to show how to use your framework and the execution results.
- Relitive files: *./test/AdvancedMatrixCalculator.java ./test/Client.java ./test/MatrixCalculator.java ./test/MatrixCalculatorImpl.java ./test/Service.java*



- **Service** creates two instances (*AdvancedMatrixCalculator* and *MatrixCalculatorImpl*) and unicast by the registry.
- **Client** looks up the remote objects from registry and calls methods.
- Running screenshot:

Service Side:	Client Side:
	

Service Side:

```
/Users/rock/Library/Java/JavaVirtualMachines/corretto-1.8.0_392/Contents/Home/bin/java ...
Stub created to 127.0.0.1:11099, object key = 0
Stub created to 127.0.0.1:53314, object key = 929338653
Stub created to 127.0.0.1:53315, object key = 1020371697
RegistryImpl: bind(random_name)
RegistryStub invoke bind
RegistryImpl: bind(fast_calculator)
RegistryStub invoke bind
RegistryImpl: lookup(fast_calculator)
RegistryImpl: lookup(random_name)
```

Client Side:

```
/Users/rock/Library/Java/JavaVirtualMachines/corretto-1.8.0_392/Contents/Home/bin/java ...
Stub created to 127.0.0.1:11099, object key = 0
RegistryStub invoke list
RegistryStub invoke lookup
------------Connect to stub: fast_calculator--------------
a: [[1, 2, 3], [1, 2, 3], [1, 2, 3]]
b: [[3, 3, 3], [0, 0, 0], [5, 5, 5]]
add:       [[4, 5, 6], [1, 2, 3], [6, 7, 8]]
subtract:  [[0, 0, 0], [0, 0, 0], [0, 0, 0]]
multiple:  [[18, 18, 18], [18, 18, 18], [18, 18, 18]]
transform: [[3, 0, 5], [3, 0, 5], [3, 0, 5]]
RegistryStub invoke lookup
------------Connect to stub: random_name--------------
a: [[1, 2, 3], [1, 2, 3], [1, 2, 3]]
b: [[3, 3, 3], [0, 0, 0], [5, 5, 5]]
add:       [[4, 5, 6], [1, 2, 3], [6, 7, 8]]
subtract:  [[-2, -1, 0], [1, 2, 3], [-4, -3, -2]]
multiple:  [[18, 18, 18], [18, 18, 18], [18, 18, 18]]
transform: [[3, 0, 5], [3, 0, 5], [3, 0, 5]]
--------------Done! :)---------------

Process finished with exit code 0
```

3 Difficulties and solutions

- Java socket programming is a little bit difficult to me, because I enrolled in Computer Network Course 1 year ago

  Sol: I review some slides and use chatgpt to correct the usage of Socket and ServerSocket
- The overall structure of RMI implement is confusing.

  Sol: I read the documentation of Java RMI, althought the implement of java is different to our codes. And I also find a great website which introduce some basic concepts of Distributed System (https://www.geeksforgeeks.org/distributed-systems-tutorial/?ref=lbp)

4 Acknowledged

Thanks for the help from TA Nan and wish you have a nice day.