Java ClassLoader

MAY 15, 2018 BY PANKAJ — 11 COMMENTS

Java ClassLoader is one of the crucial but rarely used components of Java in Project Development. Personally I have never extended ClassLoader in any of my projects but the idea of having my own ClassLoader that can customize the Java Class Loading thrills me.

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Java ClassLoader

This article will provide an overview of Java ClassLoader and then move forward to create a custom ClassLoader in Java.

What is Java ClassLoader?

We know that Java Program runs on Java Virtual Machine (JVM). When we compile a Java Class, it transforms it in the form of bytecode that is platform and machine independent compiled program and store it as a .class file. After that when we try to use a Class, Java ClassLoader loads that class into memory.

There are three types of built-in ClassLoader in Java:

1. **Bootstrap Class Loader** – It loads JDK internal classes, typically loads rt.jar and other core classes for example java.lang.* package classes
2. **Extensions Class Loader** – It loads classes from the JDK extensions directory, usually $JAVA_HOME/lib/ext directory.
3. **System Class Loader** – It loads classes from the current classpath that can be set while invoking a program using -cp or -classpath command line options.

Java ClassLoader are hierarchical and whenever a request is raised to load a class, it delegates it to its parent and in this way uniqueness is maintained in the runtime environment. If the parent class loader doesn't find the class then the class loader itself tries to load the class.

Lets understand this by executing the below java program:

ClassLoaderTest.java

```
package com.journaldev.classloader;

public class ClassLoaderTest {

	public static void main(String[] args) {

		System.out.println("class loader for HashMap: "
				+ java.util.HashMap.class.getClassLoader());
		System.out.println("class loader for DNSNameService: "
				+ sun.net.spi.nameservice.dns.DNSNameService.class
						.getClassLoader());
		System.out.println("class loader for this class: "
				+ ClassLoaderTest.class.getClassLoader());
```

```
                System.out.println(com.mysql.jdbc.Blob.class.getClassLoader());

        }

}
```

Output of the above java classloader example program is:

```
class loader for HashMap: null
class loader for DNSNameService: sun.misc.Launcher$ExtClassLoader@7c354093
class loader for this class: sun.misc.Launcher$AppClassLoader@64cbbe37
sun.misc.Launcher$AppClassLoader@64cbbe37
```

As you can see that java.util.HashMap ClassLoader is coming as null that reflects Bootstrap ClassLoader whereas DNSNameService ClassLoader is ExtClassLoader. Since the class itself is in CLASSPATH, System ClassLoader loads it.

When we are trying to load HashMap, our System ClassLoader delegates it to the Extension ClassLoader, which in turns delegates it to Bootstrap ClassLoader that found the class and load it in JVM.

The same process is followed for DNSNameService class but Bootstrap ClassLoader is not able to locate it since its in $JAVA_HOME/lib/ext/dnsns.jar and hence gets loaded by Extensions Class Loader. Note that Blob class is included in the MySql JDBC Connector jar (mysql-connector-java-5.0.7-bin.jar) that I have included in the build path of the project before executing it and its also getting loaded by System Class Loader.

One more important point to note is that Classes loaded by a child class loader have visibility into classes loaded by its parent class loaders. So classes loaded by System ClassLoader have visibility into classes loaded by Extensions and Bootstrap ClassLoader.

If there are sibling class loaders then they can't access classes loaded by each other.

Why write a Custom ClassLoader in Java?

Java default ClassLoader can load files from local file system that is good enough for most of the cases. But if you are expecting a class at the runtime or from FTP server or via third party web service at the time of loading the class then you have to extend the existing class loader. For example, AppletViewers load the classes from remote web server.

How does Java ClassLoader Work?

When JVM requests for a class, it invokes `loadClass` function of the ClassLoader by passing the fully classified name of the Class.

loadClass function calls for `findLoadedClass()` method to check that the class has been already loaded or not. It's required to avoid loading the class multiple times.

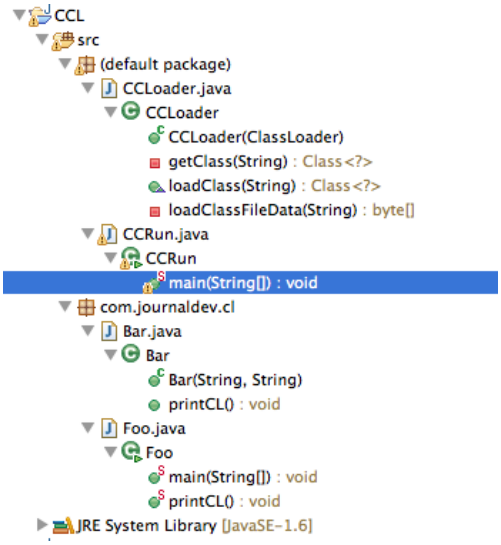
If the Class is not already loaded then it will delegate the request to parent ClassLoader to load the class.

If the parent ClassLoader is not finding the Class then it will invoke findClass() method to look for the classes in the file system.

Java Custom ClassLoader

We will create our own ClassLoader by extending ClassLoader class and overriding loadClass(String name) method. If the name will start from com.journaldev i.e our sample classes package then we will load it using our own class loader or else we will invoke the parent ClassLoader loadClass() method to load the class.

The project structure will be like the below image:



CCLoader.java: This is our custom class loader with below methods.

1. `private byte[] loadClassFileData(String name)`:
   This method will read the class file from file system to byte array.

2. `private Class<?> getClass(String name)`
   This method will call the loadClassFileData() function and by invoking the parent defineClass() method, it will generate the Class and return it.

3. `public Class<?> loadClass(String name)`:
   This method is responsible for loading the Class. If the class name starts with com.journaldev (Our sample classes) then it will load it using getClass() method or else it will invoke the parent loadClass function to load it.

4. `public CCLoader(ClassLoader parent)`:
   This is the constructor which is responsible for setting the parent ClassLoader.

`CCLoader.java`

```
import java.io.DataInputStream;
import java.io.File;
import java.io.IOException;
import java.io.InputStream;

/**
```

```
 * Our Custom Class Loader to load the classes. Any class in the com.journaldev
 * package will be loaded using this ClassLoader. For other classes, it will
 * delegate the request to its Parent ClassLoader.
 *
 */
public class CCLoader extends ClassLoader {

    /**
     * This constructor is used to set the parent ClassLoader
     */
    public CCLoader(ClassLoader parent) {
        super(parent);
    }

    /**
```

CCRun.java:

This is our test class with main function where we are creating object of our ClassLoader and load sample classes using its loadClass method. After loading the Class, we are using Java Reflection API to invoke its methods.

CCRun.java

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

public class CCRun {

    public static void main(String args[]) throws Exception {
        String progClass = args[0];
        String progArgs[] = new String[args.length - 1];
        System.arraycopy(args, 1, progArgs, 0, progArgs.length);

        CCLoader ccl = new CCLoader(CCRun.class.getClassLoader());
        Class clas = ccl.loadClass(progClass);
        Class mainArgType[] = { (new String[0]).getClass() };
        Method main = clas.getMethod("main", mainArgType);
        Object argsArray[] = { progArgs };
        main.invoke(null, argsArray);

        // Below method is used to check that the Foo is getting loaded
        // by our custom class loader i.e CCLoader
        Method printCL = clas.getMethod("printCL", null);
        printCL.invoke(null, new Object[0]);
    }
```

Foo.java and Bar.java:

These are our test classes that is getting loaded by our custom classloader. They also have a printCL() method that is getting invoked to print the ClassLoader that has loaded the Class. Foo class will be loaded

by our custom class loader which in turn uses Bar class, so Bar class will also be loaded by our custom class loader.

Foo.java

```
package com.journaldev.cl;

public class Foo {
    static public void main(String args[]) throws Exception {
        System.out.println("Foo Constructor >>> " + args[0] + " " + args[1]);
        Bar bar = new Bar(args[0], args[1]);
        bar.printCL();
    }

    public static void printCL() {
        System.out.println("Foo ClassLoader: "+Foo.class.getClassLoader());
    }
}
```

Bar.java

```
package com.journaldev.cl;

public class Bar {

    public Bar(String a, String b) {
        System.out.println("Bar Constructor >>> " + a + " " + b);
    }

    public void printCL() {
        System.out.println("Bar ClassLoader: "+Bar.class.getClassLoader());
    }
}
```

Java Custom ClassLoader Execution Steps

First of all we will compile all the classes through command line. After that we will run CCRun class by passing three arguments. The first argument is the fully classified name for Foo class that will get loaded by our class loader. Other two arguments are passed along to the Foo class main function and Bar constructor. The execution steps with output will be like below.

```
Pankaj$ javac -cp . com/journaldev/cl/Foo.java
Pankaj$ javac -cp . com/journaldev/cl/Bar.java
Pankaj$ javac CCLoader.java
Pankaj$ javac CCRun.java
CCRun.java:18: warning: non-varargs call of varargs method with inexact argument type
for last parameter;
cast to java.lang.Class<?> for a varargs call
cast to java.lang.Class<?>[] for a non-varargs call and to suppress this warning
```

```
Method printCL = clas.getMethod("printCL", null);
^
1 warning
Pankaj$ java CCRun com.journaldev.cl.Foo 1212 1313
Loading Class 'com.journaldev.cl.Foo'
Loading Class using CCLoader
Loading Class 'java.lang.Object'
Loading Class 'java.lang.String'
Loading Class 'java.lang.Exception'
Loading Class 'java.lang.System'
Loading Class 'java.lang.StringBuilder'
Loading Class 'java.io.PrintStream'
Foo Constructor >>> 1212 1313
```

If you look into the output carefully, first its trying to load com.journaldev.cl.Foo class but since its extending java.lang.Object class, its trying to load it first and the request it coming to CCLoader loadClass method that is delegating it to the parent class. So the parent class loaders are loading the Object, String and other java classes. Our ClassLoader is only loading Foo and Bar class from the file system that is getting clear when we invoke their printCL() function.

Note that we can change the loadClassFileData() functionality to read the byte array from FTP Server or by invoking any third party service to get the class byte array on the fly.

I hope that the article will be useful in understanding Java ClassLoader working and how we can extend it to do a lot more that just taking it from file system.

Updated from comment by m29

We can make our custom class loader as the default one when JVM starts by using Java Options.
For example, I will run the ClassLoaderTest program once again after providing java class loader option.

```
Pankaj$ javac -cp .:../lib/mysql-connector-java-5.0.7-bin.jar
com/journaldev/classloader/ClassLoaderTest.java
Pankaj$ java -cp .:../lib/mysql-connector-java-5.0.7-bin.jar -
Djava.system.class.loader=CCLoader com.journaldev.classloader.ClassLoaderTest
Loading Class 'com.journaldev.classloader.ClassLoaderTest'
Loading Class using CCLoader
Loading Class 'java.lang.Object'
Loading Class 'java.lang.String'
Loading Class 'java.lang.System'
Loading Class 'java.lang.StringBuilder'
Loading Class 'java.util.HashMap'
Loading Class 'java.lang.Class'
Loading Class 'java.io.PrintStream'
class loader for HashMap: null
Loading Class 'sun.net.spi.nameservice.dns.DNSNameService'
class loader for DNSNameService: sun.misc.Launcher$ExtClassLoader@24480457
class loader for this class: CCLoader@38503429
Loading Class 'com.mysql.jdbc.Blob'
sun.misc.Launcher$AppClassLoader@2f94ca6c
Pankaj$
```

As you can see that CCLoader is loading the ClassLoaderTest class because its in com.journaldev package.

Mac OS X 10.6.4 Issue with ClassLoader Java Options

If you are working on Mac OS the above execution can throw some exceptions but it will execute successfully.

```
Pankaj$$ java -cp .:../lib/mysql-connector-java-5.0.7-bin.jar -
Djava.system.class.loader=CCLoader com.journaldev.classloader.ClassLoaderTest
Intentionally suppressing recursive invocation exception!
java.lang.IllegalStateException: recursive invocation
    at java.lang.ClassLoader.initSystemClassLoader(ClassLoader.java:1391)
    at java.lang.ClassLoader.getSystemClassLoader(ClassLoader.java:1374)
    at sun.security.jca.ProviderConfig$1.run(ProviderConfig.java:64)
    at java.security.AccessController.doPrivileged(Native Method)
    at sun.security.jca.ProviderConfig.getLock(ProviderConfig.java:62)
    at sun.security.jca.ProviderConfig.getProvider(ProviderConfig.java:187)
    at sun.security.jca.ProviderList.getProvider(ProviderList.java:215)
    at sun.security.jca.ProviderList.getService(ProviderList.java:313)
    at sun.security.jca.GetInstance.getInstance(GetInstance.java:140)
    at java.security.cert.CertificateFactory.getInstance(CertificateFactory.java:148)
    at sun.security.pkcs.PKCS7.parseSignedData(PKCS7.java:244)
    at sun.security.pkcs.PKCS7.parse(PKCS7.java:141)
    at sun.security.pkcs.PKCS7.parse(PKCS7.java:110)
    at sun.security.pkcs.PKCS7.<init>(PKCS7.java:92)
    at sun.security.util.SignatureFileVerifier.<init>(SignatureFileVerifier.java:80)
    at java.util.jar.JarVerifier.processEntry(JarVerifier.java:256)
    at java.util.jar.JarVerifier.update(JarVerifier.java:188)
    at java.util.jar.JarFile.initializeVerifier(JarFile.java:321)
```

That's all for Java ClassLoader and java custom class loader example.

> You can download the ClassLoader example code from our GitHub Repository.

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Recently I started creating video tutorials too, so do check out my videos on **Youtube**.

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Comments

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MAY 20, 2018 AT 8:14 AM
Thank you for article. It was very useful for me in understanding Java class loading.
Reply

Ashok says
APRIL 23, 2018 AT 1:12 PM
Good article
Reply

Binh Thanh Nguyen says
AUGUST 18, 2017 AT 8:12 AM
Thanks, nice post
Reply

tarun says
AUGUST 3, 2017 AT 4:09 AM
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How do i do that ??
Best Regards
Tarun Kumar
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Nilesh says
JANUARY 3, 2017 AT 11:28 PM
Good article

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SEPTEMBER 14, 2015 AT 11:18 AM
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Zulma says
JULY 27, 2013 AT 5:06 AM
I blog frequently and I seriously appreciate your content.
Your article has truly peaked my interest. I am going to book mark your
site and keep checking for new information about once a week.
I opted in for your Feed as well.
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unknown says
APRIL 24, 2013 AT 4:56 PM
Hey Pankaj,
Thanks for sharing your Java experience in such a way which is easy to understand but I would like to see some interview questions & answers about more Java technologies like JSP, Servlet, Struts, XML, Web Services, Spring, Hibernate etc. because at the end our goal of learning Java is to crack an interview.
Reply

Filip says
OCTOBER 2, 2017 AT 3:22 AM
bulls***t – if you want to learn the answer to every Java interview question, without understanding the language mechanics, than you are pretty much wasting your time.
Assuming you "crack" the job interview and they hire you. What now? You know the answers of the interview questions but you can not implement a single line of code. This will be a short career I guess.
Reply

prasanth says
MARCH 28, 2011 AT 8:11 AM
very nice article pankaj.
Reply

m29 says

MARCH 23, 2011 AT 11:02 PM

System Class Loader – It loads classes from the current classpath that can be set while invoking a program using -cp or -classpath command line options.

The system classloader can also be redefined by setting the system property `java.system.class.loader`. See ClassLoader#getSystemClassLoader.

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