

Arthas&Instrumentation初步学习

Arthas

alibaba/**arthas**

Alibaba Java Diagnostic Tool Arthas/Alibaba Java诊断利器Arthas

182

Contributors

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Used by

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Discussions

33k

Stars

7k

Forks





<https://github.com/alibaba/arthas>
GitHub - alibaba/arthas: Alibaba Java Diagnostic Tool Arthas/Alibaba Java诊断利器Arthas
Alibaba Java Diagnostic Tool Arthas/Alibaba Java诊断利器Arthas - GitHub - ...

Arthas 是Alibaba开源的Java诊断工具，用于在线解决生产问题，无需 JVM 重启，功能非常全面，包含性能监控、堆栈追踪、反编译、热更新等功能，具体可参考官方文档：

<https://arthas.aliyun.com/doc/>

Arthas支持的命令和功能如下：

```

[arthas@4076]$ help
NAME      DESCRIPTION
help      Display Arthas Help
auth      Authenticates the current session
keymap    Display all the available keymap for the specified connection.
sc        Search all the classes loaded by JVM
sm        Search the method of classes loaded by JVM
classloader Show classloader info
jad       Decompile class
getstatic Show the static field of a class
monitor   Monitor method execution statistics, e.g. total/success/failure count, average rt, fail rate, etc.

stack     Display the stack trace for the specified class and method
thread    Display thread info, thread stack
trace     Trace the execution time of specified method invocation.
watch     Display the input/output parameter, return object, and thrown exception of specified method invocation

tt        Time Tunnel
jvm       Display the target JVM information
memory    Display jvm memory info.
perfcounter Display the perf counter information.
ognl      Execute ognl expression.
mc        Memory compiler, compiles java files into bytecode and class files in memory.

redefine  Redefine classes. @see Instrumentation#redefineClasses(ClassDefinition...)
retransform Retransform classes. @see Instrumentation#retransformClasses(Class...)

dashboard Overview of target jvm's thread, memory, gc, vm, tomcat info.
dump      Dump class byte array from JVM
heapdump  Heap dump
options   View and change various Arthas options
cls       Clear the screen
reset     Reset all the enhanced classes
version   Display Arthas version
session   Display current session information
sysprop   Display and change the system properties.
sysenv    Display the system env.
vmoption  Display, and update the vm diagnostic options.
logger    Print logger info, and update the logger level
history   Display command history
cat       Concatenate and print files
base64    Encode and decode using Base64 representation
echo      write arguments to the standard output
pwd       Return working directory name
mbean     Display the mbean information
grep      grep command for pipes.
tee       tee command for pipes.
profiler  Async Profiler. https://github.com/jvm-profiling-tools/async-profiler
vmtool    jvm tool
stop      Stop/Shutdown Arthas server and exit the console.

```

其中功能非常丰富，这里简单介绍几个我认为比较有意思的功能。

dashboard & thread & memory

dashboard显示当前实时数据面板，包含thread、memory、gc、runtime等信息

```
[arthas@4076]$ dashboard
ID NAME GROUP PRIORI STATE %CPU DELTA TIME INTER DAEMON
-1 VM Periodic Task Th - -1 - 0.0 0.000 0:0.52 false true
-1 C1 CompilerThread3 - -1 - 0.0 0.000 0:0.39 false true
1 main main 5 TIMED_ 0.0 0.000 0:0.30 false false
22 arthas-NettyHttpTel system 5 RUNNAB 0.0 0.000 0:0.13 false true
-1 C2 CompilerThread2 - -1 - 0.0 0.000 0:0.12 false true
-1 C2 CompilerThread1 - -1 - 0.0 0.000 0:0.12 false true
-1 C2 CompilerThread0 - -1 - 0.0 0.000 0:0.11 false true
-1 VM Thread - -1 - 0.0 0.000 0:0.04 false true
23 arthas-command-exec system 5 TIMED_ 0.0 0.000 0:0.03 false true
-1 GC task thread#8 (P - -1 - 0.0 0.000 0:0.01 false true

Memory used total max usage GC
heap 37M 304M 0.53% 1
ps_eden_space 11M 125M 0.45% gc.ps_scavenge.time 8
ps_survivor_spac 0K 20992 2099 0.00% (ms)
e K 2K gc.ps_marksweep.cou 1
ps_old_gen 26M 158M 0.49% nt
nonheap 28M 29M -1 gc.ps_marksweep.tim 21
code cache 4M 5M 240M 2.06% e(ms)

Runtime
os.name Linux
os.version 5.15.0-75-generic
java.version 1.8.0_371
```

thread显示查看当前线程信息和线程的堆栈，可以一键展示当前最忙的前 N 个线程并打印堆栈

```
[arthas@4076]$ thread 1
"main" Id=1 TIMED_WAITING
    at java.lang.Thread.sleep(Native Method)
    at java.lang.Thread.sleep(Thread.java:342)
    at java.util.concurrent.TimeUnit.sleep(TimeUnit.java:386)
    at demo.MathGame.main(MathGame.java:17)
```

vmoption & vmtool

vmoption可以查看更新VM 诊断相关的参数，比如开启PrintGCDetails等。

vmtool可以查询内存对象并执行express，强制 GC 、终止目标Thread等功能。

jad & mc & retransform

jad基于CFR可以反编译指定已加载类的源码，例如反编译官方给出的一个质因数分解的案例：

```
[arthas@4076]$ jad demo.MathGame
```

ClassLoader:

```
+--sun.misc.Launcher$AppClassLoader@70dea4e  
+-sun.misc.Launcher$ExtClassLoader@1b6d3586
```

Location:

```
/home/cyc/course/arthas/math-game.jar
```

```
/*  
 * Decompiled with CFR.  
 */  
package demo;  
  
import java.util.ArrayList;  
import java.util.List;  
import java.util.Random;  
import java.util.concurrent.TimeUnit;  
  
public class MathGame {  
    private static Random random = new Random();  
    private int illegalArgumentCount = 0;  
  
    public static void main(String[] args) throws InterruptedException {  
        MathGame game = new MathGame();  
        while (true) {  
/*16*/            game.run();  
/*17*/            TimeUnit.SECONDS.sleep(1L);  
        }  
    }  
  
    public void run() throws InterruptedException {  
        try {  
/*23*/            int number = random.nextInt() / 10000;  
/*24*/            List<Integer> primeFactors = this.primeFactors(number);  
/*25*/            MathGame.print(number, primeFactors);  
        }  
        catch (Exception e) {
```

mc可以编译.java文件生成.class

retransform加载外部的.class文件，retransform jvm 已加载的类，实现代码热更新,例如在此前的质因数分解中的代码中添加一行打印命令：

```

7
8 public class MathGame {
9     private static Random random = new Random();
10
11     private int illegalArgumentCount = 0;
12
13     public static void main(String[] args) throws InterruptedException {
14         MathGame game = new MathGame();
15         while (true) {
16             game.run();
17             TimeUnit.SECONDS.sleep(1);
18         }
19     }
20
21     public void run() throws InterruptedException {
22         System.out.println("test retransform");
23         try {
24             int number = random.nextInt()/10000;
25             List<Integer> primeFactors = primeFactors(number);
26             print(number, primeFactors);
27
28         } catch (Exception e) {
29             System.out.println(String.format("illegalArgumentCount:%3d, ", illegalArg
30         }
31     }

```

随后通过mc命令将该文件编译，使用retransform加载后，程序输出如下：

```

illegalArgumentCount:0
test retransform
132043=23*5741
test retransform
15048=2*2*2*3*3*11*19
test retransform
188478=2*3*3*37*283
test retransform

```

通过jad & mc & retransform三个命令结合可以实现线上应用的热更新。

trace

trace 命令能主动搜索 class-pattern/method-pattern 对应的方法调用路径，渲染和统计整个调用链路上的所有性能开销和追踪调用链路，并且支持调用耗时过滤，trace 次数限制等功能

```

demo.MathGame
[arthas@4076]$ trace demo.MathGame run
Press Q or Ctrl+C to abort.
Affect(class count: 1 , method count: 1) cost in 73 ms, listenerId: 1
---ts=2023-07-09 18:05:26;thread_name=main;id=1;is_daemon=false;priority=5;TCCL=sun.misc.Launcher$AppClassLoader@70dea4e
  ---[0.761335ms] demo.MathGame:run()
    ---[7.45% 0.056713ms ] demo.MathGame:primeFactors() #25 [throws Exception]

---ts=2023-07-09 18:05:27;thread_name=main;id=1;is_daemon=false;priority=5;TCCL=sun.misc.Launcher$AppClassLoader@70dea4e
  ---[0.294507ms] demo.MathGame:run()
    ---[21.88% 0.064436ms ] demo.MathGame:primeFactors() #25 [throws Exception]

---ts=2023-07-09 18:05:28;thread_name=main;id=1;is_daemon=false;priority=5;TCCL=sun.misc.Launcher$AppClassLoader@70dea4e
  ---[0.610847ms] demo.MathGame:run()
    +---[25.21% 0.154008ms ] demo.MathGame:primeFactors() #25
    ---[37.89% 0.231478ms ] demo.MathGame:print() #26

---ts=2023-07-09 18:05:29;thread_name=main;id=1;is_daemon=false;priority=5;TCCL=sun.misc.Launcher$AppClassLoader@70dea4e
  ---[0.2508ms] demo.MathGame:run()
    +---[9.49% 0.023795ms ] demo.MathGame:primeFactors() #25
    ---[15.39% 0.038602ms ] demo.MathGame:print() #26

```

watch & monitor

watch能方便的观察到指定函数的调用情况。能观察到的范围为：`返回值`、`抛出异常`、`入参`，通过编写 OGNL 表达式进行对应变量的查看。

```
[arthas@4076]$ watch demo.MathGame primeFactors -x 2
Press Q or Ctrl+C to abort.
Affect(class count: 1 , method count: 1) cost in 30 ms, listenerId: 2
method=demo.MathGame.primeFactors location=AtExceptionExit
ts=2023-07-09 18:13:36; [cost=0.449815ms] result=@ArrayList[
  @Object[][
    @Integer[-168045],
  ],
  @MathGame[
    random=@Random[java.util.Random@685f4c2e],
    illegalArgumentCount=@Integer[1155],
  ],
  null,
]
method=demo.MathGame.primeFactors location=AtExceptionExit
ts=2023-07-09 18:13:37; [cost=0.086097ms] result=@ArrayList[
  @Object[][
    @Integer[-163590],
  ],
  @MathGame[
    random=@Random[java.util.Random@685f4c2e],
    illegalArgumentCount=@Integer[1156],
  ],
  null,
]
method=demo.MathGame.primeFactors location=AtExceptionExit
ts=2023-07-09 18:13:38; [cost=0.08858ms] result=@ArrayList[
  @Object[][
```

monitor能够执行方法执行监控


```
[arthas@4076]$ monitor -c 5 demo.MathGame primeFactors
Press Q or Ctrl+C to abort.
Affect(class count: 1 , method count: 1) cost in 33 ms, listenerId: 3
```

timestamp	class	method	total	success	fail	avg-rt(ms)	fail-rate
2023-07-09 18:15:27	demo.MathGame	primeFactors	5	2	3	0.20	60.00%
2023-07-09 18:15:33	demo.MathGame	primeFactors	5	1	4	0.09	80.00%
2023-07-09 18:15:38	demo.MathGame	primeFactors	5	5	0	1.11	0.00%

除了以上介绍的命令外，还有tt（记录方法执行信息）、sc（查看JVM已加载的类信息）、profiler（集成async-profiler生成火焰图）等实用的功能。

Instrumentation

在上面的功能中，可以看到Arthas支持许多实用的分析功能，其中特别是热更新功能我认为很有意思。经过查阅资料，Arthas主要基于instrumentation api实现debug 和 profiler 能力。

那么什么是instrumentation呢？

The mechanism for instrumentation is modification of the byte-codes of methods.

instrumentation api位于java.lang.instrument包下。但我们运行Java程序时，程序会首先转换成字节码，然后使用类加载器将它们加载到JVM。使用 Instrumentation API，我们可以在运行时修改这些程序的字节码。

开发者可以基于Instrumentation API构建Agent，用来监测和协助运行在 JVM 上的程序，可以理解成 Instrumentation API提供了一种虚拟机级别的 AOP方式，使得开发者无需对原有应用做任何修改，就可以实现类的动态修改和增强。

有两种方式可以

为了能够使用instrumentation，我们必须首先加载我们的程序。

有两种方式可以加载：

- **static**–启动时使用 `-javaagent` 选项运行，实现 `premain` 函数
- **dynamic**–将代理jar包attach到目标JVM中，实现 `agentmain` 函数

这里简单介绍一个例子,目标程序不断打印字符串,我们目的是修改该输出方法,添加一些其他的打印信息。代码可以查看<https://github.com/icyclv/InstrumentationDemo>

SimpleApp.java

```
1 public class SimpleApp {
2     public static void main(String[] args) throws InterruptedException {
3         while (true){
4             doSomething();
5             Thread.sleep(1000);
6         }
7     }
8
9     public static void doSomething(){
10        System.out.println("Doing something");
11    }
12 }
```

为了实现两种方式,我们分别实现agentmain和premain函数

MyAgent.java

```
1 public class MyAgent {
2     public static void agentmain(String agentArgs, Instrumentation inst) throws
3         System.out.println("[Agent] In agentmain method");
4         inst.addTransformer(new MyTransformer(), true);
5         Class[] allLoadedClasses = inst.getAllLoadedClasses();
6         for (Class allLoadedClass : allLoadedClasses) {
7             if (allLoadedClass.getSimpleName().equals("SimpleApp")) {
8                 inst.retransformClasses(allLoadedClass);
9                 break;
10            }
11        }
12
13    }
14
15    public static void premain(String args, Instrumentation instr) {
16        System.out.println("[Agent] In premain method");
17        instr.addTransformer(new MyTransformer());
18    }
19 }
```

同时实现自定一个Transformer类,该类实现ClassFileTransformer 接口并实现transform方法,在这个类中,我们将使用javaassist读取类的字节数组,并在其上添加我们自己的功能,从而修改程序的字

节码。

MyTransformer.java

```
1 public class MyTransformer implements ClassFileTransformer {
2
3     public byte[] transform(ClassLoader loader, String className, Class clas
4         ProtectionDomain protectionDomain, byte[] classfileBuffer,
5         byte[] bytecode = classfileBuffer;
6
7         //Add instrumentation to Sample class alone
8         if (className.equals("com/cyc/InstrumentationDemo/SimpleApp")) {
9             try {
10                 ClassPool classPool = ClassPool.getDefault();
11                 CtClass ctClass = classPool.makeClass(new ByteAr
12                 CtMethod[] methods = ctClass.getDeclaredMethods(
13                 for (CtMethod method : methods) {
14                     method.insertBefore("System.out.println(
15                     method.insertAfter("System.out.println(\\
16                 }
17                 bytecode = ctClass.toBytecode();
18                 ctClass.detach();
19             } catch (Throwable ex) {
20                 System.out.println("Exception: " + ex);
21                 ex.printStackTrace();
22             }
23         }
24         return bytecode;
25     }
26 }
```

需要注意，agent程序打包时需要表明premain类等相关信息：

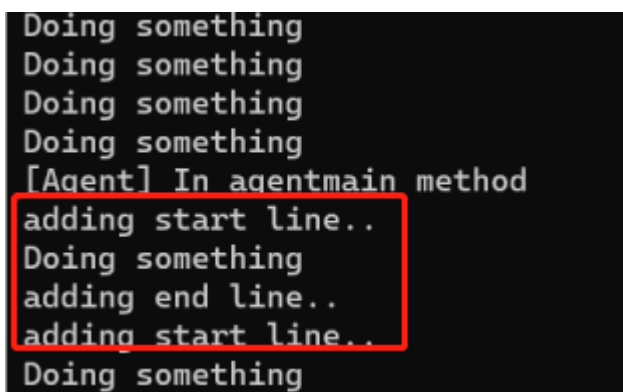
```
1 <archive>
2   <manifest>
3     <addDefaultImplementationEntries>
4       true</addDefaultImplementationEntries>
5     <addDefaultSpecificationEntries>
6       true</addDefaultSpecificationEntries>
7   </manifest>
8   <manifestEntries>
9     <Agent-Class>com.cyc.instrumentationDemo.agent.MyAgent</Agent-Class>
10    <Premain-Class>com.cyc.instrumentationDemo.agent.MyAgent</Premain-Class>
11    <Can-Redefine-Classes>true</Can-Redefine-Classes>
12    <Can-Retransform-Classes>true</Can-Retransform-Classes>
```

```
13     </manifestEntries>
14 </archive>
```

通过以上打包方式，我们可以直接通过在程序启动时指定javaagent的路径实现函数修改。而如果需要要在程序启动后动态修改，则需要将attach到目标jvm上：

```
1 public class MyAttachMain {
2     public static void main(String[] args) throws IOException, AttachNotSupportedException {
3         System.out.printf("Attaching to VM with id: %s\n", args[0]);
4         VirtualMachine vm = VirtualMachine.attach(args[0]);
5         try {
6             vm.loadAgent(args[1]);
7             System.out.println("Finished loading Agent");
8         } catch (Exception e) {
9             e.printStackTrace();
10        } finally {
11            vm.detach();
12        }
13    }
14 }
```

从而实现方法的增强，效果如下：



```
Doing something
Doing something
Doing something
Doing something
[Agent] In agentmain method
adding start line..
Doing something
adding end line..
adding start line..
Doing something
```

以上代码可以查看<https://github.com/icyclv/InstrumentationDemo>

参考

1.Arthas文档：<https://arthas.aliyun.com/doc/>

2.Java Instrumentation — A Simple Working Example in Java

<https://medium.com/javarevisited/java-instrumentation-a-simple-working-example-in-java-a2c549024d9c>

3.Guide to Java Instrumentation <https://www.baeldung.com/java-instrumentation>

