Java性能优化与实践

1. 目标与思路

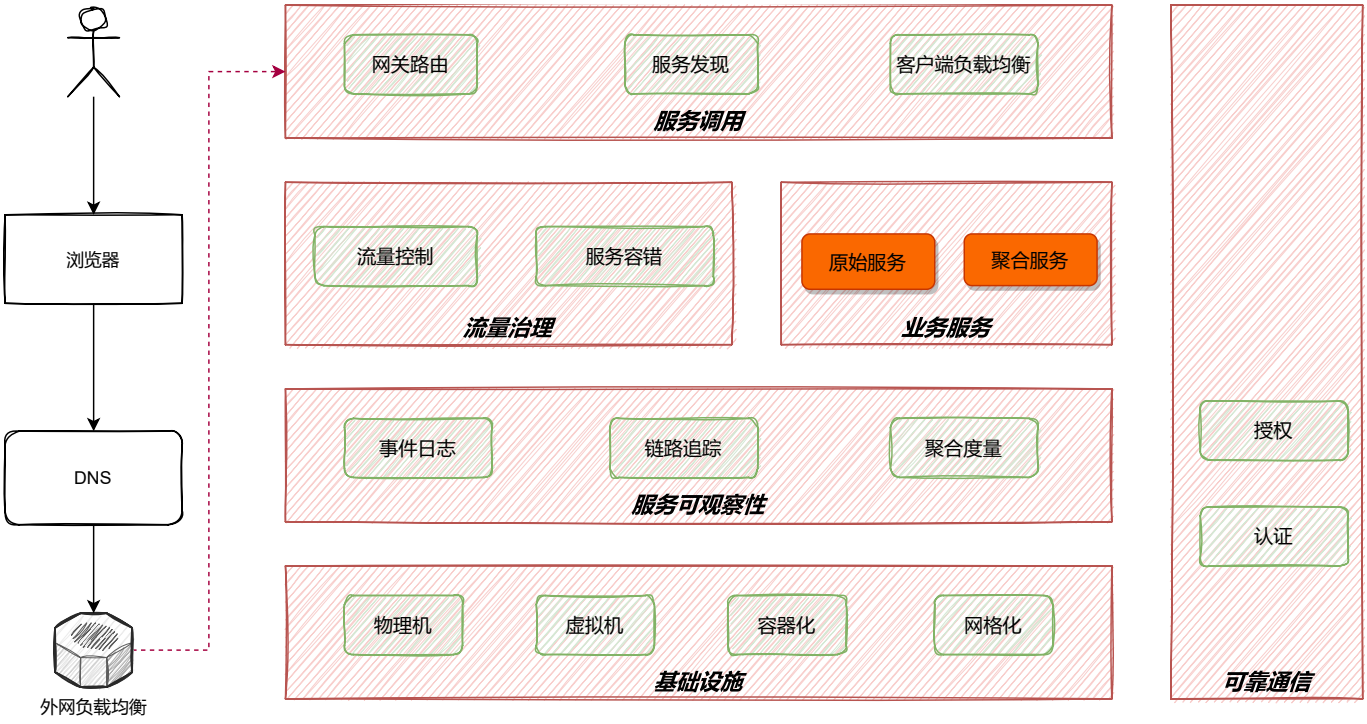
1.1. 运行架构背景

所谓运行架构是指一个系统运作逻辑，以及背后的原理，其关注的是系统的某个局部，或者瞬间。比如：

- 服务注册与发现具体是如何运作?
- 流量控制与服务熔断链路跟踪是如何运作的?
- 一个带索引条件的mysql具体是如何执行的?
- Java程序OOM是具体如何发生的?

> 面对这些问题，从系统运行的角度出发，需要一层一层的剥开、揉碎，要从算法，内存、协议，定理等低层次的原理进行解释。那么作为T4晋升到T5的架构师为什么要了解这些呢

- 首先，如果不解一些系统运行背后的底层原理，面对复杂或者一些疑难杂症我们将无从下手，失去判断能力；比如：运营商门户升级项目，宁夏云平台性能测试问题；
- 其次，作为一个技术人，面对当前浩如烟海的技术，框架，，要构建自己的技术知识体系，那具体要如何构建呢？根据我们个人的经验，一个比较有效的方法就是，对一个问题或技术要深究其原理，当我们深入研究的问题多了。



1.2. 为什么要讲JVM相关的内容?

Java程序员技术体系

我们看到市面上新技术、新概念层出不穷，每隔一段时间就会有一个新技术腾空出世替代老技术，这个是我们必须接受的可观规律，王朝更迭,江山易主,世事山河都会变迁，技术与经济、历史一样具有周期性，只是这个周期在软件行业更迭的太快，在程序员的职业生涯里面，大部分的技术可能要迭代更新很多论，"一招鲜，吃遍天"在软件行业可能不灵验，有追求的程序员需要时刻保持着一颗谦卑的心，不断的迎接变化、持续学习，从而让自己超越技术周期；

那有人可能会说，这样会很累，对于这个问题我要看**怎么定义这个累**,每个人的追求与活法都不一样，累与不累，哪些事情你觉得累，哪些事情你觉得开心、快乐，都是我们自己内心的选择。所以，我们觉得累也是非常正常的，如果觉得学习很累，那我们可以选择在生活上累一点，如果我们觉得学习、生活上我都不想那么累，并且我都可以做到不累，那，我真的要恭喜你，那你真的是**跳出三界外不在五行中**,你可以洒脱、不受世俗干扰、大彻大悟了。

如果我们下定决心要学习，那具体应该如何学呢？一个最有效的方法就是：**构建自己的技术知识体系**，有一个概念叫**知识负荷**，说的就是

本次的分享主要基于一个案例来了解java，内存模型，垃圾回收，线程池等几个基础问题；

2. 环境说明

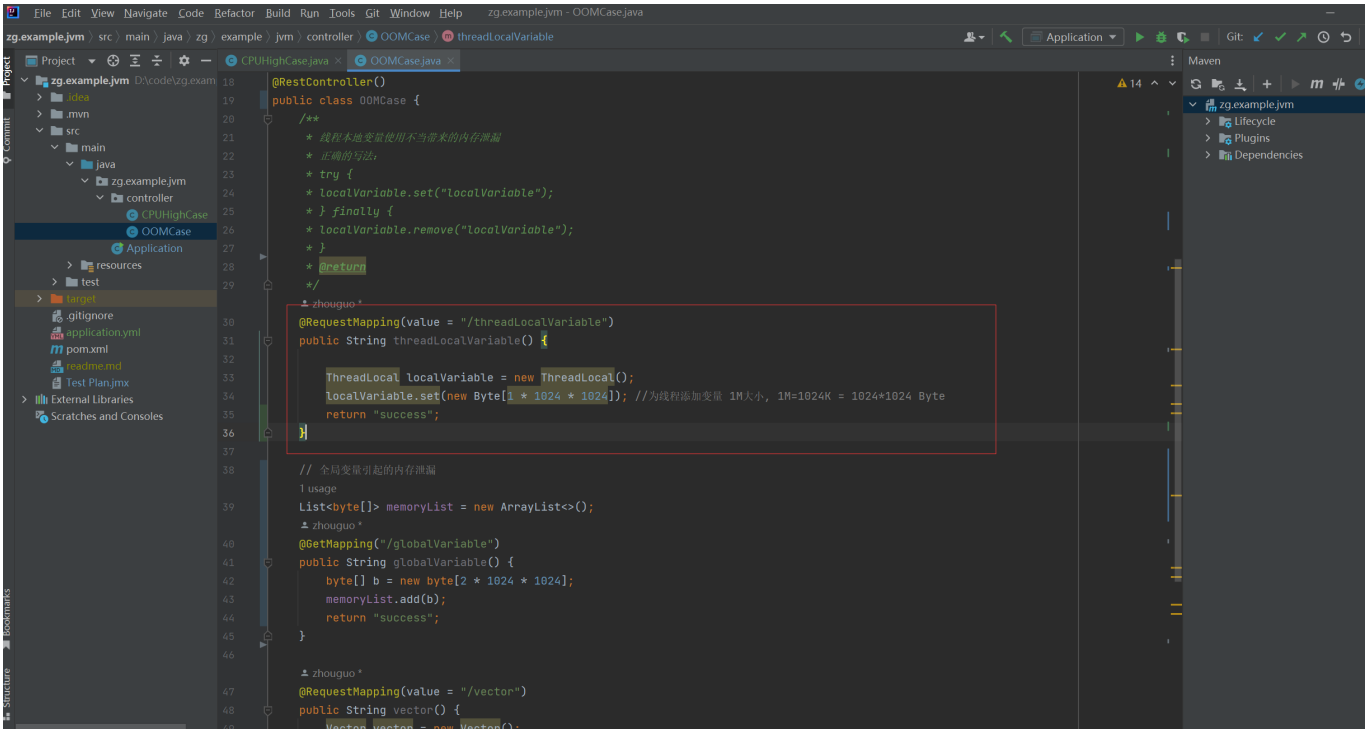
2.1. 开发环境

- IDEA 2022.1.2 (Community Edition)
- JDK-jdk1.8.0_331
- window 11 家庭版

2.2. 运行环境

- CentOS Linux 7 （Core） （虚拟机 4C8G）
- jdk1.8.0_251

2.3. 模拟代码



```
@RequestMapping(value = "/threadLocalVariable")
public String threadLocalVariable() {

    ThreadLocal localVariable = new ThreadLocal();
    localVariable.set(new Byte[1 * 1024 * 1024]); //为线程添加变量 1M大小, 1M=1024K
= 1024*1024 Byte
    return "success";
}
```

2.4. 运行参数

- 后台运行

```
nohup java -jar zg.example.jvm-0.0.1-SNAPSHOT.jar &
```

- 简易运行

```
java -jar zg.example.jvm-0.0.1-SNAPSHOT.jar
```

- 普通带参数启动

```
java -Xms1G \ -XX:+HeapDumpOnOutOfMemoryError \ -XX:HeapDumpPath=/opt/heapdump.hprof \ -
XX:+PrintGCTimeStamps \ -XX:+PrintGCDetails \ -Xloggc:/opt/heapTest.log \ -jar
zg.example.jvm-0.0.1-SNAPSHOT.jar
```

```
java -jar -Xms1G -XX:+HeapDumpOnOutOfMemoryError -XX:HeapDumpPath=/opt/heapdump.hprof -
XX:+PrintGCTimeStamps -XX:+PrintGCDetails -Xloggc:/opt/heapTest.log zg.example.jvm-
0.0.1-SNAPSHOT.jar
```

- 使用JMX远程启动（VisualVM）

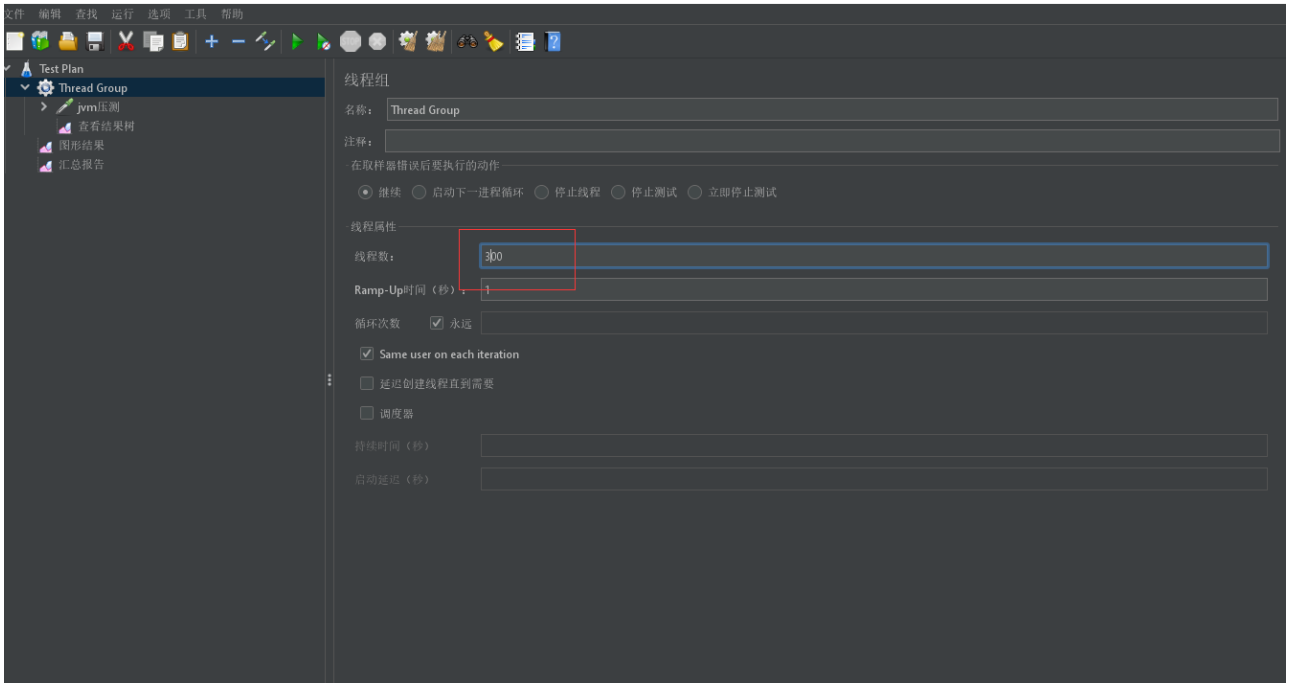
```
java -Djava.rmi.server.hostname=192.168.22.131 \ -
Dcom.sun.management.jmxremote.port=1232 \ -Dcom.sun.management.jmxremote.rmi.port=1240 \
-Dcom.sun.management.jmxremote.ssl=false \ -
Dcom.sun.management.jmxremote.authenticate=false \ -Xms1G \ -
XX:+HeapDumpOnOutOfMemoryError \ -XX:HeapDumpPath=/opt/heapdump.hprof \ -
XX:+PrintGCTimeStamps \ -XX:+PrintGCDetails \ -Xloggc:/opt/heapTest.log \ -jar
zg.example.jvm-0.0.1-SNAPSHOT.jar
```

> ***参数说明:***

- -Xms4G -最大堆内存
- -XX:+HeapDumpOnOutOfMemoryError -当内存溢出时触发java.lang.OutOfMemo: Java heap space异常
- -XX:HeapDumpPath=/tmp/heapdump.hprof -内存溢出时保存快照文件（可用MAT工具分析）
- -XX:+PrintGCTimeStamp -打印GC发发生的时间戳
- -XX:+PrintGCDetails -Xloggc:/tmp/heapTest.log -打印GC详细日志到文件

2.5. 模拟访问

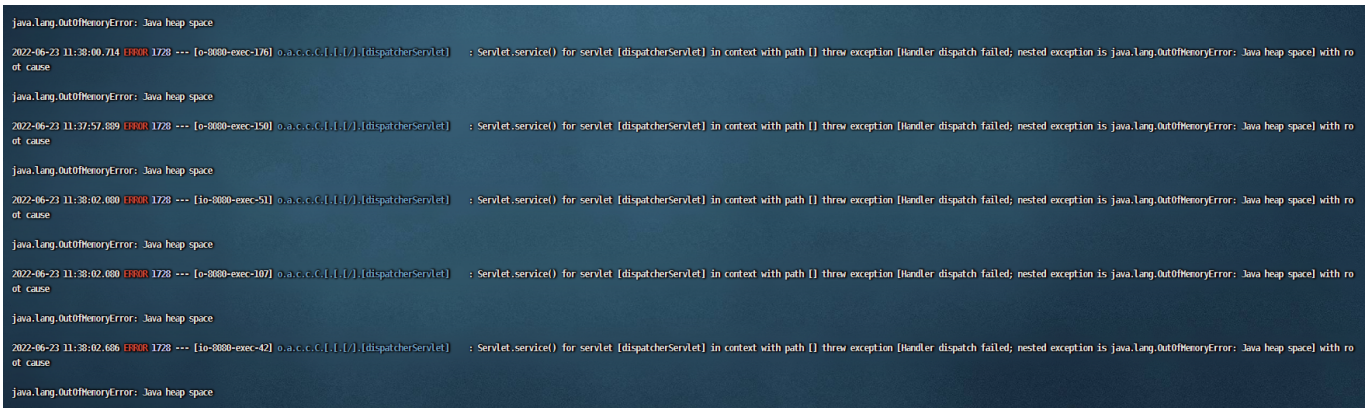
- 通过Jmeter测试工具，模拟并发访问，模拟300个并发请求；



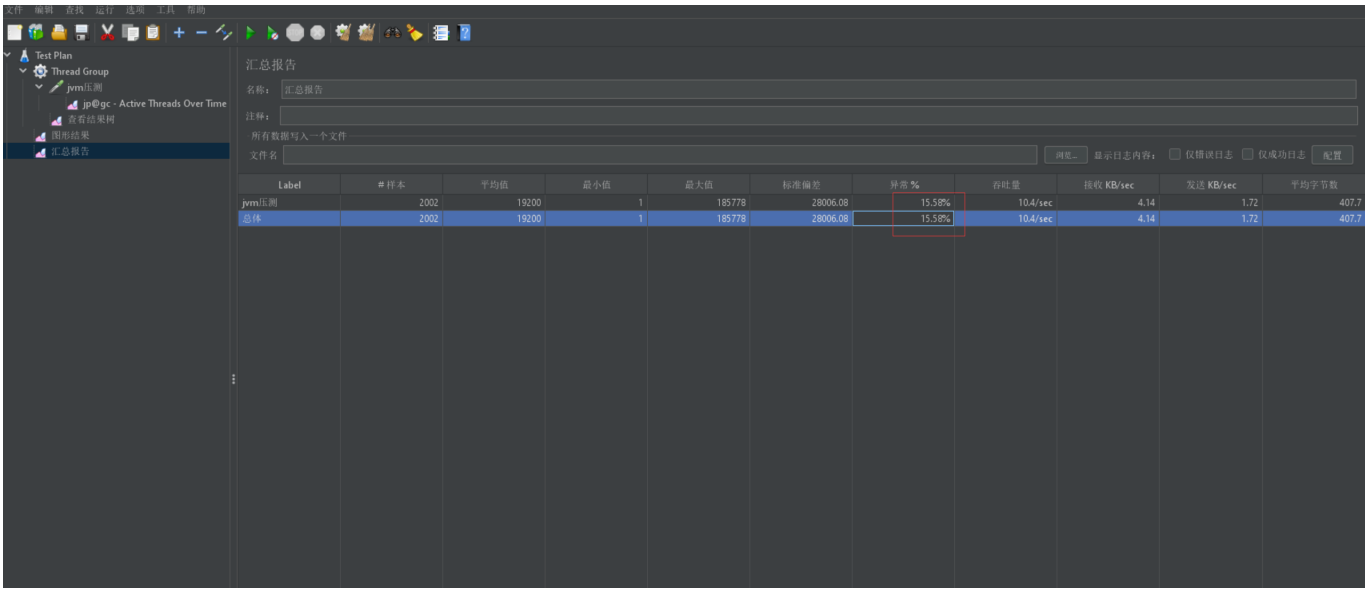
3. 运行异常(表象)

3.1. 异常监控

3.2. 控制台OOM异常



3.3. Jmeter异常返回



接口异常

4. 定位分析(里象)

4.1. JVM内存整体情况

4.1.1. jmap工具查看

- Eden Space 域Old Generatio区内存占用率都达到了99%已无内存可再分配，JVM报OOM异常
- 工具1：jmap命令查看

```
jmap -heap <pid>
```

```
Heap Usage: PS Young Generation Eden Space: capacity = 238551040 (227.5MB) used =
235735744 (224.81512451171875MB) free = 2815296 (2.68487548828125MB) 98.81983495020604%
used From Space: capacity = 215482368 (205.5MB) used = 0 (0.0MB) free = 215482368
(205.5MB) 0.0% used To Space: capacity = 238551040 (227.5MB) used = 0 (0.0MB) free =
238551040 (227.5MB) 0.0% used PS Old Generation capacity = 1431830528 (1365.5MB) used =
1430561728 (1364.2899780273438MB) free = 1268800 (1.21002197265625MB) 99.91138616091862%
used
```

4.1.2. arthas-dashboard查看

> 查看整体监控面板

命令：dashboard

timestamp/uptime				Thu Jun 23 15:08:30 CST 2022/1128s					
ID	NAME	GROUP	PRIORITY	STATE	%CPU	DELTA_TIME	TIME	INTERRUPTED	DAEMON
-1	GC task thread#2 (ParallelGC)	-	-1	-	53.24	2.542	0:24.556	false	true
-1	GC task thread#3 (ParallelGC)	-	-1	-	52.84	2.522	0:24.550	false	true
-1	GC task thread#1 (ParallelGC)	-	-1	-	52.49	2.505	0:24.560	false	true
-1	GC task thread#0 (ParallelGC)	-	-1	-	51.01	2.435	0:24.413	false	true
-1	VM Thread	-	-1	-	37.29	1.780	0:19.210	false	true
-1	C2 CompilerThread0	-	-1	-	0.38	0.018	0:3.408	false	true
-1	C1 CompilerThread2	-	-1	-	0.16	0.007	0:1.713	false	true
45	Timer-for-arthas-dashboard-c39e4771-9c8c-41fb-ba70-0d1062dad896	system	5	RUNNABLE	0.08	0.004	0:0.477	false	true
-1	VM Periodic Task Thread	-	-1	-	0.07	0.003	0:0.800	false	true
168	http-nio-8080-exec-133	main	5	WAITING	0.05	0.002	0:0.015	false	true
25	http-nio-8080-exec-10	main	5	BLOCKED	0.05	0.002	0:0.017	false	true
108	http-nio-8080-exec-73	main	5	RUNNABLE	0.05	0.002	0:0.008	false	true
85	http-nio-8080-exec-50	main	5	BLOCKED	0.04	0.002	0:0.010	false	true
82	http-nio-8080-exec-47	main	5	RUNNABLE	0.04	0.001	0:0.006	false	true
171	http-nio-8080-exec-136	main	5	RUNNABLE	0.03	0.001	0:0.013	false	true
174	http-nio-8080-exec-139	main	5	RUNNABLE	0.03	0.001	0:0.015	false	true
144	http-nio-8080-exec-109	main	5	RUNNABLE	0.03	0.001	0:0.008	false	true

Memory	used	total	max	usage	GC	
heap	1518M	1570M	1725M	87.51%	gc.ps_scavenge.count	20
ps_eden_space	220M	223M	551M	39.96%	gc.ps_scavenge.time(ms)	817
ps_survivor_space	0K	47104K	47104K	0.00%	gc.ps_marksweep.count	135
ps_old_gen	1298M	1301M	1301M	99.75%	gc.ps_marksweep.time(ms)	47110
nonheap	63M	66M	-1	95.08%		
code_cache	13M	14M	240M	5.80%		
metaspace	43M	46M	-1	94.27%		
compressed_class_space	5M	5M	1024M	0.53%		
direct	1M	1M	-	100.00%		
mapped	0K	0K	-	0.00%		

Runtime	
os.name	Linux
os.version	3.10.0-1160.el7.x86_64
java.version	1.8.0_251
java.home	/opt/jdk1.8.0_251/jre
systemload.average	1.63

4.1.3. arthas-jvm查看

> 命令： jvm

jvm能查看的重点信息

1、类加载信息

```
CLASS-LOADING
```

```
LOADED-CLASS-COUNT                                    7938
TOTAL-LOADED-CLASS-COUNT                              7938
UNLOADED-CLASS-COUNT                                  0
IS-VERBOSE                                            false
```

2、编译信息

```
COMPILATION
```

```
NAME                                                  HotSpot 64-Bit Tiered Compilers
TOTAL-COMPILE-TIME                                    6849
[time (ms)]
```

3、垃圾回收情况

```
GARBAGE-COLLECTORS
```

```
PS Scavenge                                           name : PS Scavenge
[count/time (ms)]                                     collectionCount : 3
                                                      collectionTime : 107
PS MarkSweep                                          name : PS MarkSweep
[count/time (ms)]                                     collectionCount : 3
                                                      collectionTime : 182
```

4、内存管理与内存

参数说明：

- HEAP-MEMORY-USAGE： 堆内存初始化大小

5、线性信息

```
THREAD
COUNT                                                                31
DAEMON-COUNT                                                         27
PEAK-COUNT                                                           32
STARTED-COUNT                                                        40
DEADLOCK-COUNT                                                       0
```

参数说明：

- COUNT: JVM当前活跃的线程数
- DAEMON-COUNT: JVM当前活跃的守护线程数
- PEAK-COUNT: 从JVM启动开始曾经活着的最大线程数
- STARTED-COUNT: 从JVM启动开始总共启动过的线程次数
- DEADLOCK-COUNT: JVM当前死锁的线程数

5、文件描述符相关

```
FILE-DESCRIPTOR
MAX-FILE-DESCRIPTOR-COUNT                                            4096
OPEN-FILE-DESCRIPTOR-COUNT                                           112
```

参数说明：

- MAX-FILE-DESCRIPTOR-COUNT：JVM进程最大可以打开的文件描述符数
- OPEN-FILE-DESCRIPTOR-COUNT：JVM当前打开的文件描述符数

4.2. 堆内存对象

首先，可以使用jmap命令查看，堆内存的使用量；

```
jmap -histo:live <pid>
```

> 使用jmap命令，查看具体的堆内对象，live参数只显示存活对象；

```
[root@vm002 ~]# jmap -histo:live 3244

 num     #instances         #bytes  class name
----------------------------------------------
   1:           101     360712896  [Ljava.lang.Byte;
   2:         46350       8553520  [C
   3:          6808       5807480  [B
   4:         45962       1103088  java.lang.String
   5:          8789        973480  java.lang.Class
   6:          8093        712184  java.lang.reflect.Method
   7:          7799        689136  [Ljava.lang.Object;
   8:         19532        625024  java.util.concurrent.ConcurrentHashMap$Node
   9:          4924        541408  [I
  10:          9943        397720  java.util.LinkedHashMap$Entry
  11:          4350        359160  [Ljava.util.HashMap$Node;
  12:          9008        288256  java.util.HashMap$Node
  13:         10018        225960  [Ljava.lang.Class;
  14:          3892        217952  java.util.LinkedHashMap
  15:         13594        217504  java.lang.Object
  16:           143        199344  [Ljava.util.concurrent.ConcurrentHashMap$Node;
  17:          1348        107840  java.lang.reflect.Constructor
  18:            38         99136  [Ljava.nio.channels.SelectionKey;
  19:          2048         98304  java.util.HashMap
  20:          1276         91872  java.lang.reflect.Field
```

4.3. 堆文件信息分析

第一、生成堆文件，有很多种方法生成堆文件

- 1、java程序启启动时指定OOM异常时输出hprof文件

```
-XX:+HeapDumpOnOutOfMemoryError -XX:HeapDumpPath=/opt/heapdump.hprof
```

- 2、使用 jconsole或VisualVM等工具在运行时获得堆转储生成hprof文件
- 3、是要jmap dump:live命令动态生成hprof文件

```
jmap -dump:live,file=/opt/a.hprof pid
```

- 4、使用arthas的heapdump命令生成hprof文件

```
heapdump /opt/dump2.hprof
```

第二、分析对文件信息，也有多种工具

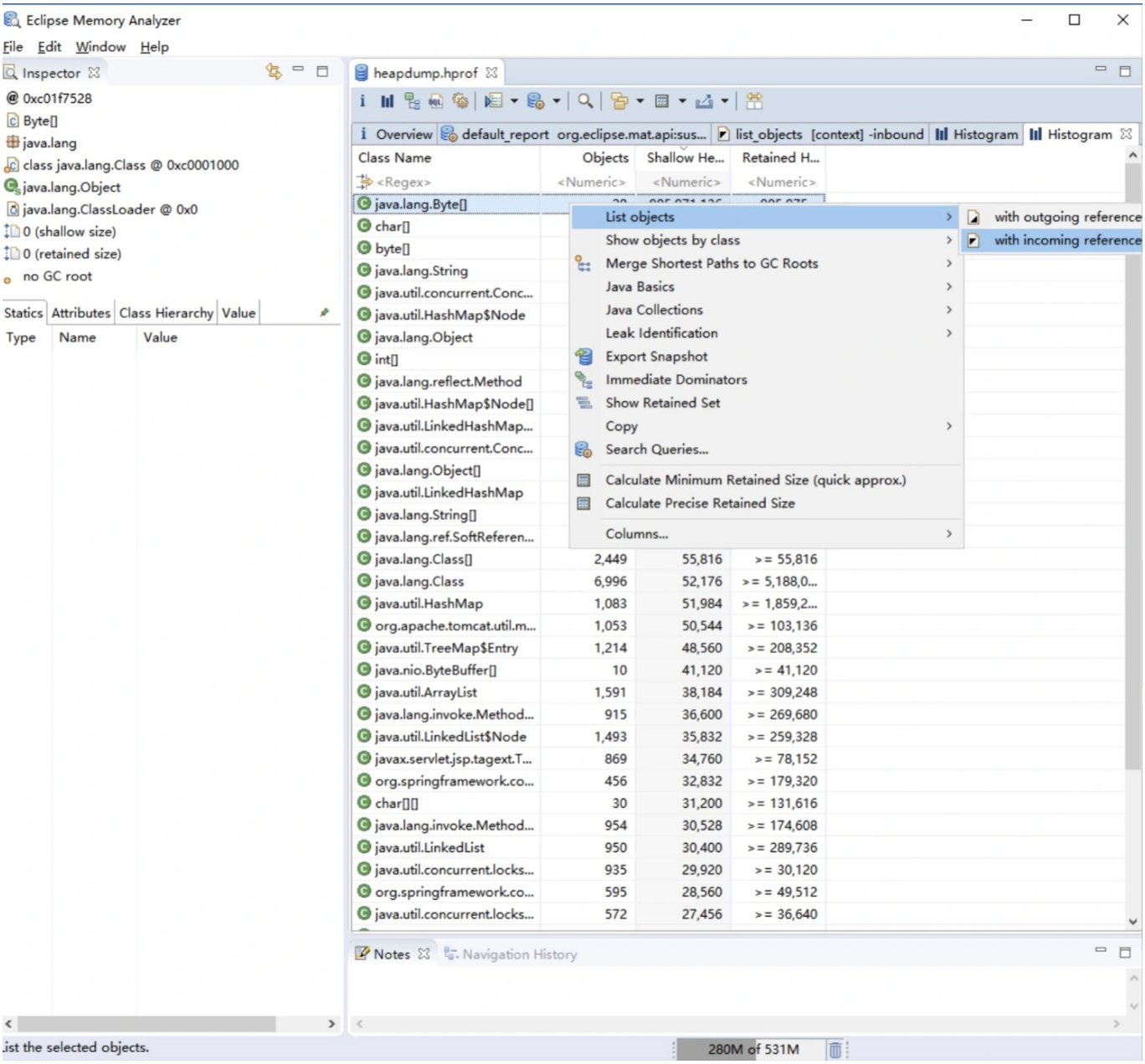
- 1、jhat 工具转化为HTML文件进行查看

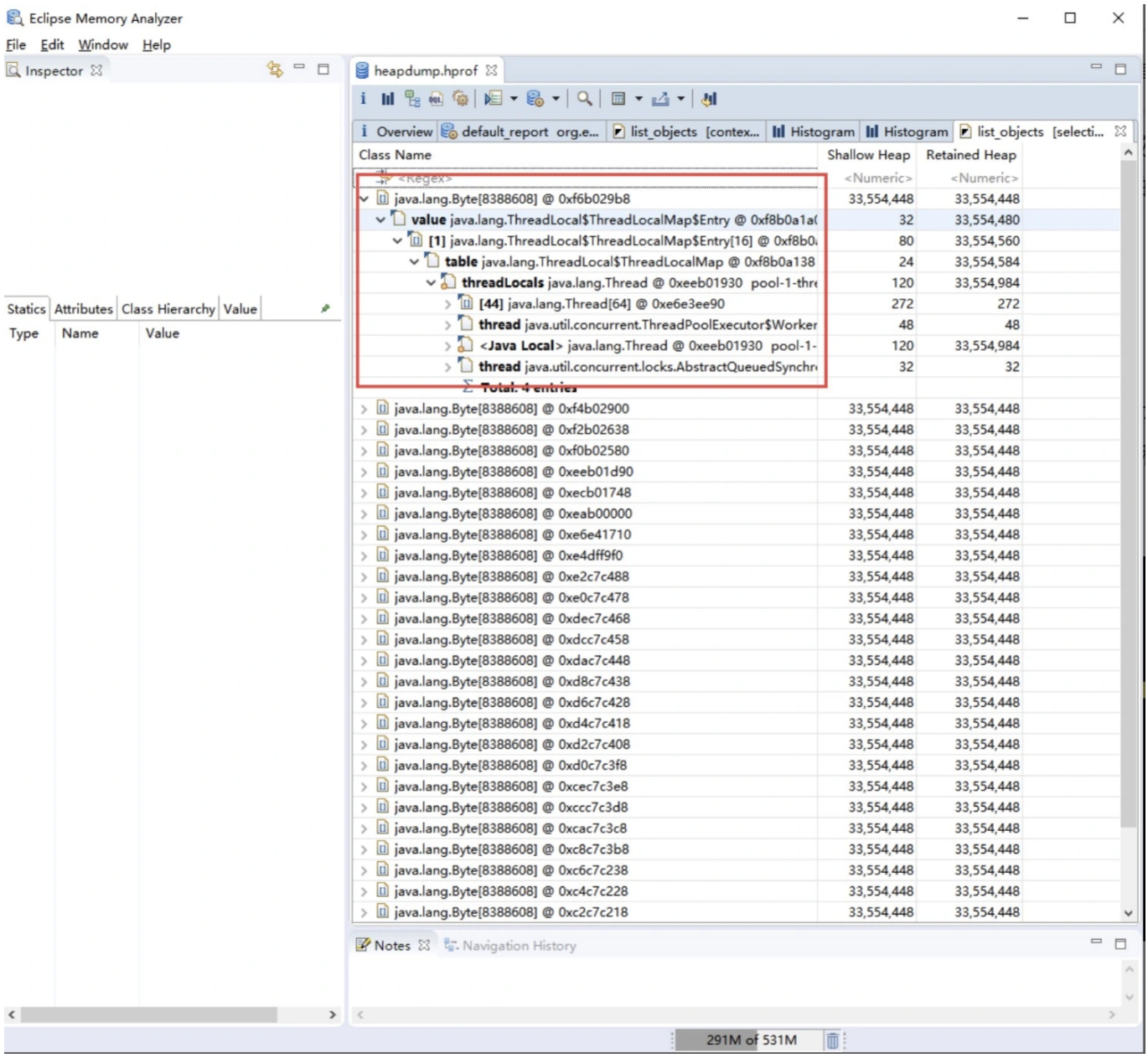
```
jhat dump.hprof

jhat -J-Xmx512m <heap dump file> --如果堆文件很大可使用参数-J-Xmx进行设置

jhat -port 8000 -J-Xmx512m dump.hprof --可指定端口号
```

- 2、使用MIT工具进行可视化查看


Eclipse Memory Analyzer
File Edit Window Help
Inspector
0xc01f7528
Byte[]
java.lang
class java.lang.Class @ 0xc0001000
java.lang.Object
java.lang.ClassLoader @ 0x0
0 (shallow size)
0 (retained size)
no GC root
Statics Attributes Class Hierarchy Value
Type Name Value
heapdump.hprof
Overview default_report org.eclipse.mat.api:sus... list_objects [context] -inbound Histogram Histogram
Class Name Objects Shallow He... Retained H...
<Regex> <Numeric> <Numeric> <Numeric>
java.lang.Byte[]
char[]
byte[]
java.lang.String
java.util.concurrent.Conc...
java.util.HashMap$Node
java.lang.Object
int[]
java.lang.reflect.Method
java.util.HashMap$Node[]
java.util.LinkedHashMap...
java.util.concurrent.Conc...
java.lang.Object[]
java.util.LinkedHashMap
java.lang.String[]
java.lang.ref.SoftReferen...
java.lang.Class[] 2,449 55,816 >= 55,816
java.lang.Class 6,996 52,176 >= 5,188,0...
java.util.HashMap 1,083 51,984 >= 1,859,2...
org.apache.tomcat.util.m... 1,053 50,544 >= 103,136
java.util.TreeMap$Entry 1,214 48,560 >= 208,352
java.nio.ByteBuffer[] 10 41,120 >= 41,120
java.util.ArrayList 1,591 38,184 >= 309,248
java.lang.invoke.Method... 915 36,600 >= 269,680
java.util.LinkedList$Node 1,493 35,832 >= 259,328
javax.servlet.jsp.tagext.T... 869 34,760 >= 78,152
org.springframework.co... 456 32,832 >= 179,320
char[][] 30 31,200 >= 131,616
java.lang.invoke.Method... 954 30,528 >= 174,608
java.util.LinkedList 950 30,400 >= 289,736
java.util.concurrent.locks... 935 29,920 >= 30,120
org.springframework.co... 595 28,560 >= 49,512
java.util.concurrent.locks... 572 27,456 >= 36,640
List objects
Show objects by class
Merge Shortest Paths to GC Roots
Java Basics
Java Collections
Leak Identification
Export Snapshot
Immediate Dominators
Show Retained Set
Copy
Search Queries...
Calculate Minimum Retained Size (quick approx.)
Calculate Precise Retained Size
Columns...
with outgoing reference
with incoming reference
Notes
Navigation History
ist the selected objects.
280M of 531M



4.4. 垃圾回收日志

Full GC变得非常频繁，并且

```
XX:+PrintGCDetails -XX:+PrintGCTimeStamps -XX:+UseCompressedClassPointers -XX:+UseCompressedOops -XX:+UseParallelGC
47.581: [GC (Metadata GC Threshold) [PSYoungGen: 199429K->5984K(611840K)] 199429K->6008K(2010112K), 0.0687019 secs] [Times: user=0.01 sys=0.17, real=0.07 secs]
47.650: [Full GC (Metadata GC Threshold) [PSYoungGen: 5984K->0K(611840K)] [ParOldGen: 24K->5830K(1398272K)] 6008K->5830K(2010112K), [Metaspace: 20114K->20114K(
1067008K)], 0.0549951 secs] [Times: user=0.02 sys=0.11, real=0.05 secs]
9788.578: [GC (Allocation Failure) [PSYoungGen: 524800K->14963K(611840K)] 530630K->20801K(2010112K), 0.0768747 secs] [Times: user=0.00 sys=0.29, real=0.08 secs]
9789.355: [GC (Allocation Failure) [PSYoungGen: 537836K->87030K(611840K)] 543675K->302014K(2010112K), 0.6647330 secs] [Times: user=0.00 sys=2.62, real=0.67 secs]

9790.028: [GC (Metadata GC Threshold) [PSYoungGen: 195994K->87014K(611840K)] 410977K->310221K(2010112K), 0.1645180 secs] [Times: user=0.00 sys=0.62, real=0.16
secs]
9790.193: [Full GC (Metadata GC Threshold) [PSYoungGen: 87014K->0K(611840K)] [ParOldGen: 223207K->306970K(1398272K)] 310221K->306970K(2010112K), [Metaspace:
32742K->32454K(1079296K)], 0.2750932 secs] [Times: user=0.00 sys=0.92, real=0.28 secs]
9790.654: [GC (Allocation Failure) [PSYoungGen: 522907K->84208K(609280K)] 829878K->722956K(2007552K), 0.8502071 secs] [Times: user=0.00 sys=2.90, real=0.85 secs]

9791.598: [GC (Allocation Failure) [PSYoungGen: 609008K->88816K(368640K)] 1247756K->1165838K(1766912K), 1.0959252 secs] [Times: user=0.00 sys=3.99, real=1.09
secs]
9792.694: [Full GC (Ergonomics) [PSYoungGen: 88816K->0K(368640K)] [ParOldGen: 1077021K->882450K(1398272K)] 1165838K->882450K(1766912K), [Metaspace: 32765K->32672
K(1081344K)], 0.2915002 secs] [Times: user=0.70 sys=0.08, real=0.30 secs]
9793.032: [GC (Allocation Failure) [PSYoungGen: 279040K->209056K(488448K)] 1161490K->1148851K(1886720K), 0.0622915 secs] [Times: user=0.23 sys=0.00, real=0.06
secs]
9793.094: [Full GC (Ergonomics) [PSYoungGen: 209056K->0K(488448K)] [ParOldGen: 939794K->1091385K(1398272K)] 1148851K->1091385K(1886720K), [Metaspace: 32708K->
32708K(1081344K)], 0.3830855 secs] [Times: user=0.99 sys=0.00, real=0.39 secs]
9793.521: [GC (Allocation Failure) [PSYoungGen: 278442K->209024K(443392K)] 1369827K->1357754K(1841664K), 0.1464605 secs] [Times: user=0.50 sys=0.05, real=0.15
secs]
9793.668: [Full GC (Ergonomics) [PSYoungGen: 209024K->0K(443392K)] [ParOldGen: 1148729K->1275672K(1398272K)] 1357754K->1275672K(1841664K), [Metaspace: 32766K->
32766K(1081344K)], 0.5070025 secs] [Times: user=0.76 sys=0.81, real=0.50 secs]

9794.210: [Full GC (Ergonomics) [PSYoungGen: 230473K->0K(443392K)] [ParOldGen: 1275672K->1390387K(1398272K)] 1506146K->1390387K(1841664K), [Metaspace: 33048K->
33048K(1081344K)], 0.6101545 secs] [Times: user=1.30 sys=0.55, real=0.61 secs]

9794.852: [Full GC (Ergonomics) [PSYoungGen: 232960K->132077K(443392K)] [ParOldGen: 1390387K->1394823K(1398272K)] 1623347K->1526901K(1841664K), [Metaspace: 33101
K->33101K(1081344K)], 0.4821186 secs] [Times: user=1.18 sys=0.00, real=0.48 secs]

9795.355: [Full GC (Ergonomics) [PSYoungGen: 231572K->173472K(443392K)] [ParOldGen: 1394823K->1394816K(1398272K)] 1626396K->1568289K(1841664K), [Metaspace: 33209
K->33209K(1081344K)], 0.4125826 secs] [Times: user=1.08 sys=0.00, real=0.41 secs]
```

> 使用在线工具gceasy分析GC日志

5. 原理解析

5.1. JVM 内存分布

> JVM内存模型

JVM专题2

> 使用查看初始JVM情况

```
jmap -heap 1728
```

1. Attaching to process ID 1728, please wait... Debugger attached successfully. Server compiler detected. JVM version is 25.251-b08
2. using thread-local object allocation. Parallel GC with 4 thread(s)
3. Heap Configuration: MinHeapFreeRatio = 0 MaxHeapFreeRatio = 100 MaxHeapSize = 2147483648 (2048.0MB) NewSize = 715653120 (682.5MB) MaxNewSize = 715653120 (682.5MB) OldSize = 1431830528 (1365.5MB) NewRatio = 2 SurvivorRatio = 8 MetaspaceSize = 21807104 (20.796875MB) CompressedClassSpaceSize = 1073741824 (1024.0MB) MaxMetaspaceSize = 17592186044415 MB G1HeapRegionSize = 0 (0.0MB)
4. Heap Usage: PS Young Generation Eden Space: capacity = 537395200 (512.5MB) used = 177346208 (169.13052368164062MB) free = 360048992 (343.3694763183594MB) 33.001077791539636% used From Space: capacity = 89128960 (85.0MB) used = 0 (0.0MB) free = 89128960 (85.0MB) 0.0% used To Space: capacity = 89128960 (85.0MB) used = 0 (0.0MB) free = 89128960 (85.0MB) 0.0% used PS Old Generation capacity = 1431830528 (1365.5MB) used = 5970864 (5.6942596435546875MB) free = 1425859664 (1359.8057403564453MB) 0.41700912805233886% used
5. 13484 interned Strings occupying 1182024 bytes.

参数说明

> *第一部分：JVM版本信息*

```
Attaching to process ID 1728, please wait... Debugger attached successfully. Server compiler detected. JVM version is 25.251-b08
```

> *第二部分：垃圾收集器信息*

```
using thread-local object allocation. Parallel GC with 4 thread(s)
```

Parallel GC 是JDK8默认（-XX:+UseParallelGC）的垃圾回收算法，Parallel GC属于并行垃圾回收算法.... TODO

> *第三部分：堆配置信息*

```
Heap Configuration: MinHeapFreeRatio = 0 MaxHeapFreeRatio = 100 MaxHeapSize = 2147483648 (2048.0MB) NewSize = 715653120 (682.5MB) MaxNewSize = 715653120 (682.5MB) OldSize = 1431830528 (1365.5MB) NewRatio = 2 SurvivorRatio = 8 MetaspaceSize = 21807104 (20.796875MB) CompressedClassSpaceSize = 1073741824 (1024.0MB) MaxMetaspaceSize = 17592186044415 MB G1HeapRegionSize = 0 (0.0MB)
```

说明：

- MinHeapFreeRatio **堆空间最小百分百** 计算公式为：HeapFreeRatio = (CurrentFreeHeapSize/CurrentTotalHeapSize) * 100.. TODO
- MaxHeapFreeRatio **堆空间最大百分百**
- MaxHeapSize **最大堆内存**：最大堆内存默认为物理内存的1/4;
- NewSize **新生代空间默认大小**：新生代默大小为堆内存的1/3 =(2048*1/3=682.5MB)
- MaxNewSize **新生代空间最大大小**
- OldSize **老年代空间大小**：老年代默大小为堆内存的2/3 =(2048*2/3=1365.5MB)
- NewRatio **新生代中New区（伊甸园区）大小**：默认为整个新生代的80% =(682.5*0.8=)
- SurvivorRatio **新什代中Survivor区大小**：默认为整个新生代的80%
- MetaspaceSize **元空间初始大小**：存储jvm中的元数据，包括byte code，class等，
- CompressedClassSpaceSize **?? TODO**
- MaxMetaspaceSize **元空间最大大小**：默认是没有限制的，会一直增长直到整个机器内存吃满，被操作系统Kill
- G1HeapRegionSize

> ***第四部：分堆使用情况***

```
Heap Usage: PS Young Generation Eden Space: capacity = 537395200 (512.5MB) used =
177346208 (169.13052368164062MB) free = 360048992 (343.3694763183594MB)
33.001077791539636% used From Space: capacity = 89128960 (85.0MB) used = 0 (0.0MB) free =
89128960 (85.0MB) 0.0% used To Space: capacity = 89128960 (85.0MB) used = 0 (0.0MB) free =
89128960 (85.0MB) 0.0% used PS Old Generation capacity = 1431830528 (1365.5MB) used =
5970864 (5.6942596435546875MB) free = 1425859664 (1359.8057403564453MB)
0.4170091280523386% used
```

说明：

该部分主要展示堆内存的实时使用情况，分别展示对堆内存4个区域中的，容量，使用量，空闲量，使用比例；

5.2. GC垃圾回收机制

- 垃圾回收算法 图解Java垃圾回收算法及详细过程！_Java_攀岩鱼_InfoQ写作社区

5.3. 线程本地变量机制

- 线程本地变量 线程本地变量执行原型

5.4. 线程池模型

线程池运行原理-Tomact 线程池运行原理AQS-JDK

6. 总结

【金山文档】 JVM问题定位与分析 https://kdocs.cn/l/clfkP4FQwvIU

7. 参考资料

- Oracle 标准的HotSpot虚拟机垃圾回收调优指南 Java Platform, Standard Edition HotSpot Virtual Machine Garbage Collection Tuning Guide, Release 8 (oracle.com)
- JVM参数优化 7 JVM arguments of Highly Effective Applications – GC easy – Universal Java GC Log Analyser
- 极客时间-Java性能调优课程
- 周志明《Java虚拟机第三版》
- 周志明《凤凰架构》 凤凰架构：构筑可靠的大型分布式系统 | 凤凰架构 (icyfenix.cn)

8. 后续改进

- 需要有一个整体的运行架构总图作为导入，告诉读者为什么要先讲JVM相关内容，后续的内容是如何规划的：
- 最好先介绍原理后介绍案例，再结合原理与案例进行系统总结；
- 所有介绍的内容的文档、代码，图形需要规范化的整理与同步输出，要给读者开箱即用的便捷性；
- 视频录制的方式最好以小微课的形式呈现，不在意多而在于精；