TheServerSide JAVA SYMPOSIUM Europe

Memory Leaks in Java Technology-Based Applications: Different Tools for Different Types of Leaks

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Goal

To understand the different types of tools available for finding memory leaks.

Agenda

- What's the Problem?
- Observing the Problem
- Inspecting the Heap
- Using Instrumentation
- Lessons Learned
- An Additional Problem...
- Q&A

Disclaimers

- **Using Sun's JDK**
- **Mostly talking about JDK5**
- **The demos use example code**

Agenda

What's the Problem?

Observing the Problem

Inspecting the Heap

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Lessons Learned

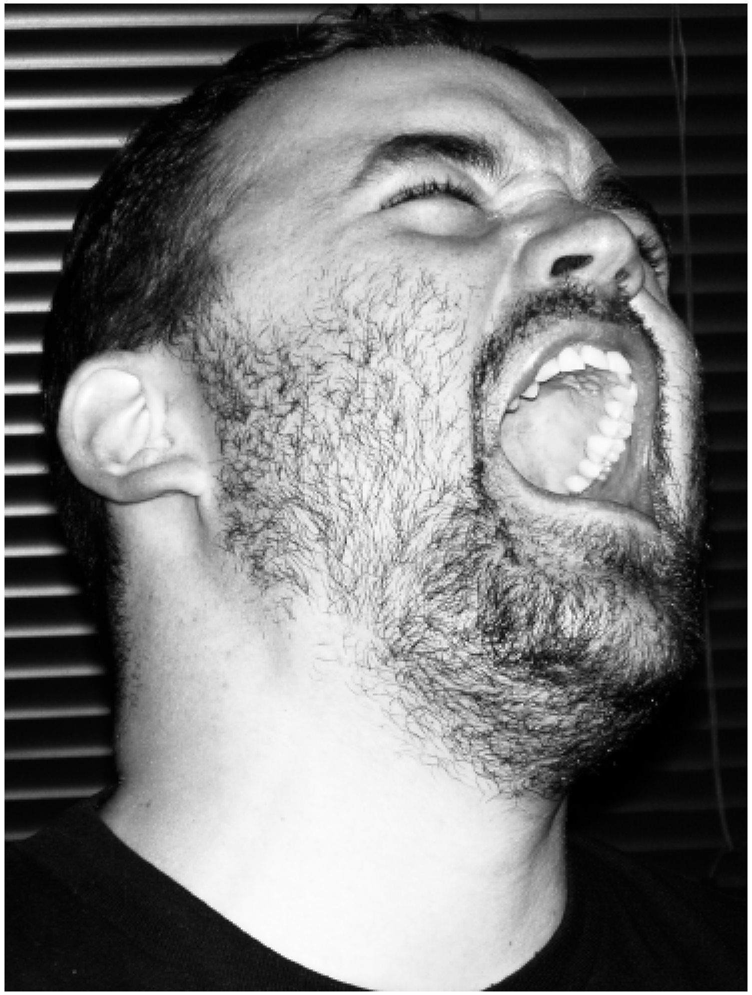
An Additional Problem...

Q&A

Have You Ever Seen This?

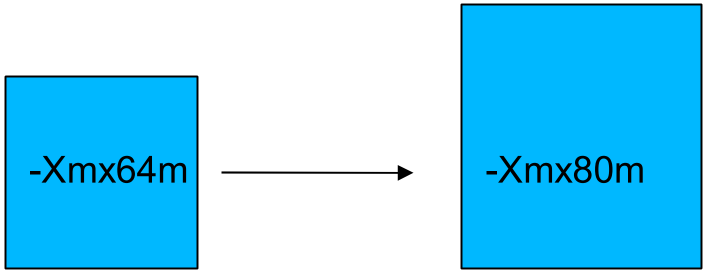
```
Exception in thread "main" java.lang.OutOfMemoryError: Java heap space
```

And Then Do Your Users Do This?



So What Do You Do?

- **Increase the size of the heap**



- **And hope that the problem is fixed….**

But If That Does Not Fix the Problem….

```
Exception in thread "main" java.lang.OutOfMemoryError: Java heap space
        at app.leaking.UhOh(leaking.java:41)
        at app.leaking.WeHadHoped(leaking.java:51)
        at app.leaking.IfWeKeptIncreasing(leaking.java:55)
        at app.leaking.TheHeapSize(leaking.java:59)
        at app.leaking.ThenMaybeThisProblemWouldGoAway(leaking.java:63)
        at app.leaking.LooksLikeItHasNotGoneAway(leaking.java:67)
        at app.leaking.Bummer(leaking.java:61)
        at app.leaking.main(leaking.java:31)
```

Result: Users Might Get Even Angrier....

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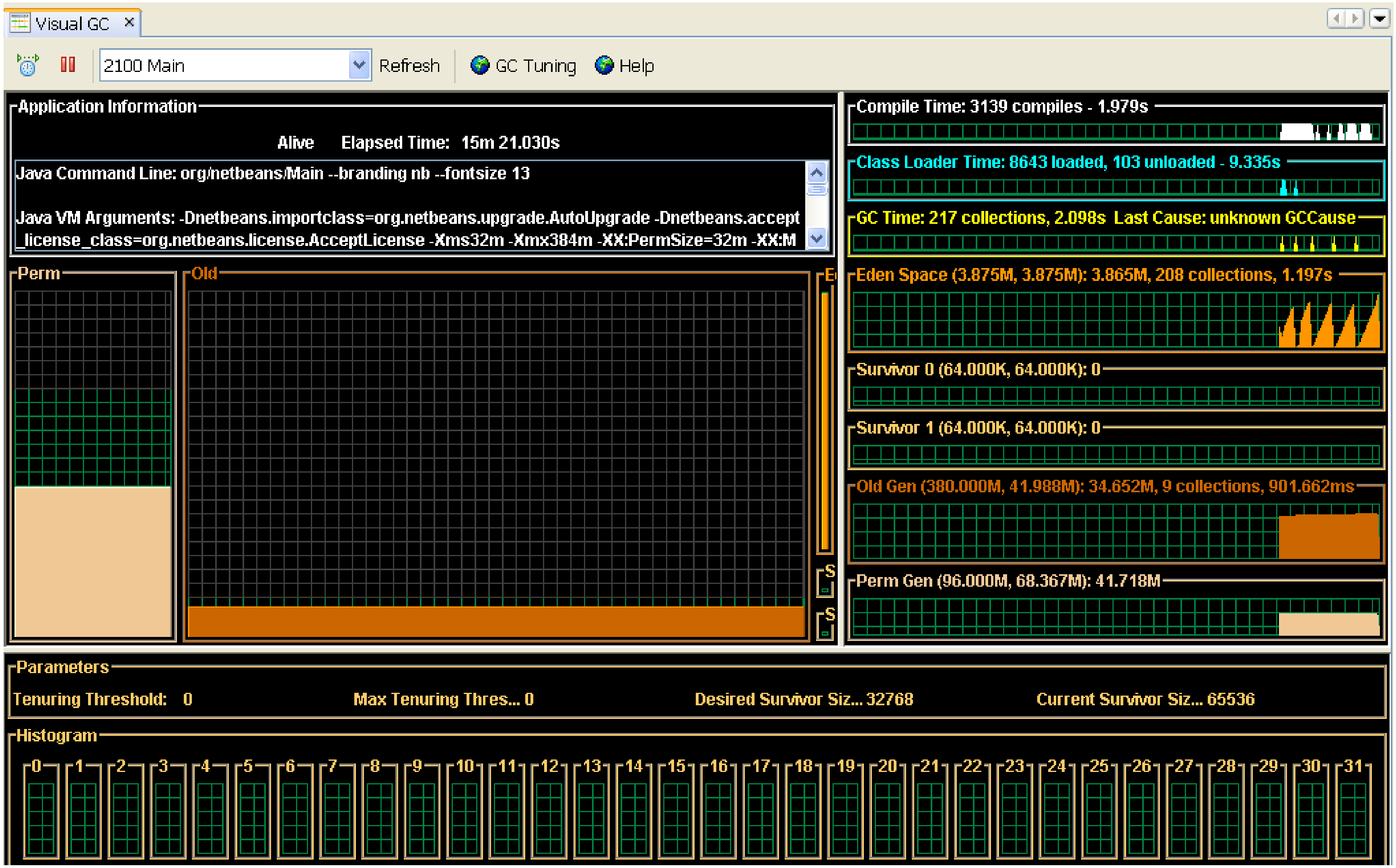
Observing the Problem

java -verbose:gc *YourApp*

```
[GC 189K->128K(1984K), 0.0016829 secs]
[Full GC 128K->128K(1984K), 0.0108424 secs]
[GC 10378K->10368K(12228K), 0.0004978 secs]
[Full GC 10368K->10368K(12228K), 0.0097568 secs]
[GC 20633K->20608K(28872K), 0.0002025 secs]
[Full GC 20608K->20608K(28872K), 0.0097892 secs]
[GC 30896K->30848K(36972K), 0.0002380 secs]
[Full GC 30848K->30847K(36972K), 0.0641433 secs]
```

Observing the Problem (continued)



Application Information

Alive Elapsed Time: 15m 21.030s

Java Command Line: org/netbeans/Main --branding nb --fontsize 13

Java VM Arguments: -Dnetbeans.importclass=org.netbeans.upgrade.AutoUpgrade -Dnetbeans.accept_license_class=org.netbeans.license.AcceptLicense -Xms32m -Xmx384m -XX:PermSize=32m -XX:M

Compile Time: 3139 compiles - 1.979s

Class Loader Time: 8643 loaded, 103 unloaded - 9.335s

GC Time: 217 collections, 2.098s Last Cause: unknown GCCause

Eden Space (3.875M, 3.875M): 3.865M, 208 collections, 1.197s

Survivor 0 (64.000K, 64.000K): 0

Survivor 1 (64.000K, 64.000K): 0

Old Gen (380.000M, 41.988M): 34.652M, 9 collections, 901.662ms

Perm Gen (96.000M, 68.367M): 41.718M

Parameters

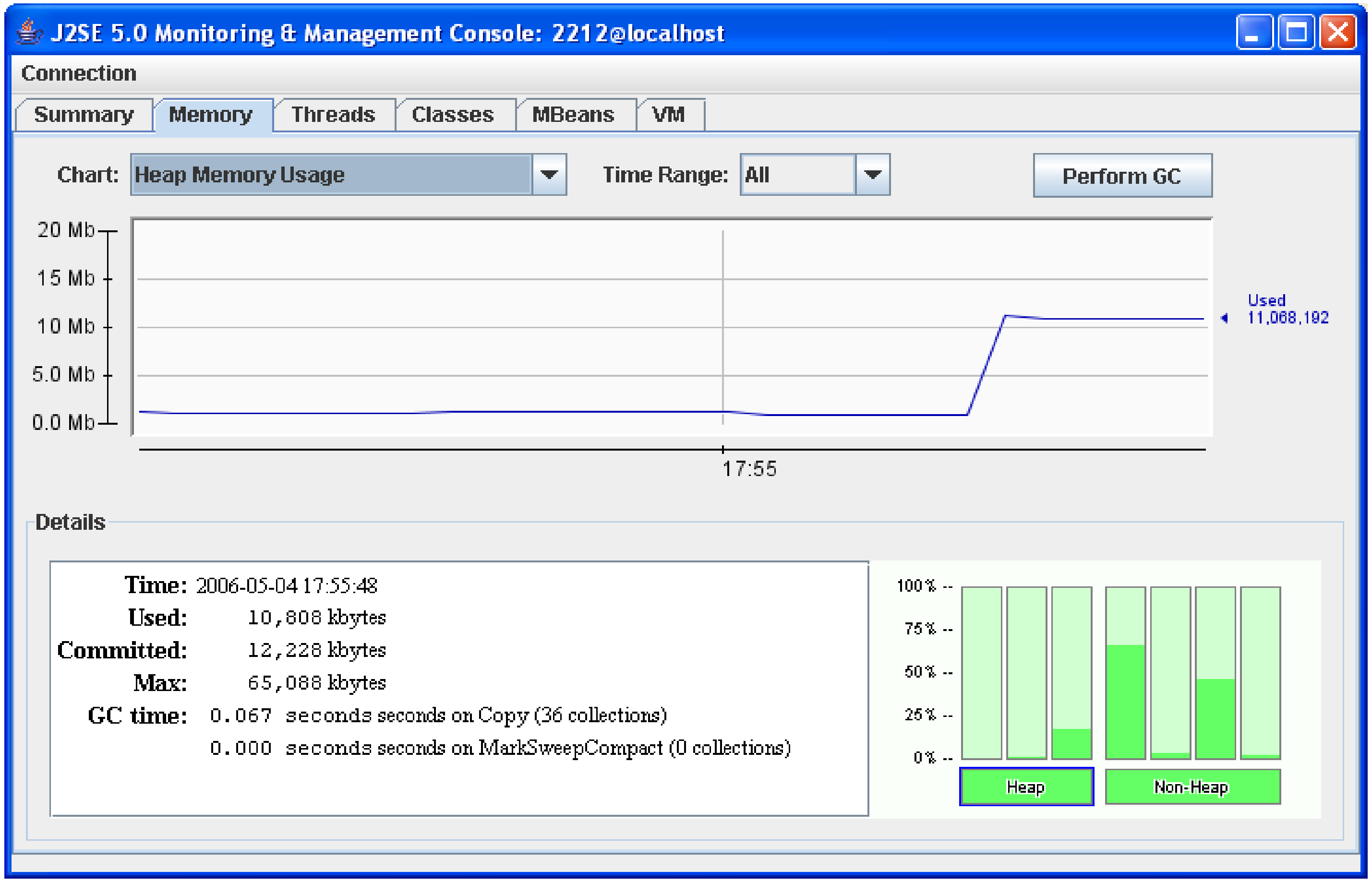
Tenuring Threshold: 0 Max Tenuring Thres... 0 Desired Survivor Siz... 32768 Current Survivor Siz... 65536

Histogram

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

Observing the Problem (continued)

```
java -Dcom.sun.management.jmxremote YourApp
```



```
     Time: 2006-05-04 17:55:48
     Used:      10,808 kbytes
Committed:      12,228 kbytes
      Max:      65,088 kbytes
  GC time:   0.067  seconds seconds on Copy (36 collections)
             0.000  seconds seconds on MarkSweepCompact (0 collections)
```

Observing the Problem (continued)

- **More Tools in JDK6:**
  - **Stack trace on OutOfMemoryError**
  - **-XX:+HeapDumpOnOutOfMemoryError**
    - **(Also available in JDK 1.4.2 and JDK 5)**
  - **jhat**
  - **jmap for Windows**

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Case Study: A Swing Application

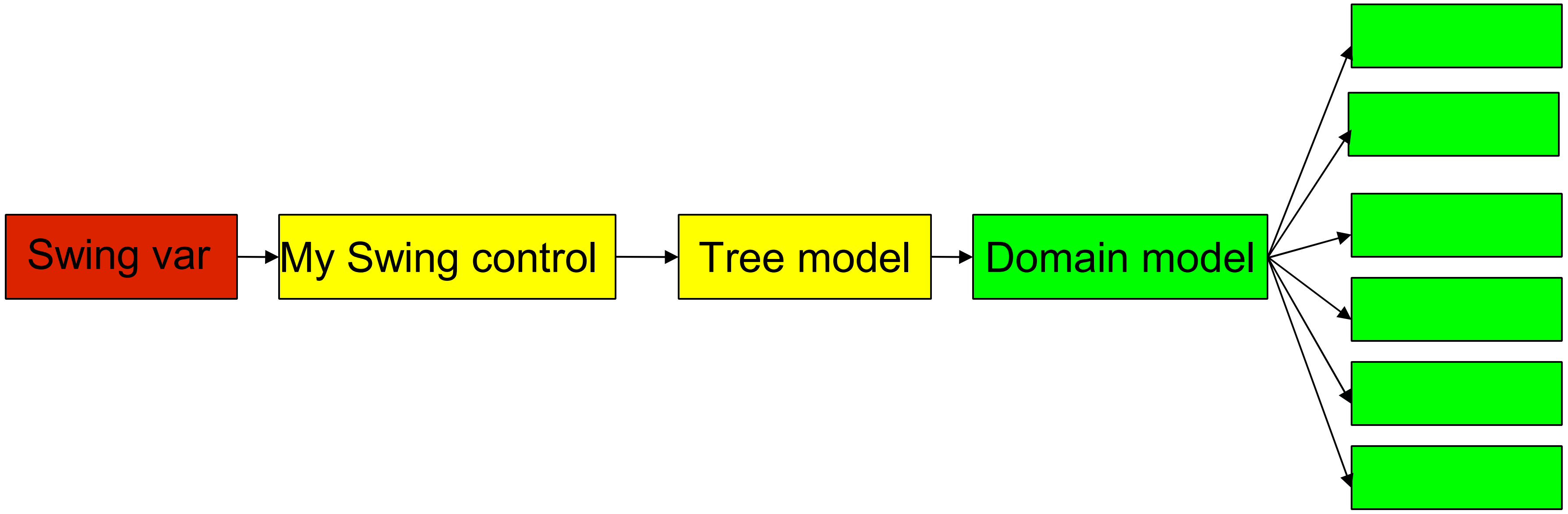
- **Production Planning application**
- **Developed during 1999-2002**
- **JDK 1.2 (later moved to JDK 1.3 and then 1.4)**
- **~263,000 LOCs**
- **~1,600 Classes**
- **Memory leak found during QA, right *before* going live**
- **Easy to reproduce the problem, with the right data, but still not obvious what the cause was**

DEMO

Inspecting the Heap With a Profiler

So What Happened?

- **A bug in someone else's code prevented garbage collection of my objects**
- **4215796: RepaintManager DoubleBuffer can cause leak...**



Agenda

What's the Problem?

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Inspecting the Heap

Using Instrumentation

Lessons Learned

An Additional Problem...

Q&A

Case Study: A Web Application

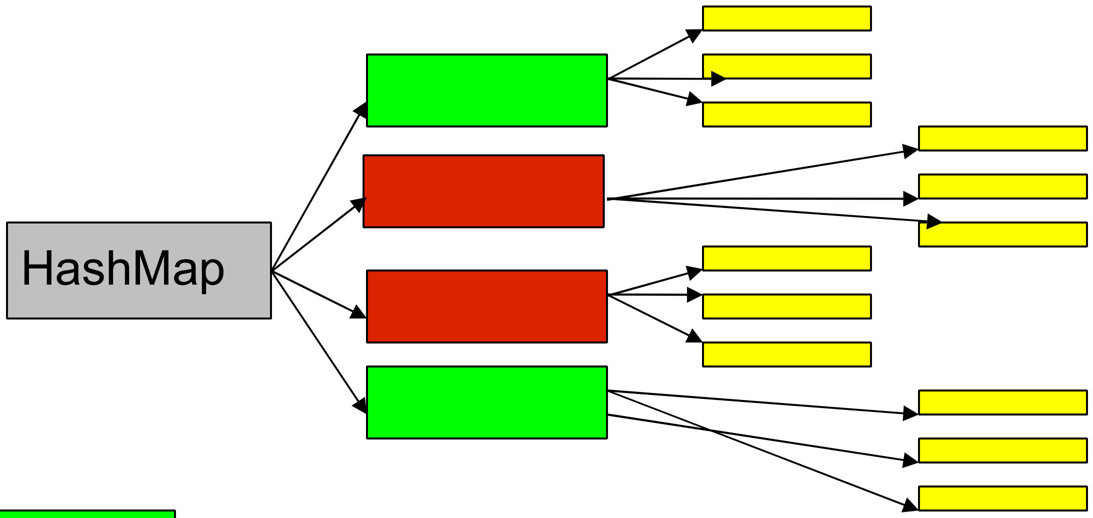
- **Hardware/software analysis system**
- **Developed during 2000-2004**
- **JDK 1.? (Later moved to JDK 1.4)**
- **>150,000 LOCs, which does not include:**
  - **the JSPs**
  - **a subsystem written in Perl**
- **Memory leak found in the live, production system**
- **Hard to reproduce the problem - seemed to occur randomly**

DEMO

Using Instrumentation

So What Happened?

- ***Multiple* places in the code were allocating AnalysisResults objects, but only *some* of those allocations were causing leaks.**

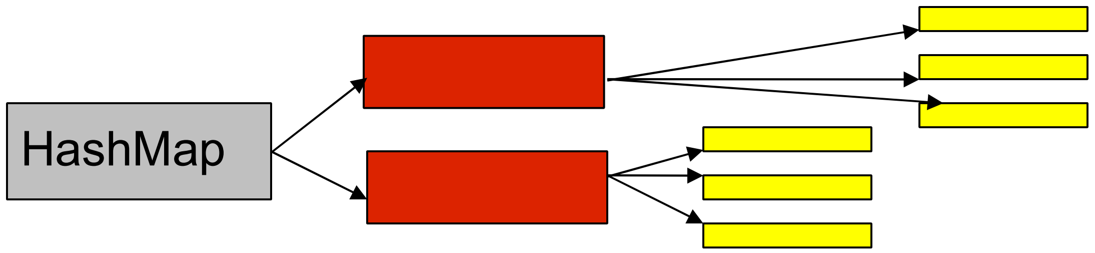


🟩 : AnalysisResult allocated by the foreground process

🟥 : AnalysisResult allocated by the background process

So What Happened? (continued)

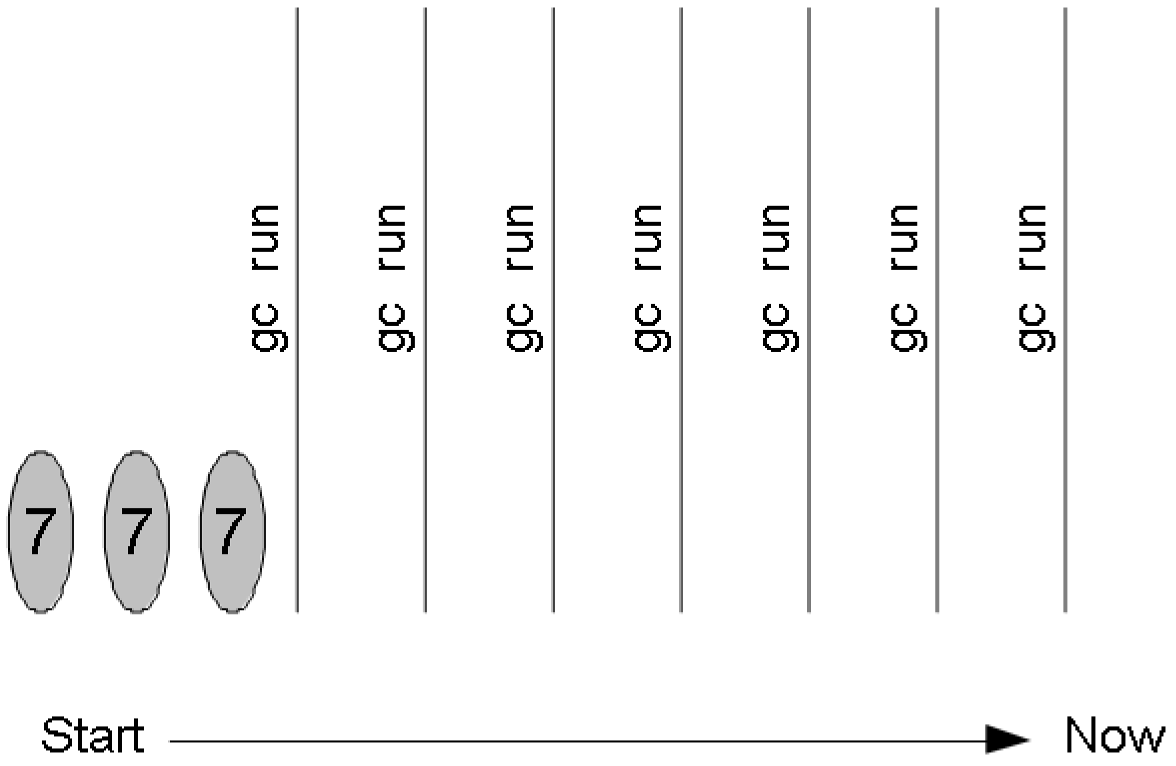
- **The foreground code always removed its entries from the HashMap. The background code *never* removed its entries.**



🟥 : AnalysisResult allocated by the background process

How Does “Generation Count” Help?

- **One Example of Healthy Behavior:**



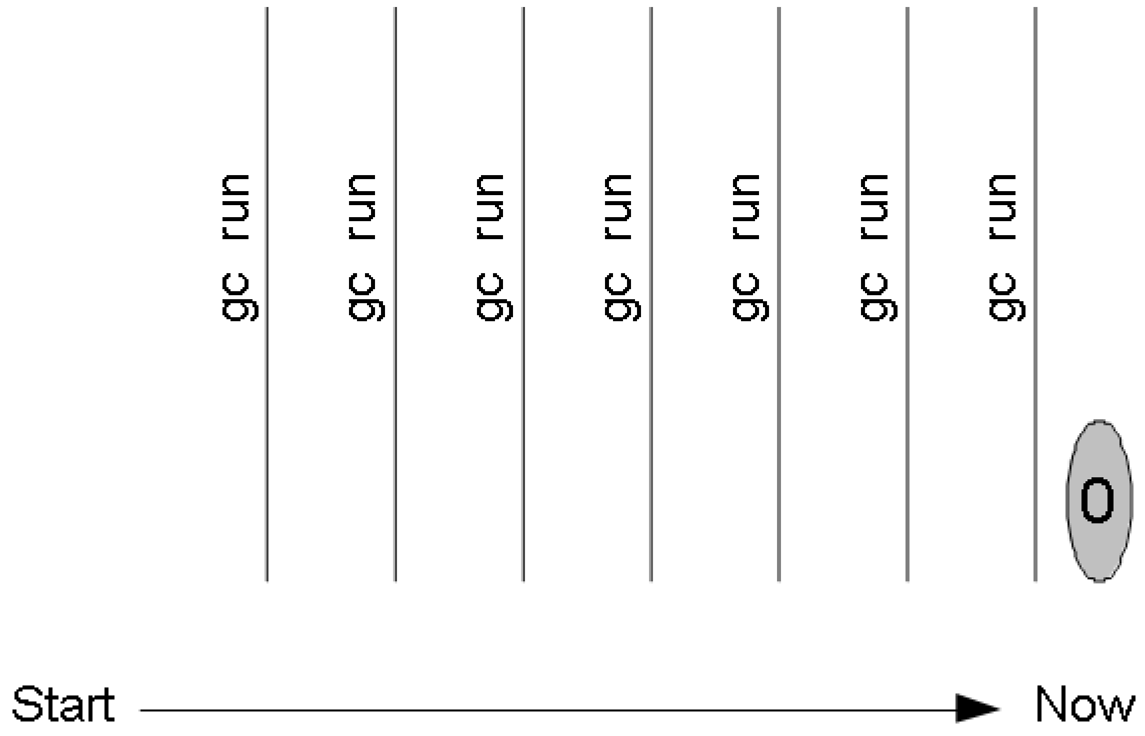
Long-lived objects.

Example: Three object instances created at startup.

Their ages continue to increase, but generation count remains stable (at 1)

How Does “Generation Count” Help?

- **Another Example of Healthy Behavior:**



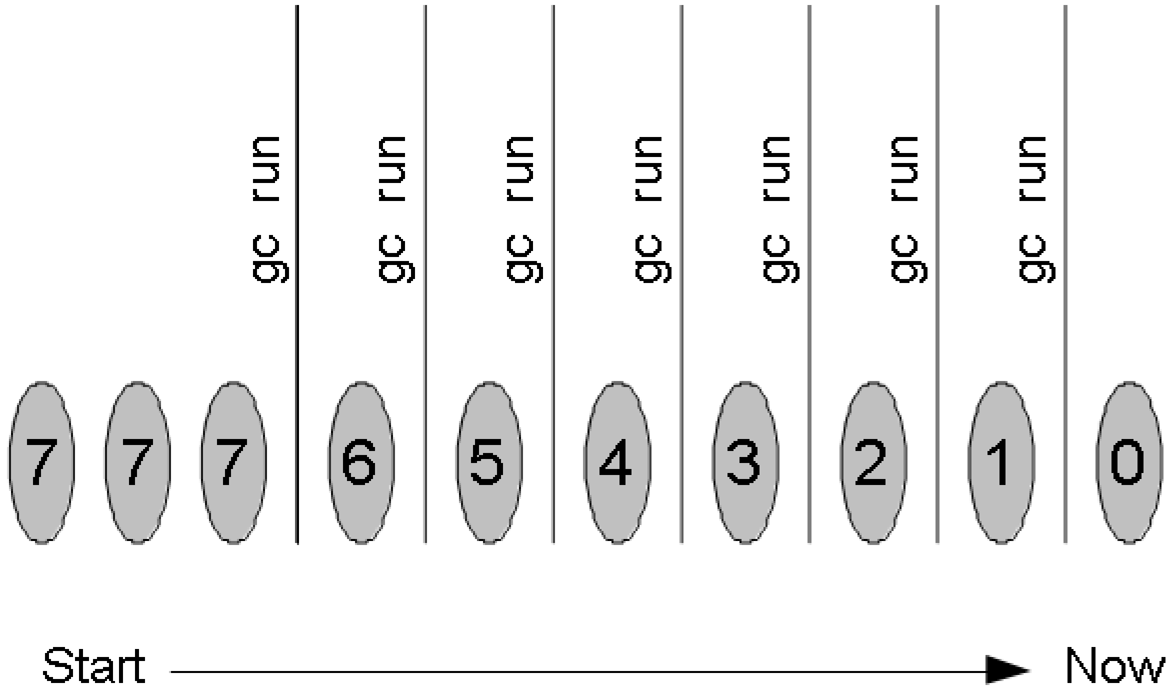
Short-lived objects

Example: Create an object, use it and then immediately let go of all references to it.

Generation count remains stable (at 1)

How Does “Generation Count” Help?

- **Unhealthy Behavior (a Memory Leak):**



Example: Continue to allocate objects without letting go of all references.

Ten objects with eight ***different*** ages.

Generation count is ***always increasing***.

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- **Lessons Learned**
- An Additional Problem...
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Lessons Learned

- Plenty of good, free tools available that provide a high-level view of the memory used by a Java application
- Beyond that, there are two broad categories:
  - Inspecting the Heap
  - Instrumentation

Lessons Learned (continued)

Inspecting the Heap	Instrumentation
•Strengths: •Less impact on performance •Easy to see relationships between objects •Weaknesses: •No information about how the objects got onto the heap – or whether they should still be there •Large heap size can lead to information overload •Can be tough to use if you don't know the code	•Strengths: •Identifies objects that are candidate memory leaks •Does not require as much knowledge of the code •Scales well •Weaknesses: •Introduces runtime overhead •Does not show relationships between the objects

Agenda

- What's the Problem?
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- Walking the Heap
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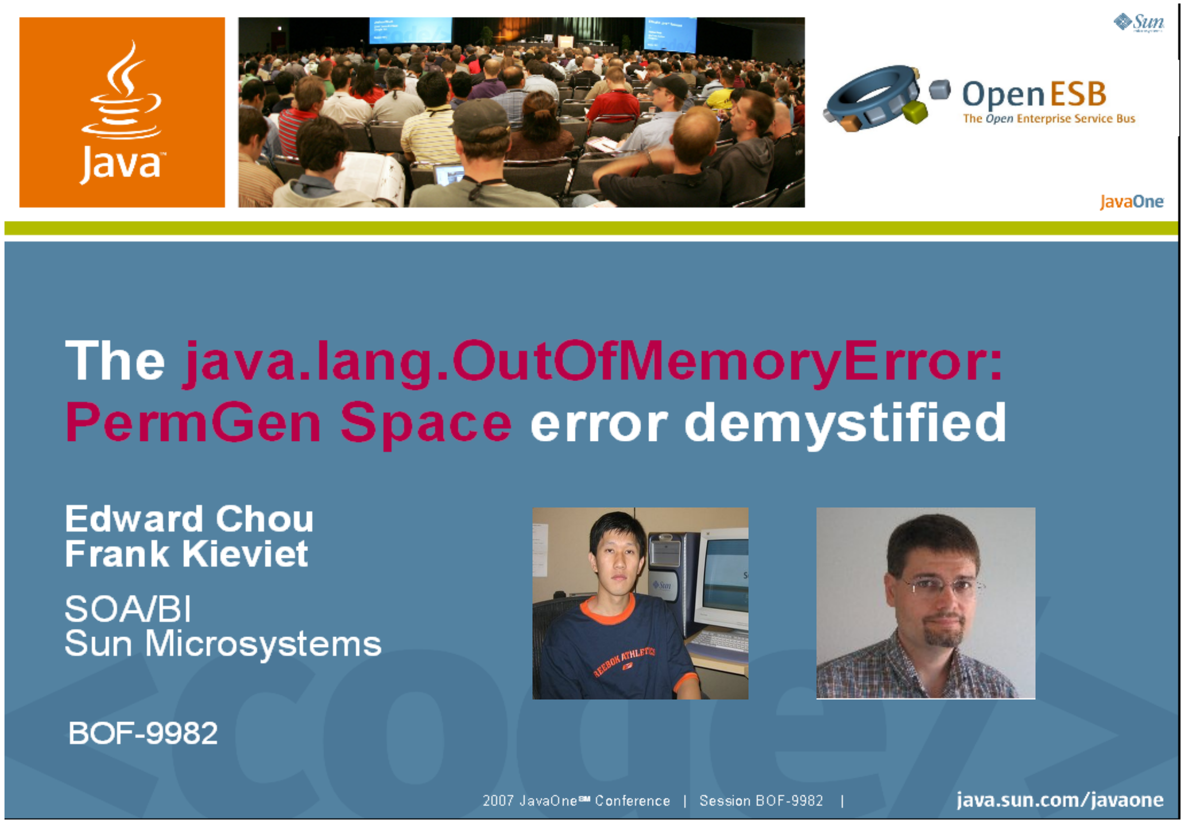
Have You Ever Seen This?

```
Exception in thread "main" java.lang.OutOfMemoryError: PermGen full
```

These Guys Have....



The java.lang.OutOfMemoryError: PermGen Space error demystified

Edward Chou
Frank Kieviet

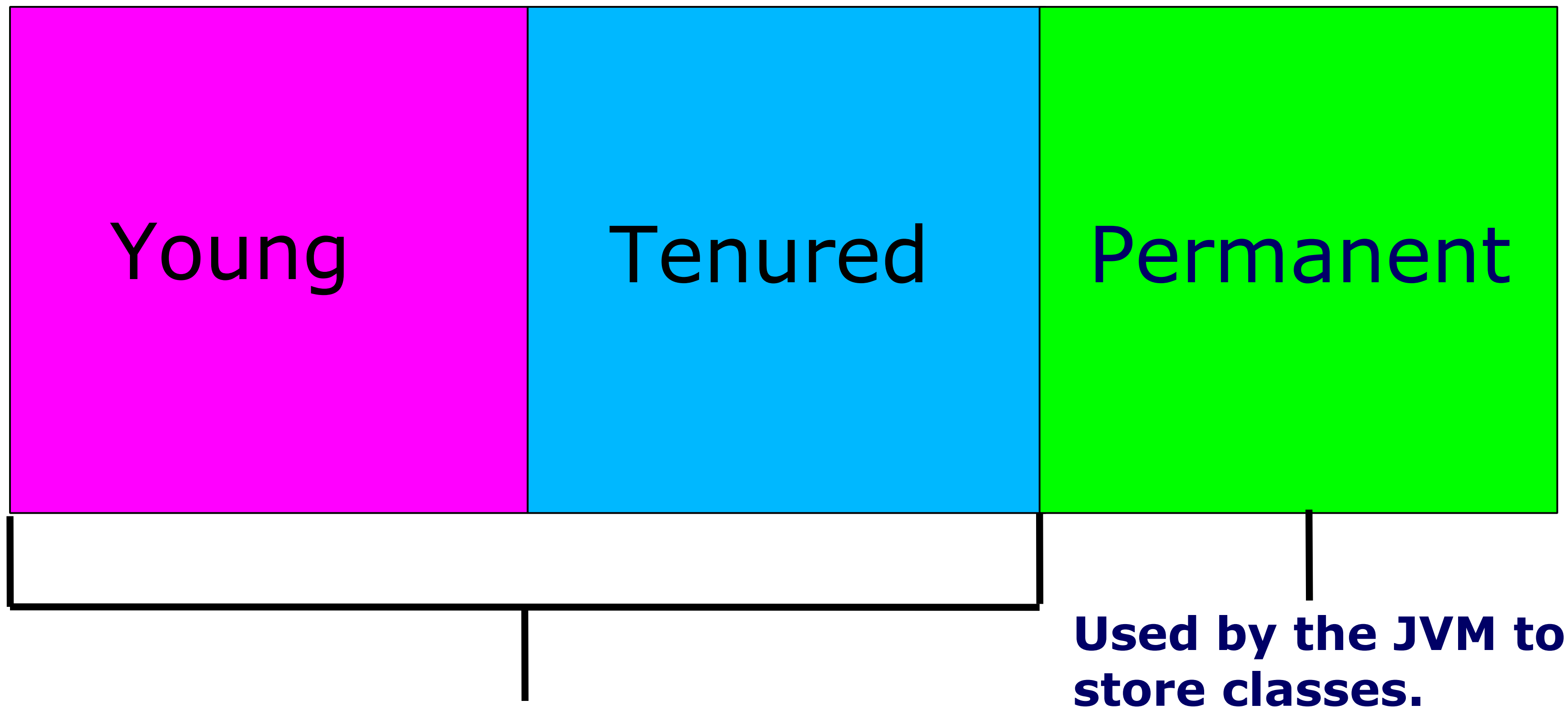
SOA/BI
Sun Microsystems

BOF-9982

Java
Sun
OpenESB
The Open Enterprise Service Bus
JavaOne
2007 JavaOne℠ Conference | Session BOF-9982 |
java.sun.com/javaone

http://blogs.sun.com/fkieviet/entry/javaone_2007
http://blogs.sun.com/edwardchou/entry/javaone_bof_on_memory_leaks

The basics: heap memory generations

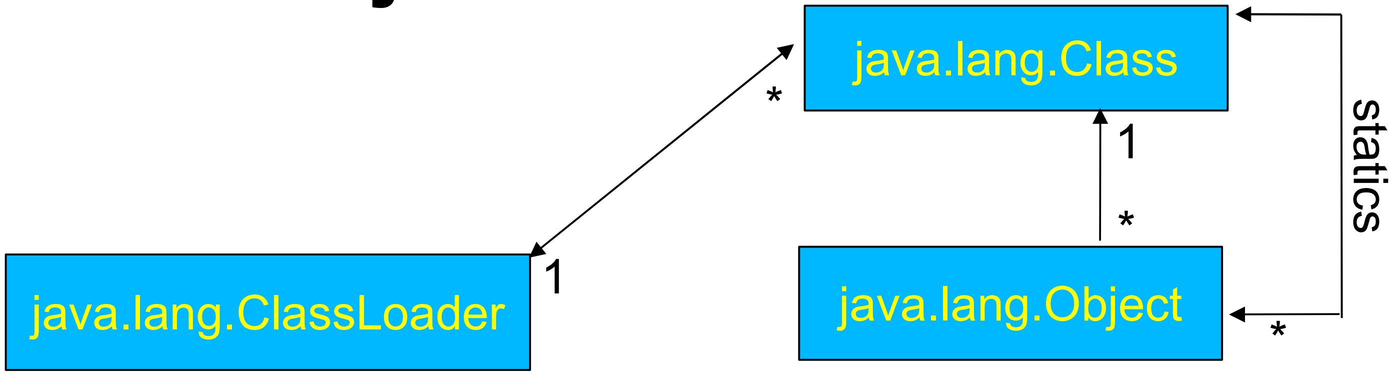


Usually referred to as "the heap." Controlled by -Xmx and -Xms

Used by the JVM to store classes. Controlled by -XX: MaxPermSize and -XX:PermSize

The basics: classes and classloaders

- Each object is an instance of a class
- A class itself is an object (class object)
  - instance of the class `Class`
- Each class object references its classloader
- A classloader references all classes it loaded
- Class objects hold static members



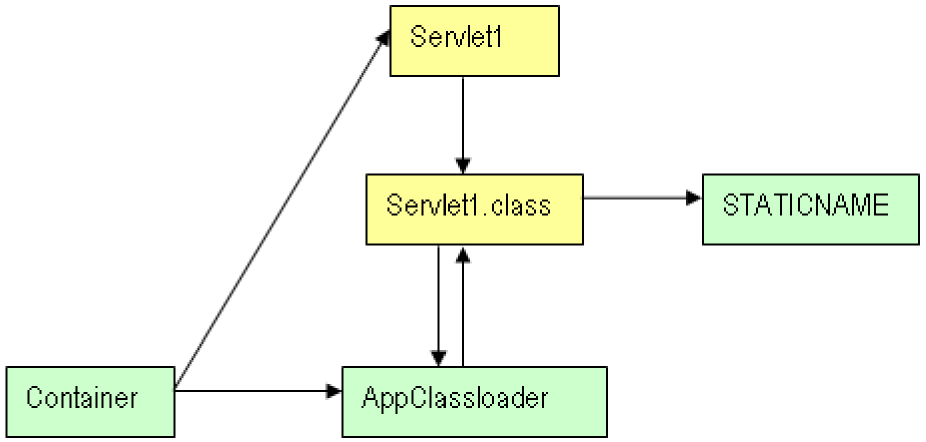
Why use classloaders?

- **Containers use classloaders to**
  - **dynamically load applications**
  - **isolate applications from each other**
  - **dynamically unload applications**

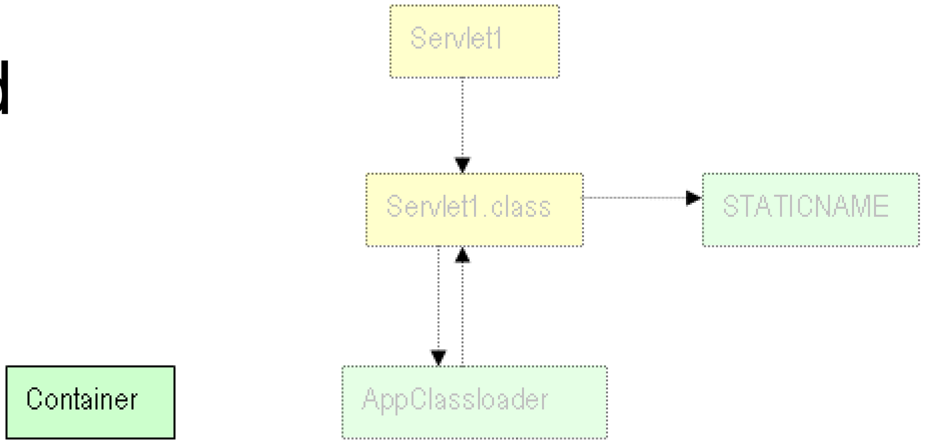
Example: empty servlet

```
package com.stc.test;

import java.io.*;
import java.net.*;
import javax.servlet.*;
import javax.servlet.http.*;

public class Servlet1 extends HttpServlet {
  private static final String STATICNAME = "Simple";
  protected void doGet(HttpServletRequest request,
      HttpServletResponse response)
      throws ServletException, IOException {
    // nothing
  }
}
```

Deployed



Undeployed



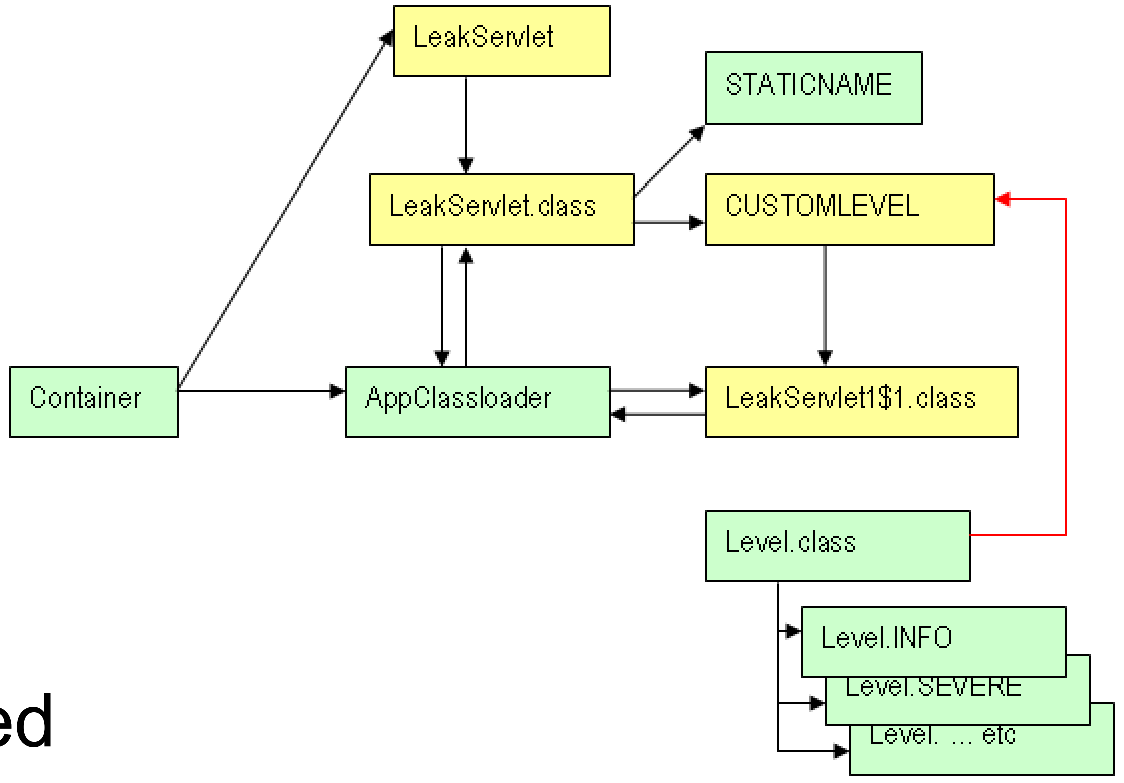
Classloader leaks

- **A classloader cannot be garbage collected if any of the instances of any of the classes it loaded are *reachable*.**

- **Such a classloader keeps *all* its classes with all their static members in memory.**
  - **Not immediately apparent from a memory dump what is a leak and what is not.**
  - **Cause of the leak difficult to find.**

Example: a leaking servlet

```
package com.stc.test;

import java.io.*;
import java.util.logging.*;
import javax.servlet.*;
import javax.servlet.http.*;

public class LeakServlet extends HttpServlet {
  private static final String STATICNAME = "Leak!";
  static Level CUSTOMLEVEL = new Level("OOPS", 555) {};
  protected void doGet(HttpServletRequest request,
     HttpServletResponse response)
     throws ServletException, IOException {
  // Log at a custom level
  Logger.getLogger("test").log(CUSTOMLEVEL, "x called");
 }
}
```

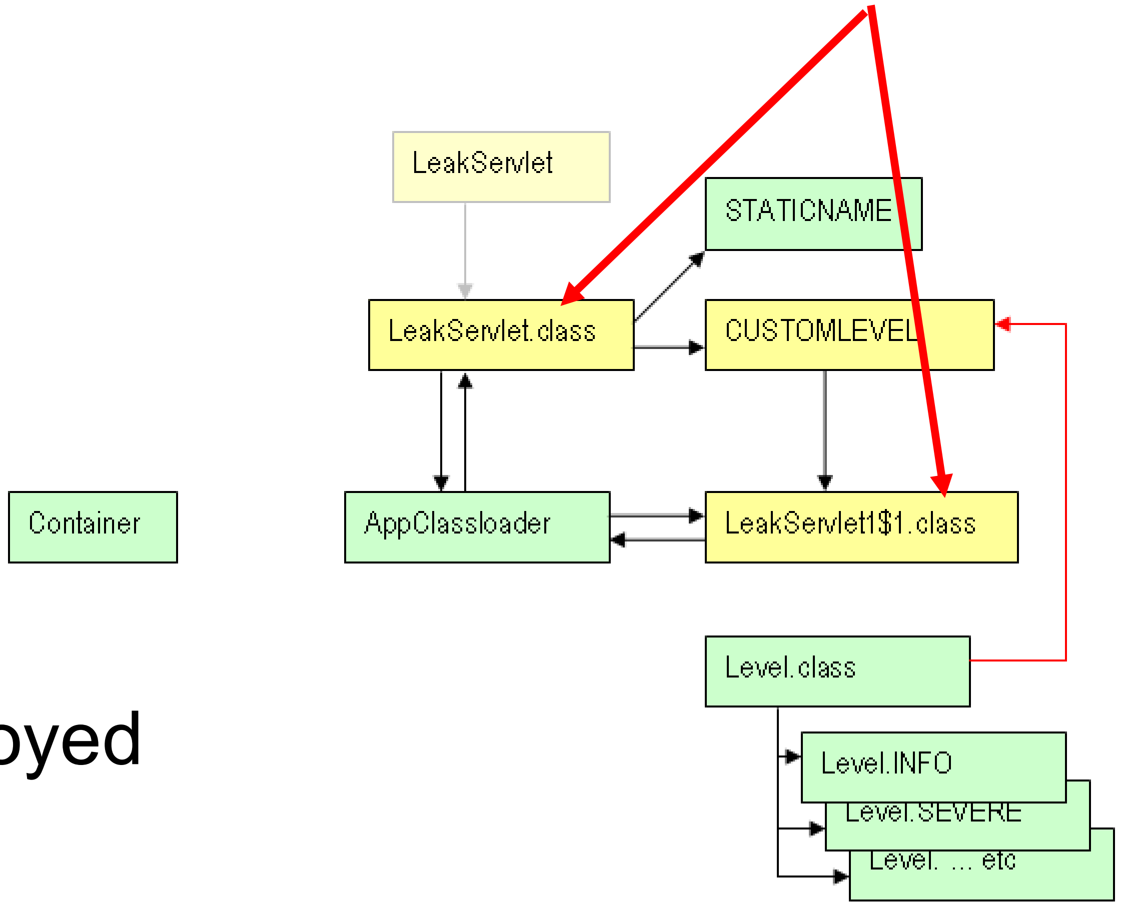

LeakServlet
STATICNAME
LeakServlet.class
CUSTOMLEVEL
Container
AppClassloader
LeakServlet1$1.class
Level.class
Level.INFO
Level.SEVERE
Level. ... etc

Deployed

java.util.logging.Level class

```
private static List known = new ArrayList();

protected Level(String name, int value) {
  this.name = name;
  this.value = value;
  synchronized (Level.class) {
    known.add(this);
  }
}
```

A Leak... These 2 are taking up space in PermGen



Undeployed

Reality:

- **Hundreds or *Thousands* of leaked classes**
- **Thousands of leaked objects**
- **Bafflement…**

Java Profilers

- **Take memory snapshots**
- **Find reference chains to root objects**
- **Most see class objects as root objects – so they are not very helpful**

DEMO

Inspecting the Heap With jhat

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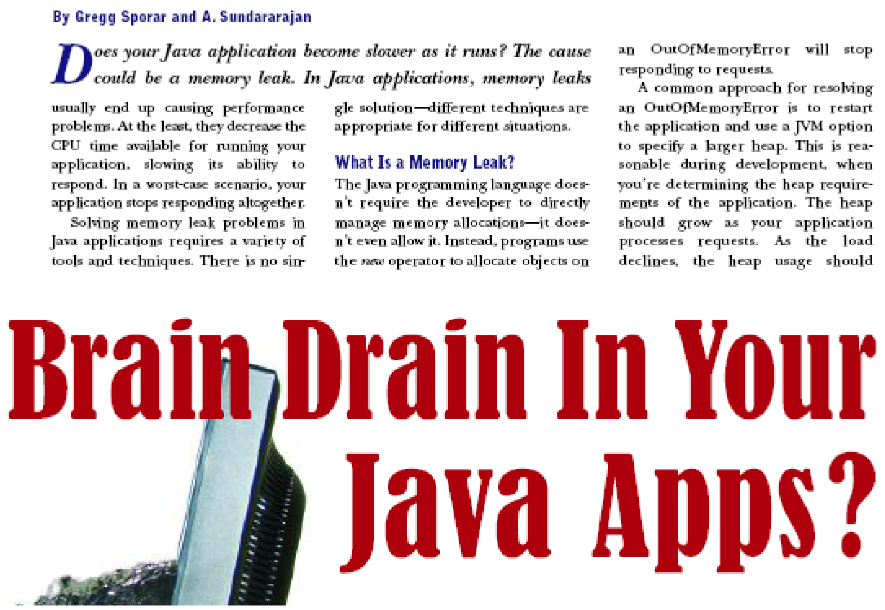
Resources

Software Test & Performance

April, 2007 issue



By Gregg Sporar and A. Sundararajan

Does your Java application become slower as it runs? The cause could be a memory leak. In Java applications, memory leaks usually end up causing performance problems. At the least, they decrease the CPU time available for running your application, slowing its ability to respond. In a worst-case scenario, your application stops responding altogether.

Solving memory leak problems in Java applications requires a variety of tools and techniques. There is no single solution—different techniques are appropriate for different situations.

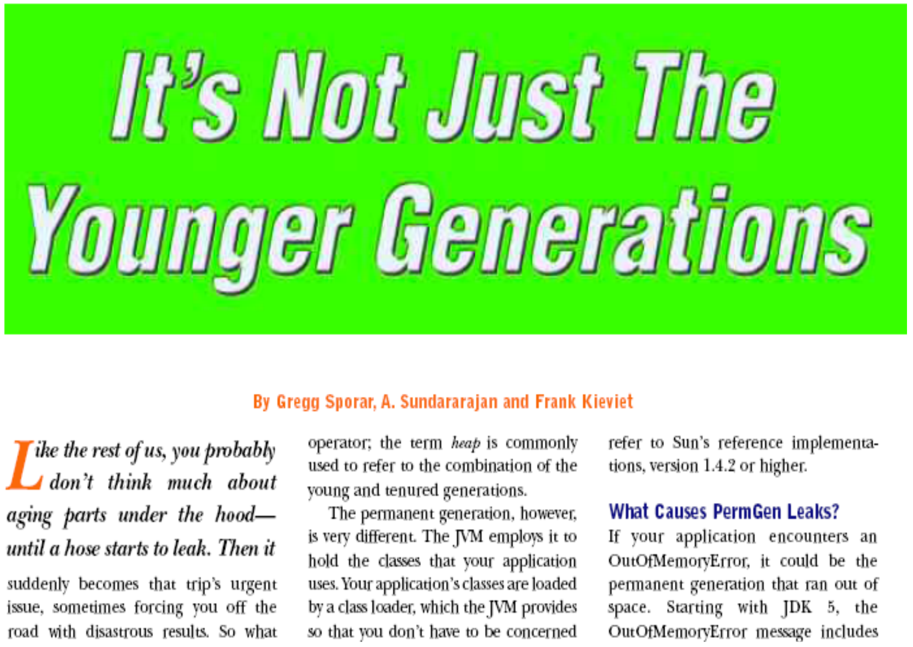
What Is a Memory Leak?

The Java programming language doesn't require the developer to directly manage memory allocations—it doesn't even allow it. Instead, programs use the *new* operator to allocate objects on an OutOfMemoryError will stop responding to requests.

A common approach for resolving an OutOfMemoryError is to restart the application and use a JVM option to specify a larger heap. This is reasonable during development, when you're determining the heap requirements of the application. The heap should grow as your application processes requests. As the load declines, the heap usage should

Brain Drain In Your Java Apps?

May, 2007 issue



It's Not Just The Younger Generations

By Gregg Sporar, A. Sundararajan and Frank Kieviet

Like the rest of us, you probably don't think much about aging parts under the hood—until a hose starts to leak. Then it suddenly becomes that trip's urgent issue, sometimes forcing you off the road with disastrous results. So what operator; the term *heap* is commonly used to refer to the combination of the young and tenured generations.

The permanent generation, however, is very different. The JVM employs it to hold the classes that your application uses. Your application's classes are loaded by a class loader, which the JVM provides so that you don't have to be concerned refer to Sun's reference implementations, version 1.4.2 or higher.

What Causes PermGen Leaks?

If your application encounters an OutOfMemoryError, it could be the permanent generation that ran out of space. Starting with JDK 5, the OutOfMemoryError message includes

Both available at http://www.stpmag.com/

Q & A

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