INSANE: Java Application Heap Postmortem Analysis In Practice

Radim Kubacki
Tonda Nebuzelsky

Sun Microsystems - NetBeans
http://performance.netbeans.org
BOF 9195

Goal of The Talk

Learn specifics of memory footprint in Java and learn how to analyze Java heap of an application using INSANE tool

Presentation Agenda

- Specifics of memory footprint in Java
- INSANE – powerful heap analysis tool
- Searching heap for suspicious patterns
- Searching for memory leaks, DEMO
- Using INSANE in tests
- Q&A

Presentation Agenda

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Measuring memory footprint

Overview

- footprint
  - virtual size (VSZ) – mem allocated from available space
    - `pmap` on Linux shows the memory consumers for a process
    - `jmap` shows mapping of shared objects (libs) for the process
  - resident size (RSS) – blocks paged in physical memory
    - pages can be shared between processes
    - sum of all RSS can be greater than total used RAM
- examples (on Linux w/ JDK 5)
    - RSS starting at 22 MB for simple Java GUI app, with VSZ around 250 MB
    - typical NetBeans resident size is 120-250 MB, with VSZ around 650MB

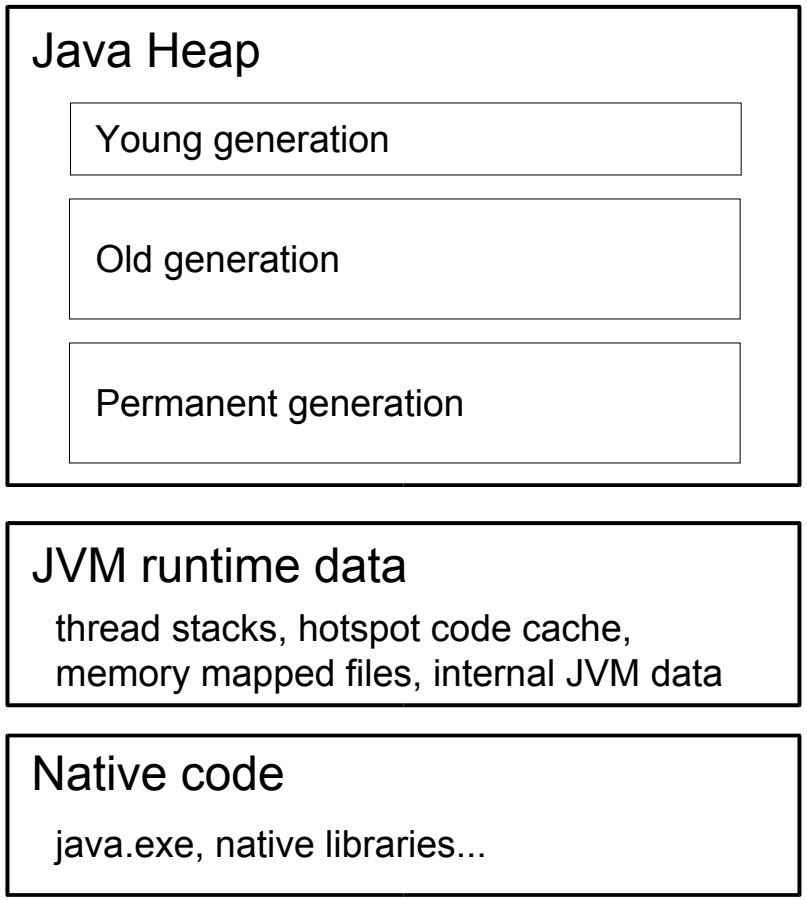
Specifics of memory footprint in Java

Overview

- Native code – java.exe, native libraries
- JVM runtime data
  - thread stacks
  - hotspot code cache
  - memory mapped files
  - internal data
- Java Heap: young+old generations, perm gen.
  - -Xms4m -Xmx64m
    - -Xmn (-XX:NewSize -XX:MaxNewSize)
    - -XX:NewRatio (new/old), -XX:SurvivorRatio (eden/surv)
  - -XX:PermSize=8m -XX:MaxPermSize=64m

Specifics of memory footprint in Java

The picture



Java specific implications

Specifics

- footprint of Java application is usually bigger than with native application
- severe consequences of memory swapping (unfriendly to GC - bad locality of objects)
  - keep size of heap reasonable, don't oversize it
  - be aware that application minimize can provoke so called “working set trimming” – especially on Windows – which will in return affect UI responsiveness at application restore time
  - non-compacting GC algorithms behave worse than the default compacting ones

Classes

Overview

- Class metadata occupy major part of permanent generation area
- Simple GUI app loads >1500 classes
- Tracking
  - `jstat -class`
  - `java -verbose:class`
- Possible improvements
  - exclude debug info (up to -15% of class file size)
  - obfuscation – common practice in J2ME world
  - write less code – reuse, eliminate dead code

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INSANE – Heap Analysis Tool

Overview

- Requirements
  - Simple enhancing of your application
  - No application runtime overhead
- Writing the information into XML file
- Postmortem analysis of the heap dump
  - Performing queries and computing stats from the dump
- Invoking INSANE methods from tests
  - to find out / verify a structure size
  - to check for unexpected outgoing references

INSANE – Heap Analysis Tool

How it works

- tracing
  - single tracing engine – BFS
  - reflection to find reference fields
  - filtering out INSANE's own objects and weak references
  - reports found objects and references for direct processing or to be stored in a dump
- finding roots
  - no JVM support
  - static, ~~native~~ and ~~stack~~ references
    - stack references are rare in an idle application
  - system classes, user classes from ClassLoader

Example of INSANE dump format

```
<insane>
...
<object id='1040' type='java.lang.String' size='24'/>
<ref to='1040' name='sun.misc.URLClassPath.USER_AGENT_
  JAVA_VERSION'/>
...
<object id='16fa' type='[C' size='48' value='UA-Java-
Version'/>
<ref from='1040' to='16fa' name='java.lang.String.value' />
...
</insane>
```

```
static String USER_AGENT_JAVA_VERSION = "UA-Java-Version";
```

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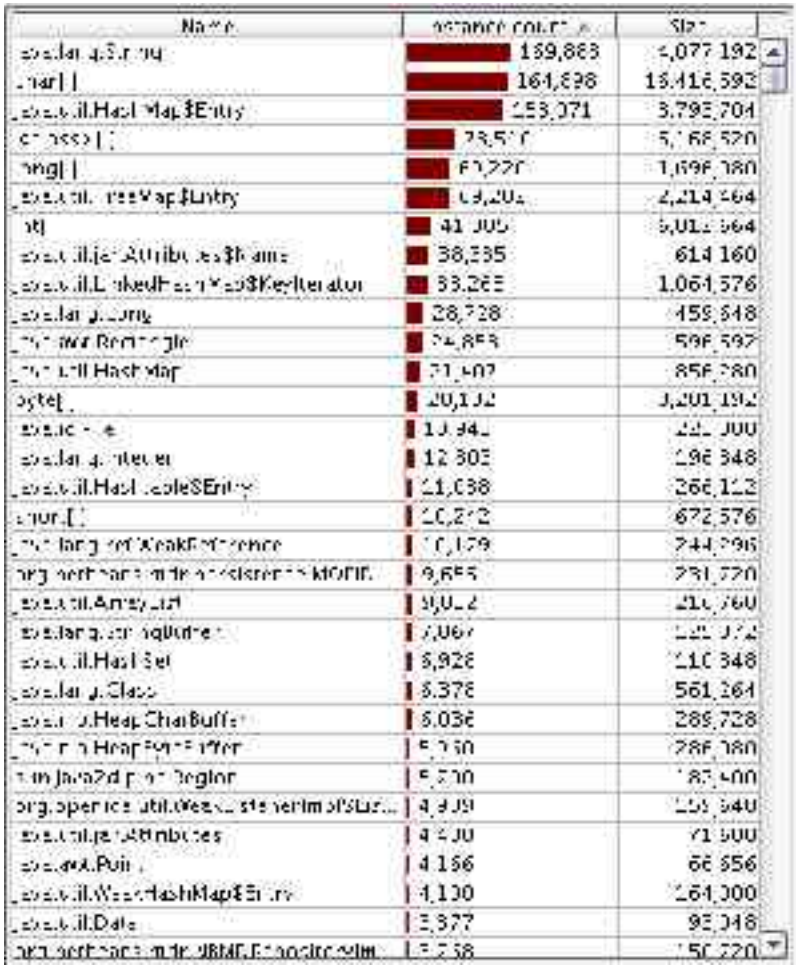
Searching for suspicious patterns

Distribution of objects

- Most frequent objects on heap
  - char[], String
  - collections
  - arrays
- Overall count of objects and their sizes does not tell us enough
- Complex data structures need to be evaluated and categorized



Searching for suspicious patterns

Part 1 – java.lang.String

- java.lang.String
  - 24 bytes (instance) + 12 bytes (arr. header) + 2*length
- patterns
  - many duplicate Strings on heap
    - `egrep '\[C' | cut -d\' -f8 | sort | uniq -c`
    - implement String pool or use `String.intern()`
  - substrings which hold the original large char[] in memory
    - result of `String.substring()` call
    - should be replaced with `new String()`
  - strings used unnecessarily as HashMap keys
    - use another data structure than String with good `hashCode()`

Searching for suspicious patterns

Part 2 - java.util.HashMap

- java.util.HashMap
  - 40 bytes (instance) + 12 bytes + 4*capacity + 24*size
  - 120 bytes for empty HashMap
- patterns
  - many unused empty hash maps on heap
  - wrongly sized hash maps
  - hash maps with bad distribution of entries, effectively collapsed to a linked list

Searching for suspicious patterns

Part 2 - java.util.HashMap

```
Model model = Support.parseXmlFile("insane-dump.xml");

Collection maps = model.getObjectsOfType
   ("java.util.HashMap");

for (Iterator it = maps.iterator(); it.hasNext(); ) {
    Item itm = (Item)it.next();
    Set reachable = reachableFrom(itm);
    if (reachable.size() <= 2) {
        // the map does not contains any entry
        // and print their root reference chains
        Support.findRoots(model, itm, false);
     }
}
```

Searching for suspicious patterns

Part 3 - other

- listeners
  - multiply registered
    - repeatedly added but never removed
    - causes performance overhead
  - leaking
    - too many listeners kept by one `PropertyChangeSupport`

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DEMO

INSANE

Searching for memory leaks

Overview

```
public class MyDialog extends JDialog
    implements PropertyChangeListener {

    public MyDialog () {
       LogManager.getLogManager().
       addPropertyChangeListener(this);
       ...

    public void propertyChange(PropertyChangeEvent evt) {
    ...
```

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Using INSANE in regression tests

Overview

- assertGC (String msg, WeakReference ref)

```
Object obj = ...;
WeakReference ref = new WeakReference (obj);
doSomething();
obj = null;
assertGC ("The object can be released", ref);
```

- assertSize (String msg, long size, Object obj)

```
class Data {
  int value;
}
Object measure = new Data();
assertSize ("The object is small", 16, measure);
```

Using INSANE in regression tests

Test output

```
Testcase: testLeak(leakdemo.MyDialogTest):  FAILED

junit.framework.AssertionFailedError: Dialog should be relased:

private static java.util.logging.LogManager
   java.util.logging.LogManager.manager->

java.util.logging.LogManager@1b994de->

java.beans.PropertyChangeSupport@11c19e6->

sun.awt.EventListenerAggregate@9e0c2d->

[Ljava.beans.PropertyChangeListener;@b524aa->

leakdemo.MyDialog@14d3343

        at org.netbeans.junit.NbTestCase.assertGC
   (NbTestCase.java:900)

        at leakdemo.MyDialogTest.testLeak(MyDialogTest.java:32)

        ...
```

For More Information

- Radim.Kubacki@sun.com
  Antonin.Nebuzelsky@sun.com
- http://performance.netbeans.org/insane
- http://openide.netbeans.org/tutorial/test-patterns.html
- BOF-9956 - Using the Tools in JDK 5.0 to Diagnose Problems and Monitor Applications
- BOF-9937 – Six Ways to Meet OutOfMemoryError

Q&A

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