Java™ 2 Platform, Standard Edition 5.0

Troubleshooting and Diagnostic Guide

This distribution may include materials developed by third parties.

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Preface

About this Document

This document is a guide to help troubleshoot problems that might arise with applications that are developed using the Sun Microsystems Inc. release of Java™ 2 Platform, Standard Edition Development Kit 5.0 (JDK™ 5.0 release or J2SE 5.0 release). The document provides a description of the tools, command line options, and other items that can be used when analyzing a problem. The document also provides guidance on how to approach some general issues such as a crash, hang, or memory resource issues. Finally the document provides direction for the data collection and the process to follow when preparing a bug report or support call.

This present document addresses possible problems between the application and the Java HotSpot™ virtual machine. For help in troubleshooting applications that use the Java SE desktop technologies (for example, AWT, Java 2D, Swing, and others), see the Troubleshooting Guide for Java SE 6 Desktop Technologies, which applies to both releases 5.0 and 6 of Java SE:

PDF: http://java.sun.com/javase/6/webnotes/trouble/TSG-Desktop/TSG-Desktop.pdf

HTML: http://java.sun.com/javase/6/webnotes/trouble/TSG-Desktop/html/toc.html

Target Audience and Prerequisites

The target audience for this document is both developers who are working with J2SE 5.0 and support or administration persons who maintain applications that are deployed with J2SE 5.0. In both cases the document assumes some prerequisite knowledge. Readers should have at least a high-level understanding of the components of the Java Virtual Machine and also have some understanding of concepts such as garbage collection, threads, native libraries, and so on. In addition, it is assumed that the reader is reasonably proficient on the operating system where the J2SE application is installed.

Structure of this Document

This document is structured into three chapters:

Chapter 1 describes the command line utilities, options, and log files available in J2SE 5.0. Many of the utilities are new in 5.0 and were not available in earlier releases. It also provides a list of the operating system tools and utilities that may be used in conjunction with the J2SE utilities and options. Readers should peruse this chapter to get acquainted with the capabilities of the utilities and options that are available.

Chapter 2 deals with issues of memory leaks, crashes, hangs, and applications that use signal handlers. The chapter includes a detailed descripion of the fatal error log and suggestions on things to try when you encounter a problem.

Chapter 3 provides guidance on how to submit a bug report. It includes suggestions on what to try before submitting a report and suggestions on what data to collect for the report.

Document History

Version Date	*Changes*
September 30, 2004	JDK5.0
April 2006	Corrections to Signal Handling section
October 2006	Correction to example output of using jdb to attach to a process
December 2006	Updated directory name in example to improve formatting
August 2007	Added links to Troubleshooting Guide for Java SE 6 Desktop Technologies. Now using new Feedback form in place of visible email address. Updated links from SDN Support site to SDN Services site. Minor corrections.
September 2007	Added 3 new options: `HeapDumpOnOutOfMemoryError`, `HeapDumpPath`, `HeapDumpOnCtrlBreak`.

Feedback and Suggestions

Troubleshooting is a very important topic. If you have feedback on this document or if you have suggestions for topics that could be covered in a future version, use the Feedback Form (http://developers.sun.com/contact/feedback.jsp?category=javase). Fill in the relevant fields and click Send.

Note: Do not use this feedback form for support requests: they will not be answered. Technical support is provided at the Services site for Sun Developer Network (http://developers.sun.com/services).

Limitations of this Document

The initial version of this document is focused on providing information about the tools and options available for diagnostics and monitoring. It does not include information on garbage collection or diagnosing performance issues at this time.

Other Resources

In addition to this document the reader should be aware of other online troubleshooting resources.

For help in troubleshooting applications that use the Java SE desktop technologies (for example, AWT, Java 2D, Swing, and others), see the Troubleshooting Guide for Java SE 6 Desktop Technologies, which applies to both releases 5.0 and 6 of Java SE:

PDF: http://java.sun.com/javase/6/webnotes/trouble/TSG-Desktop/TSG-Desktop.pdf

HTML: http://java.sun.com/javase/6/webnotes/trouble/TSG-Desktop/html/index.html

The Garbage Collection Tuning document for J2SE 5.0 can be found here:

http://java.sun.com/docs/hotspot/gc5.0/gc_tuning_5.html

The J2SE 5.0 Installation Notes for the Microsoft Windows platform provides tips to work around issues that can arises during or following installation:

http://java.sun.com/j2se/1.5.0/install-windows.html#troubleshooting

The Java Plugin Guide provides a troubleshooting FAQ and in addition provides information on how to enable tracing when trying to diagnose issues with the Java Plugin:

http://java.sun.com/j2se/1.5.0/docs/guide/plugin/developer_guide/contents.html

The Java Web Start FAQ has a troubleshooting section dealing with issues that might arise with Java Web Start:

http://java.sun.com/products/javawebstart/faq.html

The bug database can be a useful resource to search for problems and solutions. The bug database can be found at:
http://developer.java.sun.com/developer/bugParade/index.jshtml

Commercial Support

Sun provides a wide range of support offerings, from developer technical support for software developers using Sun development products or technologies, to support for production systems in enterprise environments. Two support options are summarized here:

1. Developer Technical Support

This is development time support aimed at developers who are using Sun development products or technologies, and are working at the source code level of their own applications.

Email and telephone support is available. Single incident, multiple incident, and yearly support options are available. The type of support provided by the Developer Technical Support offering includes responding to technical questions, providing diagnostic/troubleshooting help, suggesting best practices, and bug escalation.

More details on this support offering can be found at the Services site for Sun Developer Network (http://developers.sun.com/services).

2. Java Multiplatform Support offering

This support offering is designed to provide production support for shipping releases of Java technology-based applications using Sun's Java 2 Runtime Environments and distributed to end users in heterogeneous environments. The support offering helps on optimizing application performance and helps reduce time spent keeping applications up and running.

The highest level of this support offering can include accelerated access to an engineer and emergency software fixes.

More details on this support offering are available here :http://www.sun.com/service/sunps/jdc/javamultiplatform.html

Community Support

Community support can often be obtained using the Java Technology Forums. The forums provide a way to share information and locate solutions to problems. The forums are here: http://forums.java.sun.com

1 Diagnostics Tools and Options

1.1 Introduction

This chapter introduces the various diagnostic and monitoring tools which can be used with J2SE 5.0. The tools described here include command line utilities, command line options, and log files.

In almost all cases the command line utilities described in this chapter are either included in the Java 2 Platform Standard Edition Development Kit (JDK 5.0), or are operating system tools and utilities. Although the JDK 5.0 command line utilities are included in the JDK download, it is important to note that they can be used to diagnose issues and monitor applications that are deployed with the Java 2 Platform Standard Edition Runtime Environment 5.0 (JRE 5.0).

In general, the diagnostic tools and options described in this chapter use various mechanisms to obtain the information they report. In many cases the mechanisms are specific to the virtual machine implementation (5.0 in the case of this document), operating system, and version of each. Consequently, there is some overlap of the information reported by some of the tools. This should be viewed in the context of the various problems and issues for which these tools are intended. In many cases only a subset of the tools will be applicable to an issue at a particular point in time.

1.1.1 Caveats and Other Notes

Some of the command line utilities described in this chapter are *experimental*. The `jstack`, `jinfo`, and `jmap` utilities are examples of utilities that are experimental. These utilities are subject to change in future JDK releases, and may not be included in future releases.

The format of log files and other output from command line utilities or options is version specific. For example, if you develop a script that relies on the format of the fatal error log (`hs_err_pid<`*`pid`*`>.log` file) then this script may cease to work as expected if the format of the log file changes in the future.

Command line options that are prefixed with `-XX` are Java HotSpot™ Virtual Machine specific options. In general, most `-XX` options are unsupported, undocumented, and were originally included for the purposes of testing components of the HotSpot Virtual Machine during its development. However many `-XX` options are important for performance tuning and diagnostic purposes, and are therefore described in this chapter.

In some cases, the command tool utilities described here are not included in the JDK release on all operating systems. For example, the `jstack`, `jinfo`, and `jmap` command line utilities are included in the JDK release for Solaris and Linux only. In addition to operating system specific utilities we also describe a number of diagnostic features and tools that are specific to the Solaris 10 Operating Environment. Solaris 10 has many advanced diagnostic features that are usable in production environments, and many of the native tools are capable of providing information that is specific to the Java Runtime Environment.

1.1.2 Post-Mortem Diagnostics

A number of the options and tools described in this chapter are designed for post-mortem diagnostics. That is, if the application crashes because of an application or JRE bug, these are the options and tools that can be used to obtain additional information (either at the time of the crash or later using information from the crash dump).

Tool or Option	***Description and Usage***
Fatal Error Log	The fatal error log (`hs_err_<pid>.log`) contains a lot of information obtained at the time of the fatal error (crash). In many cases it will be the first thing to examine when a crash happens.
`-XX:OnError`	Used to specify a sequence of user-supplied scripts or commands to be executed when a fatal error (crash) occurs. For example, on Windows, it can be used to execute a command to force a crash dump – very useful on systems that do not have post-mortem debugger configured.
`-XX:+ShowMessageBoxOnError`	Used to suspend the process when a fatal error (crash) occurs. Depending on the user response it can launch the native debugger (`dbx`, `gdb`, `msdev`) to attach to the VM. The option is very useful in the development environment to attach the native debugger when a crash happens.
`jinfo` (Solaris and Linux only)	The `jinfo` utility can obtain configuration information from a core file obtained from a crash (or a core obtained using the gcore utility).
`jmap` (Solaris and Linux only)	The `jmap` utility can obtain memory map information, including a heap histogram, from a core file obtained from a crash (or a core obtained using the `gcore` utility).
`jstack` (Solaris and Linux only)	The `jstack` utility can obtain java and native stack information from a core file obtained from a crash (or a core obtained using the `gcore` utility).
`jdb` (Solaris and Linux only)	The debugger support in the JDK includes an AttachingConnector which allows jdb, and other Java Language debuggers to attach to a core file. This can be very useful when trying to understand what the application was doing at the time of the crash.
Native tools	Each operating system has native tools and utilities that can be used for post-mortem diagnosis. A list of native tools is provided later in this chapter.

1.1.3 Hung Processes

Some of the options and tools described in this chapter can help in scenarios involving a hung or deadlocked process. Tools in the following list do not require that the application be started with any special options.

Tool or Option	*Description and Usage*
Ctrl-Break Handler	Used to get thread dump information. It also executes a deadlock detection algorithm and will report any deadlocks detected involving synchronized code.
`jstack` (Solaris and Linux only)	The `jstack` utility can obtain java and native stack information from a running process even in cases where the ctrl-break handler does not respond.
`jdb` (Solaris and Linux only)	The debugger support in the JDK includes an AttachingConnector which allows `jdb`, and other Java Language debuggers to attach to a hung process. This can be useful when trying to understand what each thread is doing at the time of the hang/deadlock.
Native tools	Each operating system has native tools and utilities that can be useful in hang/deadlock scenarios. A list of native tools is provided later in this chapter.

1.1.4 Monitoring Tools

The following options and tools described in this chapter are designed for monitoring running applications.

Tool	*Description and Usage*
`jconsole`	The JDK includes a Java Management Extensions (JMX)-based monitoring tool called `jconsole`. The tool uses the built-in JMX instrumentation in the Java Virtual Machine to provide information on performance and resource consumption of running applications.
`jstat`	The `jstat` utility uses the built-in instrumentation in the HotSpot VM to provide information on performance and resource consumption of running applications. The tool can be used when diagnosing performance issues, and in particular issues related to heap sizing and garbage collection. The utility does not require that the application be started with any special options as instrumentation is enabled by default.
Native tools	Each operating system has native tools and utilities that can be useful for monitoring purposes. The dynamic tracing (dtrace) capability on Solaris 10 can do very advanced monitoring. A list of native tools is provided later in this chapter.

1.1.5 Other Tools and Options

In addition to the tools listed in the previous categories this chapter also describes a number of options and tools that can be useful to diagnose other issues :

Tool or Option	*Description and Usage*
HPROF Profiler	The HPROF profiler is a simple profiler included in the JDK. It is capable of presenting CPU usage, heap allocation statistics and monitor contention profiles. In addition it can also report complete heap dumps and states of all the monitors and threads in the Java virtual machine. In terms of diagnosing problems, HPROF can be useful when analyzing performance, lock contention, memory leaks, and other issues.
Heap Analysis Tool (HAT)	The Heap Analysis Tool (HAT) is not included in JDK 5.0 but it can be downloaded from the java.net site. It is a useful tool when diagnosing unnecessary object retention (or memory leaks). It can be used to browse an object dump, view all reachable objects in the heap, and understand which references are keeping an object alive.
Java Heap Analysis Tool (`jhat`)	The `jhat` utility provides several improvements over HAT. See section 1.12. It is delivered with Java SE 6 but can read heap dumps created on Java SE 5.0 systems.
`-XX:+HeapDumpOnOutOfMemoryError`	Used to generate a heap dump when the VM detects an OutOfMemoryError. (Introduced in Java SE 5.0 update 7.)
`-XX:+HeapDumpOnCtrlBreak`	Used to generate a heap dump with Ctrl-Break. (Introduced in Java SE 5.0 update 14.)
`-Xcheck:jni`	The `-Xcheck:jni` option is useful option when trying to diagnose problems with applications that use the Java Native Interface (JNI). This option can be be useful when an application employs third-party libraries (some JDBC drivers for example).

1.2 jinfo

The `jinfo` command-line utility gets configuration information from a running *java* process or crash dump. It is included in the Solaris and Linux releases of the JDK. It is not included in the JDK5.0 release on Windows.

`jinfo` prints the system properties or the command line flags that were used to start the VM. Following is an example to demonstrate the output:

```
$ jinfo 19846
Attaching to process ID 19846, please wait...
Debugger attached successfully.
Server compiler detected.
JVM version is 1.5.0-rc-b63
Java System Properties:

java.runtime.name = Java(TM) 2 Runtime Environment, Standard Edition
sun.boot.library.path =
/net/server/export/disk09/jdk/1.5.0/rc/b63/binaries/solsparc/jre/lib/sparc
java.vm.version = 1.5.0-rc-b63
java.vm.vendor = Sun Microsystems Inc.
java.vendor.url = http://java.sun.com/
path.separator = :
java.vm.name = Java HotSpot(TM) Server VM
file.encoding.pkg = sun.io
sun.os.patch.level = unknown
java.vm.specification.name = Java Virtual Machine Specification
user.dir = /space/user/jakarta-tomcat-5.0.12/bin
java.runtime.version = 1.5.0-rc-b63
java.awt.graphicsenv = sun.awt.X11GraphicsEnvironment
java.endorsed.dirs = /space/user/jakarta-tomcat-5.0.12/common/endorsed
os.arch = sparc
java.io.tmpdir = /space/user/jakarta-tomcat-5.0.12/temp
line.separator =
java.vm.specification.vendor = Sun Microsystems Inc.
java.naming.factory.url.pkgs = org.apache.naming
os.name = SunOS
sun.jnu.encoding = ISO646-US
java.library.path =
/net/server/export/disk09/jdk/1.5.0/rc/b63/binaries/solsparc/jre/lib/sparc/server
:/net/server/export/disk09/jdk/1.5.0/rc/b63/binaries/solsparc/jre/lib/sparc:/net/
server/export/disk09/jdk/1.5.0/rc/b63/binaries/solsparc/jre/../lib/sparc:/usr/lib
java.specification.name = Java Platform API Specification
java.class.version = 49.0
sun.management.compiler = HotSpot Server Compiler
os.version = 5.10
user.home = /home/user
catalina.useNaming = true
user.timezone = Asia/Calcutta
java.awt.printerjob = sun.print.PSPrinterJob
file.encoding = ISO646-US
java.specification.version = 1.5
catalina.home = /space/user/jakarta-tomcat-5.0.12
java.class.path =
/net/myserver/export1/user/j2sdk1.5.0/lib/tools.jar:/space/user/jakarta-tomcat-
5.0.12/bin/bootstrap.jar
```

```
user.name = user
java.naming.factory.initial = org.apache.naming.java.javaURLContextFactory
java.vm.specification.version = 1.0
java.home = /net/server/export/disk09/jdk/1.5.0/rc/b63/binaries/solsparc/jre
sun.arch.data.model = 32
user.language = en
java.specification.vendor = Sun Microsystems Inc.
java.vm.info = mixed mode
java.version = 1.5.0-rc
java.ext.dirs =
/net/server/export/disk09/jdk/1.5.0/rc/b63/binaries/solsparc/jre/lib/ext
sun.boot.class.path = /space/user/jakarta-tomcat-
5.0.12/common/endorsed/xercesImpl.jar:/space/user/jakarta-tomcat-
5.0.12/common/endorsed/xmlParserAPIs.jar:/net/server/export/disk09/jdk/1.5.0/rc/b
63/binaries/solsparc/jre/lib/rt.jar:/net/server/export/disk09/jdk/1.5.0/rc/b63/bi
naries/solsparc/jre/lib/i18n.jar:/net/server/export/disk09/jdk/1.5.0/rc/b63/binar
ies/solsparc/jre/lib/sunrsasign.jar:/net/server/export/disk09/jdk/1.5.0/rc/b63/bi
naries/solsparc/jre/lib/jsse.jar:/net/server/export/disk09/jdk/1.5.0/rc/b63/binar
ies/solsparc/jre/lib/jce.jar:/net/server/export/disk09/jdk/1.5.0/rc/b63/binaries/
solsparc/jre/lib/charsets.jar:/net/server/export/disk09/jdk/1.5.0/rc/b63/binaries
/solsparc/jre/classes
java.vendor = Sun Microsystems Inc.
catalina.base = /space/user/jakarta-tomcat-5.0.12
file.separator = /
java.vendor.url.bug = http://java.sun.com/cgi-bin/bugreport.cgi
sun.io.unicode.encoding = UnicodeBig
sun.cpu.endian = big
sun.cpu.isalist = sparcv9+vis2 sparcv9+vis sparcv9 sparcv8plus+vis sparcv8plus
sparcv8 sparcv8-fsmuld sparcv7 sparc

VM Flags:
-Djava.endorsed.dirs=/space/user/jakarta-tomcat-5.0.12/common/endorsed -Dcatalina
.base=/space/user/jakarta-tomcat-5.0.12 -Dcatalina.home=/space/user/jakarta-
tomcat-5.0.12 -Djava.io.tmpdir=/space/user/jakarta-tomcat-5.0.12/temp
```

The above example was based on a Jakarta Tomcat server. The "*VM Flags*" output shows that the server is using the endorsed override mechanism to override the implementation of some classes – this type of information is useful when, for example, an XML-related issue requires investigation.

The classpath and bootclasspath output can also be very useful for debugging class loader issues.

In addition to obtaining information from a process, the `jinfo` tool can use a core file as input. On Solaris, for example, we could use the `gcore` utility to get a core file of the Tomcat process in the above example. The core file will be named core.19846 and will be generated in the working directory of the process. The path to the *java* executable and the *core* file must be specified as arguments.

```
jinfo $JAVA_HOME/bin/java core.19846
```

(`JAVA_HOME` indicates the home directory of the JDK installation.)

Sometimes the binary name will not be "*java*". This arises when the VM is created using the JNI invocation API. The `jinfo` tool requires the binary from which the core file was generated.

For more information, the manual page for `jinfo` is available at:
http://java.sun.com/j2se/1.5.0/docs/tooldocs/share/jinfo.html

1.3 jmap

The `jmap` command-line utility is included in the Solaris and Linux releases of the JDK. It is not included in the JDK5.0 release on Windows. `jmap` prints memory related statistics for a running VM or core file. If `jmap` is used with a process or core file without any command line options then it prints the list of shared objects loaded (the output is similar to the Solaris `pmap` utility). For more specific information the `-heap`, `-histo`, or `-permstat` options can be used. These are described in the following sections.

1.3.1 Heap Configuration and Usage

The `-heap` option is used to obtain java heap information including:

1. GC algorithm specific information: This includes the name of the GC algorithm (Parallel GC for example) and algorithm specific details (such as number of threads for parallel GC).
2. Heap configuration: The heap configuration may have been specified as command line options or selected by the VM based on the machine configuration.
3. Heap usage summary: For each generation it prints the total capacity, in-use and available free memory. If a generation is organized as a collection of spaces (the new generation for example), then a space-wise memory size summary is included.

The following is example output from `jmap -heap`:

```
$ jmap -heap 19846
Attaching to process ID 19846, please wait...
Debugger attached successfully.

Server compiler detected.

JVM version is 1.5.0-rc-b63

using thread-local object allocation.
Parallel GC with 2 thread(s)

Heap Configuration:
   MinHeapFreeRatio = 40
   MaxHeapFreeRatio = 70
   MaxHeapSize      = 536870912 (512.0MB)
   NewSize          = 2228224 (2.125MB)
   MaxNewSize       = 4294901760 (4095.9375MB)
   OldSize          = 1441792 (1.375MB)
   NewRatio         = 2
   SurvivorRatio    = 32
   PermSize         = 16777216 (16.0MB)
   MaxPermSize      = 67108864 (64.0MB)

Heap Usage:
PS Young Generation
Eden Space:
   capacity = 9240576 (8.8125MB)
   used     = 9159544 (8.735221862792969MB)
   free     = 81032 (0.07727813720703125MB)
   99.12308496786348% used
From Space:
   capacity = 2555904 (2.4375MB)
```

```
   used     = 2431992 (2.3193283081054688MB)
   free     = 123912 (0.11817169189453125MB)
   95.1519305889423% used
To Space:
   capacity = 2686976 (2.5625MB)
   used     = 0 (0.0MB)
   free     = 2686976 (2.5625MB)
   0.0% used

PS Old Generation
   capacity = 25165824 (24.0MB)
   used     = 2426464 (2.314056396484375MB)
   free     = 22739360 (21.685943603515625MB)
   9.641901652018229% used

PS Perm Generation
   capacity = 16777216 (16.0MB)
   used     = 9523600 (9.082412719726562MB)
   free     = 7253616 (6.9175872802734375MB)
   56.765079498291016% used
```

1.3.2 Heap Histogram

The `-histo` option can be used to obtain a class-wise histogram of the heap. For each class, it prints the number of objects, memory size in bytes, and fully qualified class name. Note that internal classes in the HotSpot VM are prefixed with an "*". The histogram is useful when trying to understand how the heap is used. To get the size of an object you need to divide the total size by the count of that object type.

The following shows an example of `jmap -histo` output:

```
$ jmap -histo 19846
Attaching to process ID 19846, please wait...
Debugger attached successfully.
Server compiler detected.
JVM version is 1.5.0-rc-b63
Iterating over heap. This may take a while...
Object Histogram:

Size  Count Class description
-------------------------------------------------------
4473488     44525 char[]
2663464     21830 * ConstMethodKlass
1575128     21830 * MethodKlass
1297600     40550 java.util.HashMap$ValueIterator
1272064     34452 * SymbolKlass
1262664     52611 java.lang.String
1129928     2142  byte[]
1042984     1761  * ConstantPoolKlass
80235240186 org.apache.catalina.Container[]
6730721535  * ConstantPoolCacheKlass
6518321761  * InstanceKlassKlass
5524564326  int[]
3482404353  java.lang.reflect.Method
3189604430  org.apache.naming.resources.FileDirContext$FileResourceAttributes
```

```
2861363274  java.lang.Object[]
2321205815  java.lang.String[]
2178009075  java.util.HashMap$Entry
2020002005  java.util.HashMap$Entry[]
1760962393  short[]
1747681986  java.lang.Class
142808495   * MethodDataKlass
1393842771  java.lang.Object[]
1070246689  java.io.File
81336 3389  java.util.Hashtable$Entry
79080 1977  java.util.HashMap
70560 4410  java.lang.StringBuilder
66600 875   java.util.Hashtable$Entry[]
63400 3733  java.lang.Class[]
60032 1876  java.util.LinkedHashMap$Entry
56448 196   * ObjArrayKlassKlass
49608 2067  java.util.ArrayList
44832 1401  java.lang.ref.SoftReference
41408 1294  org.apache.xerces.dom.DeferredAttrImpl
38232 1593  java.lang.ref.WeakReference
37104 1546  java.io.ExpiringCache$Entry
35520 555   org.apache.commons.modeler.AttributeInfo
35008 2188  javax.management.modelmbean.DescriptorSupport$CaseIgnoreString
33880 847   java.util.Hashtable
31344 653   java.beans.MethodDescriptor
23160 222   java.lang.reflect.Method[]
22976 359   java.lang.reflect.Constructor
19952 325   javax.management.modelmbean.ModelMBeanAttributeInfo[]
19416 809   org.apache.xerces.xni.QName
18336 382   org.apache.xerces.dom.DeferredElementImpl
17280 720   java.util.Vector
17264 83    org.apache.catalina.core.StandardWrapper
16744 299   java.nio.DirectByteBuffer
14472 603   javax.management.ObjectName$Property
14400 450   org.apache.xerces.dom.DeferredTextImpl
13376 209   java.beans.PropertyDescriptor
11960 299   sun.misc.Cleaner
[... more lines removed here to reduce output ...]
8     1     sun.reflect.GeneratedMethodAccessor31
Heap traversal tool 7.12 seconds.
```

1.3.3 Getting Information on the Permanent Generation

The permanent generation is the area of heap that holds all the reflective data of the virtual machine itself, such as class and method objects (also called “method area” in The Java Virtual Machine Specification).

Configuring the size of the permanent generation can be important for applications that dynamically generate and load a very large number of classes (Java Server Pages/web containers for example). If an application loads “too many” classes then it is possible it will abort with an *OutOfMemoryError*. The specific error is: “*Exception in thread XXXX java.lang.OutOfMemoryError: PermGen space*” (See section 2.1.1 for a description of this and other reasons for *OutOfMemoryError.)*

To get further information about the permanent generation, the `-permstat` option can be used. It prints statistics for the objects in the permanent generation. Here is a sample of the output:

```
$ jmap -permstat 19846
Attaching to process ID 19846, please wait...
Debugger attached successfully.
Server compiler detected.
JVM version is 1.5.0-rc-b63
finding class loader instances ..
done.
computing per loader stat ..done.
please wait.. computing liveness.....................................................done.

class_loader    classes bytes   parent_loader  alive?  type

<bootstrap>     1189    2727472   null         live    <internal>
0xee431d58      1       1392    0xee22b3d0     dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee3fbd08      1       1400    0xee227418     dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee3fb860      1       1400    0xee227ba0     dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee3fc330      1       1400    0xee227418     dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee3fc4f8      1       1400    0xee227418     dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee431578      1       1400    0xee227418     dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee431198      1       1400      null         dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee431f68      1       1400    0xee22b3d0     dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee3fb4b0      1       848       null         dead    sun/reflect/DelegatingClassLoader@0xd4042360
0xee3fc628      1       1392    0xee227418     dead    sun/reflect/DelegatingClassLoader@0xd4042360
[.. more lines removed here to reduce output...]
total = 65      2303    5900688     N/A        alive=11, dead=54         N/A
```

For each class loader object, the following details are printed:

1. The address of the class loader object – at the snapshot when the utility was run.
2. The number of classes loaded (defined by this loader with the method `java.lang.ClassLoader.defineClass`).
3. The approximate number of bytes consumed by meta-data for all classes loaded by this class loader.
4. The address of the parent class loader (if any).
5. A “live” or “dead” indication – indicates whether the loader object will be garbage collected in the future.
6. The class name of this class loader.

For more information, refer to the `jmap` manual page at:
http://java.sun.com/j2se/1.5.0/docs/tooldocs/share/jmap.info

1.4 jstack

The `jstack` command-line utility is included in the Solaris and Linux releases of the JDK. It is not included in the JDK5.0 release on Windows. The utility attaches to the specified process (or core file) and prints the stack traces of all threads that are attached to the virtual machine (this includes Java threads and VM internal threads).

A stack trace of all threads can be useful when trying to diagnose a number of issues such as deadlocks or hangs. In many cases a thread dump can be obtained by pressing Ctrl-\ at the application console (standard input) or by sending the process a *QUIT* signal (section 1.16). Thread dumps can also be obtained programmatically using the `Thread.getAllStackTraces` method, or in the debugger using the debugger option to print all thread stacks (the "`where`" command in the case of the `jdb` sample debugger). In these examples the VM process must be in a state where it can execute code. In rare cases (for example if you encounter a bug in the thread library or HotSpot VM) this may not be possible, but it may be possible with the `jstack` utility as it attaches to the process using an operating system interface.

Here is example output from the `jstack` command to demonstrate how the output looks :

```
$ jstack 7034
Debugger attached successfully.
Server compiler detected.

JVM version is 1.5.0-rc-b63

Thread t@44: (state = BLOCKED)
 - java.lang.Object.wait(long) (Interpreted frame)
 - java.lang.Object.wait(long) (Interpreted frame)
 - org.apache.tomcat.util.threads.ThreadPool$MonitorRunnable.run() @bci=8,
line=549 (Interpreted frame)
 - java.lang.Thread.run() @bci=11, line=595 (Interpreted frame)


Thread t@43: (state = IN_NATIVE)
 - java.net.PlainSocketImpl.socketAccept(java.net.SocketImpl) (Interpreted frame)
 - java.net.PlainSocketImpl.socketAccept(java.net.SocketImpl) (Interpreted frame)
 - java.net.PlainSocketImpl.accept(java.net.SocketImpl) @bci=7, line=384
(Interpreted frame)
 - java.net.ServerSocket.implAccept(java.net.Socket) @bci=50, line=450
(Interpreted frame)
 - java.net.ServerSocket.accept() @bci=48, line=421 (Interpreted frame)
 - org.apache.jk.common.ChannelSocket.accept(org.apache.jk.core.MsgContext)
@bci=12, line=278 (Interpreted frame)
 - org.apache.jk.common.ChannelSocket.acceptConnections() @bci=71, line=572
(Interpreted frame)
 - org.apache.jk.common.SocketAcceptor.runIt(java.lang.Object[]) @bci=4, line=758
(Interpreted frame)
 - org.apache.tomcat.util.threads.ThreadPool$ControlRunnable.run() @bci=174,
line=666 (Interpreted frame)
 - java.lang.Thread.run() @bci=11, line=595 (Interpreted frame)


Thread t@42: (state = BLOCKED)
 - java.lang.Object.wait(long) (Interpreted frame)
 - java.lang.Object.wait(long) (Interpreted frame)
```

```
 - java.lang.Object.wait() @bci=2, line=474 (Interpreted frame)
 - org.apache.tomcat.util.threads.ThreadPool$ControlRunnable.run() @bci=19,
line=642 (Interpreted frame)
 - java.lang.Thread.run() @bci=11, line=595 (Interpreted frame)


Thread t@41: (state = BLOCKED)
 - java.lang.Object.wait(long) (Interpreted frame)
 - java.lang.Object.wait(long) (Interpreted frame)
 - java.lang.Object.wait() @bci=2, line=474 (Interpreted frame)
 - org.apache.tomcat.util.threads.ThreadPool$ControlRunnable.run() @bci=19,
line=642 (Interpreted frame)
 - java.lang.Thread.run() @bci=11, line=595 (Interpreted frame)

[... more lines removed here to reduce output ...]
```

The `jstack` utility can also try to obtain stack traces from a core dump:

```
jstack $JAVA_HOME/bin/java core
```

(`JAVA_HOME` indicates the JDK installation directory.)

For each thread, it prints the thread identifier (an integer) and the thread state. The following are the possible thread states that can be printed:

UNINTIALIZED	Thread is not created. This will normally not happen (unless there is a serious bug such as memory corruption).
NEW	Thread has been created but it has not started running yet.
IN_NATIVE	Thread is running native code.
IN_VM	Thread is running VM code.
IN_JAVA	Thread is running (either interpreted or compiled) Java code.
BLOCKED	Thread is blocked.
..._TRANS	If you see any of the above states but followed by "_TRANS", it means the thread is changing to a different state.

These are the thread states as of JDK5.0 – future releases may include new or different states.

After the thread information, there is a line of output for each java stack frame formatted as follows:

```
java.lang.Thread.run() @bci=11, line=595 (Interpreted frame)
  |               |       |        |           |
  |               |       |        |           +-- Method compiled/interpreted?
  |               |       |        +-------------- Source line number
  |               |       +----------------------- Byte code index
  |               +-----------------------------  Method name
  +---------------------------------------------- Fully qualified class name
```

The *bci* and *line* are not printed for JNI/native methods. If a method accepts arguments, then the argument types are printed (as shown below) so that overloaded methods can be differentiated.

```
org.apache.jk.common.SocketAcceptor.runIt(java.lang.Object[]) @bci=4, line=758
(Interpreted frame)
```

The `jstack` utility may also be used to print a mixed stack. That is, it can print native stack frames in addition to the java stack. Native frames are the C/C++ frames associated with VM code, and JNI/native code.

To print a mixed stack the `-m` option is used. An output example follows:

```
$ jstack -m 7034
Debugger attached successfully.
Server compiler detected.
JVM version is 1.5.0-rc-b63
----------------- t@1 -----------------
0xff32cf84   _so_accept + 0x4
0xfa8db248   Java_java_net_PlainSocketImpl_socketAccept + 0x200
0xf880c280   * java.net.PlainSocketImpl.socketAccept(java.net.SocketImpl) bci:7852
(Interpreted frame)
0xf880c224   * java.net.PlainSocketImpl.socketAccept(java.net.SocketImpl) bci:0
(Interpreted frame)
0xf8805764   * java.net.PlainSocketImpl.accept(java.net.SocketImpl) bci:7 line:384
(Interpreted frame)
0xf8805764   * java.net.ServerSocket.implAccept(java.net.Socket) bci:50 line:450
(Interpreted frame)
0xf8805764   * java.net.ServerSocket.accept() bci:48 line:421 (Interpreted frame)
0xf8805874   * org.apache.catalina.core.StandardServer.await() bci:74 line:552
(Interpreted frame)
0xf8805c2c   * org.apache.catalina.startup.Catalina.await() bci:4 line:634 (Interpreted
frame)
0xf8805764   * org.apache.catalina.startup.Catalina.start() bci:113 line:596 (Interpreted
frame)
0xf8800218   <StubRoutines>
0xfe98dfd8   void
JavaCalls::call_helper(JavaValue*,methodHandle*,JavaCallArguments*,Thread*) + 0x528
0xfea25954
oopDesc*Reflection::invoke(instanceKlassHandle,methodHandle,Handle,int,objArrayHandle,Bas
icType,objArrayHandle,int,Thread*) + 0x14a8
0xfeaeac9c   oopDesc*Reflection::invoke_method(oopDesc*,Handle,objArrayHandle,Thread*) +
0x268
0xfeae8ca8   JVM_InvokeMethod + 0x234
0xfe7a0314   Java_sun_reflect_NativeMethodAccessorImpl_invoke0 + 0x10
<interpreter> method entry point (kind = native)
0xf880c224   * sun.reflect.NativeMethodAccessorImpl.invoke0(java.lang.reflect.Method,
java.lang.Object, java.lang.Object[]) bci:0 (Interpreted frame)
0xf8805874   * sun.reflect.NativeMethodAccessorImpl.invoke(java.lang.Object,
java.lang.Object[]) bci:87 line:39 (Interpreted frame)
0xf8805874   * sun.reflect.DelegatingMethodAccessorImpl.invoke(java.lang.Object,
java.lang.Object[]) bci:6 line:25 (Interpreted frame)
0xf8805d3c   * java.lang.reflect.Method.invoke(java.lang.Object, java.lang.Object[])
bci:111 line:585 (Interpreted frame)
0xf8805874   * org.apache.catalina.startup.Bootstrap.start() bci:31 line:295 (Interpreted
frame)
0xf8805764   * org.apache.catalina.startup.Bootstrap.main(java.lang.String[]) bci:114
line:392 (Interpreted frame)
0xf8800218   <StubRoutines>
0xfe98dfd8   void
JavaCalls::call_helper(JavaValue*,methodHandle*,JavaCallArguments*,Thread*) + 0x528
0xfeac8160   jni_CallStaticVoidMethod + 0x46c
```

```
0x000123b4   main + 0x1314
0x00011088   _start + 0x108
[... more thread stacks removed here to reduce output ...]
```

Note that the output in the previous example was obtained using the following command (where `JAVA_HOME` indicates the JDK installation directory):

```
jstack -m $JAVA_HOME/bin/java core | c++filt
```

Frames prefixed with '*' are Java frames, and others are native C/C++ frames.

The output of the utility was piped through `c++filt` to demangle C++ mangled symbol names. The HotSpot Virtual Mahcine is developed in the C++ Language so `jstack` prints C++ mangled symbol names for the HotSpot internal functions.

For more information, the manual page for `jstack` is available at:
http://java.sun.com/j2se/1.5.0/docs/tooldocs/share/jstack.html

1.5 jconsole

J2SE 5.0 has comprehensive monitoring and management support. Among the tools included in the JDK download is a Java Management Extensions (JMX)-compliant monitoring tool called *jconsole*. The tool uses the built-in JMX instrumentation in the Java Virtual Machine to provide information on performance and resource consumption of running applications. Although the tool is included in the JDK download it can also be used to monitor and manage applications deployed with the Java 2 Platform Standard Edition Runtime Environment 5.0 (JRE 5.0).

jconsole can attach to any application that is started with the JMX agent. A system property defined on the command line enables the JMX agent. Once attached `jconsole` can be used to display useful information such as thread usage, memory consumption, and details about class loading, runtime compilation, and the operating system.

Following is an overview of the information that can be monitored using `jconsole`. Each heading corresponds to a tab pane in the monitoring tool:

Summary

- **Uptime**: how long the JVM has been running
- **Total compile time**: the amount of time spent in runtime compilation
- **Process CPU time**: the total amount of CPU time consumed by the JVM

Memory

- **Current heap size**: Number of Kbytes currently occupied by the heap
- **Committed memory**: Total amount of memory allocated for use by the heap
- **Maximum heap size**: Maximum number of Kbytes occupied by the heap
- **Objects pending for finalization**: Number of objects pending for finalization
- **Garbage collector information**: Information on GC, including the garbage collector names, number of collections performed, and total time spent performing GC

Threads

- **Live threads**: Current number of live daemon threads plus non-daemon threads
- **Peak**: Highest number of live threads since JVM started
- **Daemon threads**: Current number of live daemon threads
- **Total started**: Total number of threads started since the JVM started (including daemon, non-daemon, and terminated)

Classes

- **Current classes loaded**: Number of classes currently loaded into memory
- **Total classes loaded**: Total number of classes loaded into memory since the JVM started, including those subsequently unloaded
- **Total classes unloaded**: Number of classes unloaded from memory since the JVM started

Operating System

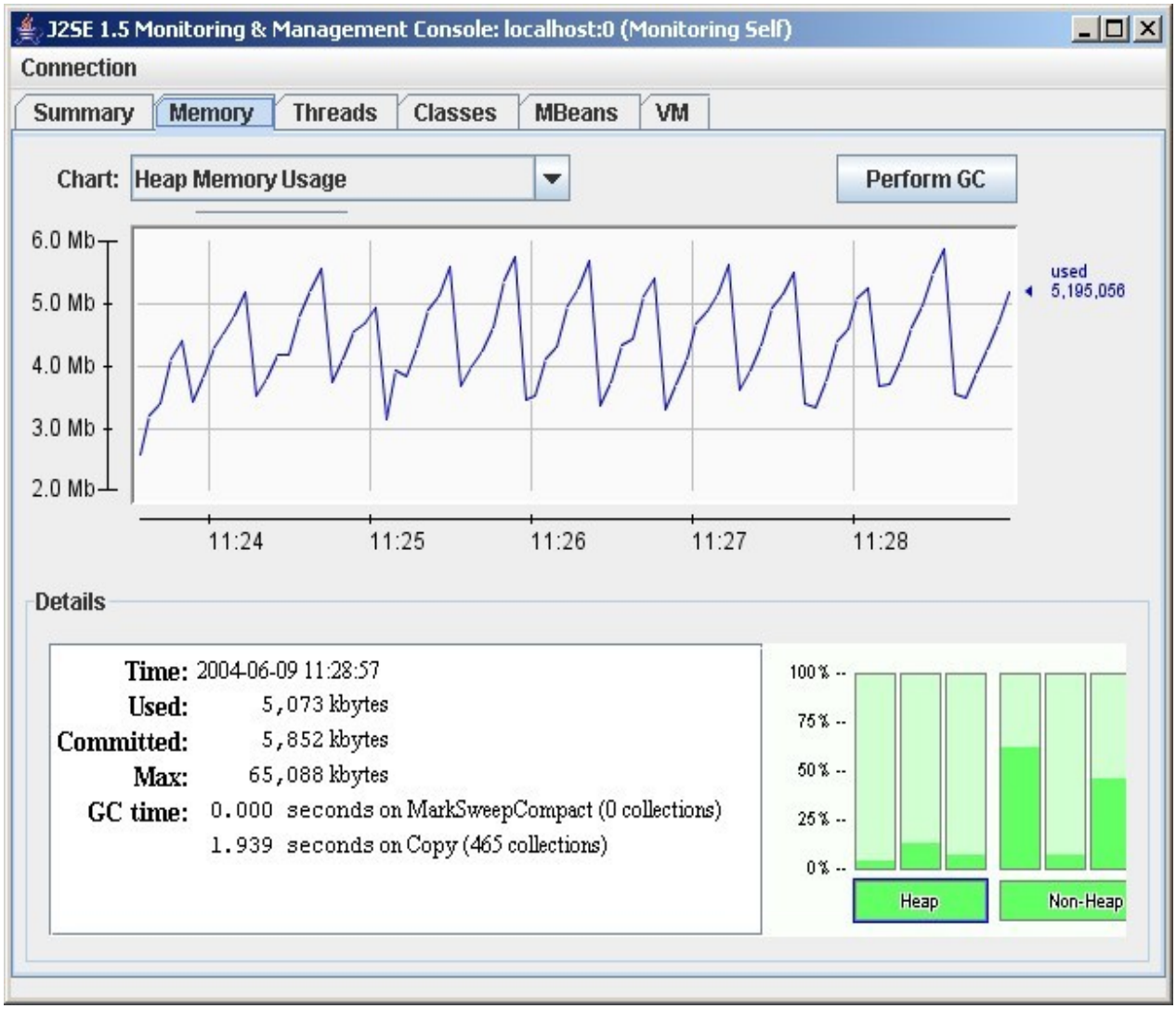
- **Total physical memory**: Amount of random-access memory (RAM) that the machine has.
- **Free physical memory**: Amount of free RAM the machine has.
- **Committed virtual memory**: Amount of virtual memory guaranteed to be available to the running process.

In addition to monitoring, `jconsole` can be used to dynamically change several parameters in the running system. For example, the setting of the `-verbose:gc` option can be changed so that garbage collection trace output can be dynamically enabled or disabled for a running application.

A complete tutorial on the `jconsole` tool is beyond the scope of this document. However getting started with `jconsole` is straight-forward :

1. Start the application with the `-Dcom.sun.management.jmxremote` option. This option sets the `com.sun.management.jmxremote` system property which enabled the JMX agent.
2. Start jconsole with the `jconsole` command. Jconsole ships as a binary in the `$JAVA_HOME/bin` directory. (`JAVA_HOME` indicates the home directory of the J2SE installation.)
3. When jconsole starts, it shows a window with the list of managed VMs on the machine. The process-id (pid) and command line arguments for each VM are printed. Select a VM, and `jconsole` will attach to it.

As an example of the output of the monitoring tool, following is a sample screen-shot showing a chart of heap memory usage:



In summary, `jconsole` can be useful in providing high-level diagnosis on problems such as memory leaks, excessive class loading or running threads. It can also be useful when tuning or heap sizing. `jconsole` can also be used to view more detailed information about the running application. For example, it can examine the stack traces of running threads, if the application has additional instrumentation.

The following documents describe in more detail the monitoring and management capabilities, and how to use `jconsole`:

Monitoring and Management for the Java Platform :
http://java.sun.com/j2se/1.5.0/docs/guide/management/index.html

Monitoring and Management Using JMX :
http://java.sun.com/j2se/1.5.0/docs/guide/management/agent.html

Using jconsole :
http://java.sun.com/j2se/1.5.0/docs/guide/management/jconsole.html

1.6 jps

The `jps` utility lists the instrumented HotSpot Virtual Machines on the target system. The utility is very useful in environments where the VM is embedded (meaning it is started using the JNI Invocation API rather than the *java* launcher). In these environments it is not always easy to recognize the java processes in the process list.

The following example demonstrates its usage :

```
$ jps
16217 MyApplication
16342 jps
```

The utility lists the virtual machines for which the user has access rights. This is determined by operating system specific access control mechanisms. On Solaris, for example, if a non-root user executes the `jps` utility then it lists the virtual machines that were started with that user's uid.

In addition to listing the process id the utility provides options to output the arguments passed to the application's main method, the complete list of VM arguments, and the full package name of the application's main class. `jps` can also list processes on a remote system if the remote system is running the jstat daemon (`jstatd`). The documentation for the utility can be found here :

http://java.sun.com/j2se/1.5.0/docs/tooldocs/share/jps.html

The document includes examples that obtain the process status from a remote host.

The utility is included in the JDK download for all operating system platforms supported by Sun. However, the HotSpot instrumentation is not accessible on Windows 98 or Windows ME. In addition the instrumentation may not be accessible on Windows if the temporary directory is on a FAT32 file system[1].

1 Workarounds to this issue can be found in the FAQ at http://developers.sun.com/dev/coolstuff/jvmstat/faq.html

1.7 jstat

The `jstat` utility uses the built-in instrumentation in the HotSpot VM to provide information on performance and resource consumption of running applications. The tool can be used when diagnosing performance issues, and in particular issues related to heap sizing and garbage collection.

The `jstat` utility does not require the VM to be started with any special options. The built-in instrumentation in the HotSpot VM is enabled by default. The utility is included in the JDK download for all operating system platforms supported by Sun. However, the instrumentation is not accessible on Windows 98 or Windows ME[2].

Following are the `jstat` utility options :

- -class – prints statistics on the behavior of the class loader.
- -compiler – prints statistics of the behavior of the HotSpot compiler.
- -gc – prints statistics of the behavior of the garbage collected heap.
- -gccapacity – prints statistics of the capacities of the generations and their corresponding spaces.
- -gccause – prints the summary of garbage collection statistics (same as *-gcutil*), with the cause of the last and current (if applicable) garbage collection events.
- -gcnew – prints statistics of the behavior of the new generation.
- -gcnewcapacity - prints statistics of the sizes of the new generations and its corresponding spaces.
- -gcold – prints statistics of the behavior of the old and permanent generations.
- -gcoldcapacity – prints statistics of the sizes of the old generation.
- -gcpermcapacity – print statistics of the sizes of the permanent generation.
- -gcutil – prints a summary of garbage collection statistics.
- -printcompilation – prints HotSpot compilation method statistics.

The `jstat` tool documentation provides a complete description of the tool :

http://java.sun.com/j2se/1.5.0/docs/tooldocs/share/jstat.html

The documentation includes a number of examples. A few of these examples are repeated here.

The `jstat` utility uses a *vmid* to identify the target process. The documentation describes the syntax of a vmid but in the simplest case a vmid can be a local virtual machine identifier. In the case of Solaris, Linux, and Windows, it can be considered to be the process id. (This is typical but may not always be the case.)

Here is an example of the `-gcutil` option. The example attaches to *lvmid* 21891 and takes 7 samples

2 Instrumentation is also not accessible on Windows NT, 2000, or XP if a FAT32 file system is used.

at 250 millisecond intervals and displays the output as specified by the `-gcutil` option.

```
jstat -gcutil 21891 250 7
  S0     S1     E      O      P      YGC     YGCT    FGC    FGCT     GCT
 12.44   0.00  27.20   9.49  96.70    78     0.176     5    0.495    0.672
 12.44   0.00  62.16   9.49  96.70    78     0.176     5    0.495    0.672
 12.44   0.00  83.97   9.49  96.70    78     0.176     5    0.495    0.672
  0.00   7.74   0.00   9.51  96.70    79     0.177     5    0.495    0.673
  0.00   7.74  23.37   9.51  96.70    79     0.177     5    0.495    0.673
  0.00   7.74  43.82   9.51  96.70    79     0.177     5    0.495    0.673
  0.00   7.74  58.11   9.51  96.71    79     0.177     5    0.495    0.673
```

The output of this example shows that a young generation collection occurred between the 3rd and 4th sample. The collection took 0.001 seconds and promoted objects from the eden space (E) to the old space (O), resulting in an increase of old space utilization from 9.49% to 9.51%. Before the collection, the survivor space was 12.44% utilized, but after this collection it is only 7.74% utilized.

The following example attaches to *lvmid* 21891 and takes samples at 250 millisecond intervals and displays the output as specified by the `-gcutil` option. In addition, it uses the `-h3` option to output the column header after every 3 lines of data.

```
jstat -gcnew -h3 21891 250
 S0C    S1C    S0U    S1U   TT MTT  DSS      EC       EU     YGC     YGCT
  64.0   64.0    0.0   31.7 31  31   32.0    512.0    178.6     249    0.203
  64.0   64.0    0.0   31.7 31  31   32.0    512.0    355.5     249    0.203
  64.0   64.0   35.4    0.0  2  31   32.0    512.0     21.9     250    0.204
 S0C    S1C    S0U    S1U   TT MTT  DSS      EC       EU     YGC     YGCT
  64.0   64.0   35.4    0.0  2  31   32.0    512.0    245.9     250    0.204
  64.0   64.0   35.4    0.0  2  31   32.0    512.0    421.1     250    0.204
  64.0   64.0    0.0   19.0 31  31   32.0    512.0     84.4     251    0.204
 S0C    S1C    S0U    S1U   TT MTT  DSS      EC       EU     YGC     YGCT
  64.0   64.0    0.0   19.0 31  31   32.0    512.0    306.7     251    0.204
```

In addition to showing the repeating header string, this example shows that between the 2nd and 3rd samples, a young GC occurred. Its duration was 0.001 seconds. The collection found enough live data that the survivor space 0 utilization (S0U) would have exceeded the Desired Survivor Size (DSS). As a result, objects were promoted to the old generation (not visible in this output), and the tenuring threshold (TT) was lowered from 31 to 2.

Another collection occurs between the 5th and 6th samples. This collection found very few survivors and returned the tenuring threshold to 31.

This example attaches to *lvmid* 21891 and takes 3 samples at 250 millisecond intervals. The `-t` option is used to generate a time stamp for each sample in the first column. A small font is used here so that the output doesn't wrap.

```
jstat -gcoldcapacity -t 21891 250 3
Timestamp          OGCMN       OGCMX        OGC           OC       YGC   FGC    FGCT     GCT
         150.1       1408.0      60544.0      11696.0      11696.0   194    80    2.874    3.799
         150.4       1408.0      60544.0      13820.0      13820.0   194    81    2.938    3.863
         150.7       1408.0      60544.0      13820.0      13820.0   194    81    2.938    3.863
```

The `Timestamp` column reports the elapsed time in seconds since the start of the target JVM. In

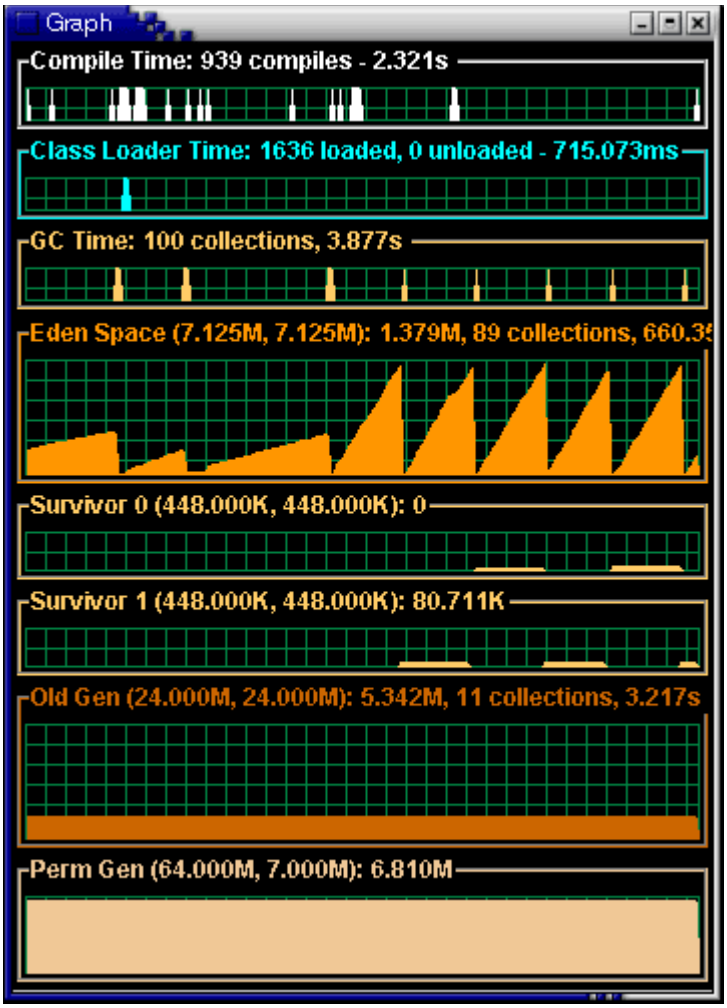
addition, the `-gcoldcapacity` output shows the old generation capacity (OGC) and the old space capacity (OC) increasing as the heap expands to meet allocation and/or promotion demands. The old generation capacity (OGC) has grown from 11696 KB to 13820 KB after the 81st Full GC (FGC). The maximum capacity of the generation (and space) is 60544 KB (OGCMX), so it still has room to expand.

1.7.1 visualgc

A related tool to jstat is the `visualgc` tool. The `visualgc` tool provides a graphical view of the garbage collection system. As with *jstat* it uses the built-in instrumentation of the HotSpot VM. The visualgc tool is not included in JDK5.0 but is available as a separate download from this site :

-http://developers.sun.com/dev/coolstuff/jvmstat/index.html

Following is a sample screen-shot to demonstrate how the GC and heap are visualized :



1.8 HPROF - Heap Profiler

HPROF is a simple profiler agent shipped with JDK 5.0. It is a dynamically-linked library that interfaces to the VM using the Java Virtual Machine Tools Interface (JVM TI). It writes out profiling information either to a file or to a socket in ASCII or binary format. This information can be further processed by a profiler front-end tool.

HPROF is capable of presenting CPU usage, heap allocation statistics and monitor contention profiles. In addition it can also report complete heap dumps and states of all the monitors and threads in the Java virtual machine. In terms of diagnosing problems, HPROF is useful when analyzing performance, lock contention, memory leaks, and other issues.

In addition to the HPROF library the JDK also includes the source to HPROF as a JVM TI demonstration code. It can be found in the `$JAVA_HOME/demo/jvmti/hprof` directory (where `$JAVA_HOME` indicates the directory where the JDK is installed).

HPROF is invoked as follows :

```
java -agentlib:hprof <ToBeProfiledClass>
```

Depending on the type of profiling requested, HPROF instructs the virtual machine to send it the relevant events and processes the event data into profiling information. For example, the following command obtains the heap allocation profile:

```
java -agentlib:hprof=heap=sites ToBeProfiledClass
```

The complete list of options is printed if the HPROF agent is provided with the `help` option:

```
$ java -agentlib:hprof=help
     HPROF: Heap and CPU Profiling Agent (JVMTI Demonstration Code)
hprof usage: java -agentlib:hprof=[help]|[<option>=<value>, ...]
Option Name and Value  Description                    Default
---------------------  -----------                    -------
heap=dump|sites|all    heap profiling                 all
cpu=samples|times|old  CPU usage                      off
monitor=y|n            monitor contention             n
format=a|b             text(txt) or binary output     a
file=<file>            write data to file             java.hprof[.txt]
net=<host>:<port>      send data over a socket        off
depth=<size>           stack trace depth              4
interval=<ms>          sample interval in ms          10
cutoff=<value>         output cutoff point            0.0001
lineno=y|n             line number in traces?         y
thread=y|n             thread in traces?              n
doe=y|n                dump on exit?                  y
msa=y|n                Solaris micro state accounting n
force=y|n              force output to <file>         y
verbose=y|n            print messages about dumps     y
Obsolete Options
----------------
gc_okay=y|n
Examples
```

```
--------
  - Get sample cpu information every 20 millisec, with a stack depth of 3:
      java -agentlib:hprof=cpu=samples,interval=20,depth=3 classname
  - Get heap usage information based on the allocation sites:
      java -agentlib:hprof=heap=sites classname
Notes
-----
  - The option format=b cannot be used with monitor=y.
  - The option format=b cannot be used with cpu=old|times.
  - Use of the -Xrunhprof interface can still be used, e.g.
       java -Xrunhprof:[help]|[<option>=<value>, ...]
    will behave exactly the same as:
       java -agentlib:hprof=[help]|[<option>=<value>, ...]
Warnings
--------
  - This is demonstration code for the JVMTI interface and use of BCI,
    it is not an official product or formal part of the J2SE.
  - The -Xrunhprof interface will be removed in a future release.
  - The option format=b is considered experimental, this format may change
    in a future release.
```

By default, heap profiling information (sites and dump) is written out to java.hprof.txt (ASCII) in the current working directory.

The output is normally generated when the VM exits, although this can be disabled by setting the "dump on exit" option to "n" (*doe=n)*. In addition, a profile is generated when Ctrl-\ or Ctrl-Break (depending on platform) is pressed. On Solaris and Linux a profile is also generated when a QUIT signal is received (*kill -QUIT <pid>*). If Ctrl-\ or Ctrl-Break is pressed multiple times then multiple profiles are generated to the one file.

The output in most cases will contain ID's for traces, threads, and objects. Each type of ID will typically start with a different number than do the other ID's. For example, traces might start with 300000.

Heap Allocation Profiles (heap=sites)

Following is the heap allocation profile generated by running the Java compiler (`javac`) on a set of input files. Only parts of the profiler output are shown here.

```
$ javac -J-agentlib:hprof=heap=sites Hello.java
SITES BEGIN (ordered by live bytes) Fri Feb  6 13:13:42 2004
          percent          live          alloc'ed  stack class
 rank   self  accum     bytes objs     bytes  objs trace name
    1 44.13% 44.13%   1117360 13967  1117360 13967 301926 java.util.zip.ZipEntry
    2  8.83% 52.95%    223472 13967   223472 13967 301927
com.sun.tools.javac.util.List
    3  5.18% 58.13%    131088    1    131088     1 300996 byte[]
    4  5.18% 63.31%    131088    1    131088     1 300995
com.sun.tools.javac.util.Name[]
```

A crucial piece of information in the heap profile is the amount of allocation that occurs in various parts of the program. The `SITES` record above tells us that 44.13% of the total space was allocated for java.util.zip.ZipEntry objects.

A good way to relate allocation sites to the source code is to record the dynamic stack traces that led to the heap allocation. Following is another part of the profiler output that illustrates the stack traces referred to by the four allocation sites in output shown above.

```
TRACE 301926:
        java.util.zip.ZipEntry.<init>(ZipEntry.java:101)
        java.util.zip.ZipFile+3.nextElement(ZipFile.java:417)
        com.sun.tools.javac.jvm.ClassReader.openArchive(ClassReader.java:1374)
        com.sun.tools.javac.jvm.ClassReader.list(ClassReader.java:1631)
TRACE 301927:
        com.sun.tools.javac.util.List.<init>(List.java:42)
        com.sun.tools.javac.util.List.<init>(List.java:50)
        com.sun.tools.javac.util.ListBuffer.append(ListBuffer.java:94)
        com.sun.tools.javac.jvm.ClassReader.openArchive(ClassReader.java:1374)
TRACE 300996:
        com.sun.tools.javac.util.Name$Table.<init>(Name.java:379)
        com.sun.tools.javac.util.Name$Table.<init>(Name.java:481)
        com.sun.tools.javac.util.Name$Table.make(Name.java:332)
        com.sun.tools.javac.util.Name$Table.instance(Name.java:349)
TRACE 300995:
        com.sun.tools.javac.util.Name$Table.<init>(Name.java:378)
        com.sun.tools.javac.util.Name$Table.<init>(Name.java:481)
        com.sun.tools.javac.util.Name$Table.make(Name.java:332)
        com.sun.tools.javac.util.Name$Table.instance(Name.java:349)
```

Each frame in the stack trace contains class name, method name, source file name, and the line number. The user can set the maximum number of frames collected by the HPROF agent. The default limit is 4. Stack traces reveal not only which methods performed heap allocation, but also which methods were ultimately responsible for making calls that resulted in memory allocation.

Heap Dump (heap=dump)

A heap dump is obtained using the `heap=dump` option. The heap dump is either ASCII or binary format depending on the setting of the `format` option. Tools such as HAT (see section 1.11) use the binary format and therefore the `format=b` option is required.

A complete dump is obtained with the command:

```
javac -J-agentlib:hprof=heap=dump Hello.java
```

The output is a large file. It consists of the root set as determined by the garbage collector, and an entry for each java object in the heap that can be reached from the root set. The following is a selection of records from a sample heap dump:

```
HEAP DUMP BEGIN (39793 objects, 2628264 bytes) Fri Sep 24 13:54:03 2004
ROOT 50000114 (kind=<thread>, id=200002, trace=300000)
ROOT 50000006 (kind=<JNI global ref>, id=8, trace=300000)
ROOT 50008c6f (kind=<Java stack>, thread=200000, frame=5)
```

```
:
CLS 50000006 (name=java.lang.annotation.Annotation, trace=300000)
       loader        90000001
OBJ 50000114 (sz=96, trace=300001, class=java.lang.Thread@50000106)
       name          50000116
       group         50008c6c
       contextClassLoader  50008c53
       inheritedAccessControlContext     50008c79
       blockerLock   50000115
OBJ 50008c6c (sz=48, trace=300000, class=java.lang.ThreadGroup@50000068)
       name          50008c7d
       threads       50008c7c
       groups        50008c7b
ARR 50008c6f (sz=16, trace=300000, nelems=1, elem type=java.lang.String[]@5000008e)
       [0]           500007a5
CLS 5000008e (name=java.lang.String[], trace=300000)
       super         50000012
       loader        90000001
:
HEAP DUMP END
```

Each record is a ROOT, OBJ, CLS, or ARR to represent a root, an object instance, a class, or an array. The hexidecimal numbers are identifiers assigned by HPROF. They are used to show the references from an object to another object. For example, in the above sample, the `java.lang.Thread` instance `50000114` has a reference to its thread group (`50008c6c`) and other objects.

In general, as the output is very large, it is necessary to use a tool to visualize or process the output of a heap dump. The Heap Analysis Tool (HAT) is one such tool (see section 1.11).

CPU Usage Sampling Profiles (cpu=samples)

HPROF can collect CPU usage information by sampling threads. Following is part of the output collected from a run of the `javac` compiler.

```
$ javac -J-agentlib:hprof=cpu=samples Hello.java
CPU SAMPLES BEGIN (total = 462) Fri Feb  6 13:33:07 2004
rank   self  accum   count trace method
   1 49.57% 49.57%     229 300187 java.util.zip.ZipFile.getNextEntry
   2  6.93% 56.49%      32 300190 java.util.zip.ZipEntry.initFields
   3  4.76% 61.26%      22 300122 java.lang.ClassLoader.defineClass2
   4  2.81% 64.07%      13 300188 java.util.zip.ZipFile.freeEntry
   5  1.95% 66.02%       9 300129 java.util.Vector.addElement
   6  1.73% 67.75%       8 300124 java.util.zip.ZipFile.getEntry
   7  1.52% 69.26%       7 300125 java.lang.ClassLoader.findBootstrapClass
   8  0.87% 70.13%       4 300172 com.sun.tools.javac.main.JavaCompiler.<init>
   9  0.65% 70.78%       3 300030 java.util.zip.ZipFile.open
  10  0.65% 71.43%       3 300175 com.sun.tools.javac.main.JavaCompiler.<init>

...
CPU SAMPLES END
```

The HPROF agent periodically samples the stack of all running threads to record the most frequently

active stack traces. The `count` field above indicates how many times a particular stack trace was found to be active. These stack traces correspond to the CPU usage hot spots in the application.

CPU Usage Times Profile (cpu=times)

HPROF can collect CPU usage information by injecting code into every method entry and exit, keeping track of exact method call counts and the time spent in each method. This uses Byte Code Injection (BCI) and runs considerably slower than `cpu=samples`. Following is part of the output collected from a run of the `javac` compiler.

```
$ javac -J-agentlib:hprof=cpu=times Hello.java
CPU TIME (ms) BEGIN (total = 2082665289) Fri Feb  6 13:43:42 2004
rank   self  accum   count trace method
   1  3.70%  3.70%       1 311243 com.sun.tools.javac.Main.compile
   2  3.64%  7.34%       1 311242 com.sun.tools.javac.main.Main.compile
   3  3.64% 10.97%       1 311241 com.sun.tools.javac.main.Main.compile
   4  3.11% 14.08%       1 311173 com.sun.tools.javac.main.JavaCompiler.compile
   5  2.54% 16.62%       8 306183 com.sun.tools.javac.jvm.ClassReader.listAll
   6  2.53% 19.15%      36 306182 com.sun.tools.javac.jvm.ClassReader.list
   7  2.03% 21.18%       1 307195 com.sun.tools.javac.comp.Enter.main
   8  2.03% 23.21%       1 307194 com.sun.tools.javac.comp.Enter.complete
   9  1.68% 24.90%       1 306392 com.sun.tools.javac.comp.Enter.classEnter
  10  1.68% 26.58%       1 306388 com.sun.tools.javac.comp.Enter.classEnter
...
CPU TIME (ms) END
```

Here the count represents the true count of the times this method was entered, and the percentages represent a measure of thread CPU time spent in those methods.

1.9 `HeapDumpOnOutOfMemoryError` Option

The `-XX:+HeapDumpOnOutOfMemoryError` command-line option was introduced in Java SE release 5.0 update 7. This option tells the HotSpot VM to generate a heap dump when the first thread throws a `java.lang.OutOfMemoryError` because the Java heap or the permanent generation is full. There is no overhead in running with this option, and so it can be useful for production systems where OutOfMemoryError takes a long time to surface.

The heap dump is in HPROF binary format, and so it can be anaylzed by any tool that can import this format, for example the Heap Analysis Tool (HAT).

By default the heap dump is created in a file called `java_pid<`*`pid`*`>.hprof` in the working directory of the VM, where `<`*`pid`*`>` is the process ID. You can specify an alternative file name or directory with the `-XX:HeapDumpPath=` option. For example, `-XX:HeapDumpPath=/disk2/dumps` will cause the heap dump to be generated in the `/disk2/dumps` directory.

1.10 `HeapDumpOnCtrlBreak` Option

The `-XX:+HeapDumpOnCtrlBreak` command-line option was introduced in Java SE release 5.0 update 14. This option tells the HotSpot VM to generate a heap dump when a Ctrl-Break or SIGQUIT signal is received. This provides a way to trigger a heap dump on demand.

The heap dump is in HPROF binary format, and so it can be anaylzed by any tool that can import this format, for example the Heap Analysis Tool (HAT). The heap dump contains only live objects.

By default the heap dump is created in a file called `java_pid<`*`pid`*`>.hprof.<`*`yyyymmdd`*`>.<`*`hhmmss`*`>` in the working directory of the VM, where `<`*`pid`*`>` is the process ID, and `<`*`yyyymmdd`*`>.<`*`hhmmss`*`>` is the approximate time when the heap dump was generated.

You can specify an alternative file name or directory with the `-XX:HeapDumpPath=` option. For example, `-XX:HeapDumpPath=/disk2/dumps` will cause the heap dump to be generated in the `/disk2/dumps` directory.

If both the `-XX:+HeapDumpOnCtrlBreak` and `-XX:+PrintClassHistogram` options are enabled, the heap dump and the heap histogram are obtained from the same heap snapshot.

1.11 Heap Analysis Tool

The Heap Analysis Tool (HAT) is a tool to help debug *unintentional object retention*. This term is used to describe an object that is no longer needed but it kept alive due to references through some path from the rootset. This can happen, for example, if an unintentional static reference to an object remains after the object is no longer needed, if an *Observer* or *Listener* fails to de-register itself from its subject when it is no longer needed, or if a *Thread* that refers to an object does not terminate when it should. Unintentional object retention is the Java Language equivalent of a *memory leak*.

HAT provides a convenient means to browse the object topology in a heap snapshot. The tool allows a number of queries, including "show me all reference paths from the rootset to this object". It is this query that is most useful for finding unnecessary object retention. HAT is not included in JDK5.0 but it can be downloaded (in both source and binary form) from the site: http://hat.dev.java.net

> **Note:** The Java Heap Analysis Tool (`jhat`) provides the same functionality as HAT, with several additional enhancements and improvements. See section 1.12.

The input to HAT (or `jhat`) must be a binary format heap dump. There are various ways to obtain this dump:

- The application can be run with the HPROF profile (see section 1.8).
- As of Java SE 5.0 update 7, the `-XX:+HeapDumpOnOutOfMemoryError` command-line option tells the HotSpot VM to generate a heap dump when an OutOfMemoryError occurs (see section 1.9).
- As of Java SE 5.0 update 14, the `-XX:+HeapDumpOnCtrlBreak` command-line option tells the HotSpot VM to generate a heap dump when a Ctrl-Break or SIGQUIT signal is received (see section 1.10).

HAT processes the heap dump and starts an HTTP server on a specified TCP port. You can then use any browser to connect to HAT and execute queries. The README in the download explains how to use HAT and describes each of the queries available. Following is an overview of the available queries. Section 2.1.2.2 provides further description on using HAT to identify memory leaks.

All Classes Query

The default page is the “All Classes” query. It shows you all of classes present in the heap, excluding platform classes. This list is sorted by fully-qualified class name, and broken out by package. By clicking on the name of a class, you are taken to the Class query. At the bottom of the page is a link you can click to be taken to other queries.

The second variant of this query includes the platform classes. Platform classes include classes whose fully-qualified names start with things like "java.", "sun.", "javax.swing.", or "char[". The list of prefixes is in a system resource file called `resources/platform_names.txt`. If you want to override this list, just replace it in the jar file, or arrange for your replacement to occur first on the classpath when HAT is invoked.

The Class Query

The Class query shows you information about a class. This includes its superclass, any subclasses, instance data members, and static data members. From this page you can navigate to any of the classes that are referenced, or you can navigate to an Instances query.

The Object Query

The Object query gives information about an object that was on the heap. From here, you can navigate to the class of the object and to the value of any object members of the object. You can also navigate to objects that refer to the current object. Perhaps the most valuable query is at the end: the Roots query ("Reference Chains from Rootset").

Note that the object query also gives you a stack backtrace of the point of allocation of the object.

The Instances Query

The instances query shows you all instances of a given class. The "allInstances" variant includes instances of subclasses of the given class as well. From here, you can navigate back to the source class, or you can navigate to an Object query on one of the instances.

The Roots Query

The roots query gives you reference chains from the rootset to a given object. It will give you one chain for each member of the rootset from which the given object is reachable. When calculating these chains, it does a depth-first search, so that it will provide reference chains of minimal length.

There are two kinds of roots query: one that excludes weak references ("roots"), and one that includes them ("allRoots"). A *weak reference* object does not prevent its referent from being made finalizable, finalized, and then reclaimed. If an object is only referred to by a weak reference, it usually isn't considered to be retained, because the garbage collector can collect it as soon as it needs the space.

This is probably the most valuable query in HAT, if you're debugging unintentional object retention. Once you find an object that is being retained, this query tells you *why* it is being retained.

The Reachable Objects Query

This query, accessible from the Object query, shows the transitive closure of all objects reachable from a given object. This list is sorted in decreasing size, and alphabetically within each size. At the end, the total size of all of the reachable objects is given. This can be useful for determining the total runtime footprint of an object in memory, at least in systems with simple object topologies.

This query is most valuable when used in conjunction with the -exclude command line option, described above. This is useful, for example, if the object being analyzed is an Observable. By default, all of its Observers would be reachable, which would count against the total size. -exclude allows you to exclude the data members java.util.Observable.obs and java.util.Observable.arr.

The Instance Counts for All Classes Query

This query shows the count of instances for every class in the system, excluding platform classes. It is sorted in descending order, by instance count. A good way to spot a problem with unintentional object retention is to run a program for a long time with a variety of input, then request a heap dump. Looking at the instance counts for all classes, you may recognize a number of classes because there are more instances than you expect. Then, you can analyze them to determine why they're being retained (possibly using the roots query). There's also a variant of this that includes platform classes. See the notes under the All Classes query for notes about what is considered to be a platform class.

The All Roots Query

This query shows all members of the rootset.

The New Instances Query

The New Instances query is only available if you invoke the hat server with two heap dumps. It is like the Instances query, but it only shows new instances. An instance is considered new if it is in the second heap dump, and there is no object of the same type with the same ID in the baseline heap dump. An object's ID is a 32 or 64 bit integer[3] that uniquely identifies the object, and it is assigned by the HPROF profile.

1.12 Java Heap Analysis Tool (`jhat`)

The Java Heap Analysis Tool (`jhat`) provides the same functionality as HAT, but uses fewer resources. In addition, `jhat` offers several enhancements and improvements, including the following:

- `jhat` can parse incomplete and truncated heap dumps.
- `jhat` can read heap dumps generated on 64-bit systems.
- `jhat` supports the Object Query Language (OQL), with which you can write your own queries on the heap dump.

The `jhat` utility is delivered with **Java SE 6** but can read and parse heap dumps created on Java SE 5.0 systems. If you have access to a machine with Java SE 6 installed, you can create a heap dump on the Java SE 5.0 system and transport it to the Java SE 6 system in order to parse and browse it with the `jhat` utility.

For detailed information on `jhat`, see the *Troubleshooting Guide for Java SE 6 with HotSpot VM*:

PDF: http://java.sun.com/javase/6/webnotes/trouble/TSG-VM/TSG-VM.pdf

HTML: http://java.sun.com/javase/6/webnotes/trouble/TSG-VM/html/index.html

3 HAT 1.1 only supports 32-bit Object IDs. This is not an issue on 64-bit VMs because HPROF always generates a 32-bit Object ID.

1.13 Fatal Error Handling

J2SE 5.0 has significantly enhanced fatal error reporting when compared to previous releases.

When a fatal error occurs, an error log is created with information and state obtained at the time of the fatal error. In addition, a user-supplied script, or a set of commands, can be configured to execute when a fatal error occurs. This is specified using the `-XX:OnError` option.This section also describes the `-XX:+ShowMessageBoxOnError` option. This option is useful in cases where you want to attach a native debugger to the process when it crashes.

1.13.1 Fatal Error Log

When a fatal error occurs an error log is created in the file `hs_err_pid<pid>.log` (where <*pid*> is the process id of the process). Where possible the file is created in the working directory of the process. In the event that the file cannot be created in the working directory (insufficient space, permission problem, or other issue) then the file is created in the temporary directory for the operating system. On Solaris and Linux the temporary directory is `/tmp`. On Windows the temporary directory is specified by the value of the `TMP` environment variable, or if that is not defined, the value of the `TEMP` environment variable.

The error log contains a lot of information obtained at the time of the fatal error. Where possible it includes:

- the operating exception or signal that provoked the fatal error
- version and configuration information
- details on the thread that provoked the fatal error and its stack trace
- the list of running threads and their state
- summary information about the heap
- the list of native libraries loaded
- command line arguments
- environment variables
- details about the operating system and cpu

It is important to note that in some cases only a sub-set of this information is output to the error log. This can happen when a fatal error is of such severity that the error handler is unable to recover and report all details.

The format of the fatal error log is detailed in section 2.2.1 (starting at page 79).

1.13.2 `OnError` Option

When a fatal error occurs the HotSpot Virtual Machine can optionally execute a user-supplied script or command. The script or command is specified using the `-XX:OnError:<string>` command line option, where <*string*> is a single command, or a list of commands separated by a semi-colon. Within <*string*> all occurrences of "`%p`" are replaced with the current process id (pid), and all occurrences of "`%%`" are replaced by a single "`%`". Following are some examples to demonstrate how the option can be used.

On Solaris the `pmap` command displays information about the address space of a process. In this example, the `pmap` command is executed to display the address space of the process after a fatal error occurs:

```
java -XX:OnError="pmap %p" MyApplication
```

Here's an example showing how the fatal error report can be mailed to a support alias when a fatal error is encountered:

```
java -XX:OnError="cat hs_err_pid%p.log|mail support@acme.com"  \
  MyApplication
```

On Solaris the `gcore` command creates a core image of the specified process. The `dbx` command launches the debugger. In this example, the `gcore` command is executed to create the core image and the debugger is started to attach to the process:

```
java -XX:OnError="gcore %p;dbx - %p" MyApplication
```

Following is a Linux example which launches the `gdb` debugger when an unexpected error is encountered. Once launched, `gdb` will attach to the VM process :

```
java -XX:OnError="gdb - %p" MyApplication
```

On Windows the *Dr. Watson* debugger can be configured as the post-mortem debugger so that a crash dump is created when an unexpected error is encountered. See section 3.2.4 for other details.

An alternative approach to obtain a crash dump on Windows it to use the `-XX:OnError` option to execute the `userdump.exe` utility[4] :

```
java -XX:OnError="userdump.exe %p" MyApplication
```

The example assumes that `userdump.exe` is on the `PATH`.

1.13.3 `ShowMessageBoxOnError` Option

In addition to the `-XX:OnError` option the HotSpot VM can also be provided with the option `-XX :+ShowMessageBoxOnError`. When this option is set and a fatal error is encountered, the HotSpot VM will output information about the fatal error and prompt the user as to whether the native debugger should be launched. In the case of Solaris and Linux, the output and prompt are sent to the application console (standard input and standard output). In the case of Windows, a Windows message box pops up. Here is an example from a fatal error encountered on a Linux system :

4 The userdump utility is part of the Microsoft OEM Support Tools package which can be downloaded from the Microsoft site. See section 3.2.4 for further details.

```
#
# ========================================================================
# Unexpected Error
# ------------------------------------------------------------------------
# SIGSEGV (0xb) at pc=0x2000000001164db1, pid=10791, tid=1026
#
# Do you want to debug the problem?
#
# To debug, run 'gdb /proc/10791/exe 10791'; then switch to thread 1026
# Enter 'yes' to launch gdb automatically (PATH must include gdb)
# Otherwise, press RETURN to abort...
# =============================================================================
```

In this case a SIGSEGV has occurred and the user is prompted as to whether the `gdb` debugger should be launched to attach to the process. If the user enters "y" or "yes" then `gdb` will be launched (assuming it is on the `PATH`).

On Solaris the message is similar to the above except that the user is promoted to start the Solaris `dbx` debugger. On Windows a message box is displayed. If the user presses the *YES* button then the VM will attempt to start the default debugger[5]. If Microsoft Visual Studio is installed then the default debugger is typically configured to be `msdev.exe`.

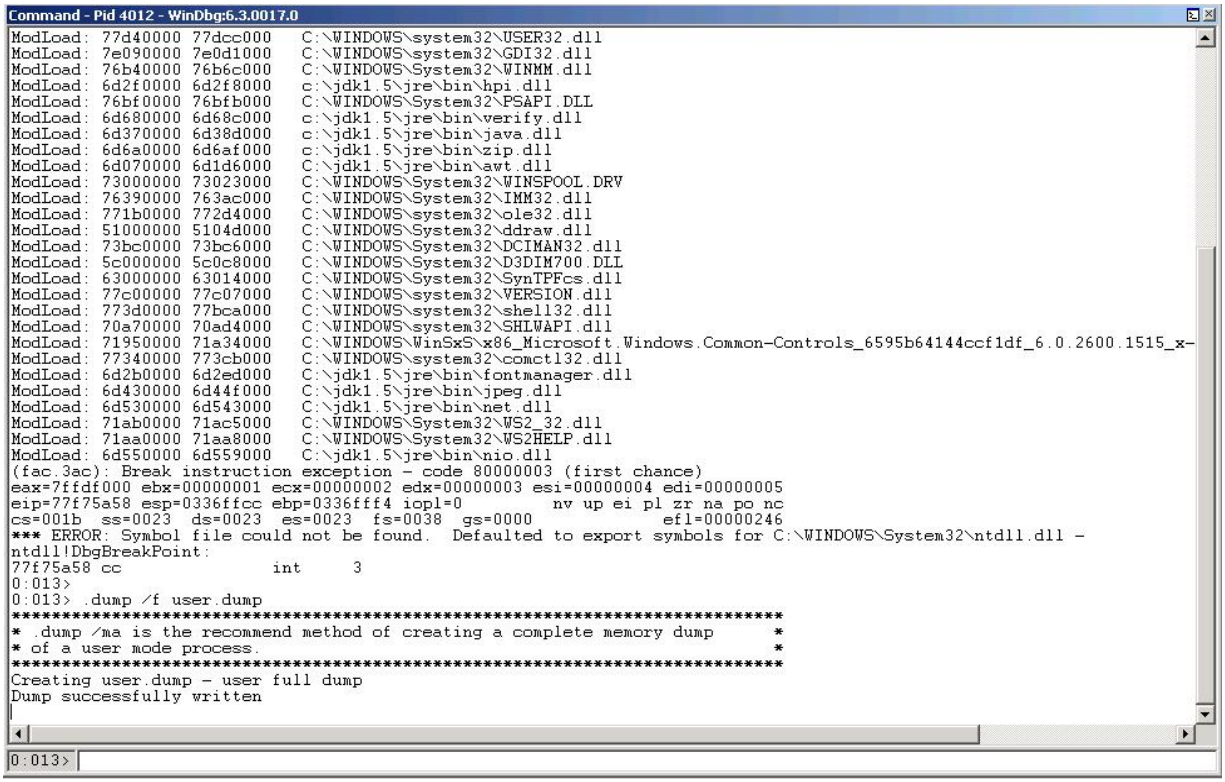
In the above example note that the output includes the process id (10791 in this case) and also the thread id (1026 in this case). If the debugger is launched then one of the initial steps in the debugger may be to select the thread and obtain its stack trace.

As the process is waiting for a response it is possible to use other tools to obtain a crash dump or query the state of the process. On Solaris, for example, a core dump can be obtained using the `gcore` utility.

On Windows a Dr. Watson crash dump can be obtained using the *userdump* or *windbg* programs[6]. In *windbg* select the "*Attach to a Process...*" menu option. This displays the list of processes and prompts for the process id. The message box displayed by the HotSpot VM includes the process id. Once selected the "`.dump /f`"command can be used to force a crash dump. In the following example a crash dump is created in file `crash.dump`.

5 Configured by a registry setting – see section 3.2.4 for further details.

6 The windbg program is included in Microsoft's Debugging Tools for Windows.- see section 3.2.4 for further information on windbg and the link to the download location.



In general the `-XX:+ShowMessageBoxOnError` option is more useful in a development environment where debugger tools are available. The `-XX:OnError` option is more suitable for production environments where a fixed sequence of commands or scripts are executed when a fatal error is encountered.

1.14 dbx

A debugger is often very useful when trying to diagnose an issue. The `dbx` debugger that ships with Sun Java Studio 9 can be used to debug java language code on Solaris in addition to native (C/C++) code.

Following is a simple debug session to demonstrate how to start an application with `dbx`:

```
$ dbx Test.class
For information about new features see `help changes'
To remove this message, put `dbxenv suppress_startup_message 7.1' in your
.dbxrc
Debug target is "Test.class"
Will be debugging "Test"
Reading -
detected a multithreaded program
(dbx) stop in Test.main
(2) java stop in Test.main(java.lang.String[])
(dbx) run
stopped in Test.main at line 4 in file "Test.java"
    4           System.out.println( "Hello" );
(dbx) dump
java.lang.String[] args = {}
(dbx) cont
```

Here is a second example, where `dbx` is attached to a process:

```
$ export LD_LIBRARY_PATH=<installation_directory>/SUNWspro/lib
$ java -Xdebug -Xrundbx_agent Hello.class&
[1]   1234
$ dbx - 1234
```

In this example <*installation_directory*> is the location where `dbx` is installed. The process id (pid) is 1234.

Here is another example where a jar file is provided to `dbx`. The jar file contains the `Main-Class` attribute in its manifest to specify the main class.

```
$ dbx Foo.jar
```

In cases where the jar file doesn't contain a Main-Class attribute, you can tell `dbx` the class to exeucte in the jar file. In this example the class is `Main`.

```
$ dbx Bar.jar!Main.class
```

Once running under `dbx` many of the traditional `dbx` commands perform the same operation that they do with native code. Examples of commands that are essentially the same are "`cont`", "`down`", "`list`", "`next`", and "`step up`". Others, such as "`print`" and "`step`" have different syntax.

Two java specific commands that are important to note are `jon` and `joff`. They are used to switch between java and native modes. When debugging a Java application, `dbx` is in one of three modes, namely, *Java mode*, *JNI mode*, or *native mode*. When `dbx` is in Java mode or JNI mode, you can inspect the state of your Java application, including JNI code, and control execution of the code. When `dbx` is in native mode, you can inspect the state of your C or C++ JNI code. The current mode (java, jni, native) is stored in the environment variable `jdbx_mode`.

In Java mode, you interact with `dbx` using Java syntax and `dbx` uses Java syntax to present information to you. This mode is used for debugging pure Java code, or the Java code in an application that is a mixture of Java code and C JNI code or C++ JNI code.

In JNI mode, `dbx` commands use native syntax and affect native code, but the output of commands shows Java-related status as well as native status, so JNI mode is a "mixed" mode. This mode is used for debugging the native parts of an application that contain a mixture of Java code and C JNI code or C++ JNI code.

In native mode, `dbx` commands affect only a native program, and all Java-related features are disabled. This mode is used for debugging non-Java related programs.

As you execute your Java application, `dbx` switches automatically between Java mode and JNI mode as appropriate. For example, when it encounters a Java breakpoint, `dbx` switches into Java mode, and when you step from Java code into JNI code, it switches into JNI mode.

The `jon` command is particularly useful if you interrupt the execution of an application (using Ctrl-C for example). When an application is interrupted `dbx` tries to set the mode automatically to Java/JNI mode by bringing the application to a safe state and suspending all threads. If `dbx` cannot suspend the application and switch to Java/JNI mode, `dbx` switches to native mode. You can then use the `jon` command to switch to Java mode in order to inspect the state of the program.

Debugging a java application with `dbx` is fully described in chapter 17 of the “Debugging a Program with dbx” manual in the Sun Studio 9 product. This chapter can be found here:

http://docs.sun.com/source/817-6692/Java_debug.html

1.15 Using jdb to Attach to a Core File or Hung Process

The Java Debug Interface (JDI) is a high level Java API providing information useful for debuggers and similar systems needing access to the running state of a (usually remote) virtual machine. JDI is a component of the Java Platform Debugger Architecture (JPDA). In JDI a *Connector* is the means by which the debugger connects to the target virtual machine. The JDK has traditionally shipped with Connectors that launch and establish a debugging session with a target VM and also Connectors that are used for remote debugging (using TCP/IP or shared memory transports).

JDK5.0 ships with three new Connectors on Solaris and Linux. These Connectors allow a Java Language debugger (such as the sample *jdb* command-line debugger) to attach to a crash dump or hung process. This can be useful when trying to diagnose what the application was doing at the time of the crash or hang. The three Connectors are:

Connector	***Description***
SA Core Attaching Connector	This Connector can be used by a debugger to debug a core file.
SA PID Attaching Connector	This Connector can be used by a debugger to debug a process.
SA Debug Server Attaching Connector	This Connector can be used by a debugger to debug a process or core file on a machine other than the machine upon which the debugger is running.

Further details about JPDA can be found at:

http://java.sun.com/j2se/1.5.0/docs/guide/jpda/index.html

Further information about these Connectors can be found at:

http://java.sun.com/j2se/1.5.0/docs/guide/jpda/conninv.html

The following demonstrates usage of these Connectors with the *jdb* command-line debugger that ships with JDK5.0. Generally, these Connectors will be used with more capable and enterprise debuggers (such as as NetBeans IDE or commerical IDEs).

1.15.1 Attaching to a Process

In this example we use the "SA PID Attaching Connector" to attach to a process. The target process is not started with any special options (*-agentlib:jdwp* option not required). When this Connector attaches to a process it does so in *read-only* mode; that is the debugger can examine threads and the running application but it cannot change anything. The command we use is as follows:

```
jdb -connect sun.jvm.hotspot.jdi.SAPIDAttachingConnector:pid=20441
```

This command instructs *jdb* to use a Connector named *sun.jvm.hotspot.jdi.SAPIDAttachingConnector*. This is a Connector name rather than a class name. The Connector takes one argument called "*pid*" and its value is the process-id of the target process (20441 in this example).

```
$ jdb -connect sun.jvm.hotspot.jdi.SAPIDAttachingConnector:pid=20441
Initializing jdb...
> threads
Group system:
  (java.lang.ref.Reference$ReferenceHandler)0x23 Reference Handler
unknown
  (java.lang.ref.Finalizer$FinalizerThread)0x22  Finalizer unknown
  (java.lang.Thread)0x21 Signal Dispatcher running
  (java.lang.Thread)0x24 main running
[... more lines removed here to reduce output ...]
Group main:
  (java.lang.Thread)0x1  TP-Monitor
unknown
  (com.ecyrd.jspwiki.PageManager$LockReaper)0x0 Thread-33
sleeping
> thread 0x24
main[1] where
  [1] java.net.PlainSocketImpl.socketAccept (native method)
  [2] java.net.PlainSocketImpl.socketAccept (native method)
  [3] java.net.PlainSocketImpl.accept (PlainSocketImpl.java:384)
  [4] java.net.ServerSocket.implAccept (ServerSocket.java:450)
  [5] java.net.ServerSocket.accept (ServerSocket.java:421)
  [6] org.apache.catalina.core.StandardServer.await (StandardServer.java:552)
  [7] org.apache.catalina.startup.Catalina.await (Catalina.java:634)
  [8] org.apache.catalina.startup.Catalina.start (Catalina.java:596)
  [9] sun.reflect.NativeMethodAccessorImpl.invoke0 (native method)
  [10] sun.reflect.NativeMethodAccessorImpl.invoke
(NativeMethodAccessorImpl.java:39)
  [11] sun.reflect.DelegatingMethodAccessorImpl.invoke
(DelegatingMethodAccessorImpl.java:25)
  [12] java.lang.reflect.Method.invoke (Method.java:585)
  [13] org.apache.catalina.startup.Bootstrap.start (Bootstrap.java:295)
  [14] org.apache.catalina.startup.Bootstrap.main (Bootstrap.java:392)
main[1] up 13
main[14] where
  [14] org.apache.catalina.startup.Bootstrap.main (Bootstrap.java:392)
```

```
main[14] locals
Method arguments:
args = instance of java.lang.String[1] (id=40)
Local variables:
command = "start"
```

In this example the *threads* command is used to get a list of all threads. Then a specific thread is selected with the *thread 0x24* command, and the *where* command is used to get a thread dump. Next the *up 13* command is used to move up 13 frames in the stack, and the *where* command is used again to get a thread dump. Finally the *locals* command is used to print the local variables for that stack frame. Note that you must compile the Java files with the *-g* option in order to use the *locals* command.

1.15.2 Attaching to a Core File

The *SA Core Attaching Connector* is used to attach the debugger to a core file. The core file may have been created after a crash (see section 2.2), or obtained by using the *gcore* command on Solaris (or *gdb's gcore* command on Linux). As the core file is a snapshot of the process at the time the core file was created, the Connector attaches in *read-only* mode; that is the debugger can examine threads and the running application at the time of the crash.

Following is an example of using this Connector:

```
jdb -connect sun.jvm.hotspot.jdi.SACoreAttachingConnector:\
   javaExecutable=$JAVA_HOME/bin/java,core=core.20441
```

This command instructs *jdb* to use a Connector named *sun.jvm.hotspot.jdi.SACoreAttachingConnector*. The Connector takes two arguments called *javaExecutable* and *core*. The *javaExecutable* argument indicates the name of the java binary. In this case the *JAVA_HOME* environment variable indicates the JDK home directory. The *core* argument is the core file name (the core from process with pid 20441 in this example).

To debug a core file that has been transported from another machine requires that the OS versions and libraries match. Sometimes this can be difficult to organize. For those environments you can run a proxy server called the *SA Debug Server*. Then, on the machine where the debugger is installed, you can use the SA Debug Server Attaching Connector to connect to the debug server.

To demonstrate this, assume that we have machine 1 and machine 2. A core file is available on machine 1 and the debugger is available on machine 2. On machine 1 we start the SA Debug Server:

```
jsadebugd $JAVA_HOME/bin/java core.20441
```

jsadebugd takes two arguments here. The first is the name of the binary/executable. In most cases this is java but it may be another name (in the case of embedded VMs for example). The second argument is the name of the core file. In this example the core file was obtained for a process with pid 20441

using the *gcore* utility.

On machine 2, we use the debugger to connect to the remote SA Debug Server using the SA Debug Server Attaching Connector. Following is an example command:

```
jdb -connect sun.jvm.hotspot.jdi.SADebugServerAttachingConnector:\
      debugServerName=machine1
```

This command instructs *jdb* to use a Connector named *sun.jvm.hotspot.jdi.SADebugServerAttachingConnector*. The Connector has a single argument *debugServerName* which is the hostname or IP address of the machine where the SA Debug Server is running.

Note that the SA Debug Server can also be used to remotely debug a hung process. In that case it takes a single argument which is the process-id of the process. Also, if it is required to run multiple debug servers on the same machine then each one must be provided with a unique ID. When using the SA Debug Server Attaching Connector this ID is provided as an additional Connector argument. These details are described in the JPDA documentation.

1.16 Ctrl-Break Handler

On Solaris or Linux the HotSpot VM will print a thread dump to the application's standard output if the Ctrl and \ keys are pressed. The thread dump consists of the thread stack for all Java threads in the VM. On Windows the equivalent key sequence is the Ctrl and Break keys. The thread dump doesn't terminate the application – it continues after the thread information is printed.

On Solaris and Linux a thread dump is also printed if the J2SE process receives a QUIT signal. So *kill -QUIT <pid>* causes the process with id <pid> to print a thread dump to its standard output.

In addition to the thread stacks, the ctrl-break handler also executes a deadlock detection algorithm. If any deadlocks are detected then it prints out additional information on each deadlocked thread. Following is an example thread dump:

```
Full thread dump Java HotSpot(TM) Client VM (1.5.0-rc-b63 mixed mode):

"AWT-EventQueue-0" prio=10 tid=0x00262048 nid=0xe waiting for monitor entry
[0xf0400000..0xf0401838]
        at java.awt.Container.removeNotify(Container.java:2503)
        - waiting to lock <0xf0c30560> (a java.awt.Component$AWTTreeLock)
        at java.awt.Window$1DisposeAction.run(Window.java:604)
        at java.awt.Window.doDispose(Window.java:617)
        at java.awt.Dialog.doDispose(Dialog.java:625)
        at java.awt.Window.dispose(Window.java:574)
        at java.awt.Window.disposeImpl(Window.java:584)
        at java.awt.Window$1DisposeAction.run(Window.java:598)
        - locked <0xf0c41ec8> (a java.util.Vector)
        at java.awt.Window.doDispose(Window.java:617)
        at java.awt.Window.dispose(Window.java:574)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.dispose(SwingUtilities.java:1743)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.windowClosed(SwingUtilities.java:172
2)
        at java.awt.Window.processWindowEvent(Window.java:1173)
        at javax.swing.JDialog.processWindowEvent(JDialog.java:407)
        at java.awt.Window.processEvent(Window.java:1128)
        at java.awt.Component.dispatchEventImpl(Component.java:3922)
        at java.awt.Container.dispatchEventImpl(Container.java:2009)
        at java.awt.Window.dispatchEventImpl(Window.java:1746)
        at java.awt.Component.dispatchEvent(Component.java:3770)
        at java.awt.EventQueue.dispatchEvent(EventQueue.java:463)
        at
java.awt.EventDispatchThread.pumpOneEventForHierarchy(EventDispatchThread.java:2
14)
        at
java.awt.EventDispatchThread.pumpEventsForHierarchy(EventDispatchThread.java:163
)
        at java.awt.EventDispatchThread.pumpEvents(EventDispatchThread.java:157)
        at java.awt.EventDispatchThread.pumpEvents(EventDispatchThread.java:149)
        at java.awt.EventDispatchThread.run(EventDispatchThread.java:110)

"AWT-Motif" daemon prio=10 tid=0x0023fc20 nid=0xd runnable
[0xf0501000..0xf05016b8]
        at sun.awt.motif.MToolkit.run(Native Method)
        at java.lang.Thread.run(Thread.java:549)
```

```
"AWT-Shutdown" prio=10 tid=0x0023f840 nid=0xc in Object.wait()
[0xf0601000..0xf0601738]
        at java.lang.Object.wait(Native Method)
        - waiting on <0xf0c4c5a8> (a java.lang.Object)
        at java.lang.Object.wait(Object.java:429)
        at sun.awt.AWTAutoShutdown.run(AWTAutoShutdown.java:259)
        - locked <0xf0c4c5a8> (a java.lang.Object)
        at java.lang.Thread.run(Thread.java:549)

"Java2D Disposer" daemon prio=10 tid=0x002007d8 nid=0xb in Object.wait()
[0xf0701000..0xf07019b8]
        at java.lang.Object.wait(Native Method)
        - waiting on <0xf0c49f28> (a java.lang.ref.ReferenceQueue$Lock)
        at java.lang.ref.ReferenceQueue.remove(ReferenceQueue.java:116)
        - locked <0xf0c49f28> (a java.lang.ref.ReferenceQueue$Lock)
        at java.lang.ref.ReferenceQueue.remove(ReferenceQueue.java:132)
        at sun.java2d.Disposer.run(Disposer.java:107)
        at java.lang.Thread.run(Thread.java:549)

"Low Memory Detector" daemon prio=10 tid=0x0012bf28 nid=0x9 runnable
[0x00000000..0x00000000]

"CompilerThread0" daemon prio=10 tid=0x0012a5a8 nid=0x8 waiting on condition
[0x00000000..0xfba800a0]

"Signal Dispatcher" daemon prio=10 tid=0x00129818 nid=0x7 waiting on condition
[0x00000000..0x00000000]

"Finalizer" daemon prio=10 tid=0x000feea8 nid=0x6 in Object.wait()
[0xfdd81000..0xfdd816b8]
        at java.lang.Object.wait(Native Method)
        - waiting on <0xf0c005b0> (a java.lang.ref.ReferenceQueue$Lock)
        at java.lang.ref.ReferenceQueue.remove(ReferenceQueue.java:116)
        - locked <0xf0c005b0> (a java.lang.ref.ReferenceQueue$Lock)
        at java.lang.ref.ReferenceQueue.remove(ReferenceQueue.java:132)
        at java.lang.ref.Finalizer$FinalizerThread.run(Finalizer.java:159)

"Reference Handler" daemon prio=10 tid=0x000fdc80 nid=0x5 in Object.wait()
[0xfde81000..0xfde81838]
        at java.lang.Object.wait(Native Method)
        - waiting on <0xf0c00498> (a java.lang.ref.Reference$Lock)
        at java.lang.Object.wait(Object.java:429)
        at java.lang.ref.Reference$ReferenceHandler.run(Reference.java:118)
        - locked <0xf0c00498> (a java.lang.ref.Reference$Lock)

"main" prio=10 tid=0x0002daa8 nid=0x1 waiting for monitor entry
[0xffbee000..0xffbeecd0]
        at java.awt.Window.getOwnedWindows(Window.java:844)
        - waiting to lock <0xf0c41ec8> (a java.util.Vector)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.installListeners(SwingUtilities.java
:1697)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.addNotify(SwingUtilities.java:1690)
        at java.awt.Dialog.addNotify(Dialog.java:370)
        - locked <0xf0c30560> (a java.awt.Component$AWTTreeLock)
        at java.awt.Dialog.conditionalShow(Dialog.java:441)
        - locked <0xf0c30560> (a java.awt.Component$AWTTreeLock)
```

```
        at java.awt.Dialog.show(Dialog.java:499)
        at java.awt.Component.show(Component.java:1287)
        at java.awt.Component.setVisible(Component.java:1242)
        at test01.main(test01.java:10)

"VM Thread" prio=10 tid=0x000fbd60 nid=0x4 runnable

"VM Periodic Task Thread" prio=10 tid=0x0012cb68 nid=0xa waiting on condition
```

The output consists of the header and stack trace for each thread. Each thread is separated by an empty line. The Java threads (threads that are capable of executing Java Language code) are printed first, and these are followed by information on VM internal threads.

For each Java thread there is a header line with information about the thread, and this is followed by the thread stack. The header line prints the thread name, indicates if the thread is a daemon thread, and also prints the java thread priority :

```
"Java2D Disposer" daemon prio=10 tid=0x002007d8 nid=0xb in Object.wait()
[0xf0701000..0xf07019b8]
        at java.lang.Object.wait(Native Method)
        - waiting on <0xf0c49f28> (a java.lang.ref.ReferenceQueue$Lock)
        at java.lang.ref.ReferenceQueue.remove(ReferenceQueue.java:116)
        - locked <0xf0c49f28> (a java.lang.ref.ReferenceQueue$Lock)
        at java.lang.ref.ReferenceQueue.remove(ReferenceQueue.java:132)
        at sun.java2d.Disposer.run(Disposer.java:107)
        at java.lang.Thread.run(Thread.java:549)
```

In the header the *tid* is the thread id that is the address of a thread structure in memory. The *nid* is the id of the native thread and this is followed by the thread state. The thread state indicates what the thread is doing at the time of the thread dump. Following are the possible states that can be printed :

allocated
initialized
runnable
waiting for monitor entry
waiting on condition
in Object.wait()
sleeping

After the thread is an address range – this is an estimate of the valid stack region for the thread.

1.16.1 Deadlock Detection

After the thread dump, the deadlock results are printed (as follows for the above example):

```
Found one Java-level deadlock:
============================
```

```
"AWT-EventQueue-0":
  waiting to lock monitor 0x000ffbf8 (object 0xf0c30560, a
java.awt.Component$AWTTreeLock),
  which is held by "main"
"main":
  waiting to lock monitor 0x000ffe38 (object 0xf0c41ec8, a java.util.Vector),
  which is held by "AWT-EventQueue-0"

Java stack information for the threads listed above:
===================================================
"AWT-EventQueue-0":
        at java.awt.Container.removeNotify(Container.java:2503)
        - waiting to lock <0xf0c30560> (a java.awt.Component$AWTTreeLock)
        at java.awt.Window$1DisposeAction.run(Window.java:604)
        at java.awt.Window.doDispose(Window.java:617)
        at java.awt.Dialog.doDispose(Dialog.java:625)
        at java.awt.Window.dispose(Window.java:574)
        at java.awt.Window.disposeImpl(Window.java:584)
        at java.awt.Window$1DisposeAction.run(Window.java:598)
        - locked <0xf0c41ec8> (a java.util.Vector)
        at java.awt.Window.doDispose(Window.java:617)
        at java.awt.Window.dispose(Window.java:574)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.dispose(SwingUtilities.java:1743)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.windowClosed(SwingUtilities.java:172
2)
        at java.awt.Window.processWindowEvent(Window.java:1173)
        at javax.swing.JDialog.processWindowEvent(JDialog.java:407)
        at java.awt.Window.processEvent(Window.java:1128)
        at java.awt.Component.dispatchEventImpl(Component.java:3922)
        at java.awt.Container.dispatchEventImpl(Container.java:2009)
        at java.awt.Window.dispatchEventImpl(Window.java:1746)
        at java.awt.Component.dispatchEvent(Component.java:3770)
        at java.awt.EventQueue.dispatchEvent(EventQueue.java:463)
        at
java.awt.EventDispatchThread.pumpOneEventForHierarchy(EventDispatchThread.java:2
14)
        at
java.awt.EventDispatchThread.pumpEventsForHierarchy(EventDispatchThread.java:163
)
        at java.awt.EventDispatchThread.pumpEvents(EventDispatchThread.java:157)
        at java.awt.EventDispatchThread.pumpEvents(EventDispatchThread.java:149)
        at java.awt.EventDispatchThread.run(EventDispatchThread.java:110)
"main":
        at java.awt.Window.getOwnedWindows(Window.java:844)
        - waiting to lock <0xf0c41ec8> (a java.util.Vector)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.installListeners(SwingUtilities.java
:1697)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.addNotify(SwingUtilities.java:1690)
        at java.awt.Dialog.addNotify(Dialog.java:370)
        - locked <0xf0c30560> (a java.awt.Component$AWTTreeLock)
        at java.awt.Dialog.conditionalShow(Dialog.java:441)
        - locked <0xf0c30560> (a java.awt.Component$AWTTreeLock)
        at java.awt.Dialog.show(Dialog.java:499)
        at java.awt.Component.show(Component.java:1287)
        at java.awt.Component.setVisible(Component.java:1242)
```

```
        at test01.main(test01.java:10)

Found 1 deadlock.
```

In the example we see that thread *main* is locking objects *<0xf0c30560>* and *<0xf0c30560>*, and is waiting to enter *<0xf0c41ec8>* that is currently locked by thread *AWT-EventQueue-0*. But, thread *AWT-EventQueue-0* is waiting to enter *<0xf0c30560>* that is locked by main. This straight-forward and classic deadlock involves 2 threads. In other cases the deadlock will be more complex and involve additional threads.

1.17 Other Options and System Properties

This section describes a variety of options and properties that may be useful in some troubleshooting situations.

1.17.1 -verbose:gc

The *-verbose:gc* option enables logging of GC information. It can be combined with other HotSpot VM specific options such as *-XX:+PrintGCDetails* and *-XX:+PrintGCTimeStamps* to get further information about the GC. The information output includes the size of the generations before and after each GC, total size of the heap, the size of objects promoted, and the time taken.

These options, together with detailed information about GC analysis and tuning, are described at the GC portal site:

http://java.sun.com/developer/technicalArticles/Programming/GCPortal

Note that the *-verbose:gc* option can be dynamically enabled at runtime using the management API or JVM TI (See section 1.19 for further information on these APIs). The *jconsole* monitoring and management tool can also enable (or disable) the option when attached to a management VM (jconsole is described in section 1.5).

1.17.2 -verbose:class

The *-verbose:class* option enables logging of class loading and unloading.

1.17.3 -Xcheck:jni option

The *-Xcheck:jni* option is useful when trying to diagnose problems with applications that use the Java Native Interface (JNI). Sometimes there can be bugs in the native code that cause the HotSpot VM to crash or behave incorrectly. To use the -Xcheck:jni option just add it to the command line when starting the application, for example:

java -Xcheck:jni MyApplication

When the *-Xcheck:jni* option is used it tells the VM to do additional validation on the arguments passed to JNI functions. It should be noted that the option is not guaranteed to find all invalid arguments or diagnose logic bugs in the application code, but it can help diagnose a large number of such problems.

When an invalid argument is detected, the VM prints a message (to the application console/standard output), prints the stack trace of the offending thread, and aborts the VM. Following is an example where a *NULL* is incorrectly passed to a JNI function that does not allow *NULL*:

```
FATAL ERROR in native method: Null object passed to JNI
    at java.net.PlainSocketImpl.socketAccept(Native Method)
    at java.net.PlainSocketImpl.accept(PlainSocketImpl.java:343)
    - locked <0x450b9f70> (a java.net.PlainSocketImpl)
    at java.net.ServerSocket.implAccept(ServerSocket.java:439)
    at java.net.ServerSocket.accept(ServerSocket.java:410)
    at org.apache.tomcat.service.PoolTcpEndpoint.acceptSocket(PoolTcpEndpoint.java:286)
    at org.apache.tomcat.service.TcpWorkerThread.runIt(PoolTcpEndpoint.java:402)
    at org.apache.tomcat.util.ThreadPool$ControlRunnable.run(ThreadPool.java:498)
    at java.lang.Thread.run(Thread.java:536)
```

Following is another exmaple of output that arises when something other than a *jfieldID* is provided to a JNI functions that expects a *jfieldID*:

```
FATAL ERROR in native method: Instance field not found in JNI get/set field operations
        at java.net.PlainSocketImpl.socketBind(Native Method)
        at java.net.PlainSocketImpl.bind(PlainSocketImpl.java:359)
        - locked <0xf082f290> (a java.net.PlainSocketImpl)
        at java.net.ServerSocket.bind(ServerSocket.java:318)
        at java.net.ServerSocket.<init>(ServerSocket.java:185)
        at jvm003a.<init>(jvm003.java:190)
        at jvm003a.<init>(jvm003.java:151)
        at jvm003.run(jvm003.java:51)
        at jvm003.main(jvm003.java:30)
```

Following are other examples of problems that *-Xcheck:jni* can help diagnose :

1. Cases where the JNI environment for the wrong thread is used.
2. Cases where an invalid JNI reference is used.
3. Cases when a reference to a non-array type is provided to a function that requires an array type.
4. Cases where a non-static field ID is provided to a function that expects a static field ID.
5. Cases where a JNI call is made with an exception pending.

In general, all errors detected by -Xcheck:jni are fatal errors. That is, the error is printed and the VM is aborted when the error is detected. One exception to this is a non-fatal warning that is printed when a JNI call is made within a JNI critical region. When this arises the following warning is printed :

```
Warning: Calling other JNI functions in the scope of Get/ReleasePrimitiveArrayCritical or
Get/ReleaseStringCritical
```

A JNI critical region arises when native code uses the JNI *GetPrimitiveArrayCritical* or *GetStringCritical* functions to obtain a reference to an array or string in the Java heap. The reference is held until the native code calls the corresponding release function. In between the *get* and *release* is called a JNI critical section and during that time the HotSpot VM cannot bring the VM to a state that allows garbage collection to occur. The general recommendation is that other JNI functions should not be used when in a JNI critical section, and in particular any JNI function that blocks could potentially cause a deadlock. The warning printed by *-Xcheck:jni* is thus an indication of a potential issue; it does not always indicate an application bug.

1.17.4 -verbose:jni

The *-verbose:jni* option enables logging of JNI. Specifically, when a JNI/native method is resolved the HotSpot VM prints a trace message to the application console (standard output). It also prints a trace message when a native method is registered using the JNI RegisterNative function. The *-verbose:jn*i option may be useful when trying to diagnose issues with applications that use native libraries.

1.17.5 JAVA_TOOL_OPTIONS Environment Variable

In many environments the command line to start the application is not readily accessible. This often arises with applications that use embedded VMs (meaning they use the JNI Invocation API to start the VM), or the startup is deeply nested in scripts. In these environments the *JAVA_TOOL_OPTIONS* environment variable may be useful to augment a command line. This environment variable is primarily intended to support the initialization of tools, specifically the launching of native or Java programming language agents using the *-agentlib* or *-javaagent* options. The environment variable is processed at the time of the JNI Invocation API create VM call; options processed by a launcher (such as VM selection options) will not be handled. When set, the `JNI_CreateJavaVM` function (in the JNI Invocation API) will prepend the value of the environment variable to the options supplied in its `JavaVMInitArgs` argument. In some cases this option is disabled for security reasons; for example, on Solaris the option is disabled when the effective user or group ID differs from the real ID.

Here is an example where we set the environment variable so that the HPROF profiler is launched when the application is started:

```
export JAVA_TOOL_OPTIONS=”-agentlib:hprof”
```

Although the option is intended to support the initialization of tools, it may be useful to augment the command line with other options for diagnostics purposes. For example, it may be a useful method to augment the command line with a *-XX:OnError* option when you want a script or command to be executed when a fatal error occurs. As the environment variable is examined at the time that `JNI_CreateJavaVM` is called it cannot be used to augment the command-line with options that would normally be handled by the launcher (vm selection using the *-client* or *-server* option for example). The *JAVA_TOOL_OPTIONS* environment variable is fully described in the JVM TI specification at:

http://java.sun.com/j2se/1.5.0/docs/guide/jvmti/jvmti.html#tooloptions

1.17.6 java.security.debug System Property

The java.security.debug system property controls whether the security checks in the JRE of the Java prints trace messages during execution. This option can be useful when trying to diagnose an issue involving a security manager when trying to explain why a *SecurityException* is thrown. The value of the property is one of the following:

- `access` — print all `checkPermission` results
- `jar` — print jar verification information
- `policy` — print policy information
- `scl` — print permissions `SecureClassLoader` assigns

With the *access* option the following sub-options can be used:

- `stack` — include stack trace
- `domain` — dumps all domains in context
- `failure` — before throwing exception, dump the stack and domain that didn't have permission

For example, to print all `checkPermission` results and trace all domains in context, set the property to “access,stack”. To trace access failures set the property to “access,failure”. Here's an example showing the output of a *checkPermission* failure:

```
$ java -Djava.security.debug=”access,failure” Application
access denied (java.net.SocketPermission server.foobar.com resolve
)
java.lang.Exception: Stack trace
    at java.lang.Thread.dumpStack(Thread.java:1158)
    at java.security.AccessControlContext.checkPermission(AccessControlContext.java:253)
    at java.security.AccessController.checkPermission(AccessController.java:427)
    at java.lang.SecurityManager.checkPermission(SecurityManager.java:532)
    at java.lang.SecurityManager.checkConnect(SecurityManager.java:1031)
    at java.net.InetAddress.getAllByName0(InetAddress.java:1117)
    at java.net.InetAddress.getAllByName0(InetAddress.java:1098)
    at java.net.InetAddress.getAllByName(InetAddress.java:1061)
    at java.net.InetAddress.getByName(InetAddress.java:958)
    at java.net.InetSocketAddress.<init>(InetSocketAddress.java:124)
    at java.net.Socket.<init>(Socket.java:178)
    at Test.main(Test.java:7)
```

1.18 Operating System Tools

This section lists a number of operating system tools that can be useful for troubleshooting or monitoring purposes. A brief description is provided for each tool. For further details, refer to the operating system documentation (or man pages in the case of Solaris and Linux).

1.18.1 Solaris Operating System

Tool	*Description*
cputrack	Per-process monitor process, LWP behavior using CPU performance counters.
cpustat	Monitor system performance/behavior using CPU performance counters.
c++filt	Demangle C++ mangled symbol names.
dbx	Solaris source debugger Note: dbx can debug java code in addition to native code (see section 1.14).
dtrace	**Solaris 10**: Dynamic tracing of Kernel functions, system calls and user-land functions. Allows arbitrary, safe scripting to be executed at entry/exit and other probe points. Script is written in C-like but safe pointer semantics language called *D*.
libumem	User space slab allocator (Solaris 9 update 3 and Solaris 10). It can be used to find and fix memory management bugs (see section 2.1.3.2).
iostat	Report I/O statistics.
netstat	Display the contents of various network-related data structures.
mdb	Modular debugger for kernel and user apps and crash dumps
pfiles	Print information on process file descriptors. **Solaris 10** version prints filename as well!
pldd	Print shared objects loaded by a process.
pmap	Print memory layout of a process or core file - heap, data, text sections. **Solaris 10** version clearly identifies stack segments with [stack] along with the thread id.
prun	Set the process to running mode (reverse of **pstop**).
prstat	Report active process statistics.
psig	List the signal handlers of a process.
pstack	Print stack of threads of a given process or core file. **Solaris 10** version can print Java method names for Java frames.
pstop	Stop the process (suspend).
ps	List all processes.
ptree	Print process tree starting at given pid.
sar	System activity reporter.

Tool	*Description*
truss	Trace entry/exit event for system calls, user-land functions, signals and optionally stop the process at one of these events. Print arguments as well.
vmstat	Report system virtual memory statistics.
gcore	Utility to force a core dump of a process. The process continues after the core dump is written.

1.18.2 Linux

Tool	*Description*
ltrace	Library call tracer (equivalent to **truss -u**) Not all distributions have this by default. May have to download separately.
mtrace / muntrace	GNU malloc tracer.
proc tools such as pmap, pstack	Not all Solaris equivalent proc tools are available – only a subset. Also core file support is not as good as for Solaris; for example **pstack** does not work for core dumps.
strace	System call tracer (equivalent to **truss -t**).
top	Display most CPU intensive processes.
vmstat	Report information about processes, memory, paging, block IO, traps, and cpu activity.
gdb	GNU debugger.

1.18.3 Microsoft Windows

Tool	*Description*
windbg	Windows debugger which can be used to debug Windows applications or crash dumps. Included in Debugging Tools for Windows download available from the Microsoft web site (see section 3.2.4).
dumpchk	Command-line utility you can use to verify that a memory dump file has been created correctly Included in Debugging Tools for Windows download available from the Microsoft web site (see section 3.2.4).
userdump	User Mode Process Dump utility. Included in the OEM Support Tools download available from the Microsoft web site (see section 3.2.4).

1.18.4 Solaris 10 Operating System Tools

The previous section listed a number of operating system tools that can be useful for troubleshooting

or monitoring purposes. Solaris 10 has an extensive range of diagnostics tools and features. A number of these tools are hightlighted here.

1.18.4.1 Improved pmap

The Solaris **pmap** utility has been improved in Solaris 10 to print stack segments as [**stack**] unlike older Solaris releases. This helps us to locate stack easily.

The follow shows some example output :

```
19846:/net/myserver/export1/user/j2sdk1.5.0/bin/java -Djava.endorsed.d
00010000      72K r-x--
/export/disk09/jdk/1.5.0/rc/b63/binaries/solsparc/bin/java
00030000      16K rwx--
/export/disk09/jdk/1.5.0/rc/b63/binaries/solsparc/bin/java
00034000   32544K rwx--    [ heap ]
D1378000      32K rwx-R    [ stack tid=44 ]
D1478000      32K rwx-R    [ stack tid=43 ]
D1578000      32K rwx-R    [ stack tid=42 ]
D1678000      32K rwx-R    [ stack tid=41 ]
D1778000      32K rwx-R    [ stack tid=40 ]
D1878000      32K rwx-R    [ stack tid=39 ]
D1974000      48K rwx-R    [ stack tid=38 ]
D1A78000      32K rwx-R    [ stack tid=37 ]
D1B78000      32K rwx-R    [ stack tid=36 ]
[.. more lines removed here to reduce output ..]
FF370000       8K r-x--  /usr/lib/libsched.so.1
FF380000       8K r-x--  /platform/sun4u-us3/lib/libc_psr.so.1
FF390000      16K r-x--  /lib/libthread.so.1
FF3A4000       8K rwx--  /lib/libthread.so.1
FF3B0000       8K r-x--  /lib/libdl.so.1
FF3C0000     168K r-x--  /lib/ld.so.1
FF3F8000       8K rwx--  /lib/ld.so.1
FF3FA000       8K rwx--  /lib/ld.so.1
FFB80000      24K -----    [ anon ]
FFBF0000      64K rwx--    [ stack ]
 total    167224K
```

1.18.4.2 Improved pstack

On Solaris 10, the *pstack* command line tool prints mixed mode stack traces (Java and C/C++ frames) from a core file or a live process. The pre-Solaris 10 *pstack* utility does not support Java. It used to print hexadecimal addresses for both interpreted and (HotSpot) compiled Java methods. The new Solaris 10 *pstack* prints Java method names for interpreted, compiled and inlined Java methods.

1.18.4.3 dtrace

The Solaris *truss* utility allows tracing of system calls, user mode functions, and signals. *truss* prints

the arguments of system calls and user functions. Solaris 10 includes *dtrace* which allows dynamic tracing of the operating system kernel and user level programs. *dtrace* allows scripting at system call entry/exit, user mode function entry/exit and many other probe points. The scripts executed at probe points are written in the *D language (a* C-like language with safe pointer semantics). You can get more details on *dtrace* at:

http://www.sun.com/bigadmin/content/dtrace/

At probe points, you can print the stack trace current thread using the **ustack** built-in function. This function prints Java method names in addition to C/C++ native function names! The following is a simple D-script that prints a full stack trace whenever a thread calls the read system call.

```
#!/usr/sbin/dtrace -s
syscall::read:entry
/pid == $1 && tid == 1/ {
   ustack(50, 0x2000);
}
```

The above script stored in a file named read.d is run with the command:

read.d <pid of the Java process traced>

If your java application generated a lot of I/O or had some unexpected latency, using *dtrace* and it's java-enabled **ustack()** action, you can track the problem down.

1.19 Developing Diagnostic Tools

JDK 5.0 has extensive Application Programing Interfaces (APIs) which can be used to develop tools to observe, monitor, profile, debug, and diagnose issues in applications that are deployed on the Java Runtime Environment. The development of new tools is beyond the scope of this document. Instead we provide a brief overview of the programming interfaces available. Refer also to example and demonstration code that is included in the JDK download.

java.lang.management

The java.lang.management package provides the management interface for monitoring and management of the Java Virtual Machine, and the operating system. Specifically it covers interfaces for the following systems :

- class loading
- compilation
- garbage collection
- memory manager
- runtime
- threads

The java.lang.management package is fully described in the API documentation found at:

http://java.sun.com/j2se/1.5.0/docs/api/index.html

JDK 5.0 includes example code that demonstrates the usage of the java.lang.management package. These examples can be found in the $JAVA_HOME/demo/management directory (where $JAVA_HOME is the directory where the JDK is installed). The examples include :

- *MemoryMonitor* - demonstrates the use of the java.lang.management API to observe the memory usage of all memory pools consumed by the application.
- *FullThreadDump* - demonstrates the use of the java.lang.management API to print a full thread dump.
- *VerboseGC* - demonstrates the use of the java.lang.management API to print the garbage collection statistics and memory usage of an application.

In addition to java.lang.management, the Sun implementation of 5.0 includes platform extensions in the com.sun.management package. The platform extensions include a management interface to obtain detailed statistics from garbage collectors which perform collections in cycles. It also includes a management interface to obtain additional memory statistics from the operating system. Details on the platform extensions can be found at:

http://java.sun.com/j2se/1.5.0/docs/guide/management/extension/index.html

java.lang.instrument

The java.lang.instument package provides services that allow Java programming language agents to instrument programs running on the JVM. Instrumentation is used by tools such as profilers, tools for tracing method calls, and many others. The package facilitates both load-time and dynamic instrumentation. It also includes methods to obtain information on the loaded classes and information about the amount of storage consumed by a given object.

The java.lang.instrument package is fully described in the API documentation which can be found at:

http://java.sun.com/j2se/1.5.0/docs/api/index.html

java.lang.Thread

The *java.lang.Thread* class has a static method called *getAllStackTraces* that returns a map of stack traces for all live threads. The *Thread* class also has a method called *getState* that returns the thread state; states are defined by the *java.lang.Thread.State* enumeration. These methods are noted here as they can be useful when adding diagnostics or monitoring capabilities to an application. They are fully described in the API documentation.

Java Virtual Machine Tools Interface

The Java Virtual Machine Tools Interface (JVM TI) is a native (C/C++) programming interface which can be used to develop a wide range of developing and monitoring tools. JVM TI provides an interface for the full breadth of tools that need access to VM state, including but not limited to: profiling, debugging, monitoring, thread analysis, and coverage analysis tools. The HPROF profiler, the Java Debug Wire Protocol (JDWP) agent, and the java.lang.instrument implementation are example agents that rely on JVM TI.

The specification for JVM TI can be found at:

http://java.sun.com/j2se/1.5.0/docs/guide/jvmti/jvmti.html

JDK 5.0 includes example code that demonstrates the usage of JVM TI. These examples can be found in the $JAVA_HOME/demo/jvmti directory (where $JAVA_HOME is the directory where the JDK is installed). The examples include :

- *mtrace* - an agent library that tracks method call and return counts. It uses byte-code instrumentation to instrument all classes loaded into the virtual machine and prints out a sorted list of the frequently used methods.
- heapTracker – an agent library that tracks object allocation. It uses byte-code instrumentation to instrument constructor methods.
- heapViewer – an agent library that prints heap statistics when Ctrl-\ or Ctrl-Break is pressed. For each loaded class it prints an instance count of that class and the space used.

Java Platform Debugger Architecture

The Java Platform Debugger Architecture (JPDA) is the architecture designed for use by debuggers and debugger-like tools. It consists of two programming interfaces and a wire protocol. JVM TI is the interface to the virtual machine (as described above); Java Debug Wire Protocol (JDWP) defines the format of information and requests transferred between the process being debugged and the debugger front end, which implements the Java Debug Interface (JDI). The Java Debug Interface defines information and requests at the user code level. It is a pure Java programming language interface for debugging Java programming language applications. In JPDA, the JDI is a remote view in the debugger process of a virtual machine in the debuggee process. It is implemented by the front-end (above) while a debugger-like application (IDE, debugger, tracer, monitoring tool, ...) is the client.

A complete description (including specifications) for JPDA can be found at:

http://java.sun.com/j2se/1.5.0/docs/guide/jpda/index.html

jdb is the example command-line debugger included in JDK 5.0. *jdb* uses JDI to launch or connect to the target VM. The source code to jdb is included in the *$JAVA_HOME/demo/jpda/examples.jar* (where *$JAVA_HOME* is the directory where the JDK is installed).

In addition to traditional debugger-type tools, JDI can also be used to develop tools that help in post mortem diagnostics and scenarios where the tool needs to attach to a process in a non-cooperative manner (a hung process for example). See section 1.15 for a description of the JDI *Connectors* which can be used to attach a JDI-based tool to a crash dump or hung process.

Java Virtual Machine Profiling Interface

Older releases of J2SE shipped with an experimental profiler interface called the Java Virtual Machine Profiling Interface (JVMPI). JVMPI is a deprecated interface as of J2SE 5.0. Its use in the development of new tools is discouraged as the interface is VM invasive, non-scalable, and as a result will be removed in the next major release of J2SE after 5.0. The new JVM TI should be used in its place.

2 Troubleshooting Information

This present document addresses possible problems between the application and the Java HotSpot™ virtual machine. For help in troubleshooting applications that use the Java SE desktop technologies (for example, AWT, Java 2D, Swing, and others), see the Troubleshooting Guide for Java SE 6 Desktop Technologies, which applies to both releases 5.0 and 6 of Java SE:

PDF: http://java.sun.com/javase/6/webnotes/trouble/TSG-Desktop/TSG-Desktop.pdf

HTML: http://java.sun.com/javase/6/webnotes/trouble/TSG-Desktop/html/toc.html

This chapter provides information and guidance on how to approach the following important issues:

- Memory Leaks
- Crashes
- Hangs
- Integrating Applications that Make Use of System Signals

2.1 Diagnosing Memory Leaks

A common issue that many developers find themselves chasing is that of applications that terminate with *java.lang.OutOfMemoryError*. A related issue arises with applications that terminate because the virtual memory on the operating system is exhausted (or close to exhaustion). Here we provide more information about what *OutOfMemoryError* means and provide some suggestions on how the issue can be diagnosed.

2.1.1 What does OutOfMemoryError mean?

The *java.lang.OutOfMemoryError* error is thrown when there is insufficient space to allocate an object in the java heap (or a particular area of the heap). That is, garbage collection cannot make any further space available to accommodate a new object and the heap cannot be expanded further. An *OutOfMemoryError* does not imply a memory leak – the issue can be as simple as a configuration issue where the specified heap size (or the default size if not specified) is insufficient for the application.

A *java.lang.OutOfMemoryError* error can also be thrown by native library code when a native allocation cannot be satisfied. This is not intuitive, but when an *OutOfMemoryError* is thrown it is not always obvious (at least initially) if the issue is that the java heap is exhausted or there is native heap exhaustion (low swap space for example).

An early step to diagnose an *OutOfMemoryError* is to determine what the error means. Does it mean that the java heap is full or does it mean that the native heap is full? Here we list some of the possible error messages and explain what they mean:

Exception in thread "main" java.lang.OutOfMemoryError: Java heap space
This indicates that an object could not be allocated in the java heap. The issue may be just a configuration issue; for example, the *-mx* option may have been used to specify a maximum heap size that is insufficient for the application.

In other cases, and in particular for a long-lived application, it may be an indication that the application (or APIs used by that application) is un-intentionally holding references to objects which prevents them from being garbage collected. This is the Java Language equivalent of a memory leak.

One other potential source of *OutOfMemoryError* arises with applications that make excessive use of finalizers. If a class has a *finalize* method then objects of that type do not have their space reclaimed at garbage collection time. Instead after garbage collection the objects are queued for finalization which occurs sometime later. In the Sun implementation finalizers are executed by a daemon thread that services the finalization queue. If the finalizer thread cannot keep up with the finalization queue then it is possible that the java heap will fill up and *OutOfMemoryError* will be thrown. One scenario that can induce this condition is when an application creates high priority threads that cause the finalization queue to increase at a rate that is faster than the rate that the finalizer thread is servicing that queue. Monitoring the number of objects for which finalization is pending is discussed in section 2.1.2.5.

Exception in thread "main" java.lang.OutOfMemoryError: PermGen space

This indicates that the permanent generation is full. The permanent generation is the area of the heap where class and method objects are stored. If an application loads a very large number of classes then the permanent generation may need to be increased using the `-XX:MaxPermSize` option.

The permanent generation is also used when *java.lang.String* objects are interned[7]. If an application interns a huge number of strings it may require the permanent generation be increased from its default setting.

Exception in thread "main" java.lang.OutOfMemoryError: Requested array size exceeds VM limit
This indicates that the application (or APIs used by that application) attempted to allocate an array that is larger than the heap size. For example if an application attempts to allocate an array of 512MB but the maximum heap size is 256MB then *OutOfMemoryError* will be thrown with this reason. In most cases this issue is likely to be a configuration issue (heap size too small), or a bug that results in an application attempting to create a huge array (the number of elements in the array have been computed using an algorithm that computes an incorrect size for example).

Exception in thread "main" java.lang.OutOfMemoryError: request <size> bytes for <reason>. Out of swap space?
Although it appears that an *OutOfMemoryError* is thrown this apparent exception is reported by the HotSpot VM code when an allocation from the native heap failed and the native heap may be close to exhaustion. The message indicates the size (in bytes) of the request that failed and also indicates what the memory is required for. In some cases the reason will be shown but in most cases the reason will be the name of a source module reporting the allocation failure.

If an *OutOfMemoryError* with this error is thrown it may require using utilities on the operating system to diagnose the issue further. Examples of issues that may not be related to the application are when the operating system is configured with insufficient swap space, or when there is another process on the system that is consuming all memory resources. If neither of these issues is the cause then it is possible that the application is failed due to native leak; for example, application or library code is continuously allocating memory but is not releasing it to the operating system.

Exception in thread "main" java.lang.OutOfMemoryError: <reason>
<stack trace>(Native method)
If the *OutOfMemoryError* is thrown and a stack trace is printed and the top frame in the stack trace is a *Native method,* this is an indication that a native method has encountered an allocation failure. The difference between this and the previous message is that the allocation failure was detected in a JNI/native method rather than VM code. As with the previous message it requires using utilities on the operating system to further diagnose the issue.

A crash instead of an OutOfMemoryError
Sometimes an application may crash soon after an allocation from the native heap fails. This arises with native code that does not check for errors returned by memory allocation functions. The *malloc*

7 `java.lang.String` maintains a pool of strings. When the `intern` method is invoked, it checks the pool to see if an equal string is already in the pool. If there is then the `intern` method returns it, otherwise it adds the string to the pool. In more precise terms, the `java.lang.String.intern` method is used to obtain the canonical representation of the string; the result is a reference to the same class instance that would be returned if that string appeared as a literal.

system call (for example) returns *NULL* if there is no memory available. If the return from *malloc* is not checked then the application may crash when it attempts to access an invalid memory location. Depending on the circumstances, this type of issue can be difficult to locate. However in some cases the information from the fatal error log or the crash dump may be sufficient to diagnose this issue. (The fatal error log is covered in detail in section 2.2.1.) If a crash is diagnosed to be because an allocation failure is not checked then the reason for the allocation failure must be examined. As per any other native heap issue, it may be that the system is configured with insufficient swap space, another process on the system is consuming all memory resources, or there is a leak in the application (or the APIs that it uses) that causes the system to run out of memory.

2.1.2 Diagnosing Leaks in Java Language Code

Diagnosing leaks in Java Language code can be a difficult task. In most cases it requires very detailed knowledge of the application. In addition the process is often iterative and lengthy.

2.1.2.1 The NetBeans Profiler

The NetBeans Profiler (previously known as *JFluid*) is an excellent profiler that can locate memory leaks very quickly. With most commercial memory leak debugging tools it can often take a long time to locate a leak in a large application. The NetBeans Profiler, however, uses the pattern of allocations and reclamations (or lack thereof) that such objects typically demonstrate. The profiler can check where these objects were allocated, which in many cases is sufficient to identify the root cause of the leak. More details can be found at http://profiler.netbeans.org.

At the time of this writing, the NetBeans Profiler relied on a special build of J2SE 1.4.2. However the profiler is in the process of being updated so that it will work with a future update release of J2SE 5.0. For this reason further discussion on the NetBeans Profiler is not included here. Readers should check the web site for updates on this issue.

2.1.2.2 Using HAT

The Heap Analysis Tool (HAT) is described in section 1.11. HAT is useful when debugging unecessary object retention (or memory leaks). It provides a way to browse an object dump, view all reachable objects in the heap, and understand which references are keeping an object alive.

> **Note:** The Java Heap Analysis Tool (`jhat`) provides the same functionality as HAT, with several additional enhancements and improvements. See section 1.12.

To use HAT (or `jhat`) it is necessary to obtain one or more binary format heap dumps of the running application.

One way to obtain a heap dump is to run the application with the HPROF profiler agent. Following is an example command line:

```
java -agentlib:hprof=file=dump.hprof,format=b <Application>
```

If the VM is embedded or is not started using a command line launcher that allows additional options

be provided then it may be possible to use the *JAVA_TOOLS_OPTIONS* environment variable so that the *-agentlib* option is automatically added to the command line. See section 1.17.5 for further information on this environment variable.

Once the application is running with HPROF, a heap dump is created by pressing *Ctrl-* or *Ctrl-Break* (depending on the platform) on the application console/standard output. An alternative approach on Solaris and Linux is to send a *QUIT* signal via the *kill -QUIT <pid>* command. When the signal is received a heap dump is created; in this case the *dump.hprof file* is created. A dump file can contain multiple heap dumps. If *Ctrl-* or *Ctrl-Break* is pressed a number of times then the second, and subsequent, dumps are appended to the file. HAT uses the #<*n*> syntax to distinguish the dump (where *n* is the dump number).

Recent update releases have introduced two new ways to obtain a heap dump in binary format:

- As of Java SE release 5.0 update 7, the `-XX:+HeapDumpOnOutOfMemoryError` command-line option tells the HotSpot VM to generate a heap dump when an OutOfMemoryError occurs (see section 1.9).
- As of Java SE release 5.0 update 14, the `-XX:+HeapDumpOnCtrlBreak` command-line option tells the HotSpot VM to generate a heap dump when a Ctrl-Break or SIGQUIT signal is received (see section 1.10).

Once a dump file is created it can be used as input to HAT. HAT processes the dump file and then starts a HTTP server on a specified port. Once started you can use any browser to connect to HAT and browse the heap. Here is an example where the input file is *dump.hprof* and HAT is started on TCP port *7000*. It assumes that *HAT_BIN* is set to the *HAT* bin directory which contains *hat.jar*.

```
java -jar $HAT_BIN/hat.jar -port 7000 dump.hprof

Started HTTP server on port 7000
Reading from dump.hprof...
Dump file created Fri Sep 03 17:13:43 BST 2004
Snapshot read, resolving...
Resolving 163131 objects...
Chasing references, expect 326
dots.....................................................................
.........................................................................
.........................................................................
.........................................................................
......
Eliminating duplicate
references...............................................................
.........................................................................
.........................................................................
.........................................................................
............
Snapshot resolved.
Server is ready.
```

Once the "*Server is ready*" message is printed you can use any browser to connect to HAT. In this example (TCP port 7000) the URL to input is:

```
http://127.0.0.1:7000/
```

The initial page returned by HAT is the *All Classes (excluding platform)* query.

This query returns a list of all classes in the heap dump excluding java.*, javax.*, and sun.* packages. At the end of the page there is a link to other queries :

1. All classes including platform
2. Show all members of the rootset
3. Show instance counts for all classes (including platform)
4. Show instance counts for all classes (excluding platform)

To get useful information from HAT often requires that you have some knowledge of the application and in addition some knowledge about the libraries/APIs that it uses. However in general it can be used to answer two important questions:

1. What is keeping an object alive?

When viewing an object instance you can check the objects listed in the section entitled "*References to this object*" to see which objects directly reference this object. More importantly you use a "*roots query*" to provide you with the reference chains from the root set to the given object. These references chains show a path from a root object to this object. With these chains you can quickly see how an object is reachable from the root set.

As noted in section 1.11 there are two kinds of roots queries: One that excludes weak references (roots), and one that includes them (allRoots). A weak reference is a reference object that does not prevent its referent from being made finalizable, finalized, and then reclaimed. If an object is only referred to by a weak reference, it usually isn't considered to be retained, because the garbage collector can collect it as soon as it needs the space.

HAT sorts the rootset reference chains by the type of the root, in this order:

- Static data members of Java classes.
- Java local variables. For these roots, the thread responsible for them is shown. Because a Thread is a Java object, this link is clickable. This allows you, for example, to easily navigate to the name of the thread.
- Native static values.
- Native local variables. Again, such roots are identified with their thread.

2. Where was this object allocated?

When viewing an object instance the section entitled "Objects allocated from" shows the allocation site in the form of a stack trace so you can see where the object was created.

If the leak cannot be identified using a single object dump then another approach is to collect a series of dumps and to focus on the objects created in the interval between each dump. HAT provides this capability using the *-baseline* option.

Specifying a baseline

The *-baseline* option[8] allows two dumps obtained from the same VM instance to be compared. If the

8 There are two bugs in the version of HPROF that shipped with JDK5.0. As a result some records in the second and subsequent dump may be missing. The bugs tracking these issues are 5105917 and 5105918.

same object appears in both dumps it will be excluded from the list of new objects reported. This approach requires that one dump be specified as a baseline and the analysis can then focus on the objects that are created in the second dump since the baseline was obtained.

Following is an example if how the baseline is specified :

```
$ java -jar hat.jar -port 7000 -baseline hprof.dump#1 hprof.dump#2

Started HTTP server on port 7000
Reading from hprof.dump...
Dump file created Mon Sep 06 10:34:44 BST 2004
Snapshot read, resolving...
Resolving 57335 objects...
Chasing references, expect 114
dots.....................................................................
.................................
Eliminating duplicate
references.....................................................................
.....................................
Snapshot resolved.
Reading baseline snapshot...
Dump file created Mon Sep 06 10:34:44 BST 2004
Resolving 57335 objects...
Discovering new objects...
Server is ready.
```

In the prior example, the dump file is *hprof.dump*. The first dump (*#1*) was created by pressing *Ctrl-* or *Ctrl-Break* (depending on platform) at the application console/standard output. Thereafter, a second dump was written to the file (#2 refers to the second dump in the file).

When HAT is started with two heap dumps the "*Show instance counts for all classes*" query includes an additional column that is the count of the number of new objects for that type. An instance is considered new if it is in the second heap dump, and there is no object of the same type with the same ID in the baseline. If you click on a new count then HAT lists the new objects of that type. Then for each instance you can view where it was allocated, which objects these new objects reference, and which other objects reference the new object.

In general, the baseline option can be very useful if the objects that need to be identified are created in the interval between the successive dumps.

2.1.2.3 Obtaining an Object Histogram on Solaris or Linux

On Solaris and Linux it may be possible to quickly narrow down a memory leak by examining a heap histogram. A heap histogram can be obtained from a running process using the *jmap -histo <pid>* command. The output shows the total size and instance count for each class type in the heap. If a sequence of histograms is obtained (every 2 minutes for example) then it may be possible to observe a trend that can lead to further analysis.

2.1.2.4 Obtaining an Object Histogram at VM Shutdown on Solaris

On Solaris the *truss* utility can be used to stop the java process before it exits. Following is an example command:

```
truss -f -t \!all -T _exit -s \!all java <Application>
```

In this case *the* "*java <Application>*" command string is provided to truss. The -f option is specified to follow forked children; this is necessary because the *java* launcher somethings needs to setup the *LD_LIBRARY_PATH* environment variable and re-exec itself. An alternative form is to specify the process-id (*pid*) of the running process.

When the *OutOfMemoryError* is thrown, and the process executes the *_exit* system call, then the process will stop. At this point you can get a core file using the *gcore* utility or you can use the *jmap* utility to obtain the histogram. Following is an example that gets the core file and use *jmap* on the core file to get the histogram:

```
$ gcore 27421
gcore: core.27421 dumped

$ jmap -histo \
  /java/re/j2se/1.5/latest/binaries/solaris-sparc/bin/java core.27421

Attaching to core core.27421 from executable
/java/re/j2se/1.5/latest/binaries/solaris-sparc/bin/java, please wait...
Debugger attached successfully.
Server compiler detected.
JVM version is 1.5.0-rc-b63
Iterating over heap. This may take a while...
Object Histogram:

Size    Count   Class description
-------------------------------------------------------
86683872        3611828 java.lang.String
20979136        204     java.lang.Object[]
403728  4225    * ConstMethodKlass
306608  4225    * MethodKlass
220032  6094    * SymbolKlass
152960  294     * ConstantPoolKlass
108512  277     * ConstantPoolCacheKlass
104928  294     * InstanceKlassKlass
68024   362     byte[]
65600   559     char[]
31592   359     java.lang.Class
27176   462     java.lang.Object[]
25384   423     short[]
17192   307     int[]
:
:
```

The example show that the OutOfMemoryError is caused due to the number of *java.lang.String* objects (3611828 instances in the heap). Without further analysis it's not clear from this where the strings are allocated. However the information is still useful and the investigation can continue with

tools such as HPROF or HAT to find out where the strings are allocated, and what references are keeping them alive and preventing them from being garbage collected.

2.1.2.5 Monitoring the Number of Objects that are Pending Finalization

The *jconsole* management tool (section 1.5) can be used to monitor the number of objects that are pending finalization. As noted in section 2.1.1, excessive use of finalizers can be the cause of *OutOfMemoryError*. In *jconsole* the pending finalization count is reported in the memory statistics on the "Summary" tab pane. The count is approximate but it can be used to characterize an application and understand if it relies a lot on finalization.

In addition to using *jconsole*, an application can also report the approximate number of objects pending finalization using the *getObjectPendingFinalizationCount* method in the *java.lang.management.MemoryMXBean* class. Links to the API documentation and example code can be found in section 1.19. The example code can easily be extended to include the reporting of the pending finalization count.

2.1.2.6 Third Party Memory Debuggers

In addition to the NetBeans Profiler and HAT there are a large number of third party memory debuggers available. JProbe from Quest Software, and OptimizeIt from Borland are two examples of commerical tools with memory debugging capability. There are many others and we do not provide any specific product recommentation here.

2.1.3 Diagnosing Leaks in Native Code

There are several techniques used to find and isolate native code memory leaks. A very common practice is to track all allocation and free calls of the native allocations. This can be a fairly simple process or a very sophisticated one. Many products over the years have been built up around the tracking of native heap allocations and the use of that memory. Tools like Purify and Sun's dbx RTC (Run Time Checking) functionality can be used to find these leaks in normal native code situations and also find any access to native heap memory that represents assignments to uninitialized memory or accesses to freed memory. Not all these types of tools will work with Java applications that use native code, and usually these tools are very platform specific. Since the virtual machine dynamically creates code at runtime, these tools can become confused and fail to run at all, or give false information. Check with your tool vendor to make sure the version of the tool works with the version of the virtual machine you are using.

Many simple and portable native memory leak detecting examples can be found at `http://sourceforge.net/` . Most of these libraries and tools assume you can re-compile or edit the source of the application and place wrapper functions over the allocation functions. The more powerful of these allow you to run your application unchanged by interposing over these allocation functions dynamically. This is the case with the Solaris 10 library libumem.so (2.1.3.2). In general there is no single ideal solution for all platforms. Anyone writing a JNI library would probably be wise to create some kind of localized way to make sure your library doesn't leak memory using a simple wrapper approach.

An easy localized allocation tracking approach for a JNI library would be something like:

```
#include <stdlib.h>
#define malloc(n) debug_malloc(n, __FILE__, __LINE__)
#define free(p) debug_free(p, __FILE__, __LINE__)
```

The above would need to be defined in all source files. And then you could use these functions to watch for leaks:

```
/* Total bytes allocated */
static int total_allocated;

/* Memory alignment is important */
typedef union { double d; struct {size_t n; char *file; int line;} s; }
Site;

void *
debug_malloc(size_t n, char *file, int line)
{
    char *rp;
    rp = (char*)malloc(sizeof(Site)+n);
    total_allocated += n;
    ((Site*)rp)->s.n = n;
    ((Site*)rp)->s.file = file;
    ((Site*)rp)->s.line = line;
    return (void*)(rp + sizeof(Site));
}

void
debug_free(void *p, char *file, int line)
{
    char *rp;
    rp = ((char*)p) - sizeof(Site);
    total_allocated -= ((Site*)rp)->s.n;
    free(rp);
}
```

The JNI library would then need to periodically (or at shutdown) check *total_allocated* to make sure it made sense. The above code could also be expanded to actually save in a linked list the allocations that remained and report where the leaked memory was allocated. This is a localized and portable way to track memory allocations in a single set of sources. You would need to make sure debug_free() was only called with a pointer that came from debug_malloc(), and you would also need to create similar functions for realloc(), calloc(), strdup(), etc. if they were used.

A more global way to look for native heap memory leaks would involve interposition of the library calls for the entire process.

Most systems include some form of global allocation tracking support.

- On Windows, go to http://msdn.microsoft.com/library/default.asp and search for debug support. The Microsoft C++ compiler has the /Md and /Mdd compiler options that will automatically include extra support for tracking memory allocations.

- Linux systems have things like mtrace and libnjamd to help in dealing with allocation tracking.
- Solaris systems have watchmalloc, and Solaris 10 and 9 update 3 started providing libumem (2.1.3.2).

2.1.3.1 Using dbx to find leaks

The Sun debugger *dbx* (which is also available on Linux) has the Run Time Checking (RTC) functionality that will find leaks. As mentioned earlier, the Virtual Machine and the way the java executable starts up can be a problem for dbx, but here is a sample dbx session:

```
$ dbx ${java_home}/bin/java
Reading java
Reading ld.so.1
Reading libthread.so.1
Reading libdl.so.1
Reading libc.so.1
(dbx) dbxenv rtc_inherit on
(dbx) check -leaks
leaks checking - ON
(dbx) run HelloWorld
Running: java HelloWorld
(process id 15426)
Reading rtcapihook.so
Reading rtcaudit.so
Reading libmapmalloc.so.1
Reading libgen.so.1
Reading libm.so.2
Reading rtcboot.so
Reading librtc.so
RTC: Enabling Error Checking...
RTC: Running program...
dbx: process 15426 about to
exec("/net/bonsai.sfbay/export/home2/user/ws/j2se/build/solaris-i586/bin/java")
dbx: program "/net/bonsai.sfbay/export/home2/user/ws/j2se/build/solaris-i586/bin/java"
just exec'ed
dbx: to go back to the original program use "debug $oprog"
RTC: Enabling Error Checking...
RTC: Running program...
t@1 (l@1) stopped in main at 0x0805136d
0x0805136d: main       :        pushl    %ebp
(dbx) when dlopen libjvm { suppress all in libjvm.so; }
(2) when dlopen libjvm { suppress all in libjvm.so; }
(dbx) when dlopen libjava { suppress all in libjava.so; }
(3) when dlopen libjava { suppress all in libjava.so; }
(dbx) cont
Reading libjvm.so
Reading libsocket.so.1
Reading libsched.so.1
Reading libCrun.so.1
Reading libm.so.1
Reading libnsl.so.1
Reading libmd5.so.1
Reading libmp.so.2
Reading libhpi.so
Reading libverify.so
Reading libjava.so
Reading libzip.so
Reading en_US.ISO8859-1.so.3
hello world
```

```
hello world
Checking for memory leaks...

Actual leaks report    (actual leaks:           27  total size:      46851 bytes)

  Total     Num of  Leaked     Allocation call stack
  Size      Blocks  Block
                    Address
==========  ====== ========== =======================================
     44376       4      -      calloc < zcalloc
      1072       1  0x8151c70  _nss_XbyY_buf_alloc < get_pwbuf < _getpwuid <
GetJavaProperties < Java_java_lang_System_initProperties < 0xa740a89a< 0xa7402a14<
0xa74001fc
       814       1  0x8072518  MemAlloc < CreateExecutionEnvironment < main
       280      10      -      operator new < Thread::Thread
       102       1  0x8072498  _strdup < CreateExecutionEnvironment < main
        56       1  0x81697f0  calloc < Java_java_util_zip_Inflater_init < 0xa740a89a<
0xa7402a6a< 0xa7402aeb< 0xa7402a14< 0xa7402a14< 0xa7402a14
        41       1  0x8072bd8  main
        30       1  0x8072c58  SetJavaCommandLineProp < main
        16       1  0x806f180  _setlocale < GetJavaProperties <
Java_java_lang_System_initProperties < 0xa740a89a< 0xa7402a14< 0xa74001fc<
JavaCalls::call_helper < os::os_exception_wrapper
        12       1  0x806f2e8  operator new < instanceKlass::add_dependent_nmethod <
nmethod::new_nmethod < ciEnv::register_method < Compile::Compile #Nvariant 1 <
C2Compiler::compile_method < CompileBroker::invoke_compiler_on_method <
CompileBroker::compiler_thread_loop
        12       1  0x806ee60  CheckJvmType < CreateExecutionEnvironment < main
        12       1  0x806ede8  MemAlloc < CreateExecutionEnvironment < main
        12       1  0x806edc0  main
         8       1  0x8071cb8  _strdup < ReadKnownVMs < CreateExecutionEnvironment < main

         8       1  0x8071cf8  _strdup < ReadKnownVMs < CreateExecutionEnvironment < main
```

As you can see, dbx appears to think there are memory leaks because any memory not freed at the time the process is about to exit is considered leaked. Memory allocated at initialization time and needed for the life of the process is often never freed in native code, so the assumption that all memory must be freed at process exit often isn't the case in reality. Note that we used two *suppress* commands to suppress the leaks reported in the Virtual Machine (libjvm.so) and the java support library (libjava.so).

2.1.3.2 Using libumem on Solaris 10 to Find Leaks

On Solaris 10 the *libumem.so* library and the modular debugger (*mdb*) can be used to debug memory leaks. The *libumem* library is also available on Solaris 9 from update 3. To use libumem requires that you preload the libumem library and set an environment variable as follows:

```
$ LD_PRELOAD=libumem.so
$ export LD_PRELOAD

$ UMEM_DEBUG=default
$ export UMEM_DEBUG
```

Now, run the Java application but stop it before it exits. Following is an example using *truss* to stop

the process when it calls the *_exit* system call:

```
truss -f -T _exit java MainClass <args>
```

At this point you can attach *mdb*:

```
mdb -p <pid>
>::findleaks
```

The *::findleaks* command is the mdb command to find memory leaks. If a leak is found, the *findleaks* command prints the address of the allocation call, buffer address and nearest symbol.

It is also possible to get the stack trace for the allocation which resulted in the memory leak by dumping the `bufctl` structure. The address of this structure can be gathered from the ouput of the `::findleaks` command. The commands to do this, and more information on using libumem to identify memory managements bugs can be found at:

http://access1.sun.com/techarticles/libumem.html

2.2 Crashes

A crash, or fatal error, causes a process to terminate. The possible reasons for a crash are varied. For example a crash can arise due to a bug in the HotSpot VM, in a system library, in a J2SE library/API , in application native code, or even a bug in the operating system. There can be external factors too. For example, a crash can arise due to resource exhaustion in the operating system.

Crashes caused by bugs in the HotSpot VM or J2SE library code should be rare. In the event that you do encounter a crash then this chapter provides suggestions on how to examine the crash. In some cases it may be possible to workaround a crash until the cause of the bug is diagnosed and fixed.

In general the first step with any crash it to locate the fatal error log. The fatal error log is a file named *hs_err_pid<pid>.log* (where *<pid>* is the process id of the process). Normally the file is created in the working directory of the process. However because of disk space, directory permissions, or other reasons, the file may instead be created in the temporary directory of the operating system. On Solaris and Linux the temporary directory is */tmp*. On Windows the temporary directory is specified by the value of the *TMP* or *TEMP* environment variable.

In this section we describe the format of the fatal error log, describe how the error log can be analyzed, and in a few cases provide suggestions on how the issue may be worked around.

2.2.1 Format of the Fatal Error Log

Section 1.13.1 provided a high level list of the information that is written to the fatal error log. Here the error log is described in more detail. The error log is a text file consisting of a header that provides a brief description of the crash. This is followed by sections with thread, process, and system information.

It should be noted that the format of the fatal error log described here is based on JDK5.0. In future releases the format may be different. If you develop scripts or tools that depend on the format then these scripts or tools may cease to work if the format is changed.

2.2.1.1 Header

At the beginning of every HotSpot error log file is a brief description about the problem. It is also printed to standard output and may show up in the application's output log.

Following is a sample header from a crash:

```
#
# An unexpected error has been detected by HotSpot Virtual Machine:
#
#  SIGSEGV (0xb) at pc=0x417789d7, pid=21139, tid=1024
#
# Java VM: Java HotSpot(TM) Client VM (1.5.0-beta2-b37 mixed mode)
# Problematic frame:
# C  [libNativeSEGV.so+0x9d7]
```

This example shows that the VM died on an unexpected signal. The second line describes the signal type, program counter (pc) that caused the signal, process ID and thread ID.

```
#  SIGSEGV (0xb) at pc=0x417789d7, pid=21139, tid=1024
      |      |           |             |         +--- thread id
      |      |           |             +------------- process id
      |      |           +--------------------------- instruction pointer
      |      +--------------------------------------- signal number
      +-------------------------------------------- signal name
```

Next line is the VM version which indicates if the Client VM or Server VM is used, and it will also indicate if the application is run in mixed or interpreted mode, and it will indicate if class file sharing is enabled.

```
# Java VM: Java HotSpot(TM) Client VM (1.5.0-rc-b63 mixed mode, sharing)
```

The version information is followed by the function frame that caused the crash:

```
# Problematic frame:
# C  [libNativeSEGV.so+0x9d7]
  |              +-- Same as pc, but represented as library name and offset.
  |                  For position independent libraries (JVM and most shared
  |                  libraries), it's possible to inspect the instructions
  |                  that caused the crash without a debugger or core file.
  |                  Just use a disassembler to dump instructions near the
  |                  offset.
  +----------------- Frame type
```

In this example the “C” indicates a native C frame. The following table lists the possible frame types:

Frame	***Description***
C	Native C frame
J	Other frame types including compiled Java frames
j	Interpreted Java frames
V	VM frames
v	VM generated stub frame

Internal errors (for example, guarantee() failure, assertion failure, ShouldNotReachHere()) will cause

the VM error handler to generate a similar error dump. However, the header format is different. Here is an example of how the header looks for an internal error :

```
#
# An unexpected error has been detected by HotSpot Virtual Machine:
#
#  Internal Error (4F533F4C494E55583F491418160E43505000F5), pid=10226, tid=16384
#
# Java VM: Java HotSpot(TM) Client VM (1.5.0-rc-b63 mixed mode)
```

There is no signal name or signal number. Instead the second line now contains "Internal Error" and a long hexadecimal string. This hexadecimal string encodes the source module and line number where the error was detected. In general this “error string” is only useful to engineers working on the HotSpot Virtual Machine but the following should be noted:

- The error string encodes a line number and therefore it changes with each code change and release. A crash with a given error string in 1.5.0 may not correspond to the same crash in 1.5.0_01 even if the strings match.
- Errors with the same root cause may have a different error string.
- Errors with the same error string may have completely different root causes.
- The error string should not be used as the sole criteria when duplicating bugs.

2.2.1.2 Thread

This section contains information about the thread that just crashed. If multiple threads crash at the same time, only one thread is printed.

The first part of the thread section shows the thread that provoked the fatal error.

```
Current thread (0x0805ac88):  JavaThread "main" [_thread_in_native, id=21139]
                      |             |         |            |          +-- id
                      |             |         |            +------------- state
                      |             |         +-------------------------- name
                      |             +-------------------------------------- type
                      +---------------------------------------------------- pointer
```

The following should be noted :

- The thread pointer is the pointer to the JVM internal Thread structure. It is generally of no interest unless you are debugging a live JVM or core file.
- Possible thread types: `JavaThread`, `VMThread`, `CompilerThread`, `JVMPIDaemonthread`, `GCTaskThread`, `WatcherThread`, `ConcurrentMarkSweepThread`. Note the list may change as the VM evolves.
- The important thread states include:

_thread_uninitialized	Thread is not created. This should never happen unless there's memory corruption
_thread_new	Thread has been created but it has not yet started.
_thread_in_native	Thread is running native code. Probably a bug in native code.
_thread_in_vm	Thread is running VM code.
_thread_in_Java	Thread is running (either interpreted or compiled) Java code.
_thread_blocked	Thread is blocked.
..._trans	If you see any of the above states but followed by "_trans", it means the thread is changing to a different state.

The thread id in the output is the native thread identifier. Finally, if a java thread is a daemon thread then "*daemon*" will be printed before the thread state.

After the thread information is the signal information (the unexpected signal that caused the VM to terminate). On Windows the output appears as follows :

```
siginfo: ExceptionCode=0xc0000005, reading address 0xd8ffecf1
```

This indicates that the exception code is 0xc0000005 (ACCESS_VIOLATION), and it occurred when the thread attempted to read address 0xd8ffecf1.

On Solaris and Linux the signal number (si_signo) and signal code (si_code) are used to identify the exception:

```
siginfo:si_signo=11, si_errno=0, si_code=1, si_addr=0x00004321
```

After the signal information the error log shows the register context at the time of the fatal error. The exact format of this output is architecture/processor dependent. Following is example output for the Intel (IA32) processor:

```
Registers:
EAX=0x00004321, EBX=0x41779dc0, ECX=0x080b8d28, EDX=0x00000000
ESP=0xbfffc1e0, EBP=0xbfffc1f8, ESI=0x4a6b9278, EDI=0x0805ac88
EIP=0x417789d7, CR2=0x00004321, EFLAGS=0x00010216
```

The register values may be useful when combined with instructions (see below).

After the register values, you will see the top of stack and the instructions/opcodes near the crashing pc. The error log prints 32 bytes which can be decoded using a disassembler to see the instructions around the location of the crash. Note that IA32 and AMD64 instructions are variable length so it's not always possible to reliably decode instructions before the crash pc.

```
Top of Stack: (sp=0xbfffc1e0)
0xbfffc1e0:   00000000 00000000 0818d068 00000000
0xbfffc1f0:   00000044 4a6b9278 bfffd208 41778a10
0xbfffc200:   00004321 00000000 00000cd8 0818d328
0xbfffc210:   00000000 00000000 00000004 00000003
0xbfffc220:   00000000 4000c78c 00000004 00000000
0xbfffc230:   00000000 00000000 00180003 00000000
0xbfffc240:   42010322 417786ec 00000000 00000000
0xbfffc250:   4177864c 40045250 400131e8 00000000

Instructions: (pc=0x417789d7)
0x417789c7:   ec 14 e8 72 ff ff ff 81 c3 f2 13 00 00 8b 45 08
0x417789d7:   0f b6 00 88 45 fb 8d 83 6f ee ff ff 89 04 24 e8
```

Where possible, the next output in the error log is the thread stack. This includes the addresses of the base and the top of the stack, the current stack pointer, and the amount of unused stack available to the thread. This is followed, where possible, by the stack frames and up to 100 frames are printed. For C/C++ frames the library name may also be printed. It's important to note that in some fatal error conditions the stack may be corrupt so this detail may not be available.

```
Stack: [0x00040000,0x00080000),  sp=0x0007f9f8,  free space=254k
Native frames: (J=compiled Java code, j=interpreted, Vv=VM code, C=native code)
V  [jvm.dll+0x83d77]
C  [App.dll+0x1047]
j  Test.foo()V+0
j  Test.main([Ljava/lang/String;)V+0
v  ~StubRoutines::call_stub
V  [jvm.dll+0x80f13]
V  [jvm.dll+0xd3842]
V  [jvm.dll+0x80de4]
C  [java.exe+0x14c0]
C  [java.exe+0x64cd]
C  [kernel32.dll+0x214c7]

Java frames: (J=compiled Java code, j=interpreted, Vv=VM code)
j  Test.foo()V+0
j  Test.main([Ljava/lang/String;)V+0
v  ~StubRoutines::call_stub
```

Note that there are two thread stacks printed. The first is *Native frames* which prints the native thread showing all function calls. However this thread stack doesn't take into account the java methods that are inlined by the runtime compiler; if methods are inlined they appear to be part of the parent's stack frame. The second stack is *Java frames* which prints the java frames including the inlined methods. It skips the native frames. Depending on the crash it will sometimes not be possible to print the native thread stack but it may be possible to print the java frames.

In the event that the error occurred in the VM Thread, or a Compiler Thread then further details may be printed – for example, in the case of the VM Thread the VM operation is printed if the VM Thread is executing a VM operation at the time of the fatal error. Following is an example of output when the Compiler Thread provokes the fatal error; in this case the task is a compiler task and the HotSpot Client VM is compiling method "hs101t004Thread.*ackermann*":

```
Current CompileTask:
HotSpot Client Compiler:754   b
nsk.jvmti.scenarios.hotswap.HS101.hs101t004Thread.ackermann(IJ)J (42 bytes)
```

For the HotSpot Server VM the output for the compiler task is slightly different but will also include the full class name and method.

2.2.1.3 Process

The process section is printed after the thread section. It contains information about the whole process, including thread list and memory usage of the process.

The thread list includes the threads that the VM is aware of. This includes all Java threads and some VM internal threads, but does not include any native threads created by the user application that have not attached to the VM. Here's the output format:

```
=>0x0805ac88 JavaThread "main" [_thread_in_native, id=21139]
|       |          |         |              |             +-----  id
|       |          |         |              +-------------------  state
|       |          |         |                                    (JavaThread only)
|       |          |         +----------------------------------  name
|       |          +--------------------------------------------  type
|       +-------------------------------------------------------  pointer
+---------------------------------------------------------- "=>" current thread
```

and here is example output :

```
Java Threads: ( => current thread )
  0x080c8da0 JavaThread "Low Memory Detector" daemon [_thread_blocked, id=21147]
  0x080c7988 JavaThread "CompilerThread0" daemon [_thread_blocked, id=21146]
  0x080c6a48 JavaThread "Signal Dispatcher" daemon [_thread_blocked, id=21145]
  0x080bb5f8 JavaThread "Finalizer" daemon [_thread_blocked, id=21144]
  0x080ba940 JavaThread "Reference Handler" daemon [_thread_blocked, id=21143]
=>0x0805ac88 JavaThread "main" [_thread_in_native, id=21139]

Other Threads:
  0x080b6070 VMThread [id=21142]
  0x080ca088 WatcherThread [id=21148]
```

The thread type and state are described in the threads section.

After the thread list is the VM state. This indicates the overall state of the virtual machine. The general states are :

- not at a safepoint – normal execution
- at safepoint – indicates that all threads are blocked in the VM waiting for a special vm operation to complete
- synchronizing – indicates that a special vm operation is required and the VM is waiting for all threads in the vm to block.

The output is a single line in the error log:

```
VM state:not at safepoint (normal execution)
```

Following this is the list of mutexes/monitors that are currently owned by a thread. These mutexes are VM internal locks rather than monitors associated with java objects. Here is an example to show how the output might look when a crash happens when VM locks are held. For each lock it prints the name of the lock, its owner, and the addresses of a VM internal mutex structure and its OS lock. In general this information is usually only useful to those intimately familiar with the HotSpot VM. The owner thread can be cross referenced to the thread list.

```
VM Mutex/Monitor currently owned by a thread:
([mutex/lock_event])[0x007357b0/0x0000031c] Threads_lock - owner thread:
0x00996318
[0x00735978/0x000002e0] Heap_lock - owner thread: 0x00736218
```

After the list of mutexes is a summary of the heap . The output depends on the GC configuration. In this example the serial collector is used, class data shared is disabled, and the tenured generation is empty (probably indicating the fatal error occurred early or during start-up and a GC has not yet promoted any objects into the tenured generation).

```
Heap
 def new generation   total 576K, used 161K [0x46570000, 0x46610000, 0x46a50000)
  eden space 512K,  31% used [0x46570000, 0x46598768, 0x465f0000)
  from space 64K,   0% used [0x465f0000, 0x465f0000, 0x46600000)
  to   space 64K,   0% used [0x46600000, 0x46600000, 0x46610000)
 tenured generation   total 1408K, used 0K [0x46a50000, 0x46bb0000, 0x4a570000)
   the space 1408K,   0% used [0x46a50000, 0x46a50000, 0x46a50200, 0x46bb0000)
 compacting perm gen  total 8192K, used 1319K [0x4a570000, 0x4ad70000, 0x4e570000)
   the space 8192K,  16% used [0x4a570000, 0x4a6b9d48, 0x4a6b9e00, 0x4ad70000)
No shared spaces configured.
```

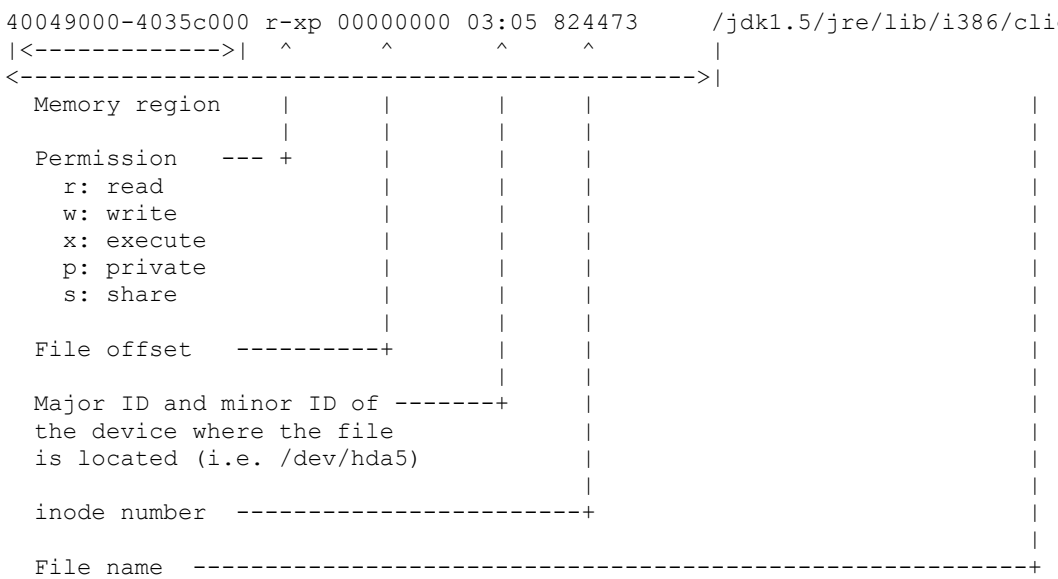
After the heap summary is the list of virtual memory regions at the time of the crash. The list can be long with large applications. The memory map can be very useful when debugging some crashes, as it can tell you what libraries are actually being used, their location in memory, as well as the location of heap, stack and guard pages.

The format of the memory map is operating system specific. On Solaris, the base address and library name are printed. On Linux the process memory map (/proc/<pid>/maps) is printed. On Windows, the base and end addresses of each library are printed. The following example output was generated on Linux/x86 :

```
Dynamic libraries:
08048000-08056000 r-xp 00000000 03:05 259171     /h/jdk1.5/bin/java
08056000-08058000 rw-p 0000d000 03:05 259171     /h/jdk1.5/bin/java
08058000-0818e000 rwxp 00000000 00:00 0
40000000-40013000 r-xp 00000000 03:0a 400046     /lib/ld-2.2.5.so
40013000-40014000 rw-p 00013000 03:0a 400046     /lib/ld-2.2.5.so
40014000-40015000 r--p 00000000 00:00 0
40015000-4001c000 r-xp 00000000 03:05 727476
/h/jdk1.5/jre/lib/i386/native_threads/libhpi.so
4001c000-4001d000 rw-p 00006000 03:05 727476
/h/jdk1.5/jre/lib/i386/native_threads/libhpi.so
4001d000-40026000 r-xp 00000000 03:0a 400092     /lib/libnss_files-2.2.5.so
40026000-40027000 rw-p 00009000 03:0a 400092     /lib/libnss_files-2.2.5.so
40027000-4002b000 rw-s 00000000 03:0a 244990     /tmp/hsperfdata_user/21139
4002b000-40031000 r--s 00000000 03:0a 624243     /usr/lib/gconv/gconv-modules.cache
40031000-4003e000 r-xp 00000000 03:0a 144065     /lib/i686/libpthread-0.9.so
4003e000-40045000 rw-p 0000d000 03:0a 144065     /lib/i686/libpthread-0.9.so
40045000-40046000 rw-p 00000000 00:00 0
40046000-40048000 r-xp 00000000 03:0a 400072     /lib/libdl-2.2.5.so
40048000-40049000 rw-p 00001000 03:0a 400072     /lib/libdl-2.2.5.so
40049000-4035c000 r-xp 00000000 03:05 824473     /h/jdk1.5/jre/lib/i386/client/libjvm.so
4035c000-40379000 rw-p 00312000 03:05 824473     /h/jdk1.5/jre/lib/i386/client/libjvm.so
40379000-40789000 rw-p 00000000 00:00 0
40789000-4078a000 rwxp 00410000 00:00 0
4078a000-4078e000 rw-p 00411000 00:00 0
4078e000-407af000 r-xp 00000000 03:0a 144063     /lib/i686/libm-2.2.5.so
407af000-407b0000 rw-p 00020000 03:0a 144063     /lib/i686/libm-2.2.5.so
407b0000-407bb000 r-xp 00000000 03:05 727487     /h/jdk1.5/jre/lib/i386/libverify.so
407bb000-407bc000 rw-p 0000b000 03:05 727487     /h/jdk1.5/jre/lib/i386/libverify.so
407bc000-407bd000 ---p 00000000 00:00 0
407bd000-407c9000 rwxp 00001000 00:00 0
407c9000-407cc000 r--s 00000000 03:05 759533     /h/jdk1.5/jre/lib/ext/dnsns.jar
407cd000-407df000 r-xp 00000000 03:0a 400076     /lib/libnsl-2.2.5.so
407df000-407e0000 rw-p 00012000 03:0a 400076     /lib/libnsl-2.2.5.so
407e0000-407e2000 rw-p 00000000 00:00 0
407e2000-40802000 r-xp 00000000 03:05 727488     /h/jdk1.5/jre/lib/i386/libjava.so
40802000-40804000 rw-p 0001f000 03:05 727488     /h/jdk1.5/jre/lib/i386/libjava.so
40804000-40817000 r-xp 00000000 03:05 727490     /h/jdk1.5/jre/lib/i386/libzip.so
40817000-40819000 rw-p 00012000 03:05 727490     /h/jdk1.5/jre/lib/i386/libzip.so
40819000-408af000 rw-p 00000000 00:00 0
408af000-4092e000 r--s 00000000 03:05 727556     /h/jdk1.5/jre/lib/jsse.jar
4092e000-40942000 r--s 00000000 03:05 727555     /h/jdk1.5/jre/lib/jce.jar
40942000-4117b000 r--s 00000000 03:05 727669     /h/jdk1.5/jre/lib/charsets.jar
4117b000-4117e000 rwxp 00000000 00:00 0
4117e000-411fb000 rwxp 00003000 00:00 0
411fb000-411fc000 rwxp 00000000 00:00 0
411fc000-411fd000 rwxp 00081000 00:00 0
411fd000-411ff000 rwxp 00000000 00:00 0
411ff000-4121b000 rwxp 00084000 00:00 0
4121b000-4121f000 rwxp 00000000 00:00 0
4121f000-4123b000 rwxp 000a4000 00:00 0
4123b000-4123d000 rwxp 00000000 00:00 0
4123d000-4125a000 rwxp 00001000 00:00 0
4125a000-4125f000 rwxp 00000000 00:00 0
4125f000-4127b000 rwxp 00023000 00:00 0
```

```
4127b000-4127e000 ---p 00003000 00:00 0
4127e000-412fb000 rwxp 00006000 00:00 0
412fb000-412fe000 ---p 00083000 00:00 0
412fe000-4137b000 rwxp 00086000 00:00 0
4137b000-413a6000 r--p 00000000 03:0a 466918     /usr/lib/locale/en_US.iso885915/LC_CTYPE
413a6000-413a9000 ---p 00003000 00:00 0
413a9000-41426000 rwxp 00006000 00:00 0
41426000-4142a000 ---p 00080000 00:00 0
4142a000-41627000 rwxp 00084000 00:00 0
41627000-4162a000 ---p 00281000 00:00 0
4162a000-416a7000 rwxp 00284000 00:00 0
416a7000-416a8000 ---p 00301000 00:00 0
416a8000-41728000 rwxp 00302000 00:00 0
41728000-4174d000 r--s 00000000 03:05 759528     /h/jdk1.5/jre/lib/ext/sunjce_provider.jar
4174d000-41778000 r--s 00000000 03:05 759529     /h/jdk1.5/jre/lib/ext/sunpkcs11.jar
41778000-41779000 r-xp 00000000 03:05 1018095    /h/bugs/NativeSEGV/libNativeSEGV.so
41779000-4177a000 rw-p 00000000 03:05 1018095    /h/bugs/NativeSEGV/libNativeSEGV.so
41800000-41808000 rw-p 00000000 00:00 0
41808000-41900000 ---p 000e0000 00:00 0
41900000-419bf000 r--s 00000000 03:05 759541     /h/jdk1.5/jre/lib/ext/localedata.jar
42000000-4212c000 r-xp 00000000 03:0a 146747     /lib/i686/libc-2.2.5.so
4212c000-42131000 rw-p 0012c000 03:0a 146747     /lib/i686/libc-2.2.5.so
42131000-42135000 rw-p 00000000 00:00 0
42135000-44570000 r--s 00000000 03:05 727670     /h/jdk1.5/jre/lib/rt.jar
44570000-44600000 rwxp 00000000 00:00 0
44600000-46570000 rwxp 00090000 00:00 0
46570000-46610000 rwxp 00000000 00:00 0
46610000-46a50000 rwxp 020a0000 00:00 0
46a50000-46bb0000 rwxp 00000000 00:00 0
46bb0000-4a570000 rwxp 02640000 00:00 0
4a570000-4ad70000 rwxp 00000000 00:00 0
4ad70000-4e570000 rwxp 06800000 00:00 0
bfe00000-bfe03000 ---p 00000000 00:00 0
bfe03000-c0000000 rwxp ffe04000 00:00 0
```

The memory map is read as follows :



Notes:

- Library names and their locations are pretty straightforward
- Every library has two virtual memory regions. One for code and one for data. The code segment is marked with `r-xp` (readable, executable, private); data segment is `rw-p` (readable, writable, private).
- The java heap is already included in the "Heap usage" output, but it doesn't hurt to check out the actual memory regions reserved for heap (they should match the value in "Heap usage") and the attributes (should be `rwxp`).
- Thread stacks usually show up in the memory map as two back-to-back regions, one with attribute `---p` (guard page) and one with `rwxp` (actual stack space). Of course, knowing the guard page size or stack size would make the job a bit easier. For example, in this memory map, `4127b000-412fb000` is stack.

On Windows here is an example of the memory map:

```
Dynamic libraries:
0x00400000 - 0x0040c000   c:\jdk1.5\bin\java.exe
0x77f50000 - 0x77ff7000   C:\WINDOWS\System32\ntdll.dll
0x77e60000 - 0x77f46000   C:\WINDOWS\system32\kernel32.dll
0x77dd0000 - 0x77e5d000   C:\WINDOWS\system32\ADVAPI32.dll
0x78000000 - 0x78087000   C:\WINDOWS\system32\RPCRT4.dll
0x77c10000 - 0x77c63000   C:\WINDOWS\system32\MSVCRT.dll
0x08000000 - 0x08183000   c:\jdk1.5\jre\bin\client\jvm.dll
0x77d40000 - 0x77dcc000   C:\WINDOWS\system32\USER32.dll
0x7e090000 - 0x7e0d1000   C:\WINDOWS\system32\GDI32.dll
0x76b40000 - 0x76b6c000   C:\WINDOWS\System32\WINMM.dll
0x6d2f0000 - 0x6d2f8000   c:\jdk1.5\jre\bin\hpi.dll
0x76bf0000 - 0x76bfb000   C:\WINDOWS\System32\PSAPI.DLL
0x6d680000 - 0x6d68c000   c:\jdk1.5\jre\bin\verify.dll
0x6d370000 - 0x6d38d000   c:\jdk1.5\jre\bin\java.dll
0x6d6a0000 - 0x6d6af000   c:\jdk1.5\jre\bin\zip.dll
0x10000000 - 0x10032000   C:\bugs\crash2\App.dll
```

Note that the format is different from the Linux example. On Windows the output is the load and end address of each loaded module.

After the list of libraries are the VM arguments (in this case the arguments were "*NativeSEGV 2*") and the environment variables.

```
VM Arguments:
java_command: NativeSEGV 2

Environment Variables:
JAVA_HOME=/h/jdk
PATH=/h/jdk/bin:.:/h/bin:/usr/bin:/usr/X11R6/bin:/usr/local/bin:/usr/dist/local/e
xe:/usr/dist/exe:/bin:/usr/sbin:/usr/ccs/bin:/usr/ucb:/usr/bsd:/usr/etc:/etc:/usr
/dt/bin:/usr/openwin/bin:/usr/sbin:/sbin:/h:/net/prt-web/prt/bin
USERNAME=user
LD_LIBRARY_PATH=/h/jdk1.5/jre/lib/i386/client:/h/jdk1.5/jre/lib/i386:/h/jdk1.5/jr
e/../lib/i386:/h/bugs/NativeSEGV
```

```
SHELL=/bin/tcsh
DISPLAY=:0.0
HOSTTYPE=i386-linux
OSTYPE=linux
ARCH=Linux
MACHTYPE=i386
```

Note that the environment list is not the full list of environment variables but rather the sub-set of the environment variables that are applicable to the JVM.

2.2.1.4 System

The final section in the error log is the system information. The output is operating system specific but in general includes the operating system version, CPU information, and summary information about the memory configuration.

Here is an example from a Windows XP system :

```
---------------  S Y S T E M  ---------------

OS: Windows XP Build 2600 Service Pack 1

CPU:total 1 family 6, cmov, cx8, fxsr, mmx, sse, sse2

Memory: 4k page, physical 1047024k(564864k free), swap 2520436k(2038092k free)

vm_info: Java HotSpot(TM) Client VM (1.5.0-beta3-b61) for windows-x86, built on
Aug  2 2004 02:43:02 by "java_re" with MS VC++ 6.0
```

Here is an example from a Solaris 9 system :

```
---------------  S Y S T E M  ---------------

OS:                       Solaris 9 12/03 s9s_u5wos_08b SPARC
           Copyright 2003 Sun Microsystems, Inc.  All Rights Reserved.
                        Use is subject to license terms.
                           Assembled 21 November 2003

uname:SunOS 5.9 Generic_112233-10 sun4u  (T2 libthread)
rlimit: STACK 8192k, CORE infinity, NOFILE 65536, AS infinity
load average:0.41 0.14 0.09

CPU:total 2 has_v8, has_v9, has_vis1, has_vis2, is_ultra3

Memory: 8k page, physical 2097152k(1394472k free)

vm_info: Java HotSpot(TM) Client VM (1.5-internal) for solaris-sparc, built on
Aug 12 2004 10:22:32 by unknown with unknown Workshop:0x550
```

On Solaris and Linux the operating system information obtained by reading /etc/*release. In general it tells you the kind of system the application is running on, and in some cases the information string may include patch level. Some system upgrades are not reflected in the /etc/*release file. This is especially true on Linux where the user can rebuild any part of the system.

On Solaris the *uname* system call is used to get the name for the kernel, and the thread library (T1 or T2 – see section 2.3.3) is also printed.

On Linux the *uname* system call is also used to get the kernel name, and is printed along with the libc version and the thread library type.

```
uname:Linux 2.4.18-3smp #1 SMP Thu Apr 18 07:27:31 EDT 2002 i686
libc:glibc 2.2.5 stable linuxthreads (floating stack)
    |<- glibc version ->|<--  pthread type       -->|
```

On Linux there are three possible thread types, namely linuxthreads (fixed stack), linuxthreads (floating stack) and NPTL. They are normally installed in /lib, /lib/i686 and/or /lib/tls. The following should be noted :

- Knowing the thread type is useful – for example if the crash appears to be related to pthread, then you may be able to workaround an issue by selecting a different pthread library. A different pthread library (and libc) can be selected by setting LD_LIBRARY_PATH or LD_ASSUME_KERNEL.
- glibc version usually does not include the patch level. "rpm -q glibc" may give more detailed version information.

On Solaris and Linux this is followed by rlimit information. Note that the default stack size of the VM is usually smaller than the system limit.

```
rlimit: STACK 8192k, CORE 0k, NPROC 4092, NOFILE 1024, AS infinity
             |          |         |           |           + virtual memory (-v)
             |          |         |           +--- max open files (ulimit -n)
             |          |         +----------- max user processes (ulimit -u)
             |          +--------------------------- core dump size (ulimit -c)
             +---------------------------------------- stack size (ulimit -s)

load average:0.04 0.05 0.02
```

The CPU information details the CPU architecture and capabilities identified by the VM at start-up.

```
CPU:total 2 family 6, cmov, cx8, fxsr, mmx, sse
          |        | |<----- CPU features ---->|
          |        |
```

```
|        +--- processor family (IA32 only):
|               3 - i386
|               4 - i486
|               5 - Pentium
|               6 - PentiumPro, PII, PIII
|              15 - Pentium 4
+------------ Total number of CPUs
```

On SPARC the possible CPU features are :

```
has_v8          supports v8 instructions
has_v9          supports v9 instructions
has_vis1        supports visualization instructions
has_vis2        supports visualization instructions
is_ultra3       UltraSparc III
no-muldiv       No hardware integer multiply and divide
no-fsmuld       No multiply-add and multiply-subtract instructions
```

On Intel/IA32 the possible CPU features are :

```
cmov            supports cmov instruction
cx8             supports cmpxchg8b instruction
fxsr            supports fxsave/fxrstor
mmx             supports MMX
sse             supports SSE extensions
sse2            supports SSE2 extensions
ht              supports Hyper-Threading Technology
```

On AMD64/EM64T the possible CPU features are :

```
amd64           AMD Opteron, Athlon64, ..
em64t           Intel EM64T processor
3dnow           Support 3DNow extension
ht              Support Hyper-Threading Technology
```

After the CPU information is the memory information :

```
                                                    unused swap space
                                total amount of swap space      |
                     unused physical memory         |           |
  total amount of physical memory     |             |           |
       page size             |        |             |           |
           v                 v        v             v           v
Memory: 4k page, physical 513604k(11228k free), swap 530104k(497504k free)
```

Notes:

- Some systems require swap space to be at lease twice the size of real physical memory, others don't care. But in general if both physical memory and swap space are almost full, there's good reason to suspect the crash was due to running out of memory.
- On Linux systems the kernel may convert most of unused physical memory to file cache. When there is a need for more memory, the Linux kernel will give the cache memory back to

the application. This is handled transparently by the kernel, but it does mean the amount of unused physical memory reported by fatal error handler could be close 0 when there is still plenty of physical memory available.

The final item in the *SYSTEM* section is "*vm_info*". This is a version string embedded in libjvm.so/jvm.dll. Every JVM has its own unique vm_info string. When you are in doubt about whether the hs_err*.log was generated by a particular JVM, check the version string.

2.2.2 Sample Crashes

This section presents a number of examples which demonstrate how the error log can be used to suggest the cause of a crash.

2.2.2.1 Crash in Native Code

If the fatal error log indicates the crash was in a native library there may be a bug in native/JNI library code. The crash could of course be caused by something else but analysis of the library and any core file/crash dump is a good starting place. For example, consider the following extract from the header of a fatal error log :

```
#
# An unexpected error has been detected by HotSpot Virtual Machine:
#
#  SIGSEGV (0xb) at pc=0x417789d7, pid=21139, tid=1024
#
# Java VM: Java HotSpot(TM) Server VM (1.5.0-beta2-b63 mixed mode)
# Problematic frame:
# C  [libApplication.so+0x9d7]
#
```

In this case a *SIGSEGV* arose with a thread executing in the library *libApplication.so*.

In some cases a bug in a native library manifests itself as a crash in VM code. Consider the following crash where a *JavaThread* crashes while in the "*_thread_in_vm*" state (meaning that it is executing in VM code) :

```
#
# An unexpected error has been detected by HotSpot Virtual Machine:
#
#  EXCEPTION_ACCESS_VIOLATION (0xc0000005) at pc=0x08083d77, pid=3700, tid=2896
#
# Java VM: Java HotSpot(TM) Client VM (1.5-internal mixed mode)
# Problematic frame:
# V  [jvm.dll+0x83d77]
#

---------------  T H R E A D  ---------------

Current thread (0x00036960):  JavaThread "main" [_thread_in_vm, id=2896]
 :
Stack: [0x00040000,0x00080000),  sp=0x0007f9f8,  free space=254k
Native frames: (J=compiled Java code, j=interpreted, Vv=VM code, C=native code)
V  [jvm.dll+0x83d77]
C  [App.dll+0x1047]          <========= C/native frame
j  Test.foo()V+0
j  Test.main([Ljava/lang/String;)V+0
v  ~StubRoutines::call_stub
V  [jvm.dll+0x80f13]
V  [jvm.dll+0xd3842]
V  [jvm.dll+0x80de4]
V  [jvm.dll+0x87cd2]
```

```
C  [java.exe+0x14c0]
C  [java.exe+0x64cd]
C  [kernel32.dll+0x214c7]
 :
```

In this case we can see, from the stack trace, that a native routine in *App.dll* has called into the VM (probably via JNI).

If you get a crash in a native application library (like the above examples) then you may be able to attach the native debugger (*dbx*, *gdb*, *windbg* depending on the operating system) to the core file/crash dump if it is available. Another approach is run with the *-Xcheck:jni* option added to the command line (section 1.17.3). The *-Xcheck:jni* option is not guaranteed to find all issues with JNI code but it can help identify a significant number of issues.

If the native library where the crash happended is part of the Java Runtime Environment (for example *awt.dll*, *net.dll*, ..) then it is possible that you have encountered a library/API bug. If after further analysis you conclude this is a library/API bug then gather a much data as possible and submit a bug or support call. (See chapter 3 for more on data collection.)

2.2.2.2 Crash due to a Stack Overflow

A stack overflow in Java Language code will normally result in the offending thread throwing *java.lang.StackOverflowError*. On the other hand, a stack overflow in native/JNI code is a fatal error which causes the process to terminate. The following is a fragment from a fatal error log where a thread has provoked a stack overflow in native code. The following example was obtained on a Windows system.

```
#
# An unexpected error has been detected by HotSpot Virtual Machine:
#
#  EXCEPTION_STACK_OVERFLOW (0xc00000fd) at pc=0x10001011, pid=296, tid=2940
#
# Java VM: Java HotSpot(TM) Client VM (1.5-internal mixed mode, sharing)
# Problematic frame:
# C  [App.dll+0x1011]
#

---------------  T H R E A D  ---------------

Current thread (0x000367c0):  JavaThread "main" [_thread_in_native, id=2940]

:


Stack: [0x00040000,0x00080000),  sp=0x00041000,  free space=4k
Native frames: (J=compiled Java code, j=interpreted, Vv=VM code, C=native code)
C  [App.dll+0x1011]
C  [App.dll+0x1020]
C  [App.dll+0x1020]
:
C  [App.dll+0x1020]
C  [App.dll+0x1020]
...<more frames>...
```

```
Java frames: (J=compiled Java code, j=interpreted, Vv=VM code)
j  Test.foo()V+0
j  Test.main([Ljava/lang/String;)V+0
v  ~StubRoutines::call_stub
```

There are a number of items to note in this output:

1. The exception is *EXCEPTION_STACK_OVERFLOW*.
2. The thread state is *_thread_in_native*, meaning that the thread is executing native/JNI code.
3. In the stack information the free space is only 4k (a single page on a Windows system). In addition we can see that the stack pointer (sp) is a `0x00041000` which is close to the end of the stack (`0x00040000`).
4. The print out of the native frames makes it clear that a recursive native function is the issue in this case. Also note the output "...<*more frames*>..." which indiciates there are further frames which were not printed. The output is limited to 100 frames.

2.2.2.3 Crash in a HotSpot Compiler Thread

If the "*Current thread*" is a *JavaThread* named "*CompilerThread0*", "*CompilerThread1*", or "*AdapterCompiler*" then it is possible that you have encountered a compiler bug. In this case it may be necessary to temporarily workaround the issue by switching the compiler (use HotSpot Client VM instead of HotSpot VM or visa versa), or excluding the method that provokes the crash from being compiled. This is discussed later.

2.2.2.4 Crash in Compiled Code

If the crash is in compiled code then it is possible that you have encountered a compiler bug that has resulted in incorrect code generation. You can recognize a crash in compiled code if the problematic frame is marked with a "J" (meaning a compiled Java frame). Here is an example of a such a crash :

```
#
# An unexpected error has been detected by HotSpot Virtual Machine:
#
#  SIGSEGV (0xb) at pc=0x0000002a99eb0c10, pid=6106, tid=278546
#
# Java VM: Java HotSpot(TM) 64-Bit Server VM (1.5.0-beta2-b51 mixed mode)
# Problematic frame:
# J  org.foobar.Scanner.body()V
#

:

Stack: [0x0000002aea560000,0x0000002aea660000),  sp=0x0000002aea65ddf0,  free
space=1015k
Native frames: (J=compiled Java code, j=interpreted, Vv=VM code, C=native code)
J  org.foobar.Scanner.body()V

[error occurred during error reporting, step 120, id 0xb]
```

In this case you should note that a complete thread stack is not available – the "*error occurred during error reporting*" here meaning that a problem arose trying to obtain the stack trace (perhaps stack

corruption in this example).

As with the previous example it may be possible to temporarily workaround the issue by switching the compiler or excluding the method that provokes the crash from being compiled. In this specific example it may not be possible to switch the compiler as it was taken from the 64-bit Server VM and hence it may not be feasible to switch to the 32-bit Client VM.

2.2.2.5 Crash in the VM Thread

If the "*Current thread*" is the *VMThread* then you need to look for the "*VM_Operation*" line in the *THREAD* section. The VM thread is a special thread in the HotSpot VM. It performs special tasks in the VM such as garbage collection. If the VM_Operation suggests that the operation is a garbage collection then it is possible that you have encountered as issue such as heap corruption. The crash might also be a garbage collector issue, but it could equally be something else (such as a compiler or runtime bug) that leaves object references in the heap in an inconsistent or incorrect state. In this case it is best to collect as much information as possible about the environment and try out possible workarounds. If the issue is GC related then you may be able to temporarily workaround the issue by changing the GC configuration. This is discussed in the following section.

2.2.3 Finding a Workaround

If a crash arises with a critical application, and the crash appears to be caused by a bug in the HotSpot VM, then it may be desirable to find a temporary workaround in a hurry. The purpose of this section is to suggest some possible workarounds. If the crash arises with an application that is deployed with the most up-to-date release of 5.0 then the crash should always be reported to Sun Microsystems either by logging a support call (for customers with support contracts), as a once-off-incident (see page 8 for links to support options), or by submitting a bug to the bug database (see page for the link to the bug database).

It should be noted that if any of the workarounds suggested in this section successively eliminate the crash then the workaround should not be considered to be the fix. Instead the workaround should be considered a temporary workaround and a support call or bug report should be submitted with the original configuration that demonstrated the issue.

2.2.3.1 Crash in HotSpot Compiler Thread or Compiled Code

If the fatal error log indicates that the crash has arisen in a compiler thread then it is possible (but not always the case) that you have encountered a compiler bug. Similarly, if the crash is in compiled code then it is possible that the compiler has generated incorrect code.

In the case of the HotSpot Client VM (*-client* option) the compiler thread appears in the error log as *CompilerThread0.* With the HotSpot Server VM there are multiple compiler threads and these appear in the error log file as *CompilerThread0, CompilerThread1*, and *AdapterThread.*

Following is a fragment of an error log for a compiler bug that was encountered and fixed during the development of J2SE 5.0. In the log file we see that the HotSpot Server VM is used and the crash happended in *CompilerThread0.* Further the log file shows that the current "*compiler task*" was the

compilation of *java.lang.Thread.setPriority* method :

```
#
# An unexpected error has been detected by HotSpot Virtual Machine:
#

:

# Java VM: Java HotSpot(TM) Server VM (1.5-internal-debug mixed mode)
:

---------------  T H R E A D  ---------------

Current thread (0x001e9350): JavaThread "CompilerThread1" daemon [_thread_in_vm,
id=20]

Stack: [0xb2500000,0xb2580000),  sp=0xb257e500,  free space=505k
Native frames: (J=compiled Java code, j=interpreted, Vv=VM code, C=native code)
V  [libjvm.so+0xc3b13c]
:


Current CompileTask:
opto: 11      java.lang.Thread.setPriority(I)V (53 bytes)


---------------  P R O C E S S  ---------------

Java Threads: ( => current thread )
  0x00229930 JavaThread "Low Memory Detector" daemon [_thread_blocked, id=21]
=>0x001e9350 JavaThread "CompilerThread1" daemon [_thread_in_vm, id=20]

 :
```

In this case there are two potential workarounds :

1. The brute force approach: change the configuration so that the application is run with the *-client* option to specify the HotSpot Client VM.
2. Assume that the bug only arises when compiling the *setPriority* method and exclude this method from compilation.

The first approach (to use the *-client* option) may be trivial to configure in some envrionments. In others, it may be more complex because the configuration may be complex or the command line to configure the VM may not be readily accessible. In general, switching from the HotSpot Server VM to the HotSpot Client VM will also reduce the peak performance of an application. Depending on the environment, this may be acceptable until the actual issue is diagnosed and fixed.

The second approach (exclude the method from compilation) requires creating the file "*.hotspot_compiler*" in the working directory of the application. Following is an example file:

```
      exclude     java/lang/Thread  setPriority
```

In general the format of this file is "*exclude CLASS METHOD*" where "*CLASS*" is the class (fully qualified with the package name) and "*METHOD*" is the name of the method. Constructor methods are specified as "*<init>*" and static initializers are specified as "*<clinit>*".

Note:
The .hotspot_compiler file is an unsupported interface. It is documented here soley for the purposes of troubleshooting and finding a temporary workaround.

Once the application is restarted the compiler will not attempt to compile any of the methods listed as excluded in the *.hotspot_compiler* file. In some cases this will provide temporary relief until the root cause of the crash is diagnosed and the bug fixed.

2.2.3.2 Crash during Garbage Collection

If a crash arises during garbage collection then it will normally be reported in the fatal error log that a *VM_Operation* is in progress[9]. The VM_Operation is shown in the *THREAD* section of the log and will indicate one of the following :

- generation collection for allocation
- full generation collection
- parallel gc failed allocation
- parallel gc failed permanent allocation
- parallel gc system gc

Most likely the current thread reported in the log is the *VMThread* – this is the special thread used to execute special tasks in the HotSpot VM. The following fragment shows an example of how a crash in the serial garbage collector might look :

```
---------------  T H R E A D  ---------------

Current thread (0x002cb720):  VMThread [id=3252]

siginfo: ExceptionCode=0xc0000005, reading address 0x00000000

Registers:
EAX=0x0000000a, EBX=0x00000001, ECX=0x00289530, EDX=0x00000000
ESP=0x02aefc2c, EBP=0x02aefc44, ESI=0x00289530, EDI=0x00289530
EIP=0x0806d17a, EFLAGS=0x00010246

Top of Stack: (sp=0x02aefc2c)
0x02aefc2c:   00289530 081641e8 00000001 0806e4b8
0x02aefc3c:   00000001 00000000 02aefc9c 0806e4c5
0x02aefc4c:   081641e8 081641c8 00000001 00289530
0x02aefc5c:   00000000 00000000 00000001 00000001
0x02aefc6c:   00000000 00000000 00000000 08072a9e
0x02aefc7c:   00000000 00000000 00000000 00035378
0x02aefc8c:   00035378 00280d88 00280d88 147fee00
0x02aefc9c:   02aefce8 0806e0f5 00000001 00289530

Instructions: (pc=0x0806d17a)
0x0806d16a:   15 08 83 3d c0 be 15 08 05 53 56 57 8b f1 75 0f
0x0806d17a:   0f be 05 00 00 00 00 83 c0 05 a3 c0 be 15 08 8b
```

9 For the purposes of this discussion we assume the mostly concurrent GC (-XX:+UseConcMarkSweep) is not in use.

```
Stack: [0x02ab0000,0x02af0000),  sp=0x02aefc2c,  free space=255k
Native frames: (J=compiled Java code, j=interpreted, Vv=VM code, C=native code)
V  [jvm.dll+0x6d17a]
V  [jvm.dll+0x6e4c5]
V  [jvm.dll+0x6e0f5]
V  [jvm.dll+0x71771]
V  [jvm.dll+0xfd1d3]
V  [jvm.dll+0x6cd99]
V  [jvm.dll+0x504bf]
V  [jvm.dll+0x6cf4b]
V  [jvm.dll+0x1175d5]
V  [jvm.dll+0x1170a0]
V  [jvm.dll+0x11728f]
V  [jvm.dll+0x116fd5]
C  [MSVCRT.dll+0x27fb8]
C  [kernel32.dll+0x1d33b]

VM_Operation (0x0373f71c): generation collection for allocation, mode: safepoint,
requested by thread 0x02db7108
```

It is important to stress that a crash during garbage collection does not imply a bug in the garbage collection implementation. It is equally possible that the issue is in another area (such as a compiler or runtime bug).

There are several things to try if you get a repeated crash during garbage collection :

1. Switch GC configuration: For example if you are using the the serial collector then try the through-put collector (or visa versa).
2. If you are using the HotSpot Server VM, try the HotSpot Client VM.

If you are not sure which garbage collector is in use then you can use the *jmap* utility on Solaris and Linux to obtain the heap information from the core file (assuming that the core file is available). In general if the GC configuration is not specified on the command line then the serial collector will be used on Windows. On Solaris and Linux it depends on the machine configuration. If the machine has >= 2GB of memory and has >= 2 processors then the through-put collector (Parallel GC) will be used. For smaller machines the serial collector is the default. The option to select the serial collector is -XX :+UseSerialGC and the option to select the through-put collector is -XX:+UseParallelGC. If, as a workaround, you switch from the through-put collector to the serial collector then you may experience some performance degradation on multi-processor systems. This may be acceptable until the root issue is diagnosed and resolved.

2.2.3.3 Class Data Sharing

Class data sharing is a new feature in J2SE 5.0. When the JRE is installed on 32-bit platforms using the Sun provided installer, the installer loads a set of classes from the system jar file into a private internal representation and dumps that representation to a file called a *shared archive.* When the VM is started the shared archive is memory-mapped in. This saves on class loading and allows much of the metadata associated with the classes to be shared across multiple VM instances. In J2SE 5.0, class

data sharing is only enabled when the HotSpot Client VM is used. In addition sharing is only supported with the serial garbage collector.

The fatal error log will print the version string in the header of the log. If sharing is enabled it should be obvious as shown in the following example :

```
#
# An unexpected error has been detected by HotSpot Virtual Machine:
#
#  EXCEPTION_ACCESS_VIOLATION (0xc0000005) at pc=0x08083d77, pid=3572, tid=784
#
# Java VM: Java HotSpot(TM) Client VM (1.5-internal mixed mode, sharing)
# Problematic frame:
# V  [jvm.dll+0x83d77]
#
```

Although the sharing feature was thoroughly tested for 5.0 it may be possible that a crash stems from this new feature. Sharing can be disabled by providing the *-Xshare:off* option on the command line. If the crash cannot be duplicated with sharing disabled but can be duplicated with sharing enabled then it is possible that you have encountered a bug. In that case gather as much information as possible and submit a bug.

2.2.4 Visual C++ Version

JDK5.0 is compiled on Windows using Microsoft Visual C++ 6.0 Service Pack 3. This is an old but stable release of the compiler. If you experience a crash with a J2SE-based application and if you have native/JNI libraries that are compiled with a newer release of the compiler (VC.++ NET 2002 or VC++ .NET 2003 for example) then you need to be aware of compatibility issues between the 6.0 and newer runtimes. Specifically, you only have a supported environment if you follow the Microsoft guidelines when dealing with multiple runtimes. For example, if you allocate memory using one runtime then you must release it using the same runtime. Unpredictable behavior or crashes can arise if you release a resource using a different library than the one that allocated it.

2.3 Hangs and Looping Processes

Issues may arise involving hangs or looping processes. A hang can arise for many reasons but often stems from a deadlock in application code, API/library code, or even a bug in the HotSpot Virtual Machine. Sometimes an apparent hang turns out not to be a hang but rather that the VM process is consuming all available CPU cycles – most likely caused by a bug that causes one or more threads to go into an infinite loop.

An initial step when diagnosing a hang is to find out if the VM process is idle or consuming all available CPU cycles. To do this requires using an operating system utility. If the process appears to be busy and is consuming all available CPU cycles then it is likely that the issue is a looping thread rather than a deadlock. On Solaris, for example, *prstat -L -p <pid>* can be used to report the statistics for all LWPs in the target process and thus will identify the thread(s) that are consuming a lot of CPU cycles.

2.3.1 Diagnosing a Looping Process

If a VM process appears to be looping then the first step is to try and get a thread dump. If a thread dump can be obtained it will often be clear which thread is looping. If the looping thread can be identified then the trace stack in the thread dump should provide direction on where (and maybe why) the thread is looping.

If the application console (standard input/output) is available then pressing the *Ctrl-* or *Ctrl-Break* keys (depending on platform) will result in the HotSpot VM printing a thread dump. On Solaris and Linux the thread dump can also be obtained by sending a SIGQUIT to the process (*kill -QUIT <pid>*). In this case the thread dump will be printed to the standard output of the target process (which may be directed to a file depending on how it was started).

If a thread dump can be obtained then a good place to start is the thread stacks of the threads that are in the *runnable* state. Section 1.16 provides information on the format of the thread dump and includes a table of the possible thread states in the thread dump. In some cases it may be necessary to get a sequence of thread dumps in order to determine which threads appear to be continuously busy.

If the application console is not available (process is running as a background process, or the VM output is directed to an unknown location) then the *jstack* utility on Solaris or Linux can be used to obtain the stack thread. Section 1.4 provides information on the output of the *jstack* utility. The *jstack* utility should also be used if the thread dump does not provide any evidence that a java thread is looping.

When reviewing the output of *jstack* utility it is best to initially focus on the threads that are in the *IN_JAVA, IN_NATIVE* or *IN_VM* states. These are the most likely states for threads that are busy and likely to be looping. It may be necessary to execute *jstack* a number of times to get a more complete picture of which threads are looping. If a thread appears to be always in the *IN_VM* state then the *-m* option can be used to print the native frames and may provide a further hint on what the thread is doing. If a thread appears to be looping continuously while in the *IN_VM* state this may indicate a potential HotSpot VM bug that needs further investigation.

If the VM does not respond to a Ctrl-\ this may suggest a possible VM bug rather than an issue with

application or library code. In this case use *jstack* with the -m option to get a thread stack for all threads. The output will include the thread stacks for VM internal threads. In this stack trace the focus should be to identify threads that do not appear to be waiting (for example on Solaris you would identify the threads that are not in functions such as *__lwp_cond_wait*, __lwp_park, *___pollsys*, or other blocking functions). If it appears that the looping is caused by a VM bug then it is important to collect as much data as possible and submit a bug. See chapter 3, page 112 for more details on data collection.

2.3.2 Diagnosing a Hung Process

If the application appears to be hung and the process appears to be idle then the first step is to try to obtain a thread dump. If the application console is available then pressing the *Ctrl-* or *Ctrl-Break* keys (depending on platform) will result in the HotSpot VM printing a thread dump. On Solaris and Linux the thread dump can also be obtained by sending a SIGQUIT to the process (*kill -QUIT <pid>*).

Deadlock Found

If the hung process is capable of generating a thread dump then the output will be printed to standard output of the target process. After printing the thread dump the HotSpot VM also executes a deadlock detection algorithm. If a deadlock is detected it will be printed along with the stack trace of the threads involved in the deadlock. Here is a sample deadlock to demonstrate how the output will appear :

```
Found one Java-level deadlock:
=============================
"AWT-EventQueue-0":
  waiting to lock monitor 0x000ffbf8 (object 0xf0c30560, a
java.awt.Component$AWTTreeLock),
  which is held by "main"
"main":
  waiting to lock monitor 0x000ffe38 (object 0xf0c41ec8, a java.util.Vector),
  which is held by "AWT-EventQueue-0"

Java stack information for the threads listed above:
===================================================
"AWT-EventQueue-0":
        at java.awt.Container.removeNotify(Container.java:2503)
        - waiting to lock <0xf0c30560> (a java.awt.Component$AWTTreeLock)
        at java.awt.Window$1DisposeAction.run(Window.java:604)
        at java.awt.Window.doDispose(Window.java:617)
        at java.awt.Dialog.doDispose(Dialog.java:625)
        at java.awt.Window.dispose(Window.java:574)
        at java.awt.Window.disposeImpl(Window.java:584)
        at java.awt.Window$1DisposeAction.run(Window.java:598)
        - locked <0xf0c41ec8> (a java.util.Vector)
        at java.awt.Window.doDispose(Window.java:617)
        at java.awt.Window.dispose(Window.java:574)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.dispose(SwingUtilities.java:1743)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.windowClosed(SwingUtilities.java:172
2)
        at java.awt.Window.processWindowEvent(Window.java:1173)
        at javax.swing.JDialog.processWindowEvent(JDialog.java:407)
        at java.awt.Window.processEvent(Window.java:1128)
```

```
        at java.awt.Component.dispatchEventImpl(Component.java:3922)
        at java.awt.Container.dispatchEventImpl(Container.java:2009)
        at java.awt.Window.dispatchEventImpl(Window.java:1746)
        at java.awt.Component.dispatchEvent(Component.java:3770)
        at java.awt.EventQueue.dispatchEvent(EventQueue.java:463)
        at
java.awt.EventDispatchThread.pumpOneEventForHierarchy(EventDispatchThread.java:2
14)
        at
java.awt.EventDispatchThread.pumpEventsForHierarchy(EventDispatchThread.java:163
)
        at java.awt.EventDispatchThread.pumpEvents(EventDispatchThread.java:157)
        at java.awt.EventDispatchThread.pumpEvents(EventDispatchThread.java:149)
        at java.awt.EventDispatchThread.run(EventDispatchThread.java:110)
"main":
        at java.awt.Window.getOwnedWindows(Window.java:844)
        - waiting to lock <0xf0c41ec8> (a java.util.Vector)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.installListeners(SwingUtilities.java
:1697)
        at
javax.swing.SwingUtilities$SharedOwnerFrame.addNotify(SwingUtilities.java:1690)
        at java.awt.Dialog.addNotify(Dialog.java:370)
        - locked <0xf0c30560> (a java.awt.Component$AWTTreeLock)
        at java.awt.Dialog.conditionalShow(Dialog.java:441)
        - locked <0xf0c30560> (a java.awt.Component$AWTTreeLock)
        at java.awt.Dialog.show(Dialog.java:499)
        at java.awt.Component.show(Component.java:1287)
        at java.awt.Component.setVisible(Component.java:1242)
        at test01.main(test01.java:10)

Found 1 deadlock.
```

In J2SE 5.0 deadlock detection works only with locks that are obtained using the *synchronized* keyword. This means that deadlocks that arise through the use of the *java.util.concurrency* package are not detected.

If the deadlock detection algorithm detects a deadlock then it is necessary to examine the output in more detail so that the deadlock can be understood. In the above example we see that thread "main" is locking object <0xf0c30560> and is waiting to enter <0xf0c41ec8> which is locked by thread "AWT-EventQueue-0". But, thread "AWT-EventQueue-0" is waiting to enter <0xf0c30560> that is locked by "main".

The detail in the stack traces should provide information to suggest where the deadlock is.

No Deadlock Found

If the thread dump is printed and no deadlocks are found (and you know that the application or its libraries do not use the concurrency package) then the issue may be a bug whereby a thread waiting on a monitor is never notified. This could be a timing issue or a general logic bug.

To find out more about the issue, you need to examine each of the threads in the thread dump and examine each thread that is blocked in *Object.wait()*. The caller frame in the stack trace should indicate the class and method that is invoking the *wait*() method. If the code was compiled with line number information (the default) then this provides direction as to the code to examine. In most cases

some knowledge of the application logic or library is required to diagnose this issue further. In general you will need to understand how the synchronization works in the application and in particular the details and conditions for when and where monitors are notified.

No Thread Dump

If the VM does not respond to a *Ctrl-* or *Ctrl-Break* then it is possible that the VM may be deadlocked or hung for some other reason. In that case use the *jstack* utility to obtain a thread dump. This also applies in the case where the application is not accessible or the output is directed to an unknown location.

With the *jstack* output examine each of the threads in the BLOCKED state. The top frame can sometimes indicate why the thread is blocked (*Object.wait*, or *Thread.sleep* for example), and the rest of the stack should give an indication as to what the thread is doing. This is particularly true when the source has been compiled with line number information (the default) and you can cross reference the source code.

If a thread is BLOCKED and the reason is not clear then use the *-m* option to get a mixed stack. With the mixed stack output, it should be possible to identify why the thread is blocked. If a thread is blocked trying to enter a synchronized method or block then you will see frames like *ObjectMonitor::enter* near the top of the stack. Following is an example :

```
----------------- t@13 -----------------
0xff31e8b8       ___lwp_cond_wait + 0x4
0xfea8c810       void ObjectMonitor::EnterI(Thread*) + 0x2b8
0xfeac86b8       void ObjectMonitor::enter2(Thread*) + 0x250
:
:
```

Threads in the IN_NATIVE state may also be blocked. The top most frames in the mixed stack should indicate what the thread is doing.

The other thread states that *jstack* can report are the *IN_JAVA* or *IN_VM* states. Threads in the *IN_JAVA* state are executing java code. Threads the *IN_VM* state are executing in the VM code – the mixed stack option should help indicate what the thread is doing.

One specific thread to check is *VMThread.* This is the special thread used to execute operations like garbage collection. It can be identified as the thread that is executing *VMThread::run()* in its initial frames. On Solaris it is typically "*t@4*". On Linux it should be identifiable using the C++ mangled name "*_ZN8VMThread4loopEv*". In general the VM thread is in one of 3 states: waiting to execute a VM operation, synchronizing all threads in preparation for a VM operation, or executing a VM operation. If you suspect that a hang is a HotSpot VM bug rather than an application or class library deadlock then pay special attention to the VM thread. If the VM thread appears to be stuck in *SafepointSynchronize::begin* then this could indicate an issue bringing the VM to a safepoint[10]. If the thread appears to to be stuck in *<function> where <function> ends in* "doit" then this could also indicate a VM problem.

In general, if you can execute the application from the command line, and you get to a state where the

10 A safepoint indicates that all threads executing in the VM are blocked and waiting for a special operation, such as garbage collection, to complete.

VM does not respond to a *Ctrl-* or *Ctrl-Break* it is more likely that you have uncovered a VM bug, a thread library issue, or a bug in another library. If this arises it is best to obtain a crash dump (see section 3.2 for instructions on how to do this), gather as much information as possible, and submit a bug or support call.

One other tool to mention in the context of hung processes is the *pstack* utility on Solaris. On Solaris 8 and 9 it prints the thread stacks for LWPs in the target process. On Solaris 10 and JDK5.0 the output of *pstack* is similar (though not identical) to the output from *jstack -m*. As with *jstack*, the Solaris 10 implementation of *pstack* prints the fully qualified class name, method name, and bci. It will also print line numbers for the cases where the source was compiled with line number information (the default). This is useful for developers and administrators who are used to *pstack* and the other proc utilities on Solaris.

The equivalent tool of *pstack* on Linux is *lsstack* (included in some distributions; otherwise obtained from the sourceforge.net web site). At the time of this writing, *lsstack* reported native frames only.

2.3.3 Solaris 8 Thread Library

The default thread library on Solaris 8 is often referred to as the T1 library. This thread library implemented the *m:n* threading model where *m* user threads are mapped to *n* kernel-level threads (LWPs). Solaris 8 also shipped with an alternative and newer thread library in */usr/lib/lwp*. The alternative thread library is often referred to as the T2 library and it became the default thread library in Solaris 9 and 10. In older releases of J2SE (pre-1.4.0 in particular) there were a number of issues with the default thread library. In some cases the issues were bugs in the thread library, in other cases the issues related to LWP synchronization or LWP starvation (a scenario that arises when there are user threads in the runnable state but there aren't any kernel level threads available).

Although the issues cited are historical, it should be noted that when JDK5.0 is deployed on Solaris 8 it still uses the T1 library by default. LWP starvation type issues do not arise because JDK5.0 uses "*bound threads*" so that each user thread is bound to a kernel thread. However in the event that you encounter an issue, such as a hang, which you believe is a thread library issue then you can instruct the HotSpot VM to use the T2 library by adding */usr/lib/lwp* to the *LD_LIBRARY_PATH*. To check if the T2 library is in use then the "*pldd <pid>*" command can be used to list the libraries loaded by the specified process.

2.4 Signal Handling

Sometimes developers have to integrate J2SE applications with code that uses signal or exception handlers. This section provides information on how signals are handled in the HotSpot Virtual Machine. It also describes the signal chaining facility that facilitates applications that need to install their own signal handlers. This facility is available on Solaris and Linux.

2.4.1 Signal Handling on Solaris and Linux

The HotSpot Virtual Machine installs signal handlers to implement various features and to handle fatal error conditions. For example, an optimization to avoid explicit null checks in cases where *java.lang.NullPointerException* will be thrown rarely, is implemented using the *SIGSEGV* signal. In this case, the *SIGSEGV* signal is caught, handled, and the *NullPointerException* is thrown.

In general there are two categories of situations where signal/traps arise:

1. Situations where signals are expected and handled – Examples include the implict null handling cited above. Another example is the safepoint polling mechanism which protects a page in memory when a safepoint is required. Any thread that accesses that page causes a *SIGSEGV* which results in the execution of a stub that brings the thread to a safepoint.
2. Unexpected signals – This includes a SIGSEGV when executing in VM or JNI/native code. In these cases the signal is unexpected, so fatal error handling is invoked to create the error log and terminate the process.

The following table lists the signals currently used on Solaris and Linux :

Signal	***Usage***
SIGSEGV, SIGBUS, SIGFPE, SIGPIPE, SIGILL	Used in the implementation for things like implicit null check, and others.
SIGQUIT	Thread dump support: To dump Java stack traces at the standard error stream. (**optional**)
SIGTERM, SIGINT, SIGHUP	Used to support the shutdown hook mechanism (java.lang.Runtime.addShutdownHook) when the VM is terminated abnormally. (**optional**)
SIGUSR1	Used in the implementation of the java.lang.Thread.interrupt method. (**configurable**). Not used on Solaris 10 or greater. Reserved on Linux.
SIGUSR2	Used internally. (**configurable**). Not used on Solaris 10 or greater.

Signal	*Usage*
SIGABRT	The HotSpot VM doees not handle this signal. Instead it calls the abort function after fatal error handling. If an application uses this signal then it should terminate the process to preserve the expected semantics.

2.4.1.1 Reducing Signal Usage

The *-Xrs* option instructs the HotSpot VM to *reduce its signal usage*. The option results in fewer signals being used although the VM still installs its own signal handler for essential signals such as *SIGSEGV*. In the previous table the signals tagged as **optional** are not used when the *-Xrs* option is specified. Note that the option means that the shutdown hook mechanism will not execute if the process receives a *SIGTERM*, *SIGINT*, or *SIGHUP*. Shutdown hooks will execute, as expected, if the VM terminates normally (last non-daemon thread complets or the *System.exit* method is used).

2.4.1.2 Alternative Signals

On Solaris 8 and 9 the *-XX:+UseAltSigs* option can be used to instruct the HotSpot VM to use alternative signals to *SIGUSR1* and *SIGUSR2*. On Solaris 10 or greater this option is ignored, as the operating system reserves two additional signals (called *SIGJVM1* and *SIGJVM2*).

On Linux the handler for *SIGUSR1* cannot be overridden. *SIGUSR2* is used to implement suspend and resume. However it is possible to specify an alternative signal to be used instead of *SIGUSR2*. This is done by specifying the *_JAVA_SR_SIGNUM* environment variable. If this environment variable is set, it must be set to a value larger than the maximum of *SIGSEGV* and *SIGBUS*.

2.4.1.3 Signal Chaining

If an application with native code requires it own signal handlers then it may need to be used with the signal chaining facility. The signal chaining facility offers :

1. Support for pre-installed signal handlers when the HotSpot VM is created.

2. Support for signal handler installation after the HotSpot VM is created, inside JNI code or from another native thread.

Pre-installed signal handlers (1.) are supported by means of saving existing signal handlers, for signals that are used by the VM, when the VM is first created. Later, when any of these signals are raised and found not to be targeted at the Java HotSpot VM, the pre-installed handlers are invoked. In other words, pre-installed handlers are "chained" behind the VM handlers for these signals.

The signal-chaining facility also allows an application to link and load the `libjsig.so` shared

library before `libc/libthread/libpthread`. This library ensures that calls such as `signal()`, `sigset()`, and `sigaction()` are intercepted so that they do not actually replace the Java HotSpot VM's signal handlers if the handlers conflict with those already installed by the Java HotSpot VM (2.). Instead, these calls save the new signal handlers, or "chain" them behind the VM-installed handlers. Later, when any of these signals are raised and found not to be targeted at the Java HotSpot VM, the pre-installed handlers are invoked. `libjsig.so` is not needed if (2.) is not required.

To use `libjsig.so`, either link it with the application that creates/embeds a HotSpot VM, for example:

```
cc -L <libjvm.so dir> -ljsig -ljvm java_application.c
```

or use the **LD_PRELOAD** environment variable, for example:

```
export LD_PRELOAD=<libjvm.so dir>/libjsig.so; java_application(ksh)

setenv LD_PRELOAD <libjvm.so dir>/libjsig.so; java_application(csh)
```

The interposed `signal()/sigset()/sigaction()` return the saved signal handlers, not the signal handlers installed by the Java HotSpot VM and which are seen by the OS.

Note that the *SIGUSR1* signal cannot be chained. If an application attempts to chain this signal on Solaris then the HotSpot VM will terminate with the fatal error: "*Signal chaining detected for VM interrupt signal, try -XX:+UseAltSigs*". In addition the *SIGQUIT*, *SIGTERM*, *SIGINT* and *SIGHUP* signals cannot be chained. If the application needs to handle these signals then the *-Xrs* option should be considered.

On Solaris, the *SIGUSR2* signal can be chained but only for non-Java and non-VM threads; that is, it can only be used for native threads created by the application that do not attach to the virtual machine.

2.4.2 Exception Handling on Windows

On Windows, an exception is an event that occurs during the execution of a program. There are two kinds of exceptions: hardware exceptions and software exceptions. Hardware exceptions are comparable to signals such as *SIGSEGV* and *SIGILL* on Solaris and Linux. Software exceptions are initiated explicitly by applications or the operating system using the *RaiseException*() API.

On Windows, the mechanism for handling both hardware and software execptions is called *Structured Exception Handling* (*SEH*). This is stack frame-based exception handling similar to the C++, Java exception handling mechanism. In C++ the **__try** and **__except** keywords are used to guard a section of code that may result in an exception :

```
__try {
    // guarded body of code
} __except (filter-expression) {
    // exception-handler block
}
```

The **__except** block is filtered by a filter expression that uses exception code (integer code returned by *GetExceptionCode*() API) and/or exception information (*GetExceptionInformation*() API).

The filter expression should evaluate to one of the following values:

1. EXCEPTION_CONTINUE_EXECUTION = -1

   The filter expression has repaired the situation and execution continues where the exception occurred. Unlike some exception schemes, SEH supports the *resumption mode*l as well. This is much like Unix signal handling in the sense that after the signal handler finishes, the execution continues where the program was interrupted. The difference is that the handler in this case is just the filter expression itself and not the **__except** block. But, the filter expression may involve a function call as well.

2. EXCEPTION_CONTINUE_SEARCH = 0

   The current handler can't handle this exception. Continue the handler search for a next handler. This is similar to the catch block not matching an exception type in C++, Java.

3. EXCEPTION_EXECUTE_HANDLER = 1

   The current handler matches and can handle the exception. The **__except** block is executed.

The **__try** and **__finally** keywords are used to construct a termination handler as shown below.

```
__try {
    // guarded body of code
} __finally {
    // __finally block
}
```

When control leaves the **__try** block (after exception or without exception), the **__finally** block is executed. Inside the **__finally** block, the AbnormalTermination() API may be called to test whether control continued after the exception or not.

Windows programs may also install a top level *unhandled exception filter* function to catch exceptions that are not handled in a **__try**/**__except** on a process-wide basis using the *SetUnhandledExceptionFilter*() API. If there is no handler for an exception, then UnhandledExceptionFilter() is called and this will call the top level unhandled exception filter function, if any, to catch that exception. This function also shows a message box to notify the user about the unhandled exception.

Windows exceptions are comparable to Unix synchronous signals that are attributable to the current execution stream. In Windows, asynchronous events such as console events (such as the user pressing Ctrl-C at the console) are handled by the console control handler registered using the SetConsoleCtlHandler() API.

If an application uses the *signal*() API on Windows, then the C runtime library (CRT) maps both

Windows exceptions and console events to appropriate signals or C runtime errors. For example, CRT maps Ctrl-C to SIGINT and all other console events to SIGBREAK. Similarly, if you register the SIGSEGV handler, the C runtime library translates the corresponding exception to a signal. CRT library startup code implements a __try/__except block around the main() function. CRT's exception filter function (named _XcptFilter) maps the Win32 exceptions to signals and dispatches signals to their appropriate handlers. If a signal's handler is set to SIG_DFL (default handling), _XcptFilter calls the UnhandledExceptionFilter.

With Windows XP or Windows 2003, the new vectored exception handling mechanism may also be used. Vectored handlers are not frame-based handlers. A program may register zero or more vectored exception handlers using AddVectoredExceptionHandler API. Vectored handlers are invoked before invoking structured exception handlers, if any, regardless of where the exception actually occurred.

Vectored exception handler may return:

1. EXCEPTION_CONTINUE_EXECUTION to skip next vectored and SEH handlers or
2. EXCEPTION_CONTINUE_SEARCH to continue next vectored or SEH handler.

Refer to the Microsoft web site (http://www.microsoft.com) for further information on Windows exception handling.

2.4.2.1 Signal Handling in the HotSpot Virtual Machine

The HotSpot Virtual Machine installs a top level exception handler using the *SetUnhandledExceptionFilter* (or the *AddVectoredExceptionHandler* API for 64-bit) API during VM initialization. It also installs win32 SEH using a __try / __except around the thread (internal) start function call for each thread created. And, finally it installs an exception handler around JNI functions. If an application wishes to handle structured exceptions in JNI code, it can use __try / __except statements. But, if it must use the vectored exception handler in JNI code then the handler must return *EXCEPTION_CONTINUE_SEARCH* to continue to the VMs exception handler.

In general, there are two categories of situations in which exceptions arise :

1. Situations where signals are expected and handled – Examples include the implict null handling cited above where accessing a null casues an *EXCEPTION_ACCESS_VIOLATION* that is handled.
2. Unexpected exceptions – An example is *EXCEPTION_ACCESS_VIOLATION* when executing in VM or JNI/native code. In these cases the signal is unexpected, and fatal error handling is invoked to create the error log and terminate the process.

2.4.2.2 Console Handlers

The HotSpot Virtual Machine registers console events as shown in the following table:

Console event	*Signal*	*Usage*
CTRL_C_EVENT	SIGINT	Terminate process.(**optional**)
CTRL_CLOSE_EVENT CTRL_LOGOFF_EVENT CTRL_SHUTDOWN_EVENT	SIGTERM	Used by the shutdown hook mechansim when the VM is terminated abnormally.(**optional**)
CTRL_BREAK_EVENT	SIGBREAK	Thread dump support: To dump Java stack traces at the standard error stream. (**optional**)

If an application must register its own console handler then the *-Xrs* option can be used. With this option, shutdown hools are not run on SIGTERM (with above mapping of events) and thread dump support is not available on SIGBREAK (with above mapping Ctrl-Break event).

3 Submitting Bug Reports

This chapter provides guidance on how to submit a bug report. It includes suggestions about what to try before submitting a report and what data to collect for the report.

J2SE 5.0 was released in September 2004. Updates to J2SE 5.0 are scheduled for release every 3 months thereafter. These releases are called *update releases* and fix a set of critical bugs identified since the initial release of 5.0. When a 5.0 update release becomes available, it becomes the default 5.0 download at the following location:

http://java.sun.com/j2se/1.5.0/download.jsp

The download site includes release notes that list the bug fixes in the release. Each bug in the list is linked to the bug description in the bug database. The list of fixes in previous 5.0 update releases is also included in the release notes. If you encounter an issue, or suspect a bug, then you should, as an early step in the diagnosis, check the list of fixes that are available in the most recent update release. Sometimes it is not obvious if an issue is a duplicate of a bug that is already fixed, so where possible, you should test with the latest update release to see if the problem persists.

In addition to testing with the latest 5.0 update release, the following provides some very general guidelines on steps to follow before submitting a bug report :

1. Collect as much relevant data as possible. For example, generate a thread-dump in the case of a deadlock, or locate the core file (where applicable) and hs_err file in the case of a crash. In all cases it is important to document the environment and the actions performed just before the problem is encountered.
2. Where applicable, try to restore the original state and reproduce the problem using the documented steps. This helps to determine if the problem is reproducible or an intermittent issue.
3. If the issue is reproducible then try to narrow down the problem. In some cases, a bug can be demonstrated with a small standalone test case. Bugs demonstrated by small test cases will typically be easy to diagnose when compared to test cases that consists of a large complex application.
4. Search the bug database to see if the bug, or similar bugs, have been reported. If the bug has already been reported, the bug report may have further information. For example, if the bug has already been fixed it will indicate the release that the bug was fixed in. The bug may also contain information such as a workaround or include comments in the evaluation that explain, in further detail, the circumstances that cause the bug to arise. The bug database is at:
    - http://developer.java.sun.com/developer/bugParade/index.jshtml
5. If you conclude that the bug has not already been reported, then it is important to submit a new bug.

Before submitting a bug it is important to verify that the environment where the problem arises is a supported configuration. The set of supported systems configurations can be found here :

http://java.sun.com/j2se/1.5.0/system-configurations.html

In addition to the system configurations the list of supported locales should also be checked. The page with the list of supported locales is linked from the configuration page.

In the case of the Solaris Operating System you should check the recommended patch cluster for the operating system release to ensure the recommended patches are installed. The recommended patch list can be obtained at this site :

http://sunsolve.sun.com/pub-cgi/show.pl?target=patches/J2SE

3.1 Collecting Data for a Bug Report

In general it is recommended to collect as much relevant data as possible when creating a bug report or submitting a support call. This section suggests the data to collect and, where applicable, it provides guidance as to the commands or general procedure required to obtain the data.

The data that should be collected prior to submitting a bug report includes :

- Hardware details
- Operating system details
- J2SE version information
- Command line options
- Environment variables
- Fatal error log (in the case of a crash)
- Core/crash dump (in the case of a crash, and possibly a hang).
- Detailed description of the problem including test case (where possible)
- Logs or trace information (where applicable)
- Results from troubleshooting steps to date

Hardware

Sometimes a bug only arises, or can only be reproduced, on certain hardware configurations. If a fatal error occurs then the error log may contain the hardware details. If an error log is not available then it is important to document, in the bug report, the number and the type of processors in the machine, the clock speed, and where applicable some details on the features of that processor (if known). For example, it may be relevant that hyper-threading is available (in the case of Intel processors).

Operating System

On Solaris, the *showrev -a* command prints the operating system version and patch information.

On Linux, it is important to know which distribution and version is used. Sometimes the */etc/*release* file indicates the release information, but as components and packages can be upgraded independently, it is not always a reliable indication of the configuration. So, in addition to the information from the **release* file the following should be collected :

- The kernel version – This can be obtained using the *uname -a* command
- The glibc version – The *rpm -q glibc* command should indicate the patch level of glibc.
- The thread library – Linux has three possible thread types, namely linuxthreads (fixed stack), linuxthreads (floating stack) and NPTL. They are normally installed in /lib, /lib/i686 and/or /lib/tls.

On Windows, the Control Panel the *General* tab on the *System* applet indicates the operating system and service pack installed.

J2SE Version

The J2SE version string can be obtained using the ***java -version*** command. Following is sample output of this command:

```
java version "1.5.0-rc"
Java(TM) 2 Runtime Environment, Standard Edition (build 1.5.0-rc-b63)
Java HotSpot(TM) Server VM (build 1.5.0-rc-b63, mixed mode
```

As multiple versions of J2SE may be installed on the same machine, it's important to ensure that the appropriate version of the *java* command is used. To do this, make sure that the installation bin directory appears in your *PATH* before other installations.

Command Line Options

If the bug report does not include a fatal error log then it is important to document the full command line and options. This includes any options that specify heap settings (*-mx* option for example), or any -XX options to specify HotSpot specific options.

One of the features in J2SE 5.0 is garbage collector ergonomics. On *server-class* machines the *java* command launchs the HotSpot Server VM and parallel garbage collector. A machine is considered to be be a server machine if it has two processors and 2GB or more of memory.

To be sure of the command line options, the -XX:+PrintCommandLineFlags option may be useful. If this option is provided on the command line then it will print out all command line flags to the VM. The command line options can also be obtained for a running VM or core file using the *jmap* utility (see section 1.3).

Environment Variables

Sometimes problems arise due to environment variable settings. When creating the bug report you should indicate the values of the following java environment variables (if set) :

JAVA_HOME, JRE_HOME, JAVA_TOOL_OPTIONS, _JAVA_OPTIONS, CLASSPATH, JAVA_COMPILER, PATH, USERNAME

In addition to this list, there are operating system specific environment variables that should be collected.

On Solaris and Linux the values of the following environment variables should be collected :

LD_LIBRARY_PATH, LD_PRELOAD, SHELL, DISPLAY, HOSTTYPE, OSTYPE, ARCH, MACHTYPE

On Linux, the values of the *LD_ASSUME_KERNEL* and *_JAVA_SR_SIGNUM* environment variables should be examined.

On Windows, the values of the following environment variables should be collected :

*OS, PROCESSOR_IDENTIFIER, _ALT_JAVA_HOME_DI*R

Fatal Error Log

When a fatal error occurs an error log is created in the file *hs_err_pid<pid>.log* (where *<pid>* is the process id). The format of the error log is described in section 2.2.1.

Where possible the file is created in the working directory of the process. In the event that the file cannot be created in the working directory (insufficient space, permission problem, or other issue) then the file is created in the temporary directory for the operating system. On Solaris and Linux the temporary directory is */tmp*. On Windows, the temporary directory is specified by the value of the *TMP* environment variable, or if that is not defined, the value of the *TEMP* environment variable.

The error log contains a lot of information obtained at the time of the fatal error. Where possible it includes version and environment information, details on the threads that provoked the crash, etc.

If the fatal error log is generated then it should be included in the bug report or support call.

Core/Crash Dump

Core dumps can be very useful when trying to diagnose a crash or hung process. The procedure for generating a core/crash dump is described later in this chapter.

Description
When creating a problem description the general rule is to include as much relevant information as possible. Describe the application, the environment, and most importantly the events leading up to when the problem was encountered. In addition:

1. If the problem is reproducible then list the steps required to demonstrate the problem.
2. If the problem can be demonstrated with a small test case then include the test case and the commands to compile and execute the test case.
3. If the test case or problem requires third-party code (for example a commercial or open source library or package) then provide details on where/how to obtain the library.

If the problem can only be reproduced in a complex application environment then the description, coupled with logs, core file, and other relevant information may be the sole means to diagnose the issue. In these situations the description should indicate if the submitter is willing to run further diagnosis or run test binaries on the system where the issue arises.

Logs/Traces
Sometimes a problem can be determined quickly using log or trace output.

For example in the case of a performance issue it may be possible to diagnose the problem based on the output of the *-verbose:gc* option (the option to enable output from the garbage collector). In other cases the output from the *jstat* command (section 1.7) could be used to capture statistical information over the time period leading up to the problem. In the case of a deadlock or hung VM then the thread stacks (obtained using Ctrl-\ on Solaris and Linux, or Ctrl-Break on Windows) may be used to diagnose the deadlock (or loop).

In general, all relevant logs, traces and other output should be included in the bug report or support call.

Results from Troubleshooting Steps
It is often very useful to document any troubleshooting steps performed before submitting the bug report.

For example, if the problem is a crash and the application has native libraries then you may have already run the application with *-Xcheck:jni* to reduce the likelihood that the bug is in the native code. Another case might be of a crash that occurs with the HotSpot Server VM (*-server* option). If you have also tested with the HotSpot Client VM (*-client* option) and the problem does not occur then this gives an indication that the bug may be specific to the HotSpot Server VM.

In general the bug report should include all steps and results to date – this type of information can often reduce the time it takes to diagnose an issue.

3.2 Collecting Core Dumps

This section explains how to generate and collect core dumps (also known as *crash dumps*). A core dump or a crash dump is a memory snapshot of a running process. A core dump may be automatically created by the operating system when a fatal or unhandled error occurs (an unhandled signal or system exception for example). Alternatively, a core dump may also be forced by means of system provided command line utilities. Sometimes, a core dump is useful when diagnosing a process that appears to be hung; the core dump may reveal information as to what is causing the hang.

When collecting a core dump it is important to gather other information about the environment so that the core file can be analyzed (for example OS version, patch information, and the fatal error log).

Core dumps do not usually contain all the memory pages of the crashed or hung process. With each of the operating systems discussed here, the text (or code) pages of the process are not included in core dumps. But to be useful, a core dump should consist of pages of heap and stack at the least. Collecting non-truncated good core dump files is essential for postmortem analysis of the crash.

3.2.1 Collecting Core Dumps on Solaris

With the Solaris Operating System, unhandled signals such as a segmentation violation, illegal instruction, etc. result in a core dump. By default, the core dump is created in the current working directory of the process and the name of the core dump file is "core". The user can configure the location and name of the core dump using the core file administration utility, *coreadm*. This is fully described in the man page for the *coreadm* utility.

To configure core dump creation you need to check the code file size limit using *ulimit -c*. *ulimit* is the utility to set or get limitations on the system resources available to the current shell and its descendants. Make sure that the limit is set to *unlimited,* otherwise the core file may be truncated.

The *gcore* utility can be used to get a core image of running processes. This utility accepts a process id (pid) of the process to which we want to force core dump.

To get the list of Java processes running on the machine, we can use any of the following commands:

1. **ps -ef | grep java**
2. **pgrep java**
3. **jps** is a new command line utility in J2SE 5.0. jps does not work by name matching (looking for "java" in the process command name) and so it can list JVM embedding processes as well. See section 1.6.

ShowMessageBoxOnError

A Java process may also be started with the -XX:+ShowMessageBoxOnError command line option. When a fatal error is encountered, the process prints a message to standard error and waits for a yes/no response from standard input. Here is the example output for when an unexpected signal occurs :

```
Unexpected Error
SIGSEGV (0xb) at pc=0xfe610218, pid=13429, tid=1

Do you want to debug the problem?

To debug, run 'dbx - 13429'; then switch to thread 1
Enter 'yes' to launch dbx automatically (PATH must include dbx)
Otherwise, press RETURN to abort...
```

Before answering yes or pressing RETURN, one can use above mentioned *gcore* utility to force a core dump.

3.2.1.1 Suspending a Process using truss

In some situations it may not be possible to specify the -XX:+ShowMessageBoxOnError option. In such situations it may be possible to use the *truss* utility to suspend the process when it reaches a specifiic function or system call. *truss* is the Solaris utility to trace system calls and signals.

Following is an example of using *truss* to suspend a process when the *exit* system call is executed (in other words, the process is about to exit).

```
truss -t \!all -s \!all -T exit -p <pid>
```

When the process calls *exit* it will be suspended. At this point, the debugger can be attached to the process or *gcore* to force a core dump.

3.2.2 Collecting Core Dumps on Linux

On Linux, unhandled signals such as segmentation violation, illegal instruction, etc. result in a core dump. By default, the core dump is created in the current working directory of the process and the name of the core dump file is *core.<pid>* where pid is the process id of the crashed Java process.

On Linux, use the *ulimit -c* command to set the core file size limit. Make sure that it's set to *unlimited.* Note that this is a Bash shell built-in command. On C shell, you must use the *limit* command.

The gdb *gcore* command can be used to get a core image of a running process. This utility accepts the pid of the process for which you want to force the core dump.

The list of java processes can be obtained using any of the following commands:

1) **ps -ef | grep java**
2) **pgrep java**
3) **jps** is a new command line utility in J2SE 5.0. jps does not work by name matching (looking for "java" in the process command name) and so it can list JVM embedding processes as well.

ShowMessageBoxOnError

A java process may also be started with the -XX:+ShowMessageBoxOnError command line option. When a fatal error is encountered, the process prints a message to standard error and waits for a yes/no response from standard input. Here is the example output for when an unexpected signal occurs :

```
Unexpected Error
------------------------------------------------------------------------
SIGSEGV (0xb) at pc=0x40029604, pid=22099, tid=1024

Do you want to debug the problem?

To debug, run 'gdb /proc/22099/exe 22099'; then switch to thread 1024
Enter 'yes' to launch gdb automatically (PATH must include gdb)
Otherwise, press RETURN to abort...
```

Type "yes" to launch *gdb* as suggested by the error report shown above. In the gdb prompt, you can give the *gcore* command. This command creates a core dump of the debugged process with the name *core.<pid>* where pid is the process id of the crashed process. Note that the gdb gcore command is supported only in the latest versions of gdb. Look for "help gcore" in the gdb command prompt.

3.2.3 Reasons for Not Getting a Core File

Following is a list of the top 10 reasons why a core file may not be generated:

1. The current user does not have permission to write in the current working directory of the process.
2. The current user has write permission on the current working directory, but there is already a file named "core" that has read-only permission.
3. The current directory does not have enough space or there's no space left!
4. The current directory has a subdirectory named "core".
5. The current working directory is remote. It may be NFS (Network File System) mapped, and NFS

failed just at the time the core dump was about to be created – Murphy's law!

6. **Solaris only**: The *coreadm* tool has been used to configure the directory and name of the core file, but any of the above reasons apply for the configured directory or filename.
7. The core file size limit has been set to zero using the *limit* tool. Check your core file limit using the ulimit -c command. This should print "unlimited". The core dump file size has to be large enough. Otherwise, you will get truncated core dumps or no core dump if the core file limit is zero.
8. The process is running a *setuid* program and therefore the OS will not dump core unless configured explicitly.
9. **Java specific:** The process received SIGSEGV or SIGILL but no core dump! May be the process handled it! For example, HotSpot VM uses the SIGSEGV signal for legitimate purposes such as throwing NullPointerException, deoptimization etc. Not all SIGSEGVs are bad! Only if the current instruction (PC) falls outside JVM generated code, the signal is unhandled by the JVM. Only in such cases, HotSpot dumps core.
10. **Java specific:** The JNI Invocation API was used to create the VM. The standard Java launcher was not used. The custom Java launcher program handled the signal by just consuming it and produced the log entry silently. This has been seen with certain AppServers, WebServers. These JVM embedding programs transparently attempt to re-start (fail over) the system after abnormal termination. Not producing core is a feature and not a bug.

3.2.4 Collecting Crash Dumps on Windows

On Windows there are three types of crash dumps:

1. Dr Watson logfile – This is a text error log file that includes faulting stack trace and a few other details.
2. User minidump – This is a sort of "partial" coredump. It is not a complete core dump as it does not contain all the useful memory pages of the process.
3. Dr Watson full-dump – This is equivalent to Unix core dump. This contains most memory pages of the process (except for code pages).

When an unexpected exception occurs on Windows the action taken depends on two values in the following registry key :

```
\\HKEY_LOCAL_MACHINE\Software\Microsoft\Windows NT\CurrentVersion\AeDebug
```

The two values are named *Debugger* and *Auto*. The *Auto* value indicates if the debugger specified in the value of the *Debugger* entry starts automatically when an application error occurs :

Value	***Meaning***
0	The system displays a message box notifying the user when an application error occurs.
1	The debugger starts automatically.

The *Debugger* value is the deubgger command to use to debug program errors.

When a program error occurs, Windows examines the *Auto* value and if the value is 0 it executes the command in the *Debugger* value. If the value for the Debugger is a valid command, a message box is created with two buttons: **OK** and **Cancel**. If the user clicks **OK**, then the program is terminated. If the user clicks **Cancel**, the specified debugger is started. If the value for the Auto entry is set to one and the value for the Debugger entry specifies the command for a valid debugger, the system automatically starts the debugger and does not generate a message box.

3.2.4.1 Configuring Dr Watson

The Dr Watson debugger is used to create crash dump files. By default, Dr Watson debugger (**drwtsn32.exe)** is installed into the Windows system folder (*%SystemRoot%\System32*).

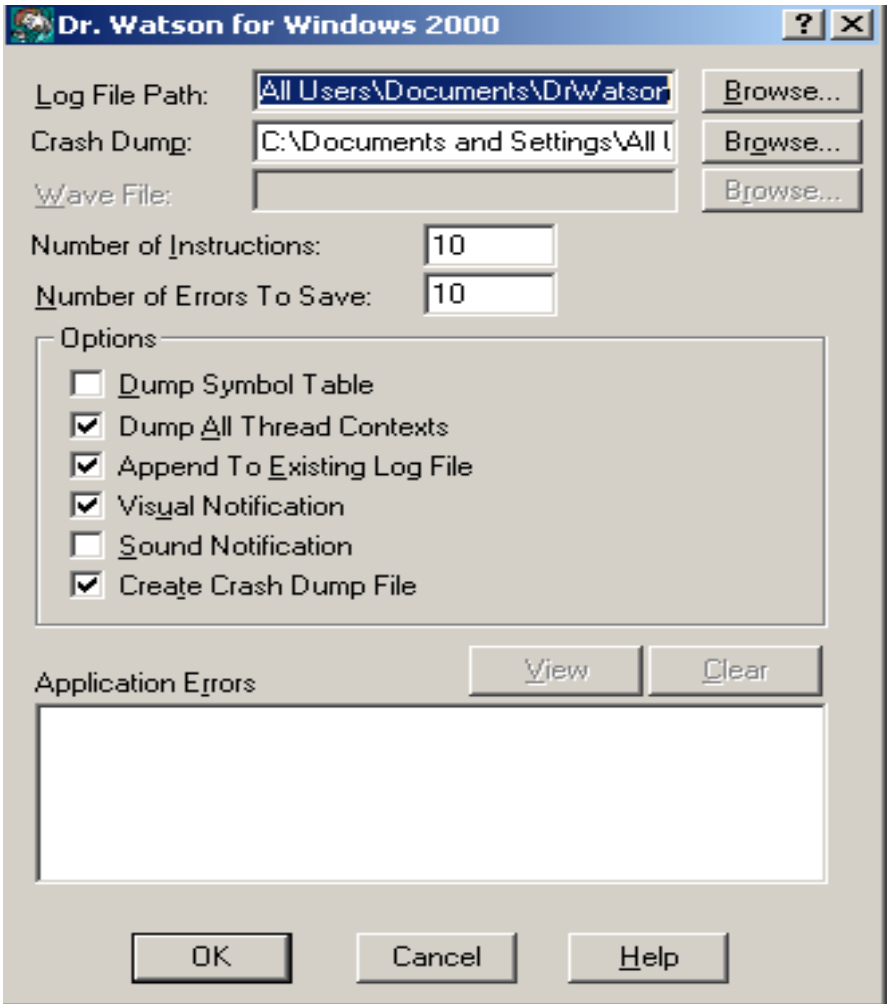
To install Dr Watson as the postmortem debugger, run the following command:

drwtsn32 -i

To configure name and location of crash dump files, run drwtsn32 without any options.

drwtsn32

In the Dr Watson GUI Window, you need to make sure that the "*Create Crash Dump File*" checkbox is set . Also the crash dump file path and log file path are configured in their respective text fields. See the following sample screen-shot:



Dr Watson may be configured to create a full dump using the registry. The registry key is:

System Key: [**HKEY_LOCAL_MACHINE\SOFTWARE\Microsoft\DrWatson**]
Entry Name: **CreateCrashDump**
Value: (0 = disabled, 1 = enabled)

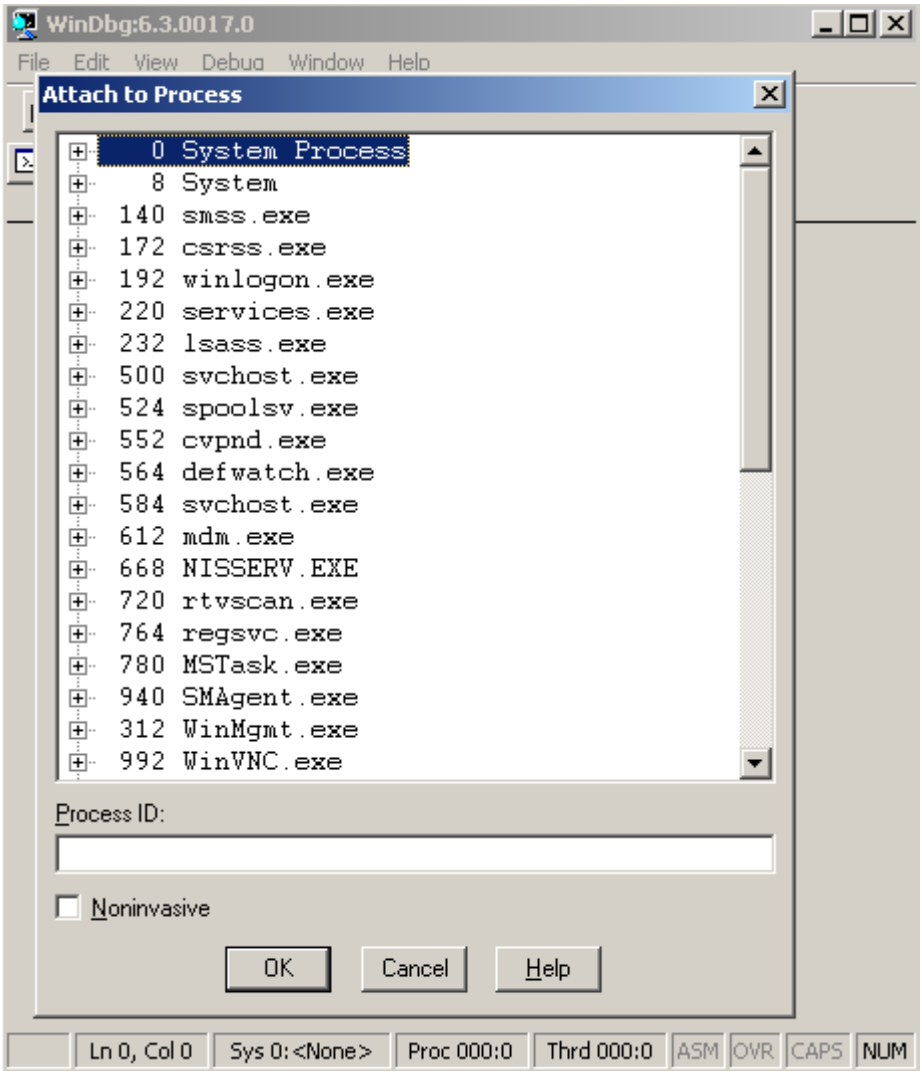
Note that if the application handles the exception, then the registry configured debugger is not invoked. In that case it may be appropriate to use the *-XX:+ShowMessageBoxOnError* command-line option to force process to wait for user intervention on fatal error conditions.

3.2.4.2 Forcing a Crash Dump

On Windows, the *userdump* command-line utility can be used to force Dr Watson dump of a running process. The *userdump* utility does not ship with Windows but instead is released as a component of the *OEM Support Tools* package. The documentation for userdump and the link to the download location can be found at:

http://support.microsoft.com/default.aspx?kbid=241215

An alternative way to force a crash dump is to use the *windbg* debugger. The main advantage of using *windbg* is that it can attach to process in a non-invasive manner (ie: read-only). Normally Windows terminates a process after a crash dump is obtained but with the non-invasive attach it is possible to obtain a crash dump and let the process continue. To attach non-invasively requires selecting the "*Attach to Process*" option and clicking the "*Noninvasive"* checkbox as shown in the following screen-shot:



Once attached, a crash dump can be obtained using the following command :

```
.dump /f crash.dmp
```

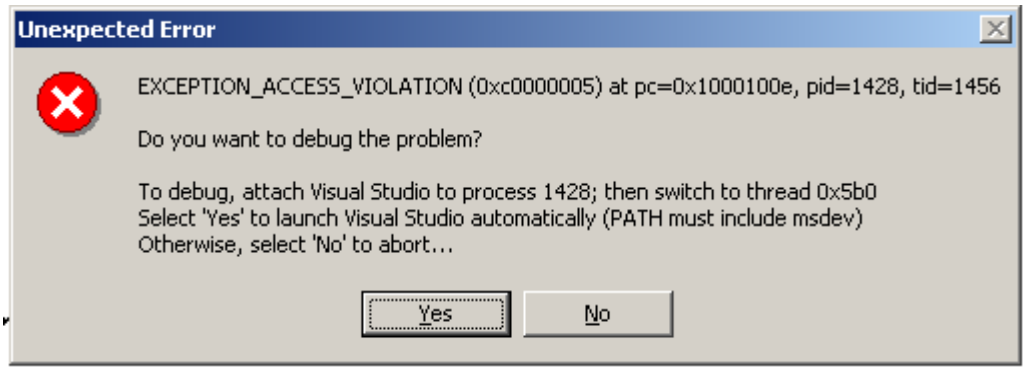
windbg is included in the "Debugging Tools for Windows" download which can be found at:

http://www.microsoft.com/whdc/ddk/debugging

One additional utility in this download worth noting is the *dumpchk.exe* utility. It can verify that a memory dump file has been created correctly.

Both *userdump.exe* and *windbg* require that you know the process id (pid) of the process. *userdump -p* lists the process and program for all processes. This is useful if you know that the application is started with the *java.exe* launcher. However if a custom launcher is used (embedded VM) then it may not be easy to recognize the process. In that case you can uee the the *jps* command line utility (see section 1.6) as it lists the pids of the java processes only.

As with Solaris and Linux, you can also use the *-XX:+ShowMessageBoxOnError* command line option on Windows. When a fatal error is encountered, the the process shows a message box and waits for a yes or no response from the user:



Before clicking on *Yes* or *No*, you can use *userdump.exe* utility to generate the Dr Watson dump for the Java process. The utility can also be used for the case where the process appears to be hung.