JVM Crash Dump Analysis

Andrei Pangin, OK.RU
Lead software engineer

Java vs. C

- `nullRef.callMethod();`
  - NullPointerException

  `nullRef->callMethod();`
  - Crash!
- `array[999999] = 42;`
  - ArrayIndexOutOfBoundsException

  `array[999999] = 42;`
  - Crash!
- `int y = x / 0;`
  - ArithmeticException

  `int y = x / 0;`
  - Crash!

Is Java bulletproof?

No-o-o-o!

```
#
# A fatal error has been detected by the Java Runtime Environment:
#
#  SIGSEGV (0xb) at pc=0x00002b47f02da0c3, pid=20644, tid=1096538432
#
# JRE version: 6.0_26-b03
# Java VM: Java HotSpot(TM) 64-Bit Server VM (20.1-b02 mixed mode linux-amd64)
# Problematic frame:
# V  [libjvm.so+0x8400c3]
#
# An error report file with more information is saved as:
# /one/bin/hs_err_pid20644.log
#
# If you would like to submit a bug report, please visit:
#   http://java.sun.com/webapps/bugreport/crash.jsp
#
```

Fatal errors

1. Problems in native code
2. Misuse of private API (e.g. sun.misc.Unsafe)
3. JVM bugs (saw them many times!)
4. Hardware issues (yes, we hit them, too!)

Want to crash JVM?

одноклассники

Header

```
#
# A fatal error has been detected by the Java Runtime Environment:
#
#  SIGFPE (0x8) at pc=0x00007f1c1197b585, pid=3898, tid=139758846732032
#
# JRE version: Java(TM) SE Runtime Environment (7.0_40-b43) (build 1.7.0_40-b43)
# Java VM: Java HotSpot(TM) 64-Bit Server VM (24.0-b56 mixed mode linux-amd64 compressed oops)
#
```

Signal code

Instruction address

Process ID

Thread ID

JRE & JVM build

Frame

```
# Problematic frame:
# C  [libdiv.so+0x585]  Java_demo1_NativeDiv_div+0x5
```

Instruction address with the nearest symbol

Frame type

C	Native C frame
V	VM function
v	VM generated stub
j	Interpreted Java frame
J	Compiled Java frame

Signal

```
siginfo:si_signo=SIGFPE: si_errno=0, si_code=1 (FPE_INTDIV), si_addr=0x00007f1c1197b585
```

Signal code

Linux	Windows
SIGSEGV	EXCEPTION_ACCESS_VIOLATION EXCEPTION_STACK_OVERFLOW
SIGBUS	EXCEPTION_ACCESS_VIOLATION EXCEPTION_DATATYPE_MISALIGNMENT
SIGILL	EXCEPTION_ILLEGAL_INSTRUCTION EXCEPTION_PRIV_INSTRUCTION
SIGFPE	EXCEPTION_INT_* EXCEPTION_FLT_*

Address of an instruction or a memory accessed

Signal reason

SEGV_MAPERR	Missing page
SEGV_ACCERR	Access violation
BUS_ADRALN	Unaligned address
BUS_ADRERR	Invalid address
ILL_ILLOPC	Illegal instruction
ILL_PRVOPC	Privileged instruction
FPE_INTDIV	Integer division by 0
FPE_FLTDIV	Floating point division by 0

CPU registers

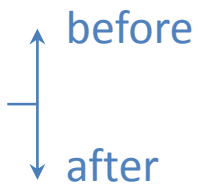
```
Registers:
RAX=0x00000000c5448e8f, RBX=0x00000000bd250ff0, RCX=0x0000000000000000, RDX=0x00000000ffffffff
RSP=0x00007f1c2469d798, RBP=0x00007f1c2469d7f0, RSI=0x00007f1c2469d800, RDI=0x00007f1c1c0099e8
R8 =0x0000c5448e8f8389, R9 =0x00000850b3941760, R10=0x00007f1c1901270c, R11=0x00007f1c234de260
R12=0x0000000000000000, R13=0x00000000bd250ff0, R14=0x00007f1c2469d818, R15=0x00007f1c1c009800
RIP=0x00007f1c1197b585, EFLAGS=0x0000000000010287, CSGSFS=0x0000000000000033
```

Stack contents

```
Top of Stack: (sp=0x00007f1c2469d798)
0x00007f1c2469d798:   00007f1c19012738 00000000bd1a53e8
0x00007f1c2469d7a8:   0000000000000000 00007f1c2469d7b0
0x00007f1c2469d7b8:   0000000000000000 00007f1c2469d818
0x00007f1c2469d7c8:   00000000bd251480 0000000000000000
0x00007f1c2469d7d8:   00000000bd250ff0 0000000000000000
0x00007f1c2469d7e8:   00007f1c2469d810 00007f1c2469d860
0x00007f1c2469d7f8:   00007f1c190061d4 00000000eb64ad68
0x00007f1c2469d808:   00007f1c1900ecd6 0000000000000000
```

Machine code

```
Instructions: (pc=0x00007f1c1197b585)
0x00007f1c1197b565:   48 85 c0 74 0e 5d 48 8d 3d c6 08 20 00 ff e0 0f
0x00007f1c1197b575:   1f 40 00 5d c3 90 90 90 90 90 90 89 d0 c1 fa 1f
0x00007f1c1197b585:   f7 f9 c3 90 90 90 90 90 90 90 90 55 48 89 e5 53
0x00007f1c1197b595:   48 83 ec 08 48 8b 05 78 08 20 00 48 83 f8 ff 74
```



- Disassembler
  - http://www.onlinedisassembler.com
- x86 architecture manual
  - http://www.intel.com/content/www/us/en/processors/architectures-software-developer-manuals.html

Disassembler

```
.data:0x00000018    90          nop
.data:0x00000019    90          nop
.data:0x0000001a    90          nop
.data:0x0000001b    89d0        mov     eax,edx
.data:0x0000001d    c1fa1f      sar     edx,0x1f
.data:0x00000020    f7f9        idiv    ecx
.data:0x00000022    c3          ret
.data:0x00000023    90          nop
.data:0x00000024    90          nop
.data:0x00000025    90          nop
.data:0x00000026    90          nop
.data:0x00000027    90          nop
```

Offset

Opcodes

Decoded instructions

Crash location

idiv r/m32

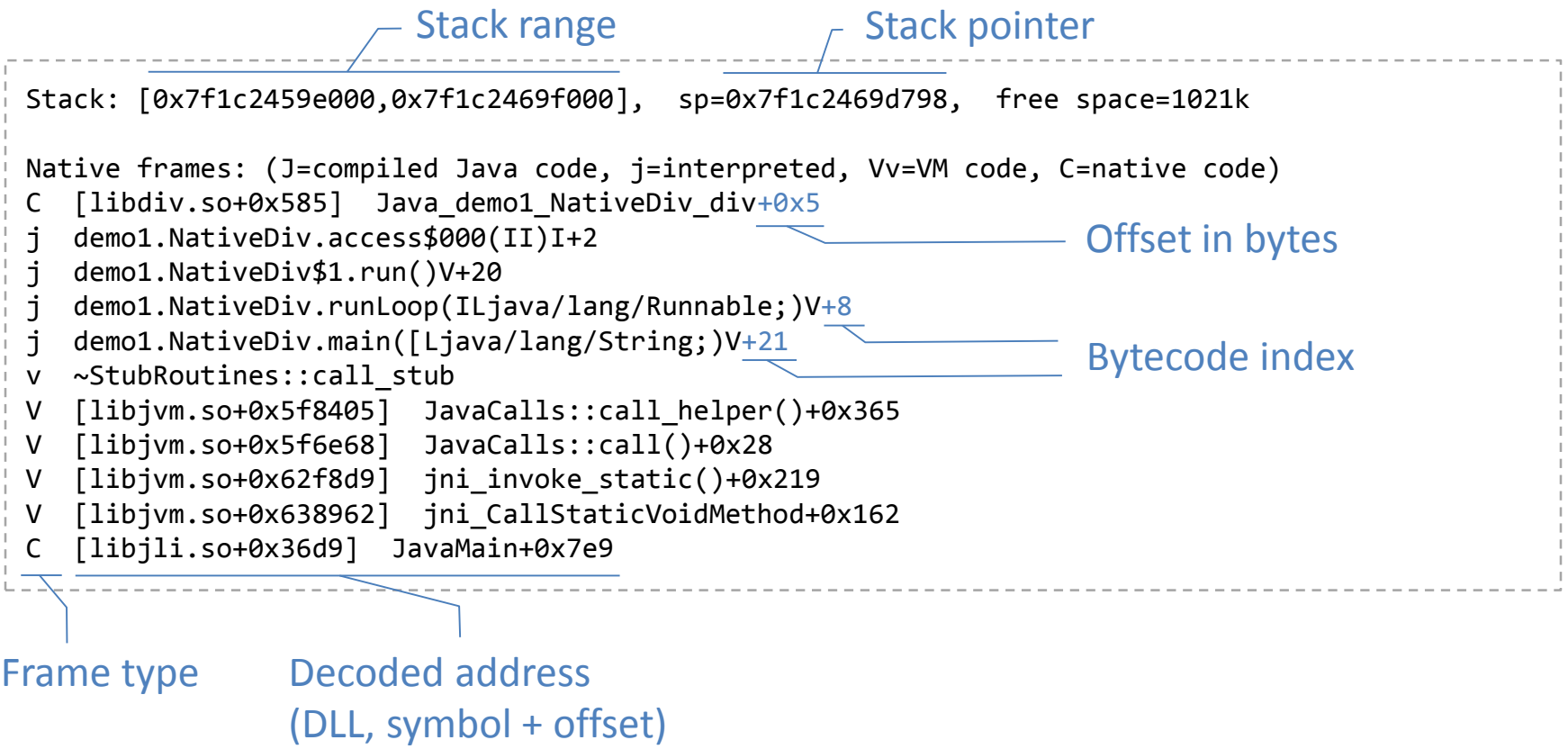
signed divide edx:eax by r/m32

Register values

```
Register to memory mapping:

RAX=0x00000000c5448e8f is an unallocated location in the heap
RBX=0x00000000bd250ff0 is an oop
{method}
 - klass: {other class}
RCX=0x0000000000000000 is an unknown value
RDX=0x00000000ffffffff is an unallocated location in the heap
RSP=0x00007f1c2469d798 is pointing into the stack for thread: 0x00007f1c1c009800
RBP=0x00007f1c2469d7f0 is pointing into the stack for thread: 0x00007f1c1c009800
RSI=0x00007f1c2469d800 is pointing into the stack for thread: 0x00007f1c1c009800
RDI=0x00007f1c1c0099e8 is an unknown value
R8 =0x0000c5448e8f8389 is an unknown value
R9 =0x00000850b3941760 is an unknown value
R10=0x00007f1c1901270c is at code_begin+620 in an Interpreter codelet
method entry point (kind = native)  [0x00007f1c190124a0, 0x00007f1c19012d00]  2144 bytes
R11=0x00007f1c234de260: <offset 0x8a7260> in libjvm.so at 0x00007f1c22c37000
R12=0x0000000000000000 is an unknown value
R13=0x00000000bd250ff0 is an oop
{method}
 - klass: {other class}
R14=0x00007f1c2469d818 is pointing into the stack for thread: 0x00007f1c1c009800
R15=0x00007f1c1c009800 is a thread
```

Stack


Stack range
Stack pointer
Stack: [0x7f1c2459e000,0x7f1c2469f000], sp=0x7f1c2469d798, free space=1021k
Native frames: (J=compiled Java code, j=interpreted, Vv=VM code, C=native code)
C [libdiv.so+0x585] Java_demo1_NativeDiv_div+0x5
j demo1.NativeDiv.access$000(II)I+2
j demo1.NativeDiv$1.run()V+20
j demo1.NativeDiv.runLoop(ILjava/lang/Runnable;)V+8
j demo1.NativeDiv.main([Ljava/lang/String;)V+21
v ~StubRoutines::call_stub
V [libjvm.so+0x5f8405] JavaCalls::call_helper()+0x365
V [libjvm.so+0x5f6e68] JavaCalls::call()+0x28
V [libjvm.so+0x62f8d9] jni_invoke_static()+0x219
V [libjvm.so+0x638962] jni_CallStaticVoidMethod+0x162
C [libjli.so+0x36d9] JavaMain+0x7e9
Offset in bytes
Bytecode index
Frame type
Decoded address
(DLL, symbol + offset)

Threads

```
Java Threads: ( => current thread )
  0x7f1c1c096000 JavaThread "Service Thread" daemon
                 [_thread_blocked, id=3910, stack(0x7f1c11c7e000,0x7f1c11d7f000)]
  0x7f1c1c093800 JavaThread "C2 CompilerThread1" daemon
                 [_thread_blocked, id=3909, stack(0x7f1c11d7f000,0x7f1c11e80000)]
  0x7f1c1c090800 JavaThread "C2 CompilerThread0" daemon
                 [_thread_blocked, id=3908, stack(0x7f1c18014000,0x7f1c18115000)]
  0x7f1c1c08e800 JavaThread "Signal Dispatcher" daemon
                 [_thread_blocked, id=3907, stack(0x7f1c18115000,0x7f1c18216000)]
  0x7f1c1c06f800 JavaThread "Finalizer" daemon
                 [_thread_blocked, id=3906, stack(0x7f1c188f9000,0x7f1c189fa000)]
  0x7f1c1c06b800 JavaThread "Reference Handler" daemon
                 [_thread_blocked, id=3905, stack(0x7f1c189fa000,0x7f1c18afb000)]
=>0x7f1c1c009800 JavaThread "main"
                 [_thread_in_native, id=3899, stack(0x7f1c2459e000,0x7f1c2469f000)]
```

Thread* pointer

State

in_java
in_native
in_vm
blocked
trans

Thread ID

Name and type

Stack bounds

Heap

```
Heap
 PSYoungGen      total 18944K, used 327K [0x0eb600000, 0x0ecb00000, 0x100000000)
  eden space 16384K, 2% used [0x0eb600000,0x0eb651f28,0x0ec600000)
  from space 2560K, 0% used [0x0ec880000,0x0ec880000,0x0ecb00000)
  to   space 2560K, 0% used [0x0ec600000,0x0ec600000,0x0ec880000)
 ParOldGen       total 41984K, used 0K [0x0c2200000, 0x0c4b00000, 0x0eb600000)
  object space 41984K, 0% used [0x0c2200000,0x0c2200000,0x0c4b00000)
 PSPermGen       total 21504K, used 2378K [0x0bd000000, 0x0be500000, 0x0c2200000)
  object space 21504K, 11% used [0x0bd000000,0x0bd2529f0,0x0be500000)
```

Current bounds

Limit

Code Cache

```
Code Cache  [0x2aaaab977000, 0x2aaaabbe7000, 0x2aaaae977000)
 total_blobs=701 nmethods=360 adapters=295 free_code_cache=48574272 largest_free_block=20224
```

nmethods + adapters + stubs

Number of compiled methods

Free memory

Compilation events

```
Compilation events (10 events):
Event: 0.135 Thread 0x7fb4090800    5     java.util.Random::nextInt (7 bytes)
Event: 0.136 Thread 0x7fb4093800    6     demo1.NativeDiv$1::run (28 bytes)
Event: 0.140 Thread 0x7fb4090800 nmethod 5 0x7fb1060090 code [0x7fb10601e0, 0x7fb10602d8]
Event: 0.140 Thread 0x7fb4090800    7     java.util.Random::nextInt (60 bytes)
Event: 0.144 Thread 0x7fb4090800 nmethod 7 0x7fb105fb50 code [0x7fb105fca0, 0x7fb105fe98]
Event: 0.144 Thread 0x7fb4090800    8     demo1.NativeDiv::access$000 (6 bytes)
Event: 0.145 Thread 0x7fb4090800 nmethod 8 0x7fb1062290 code [0x7fb10623e0, 0x7fb1062448]
Event: 0.145 Thread 0x7fb4093800 nmethod 6 0x7fb105f510 code [0x7fb105f680, 0x7fb105f888]
Event: 0.146 Thread 0x7fb4090800   10 %     demo1.NativeDiv::runLoop @ 2 (20 bytes)
Event: 0.150 Thread 0x7fb4090800 nmethod 10% 0x7fb10649d0 code [0x7fb1064b40, 0x7fb1064ec8]
```

Begin

End

On-stack replacement

Compiled code bounds

Other events

```
GC Heap History (10 events):

Deoptimization events (10 events):

Internal exceptions (10 events):

Events (10 events):
Event: 0.113 loading class 0x7f03b86cb520
Event: 0.114 loading class 0x7f03b86cb520 done
Event: 0.114 loading class 0x7f03b869aa50
Event: 0.114 loading class 0x7f03b869aa50 done
Event: 0.115 loading class 0x7f03b8682cd0
Event: 0.115 loading class 0x7f03b8682cd0 done
Event: 0.115 loading class 0x7f03b8682c70
Event: 0.115 loading class 0x7f03b8682c70 done
Event: 0.119 loading class 0x7f03b40a6c70
Event: 0.119 loading class 0x7f03b40a6c70 done
```

Memory map

```
Dynamic libraries:
00400000-00401000 r-xp 00000000 08:03 156103           /usr/java/jdk1.7.0_40/bin/java
00600000-00601000 rw-p 00000000 08:03 156103           /usr/java/jdk1.7.0_40/bin/java
00bc6000-00be7000 rw-p 00000000 00:00 0                [heap]
7f1bdc000000-7f1bdc021000 rw-p 00000000 00:00 0
7f1bdc021000-7f1be0000000 ---p 00000000 00:00 0
7f1c1197b000-7f1c1197c000 r-xp 00000000 00:15 287      /media/crash/lib/libdiv.so
7f1c11b7c000-7f1c11b7d000 rw-p 00001000 00:15 287      /media/crash/lib/libdiv.so
7f1c11b7e000-7f1c11c7e000 rw-p 00000000 00:00 0        [stack:3911]
7f1c11c81000-7f1c11d7f000 rw-p 00000000 00:00 0        [stack:3910]
7f1c14000000-7f1c14021000 rw-p 00000000 00:00 0
7f1c14021000-7f1c18000000 ---p 00000000 00:00 0
7f1c20c45000-7f1c20e02000 r--s 039d3000 08:03 156934   /usr/java/jdk1.7.0_40/jre/lib/rt.jar
7f1c24494000-7f1c244b6000 r-xp 00000000 08:03 265734   /lib/x86_64-linux-gnu/ld-2.15.so
7f1c246b7000-7f1c246b9000 rw-p 00023000 08:03 265734   /lib/x86_64-linux-gnu/ld-2.15.so
```

Memory region

Access rights

- read
- write
- execute
- private
- shared

Offset

Device ID (/dev/hda3)

inode

Mapped file

Environment

```
VM Arguments:
jvm_args: -Djava.library.path=/media/crash/lib
java_command: demo1.NativeDiv
Launcher Type: SUN_STANDARD

Environment Variables:
PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/java/jdk1.7.0_40/bin
USERNAME=root
SHELL=/bin/bash
DISPLAY=:0
```

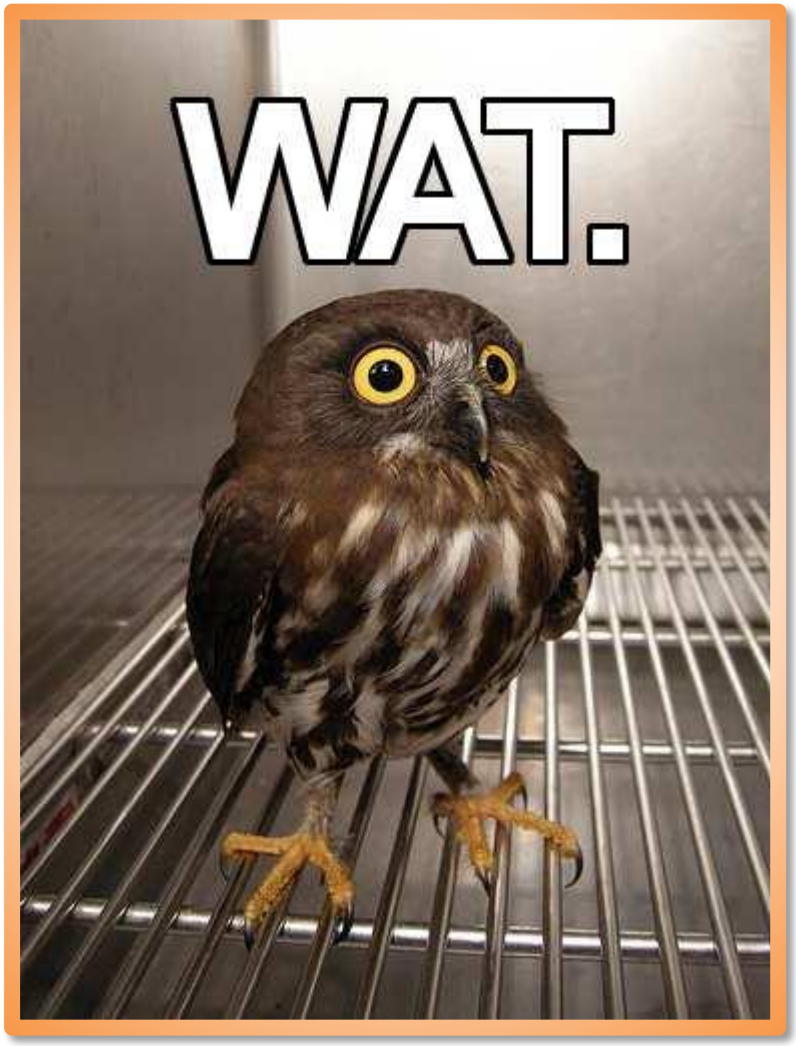
Memory

```
/proc/meminfo:
MemTotal:        4048960 kB
MemFree:         2783932 kB
Buffers:          136360 kB
Cached:           437332 kB
SwapCached:            0 kB
Active:           500384 kB
Inactive:         405308 kB
Unevictable:           0 kB
Mlocked:               0 kB
SwapTotal:       1500156 kB
SwapFree:        1500156 kB
Dirty:               252 kB
Writeback:             0 kB
AnonPages:        332152 kB
Mapped:            89372 kB
Shmem:              4920 kB
Slab:             289216 kB
SReclaimable:     269068 kB
SUnreclaim:        20148 kB
```

CPU

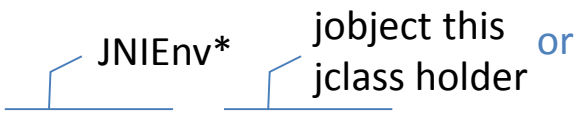
```
CPU:total 4 (4 cores per cpu, 1 threads per core) family 6 model 58 stepping 9, cmov, cx8,
fxsr, mmx, sse, sse2, sse3, ssse3, tsc

/proc/cpuinfo:
processor               : 0
vendor_id               : GenuineIntel
cpu family              : 6
model                   : 58
model name              : Intel(R) Core(TM) i7-3517U CPU @ 1.90GHz
stepping                : 9
cpu MHz                 : 2369.955
cache size              : 6144 KB
physical id             : 0
siblings                : 4
core id                 : 0
cpu cores               : 4
fpu                     : yes
fpu_exception           : yes
cpuid level             : 5
wp                      : yes
flags                   : fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36
clflush mmx fxsr sse sse2 ht syscall nx rdtscp lm constant_tsc rep_good nopl pni ssse3 lahf_lm
```


WAT.

x86-64 calling convention

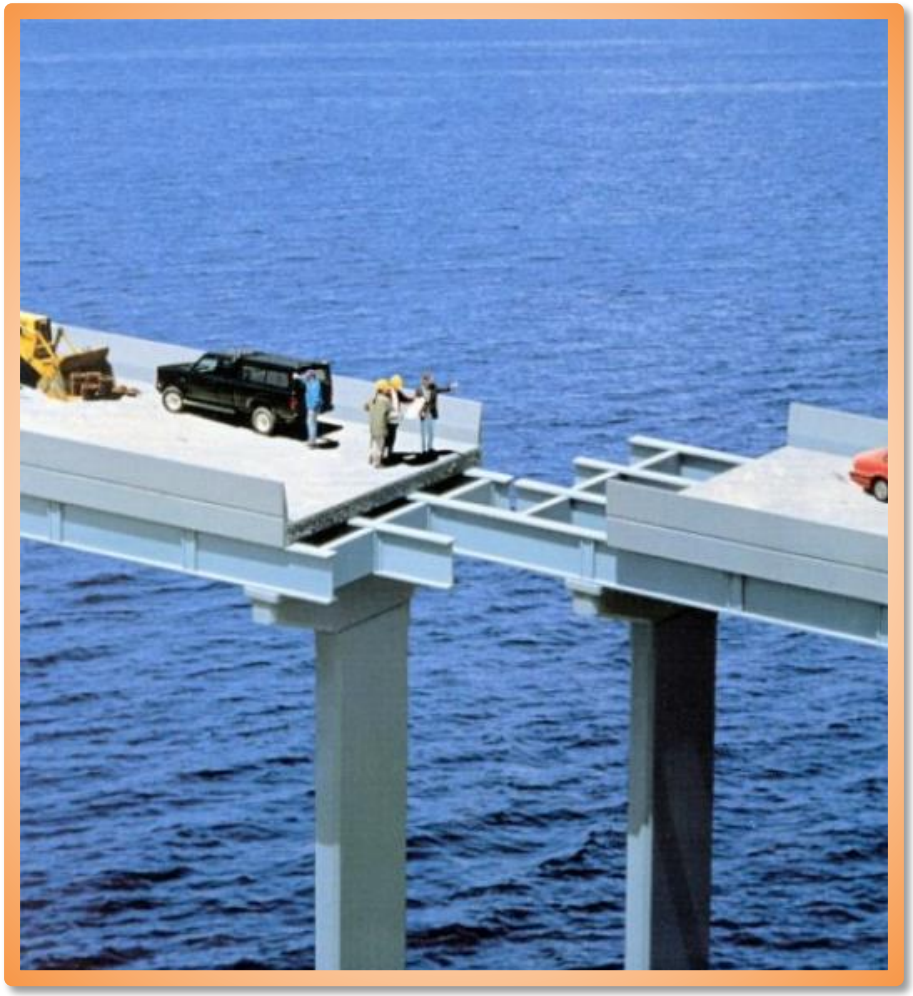
- http://hg.openjdk.java.net/jdk7/jdk7/hotspot/file/tip/src/cpu/x86/vm/assembler_x86.hpp



C args	c0	c1	c2	c3	c4	c5
Windows	RCX	RDX	R8	R9	RDI*	RSI*
Linux	RDI	RSI	RDX	RCX	R8	R9
Java args	**j5**	**j0**	**j1**	**j2**	**j3**	**j4**

* Java only

Nobody’s perfect



Debugging compiled code

- -Xint
- -XX:+PrintCompilation
- -XX:+UnlockDiagnosticVMOptions -XX:+PrintAssembly

- -XX:CompileCommandFile=.hotspot_compiler

```
compileonly demo4/*.*
exclude demo4/TextSearch.main
print demo4/BoyerMooreTextSearchStrategy.indexOf
```

Configure error report

- -XX:ErrorFile=./hs_err_pid%p.log
- -XX:OnError="cat hs_err_pid%p.log | mail my@email.com"
- -XX:+ShowMessageBoxOnError

- -XX:+CreateMinidumpOnCrash (Windows only)
- -XX:+UseOSErrorReporting
- -XX:+SuppressFatalErrorMessage

Thank you!

- Contact
  - andrey.pangin@corp.mail.ru
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