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DIY Java Profiling

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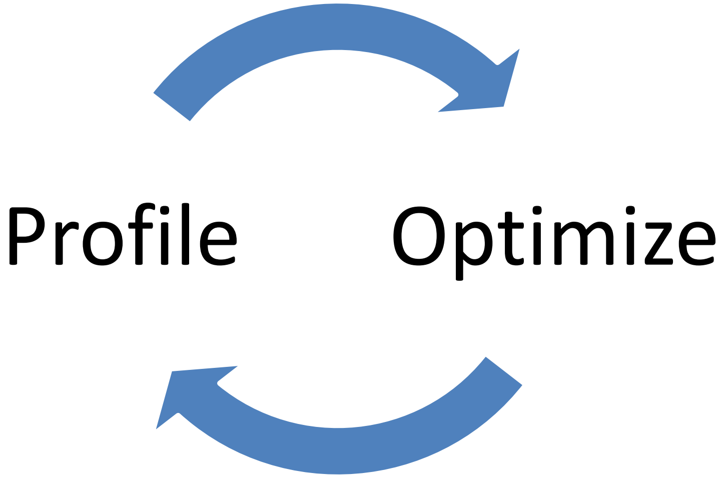
Profiling

“**Profiling** … is the investigation of a program's behavior using information gathered as the program executes. The usual purpose of this analysis is to determine which sections of a program to **optimize** - to increase its overall *speed*, decrease its *memory requirement* or sometimes both.”

-- Wikipedia



Profile Optimize

Why Do-It-Yourself?

What are the problems with tools?

- When you cannot run 3rd party code in production/live environment
  - Reliability concerns
  - Compliance concerns

Yes, we work for financial industry

- Tools are often opaque (even if open source)
  - In their performance effect
  - In their means of operation
- *Tools have their learning curve*
  - While DIY is Fun!

Learning curve?

Learning a tool:

- Pays off if you use it often
- Pays off if it gets you results faster/better
  - It is good to know modern tools to avoid NIH syndrome

DIY for knowledge reuse:

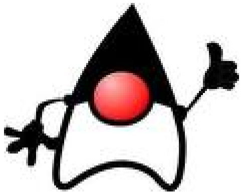
- Apply your existing knowledge
- Expand and deepen your existing knowledge
  - Know your day-to-day tools (like Java VM) better

Why Java?

Top language since 2001 (TIOBE)

Great for enterprise applications

- Write front & back in the same language
  - share code and libraries between them
- Run everywhere
  - Windows, Mac OS (typical for front)
  - Linux, Solaris (typical for back)



Managed language – makes it easy to profile

Agenda: Java DIY Approaches

Just code it in Java

- Standard Java classes are your friends

Know your JVM features

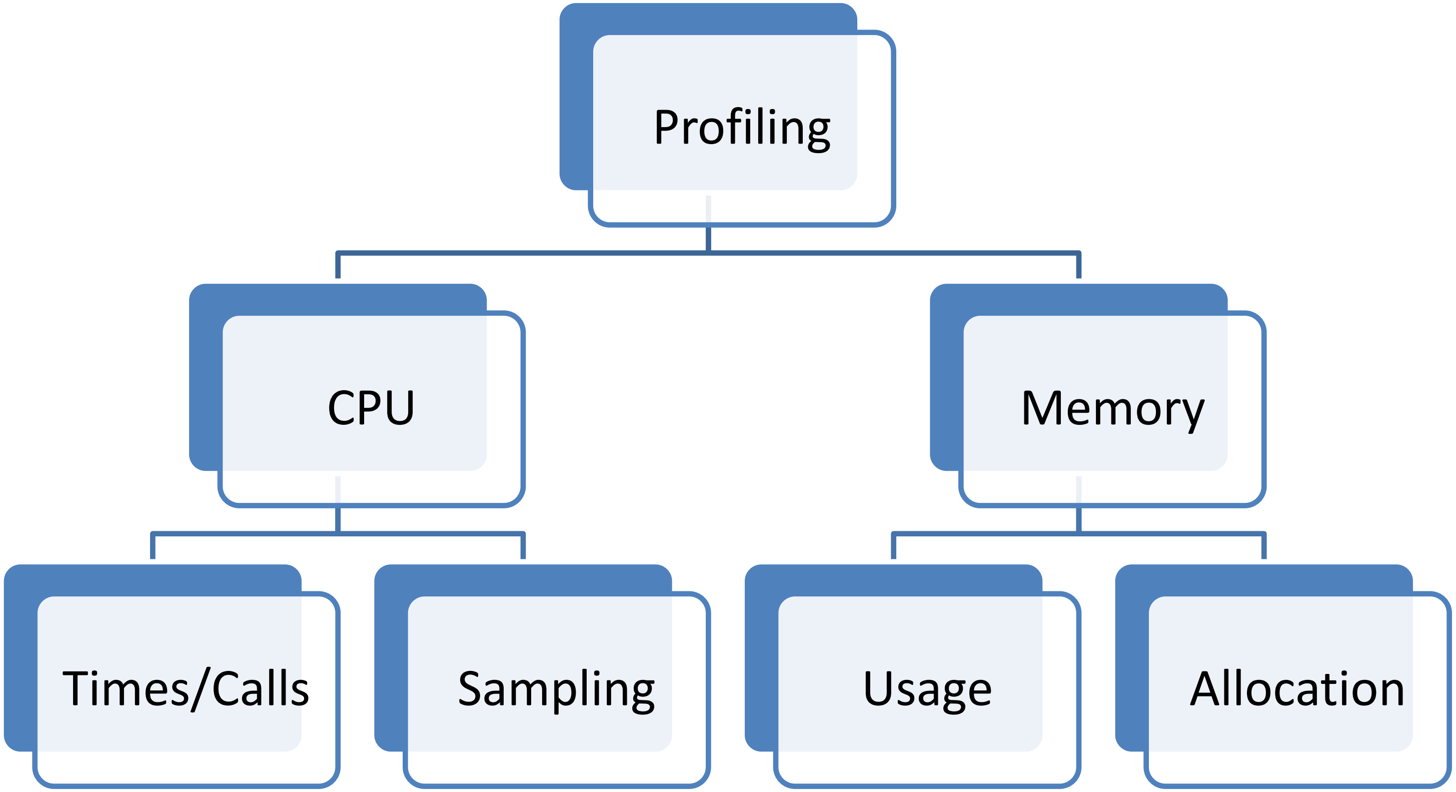
- -X… and -XX:… JVM options are your friends

Use bytecode manipulation

- Java Virtual Machine specification is your friend

The knowledge of all the above gets you more that just profiling!

Agenda: Profiling types



CPU profiling: Wall clock time/Calls

Straight in code

```
Account getAccount(AccountKey key) {
    long startTime = System.currentTimeMillis();
    checkAccountPermission(key);
    Account account = AccountCache.lookupAccount(key);
    if (account != null) {
        Profiler.record(“getAccount.cached”,
            System.currentTimeMillis() - startTime);
        return account;
    }
    account = AccountDAO.loadAccount(key);
    AccountCache.putAccount(account);
    Profiler.record(“getAccount.loaded”,
        System.currentTimeMillis() - startTime);
    return account;
}
```

Goes to DB, slow

CPU profiling: Wall clock time/Calls

Profiler class implementation can be as simple as concurrent map

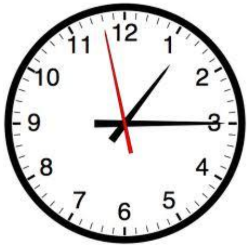
- Maps string keys to any stats you want
  - Total number of calls, total time, max time
  - Easy to compute avg time
  - Can store histograms and compute percentiles
- Periodically dump stats to console/logs
- Report stats via JMX, HTTP, or <insert approach that you use in your project>

CPU profiling: Wall clock time/Calls

When to use

- Relatively “big” business methods
  - Where number of invocations per second are under 1000s and time per invocation is measured in ms.
- If you need to know the number of calls and the actual (wall clock) time spent in the method
- If you need to trace different execution paths
- If you need to integrate profiling into your code as “always on” feature

Shorter/faster methods?



CPU Profiling: Short/Fast Calls

```
static final AtomicLong lookupAccountCalls =
    new AtomicLong();

Account lookupAccount(AccoutKey key) {
    lookupAccountCalls.incrementAndGet();
    return accountByKey.get(key);
}
```

Just count

Way under 1ms

CPU Profiling: Short/Fast Calls

When to use

- If number of calls is in the order of 10k per second
- If you don’t need to measure time spent
  - Counting distorts time for very short methods
  - Attempt to measure time distorts it even more
  - To *really* measure time go native with **rdtsc** on x86

Solution for 100k+ calls per second?

- Sampling!

CPU Profiling: Sampling

JVM has ability to produce “thread dump”

- Press Ctrl+Break in Windows console
- “kill -3 <pid>” on Linux/Solaris

If program spends most of its time on one line:

```
double[][] multiply(double[][] a, double [][] b) {
    int n = a.length, r = a[0].length, m = b[0].length;
    double[][] c = new double[n][m];
    for (int i = 0; i < n; i++)
        for (int j = 0; j < m; j++)
            for (int k = 0; k < r; k++)
                c[i][j] += a[i][k] * b[k][j];
    return c;
}
```

Hotspot

CPU Profiling: Sampling

You get something like this on the console:

```
Full thread dump Java … <JVM version info>

<other threads here>

"main" prio=6 tid=0x006e9c00 nid=0x18d8 runnable
   java.lang.Thread.State: RUNNABLE
        at YourClass.multiply(YouClass.java:<lineno>)
        at <the context of the call> …
```

CPU Profiling: Sampling

Hotspot – is where the most of CPU is spent

Next time you need to find hotspot

- Don’t reach for profiling tools
- Just try a single thread dump first
- Multiple thread dumps will help you verify it

You can use “jstack <pid>”

- Gets more detailed info about native methods with “-m” option on Solaris

CPU Profiling: More thread dumps

More ideas

- Redirect output to a file
- Use a script to do “kill -3” every 3 seconds
  - Minimal impact on system stability (TD is well tested)
- Write a simple code to parse resulting file
  - Count a number of occurrences of certain methods
  - Analyze traces to get better data than any 3rd party tool
    - – Figure what methods block going to DB or Network
    - – Figure what methods block synchronizations
    - – Figure out what *you* need to know

CPU Profiling: Integration

You can get “thread dump” programmatically:

- See Thread.getAllStackTraces
  - Or Thread.getStackTrace
    - If you’re interested in a particular one, like Swing EDT
- Great and lean way to integrate “always on” profiling into end-user Java application or server

CPU Profiling: Caveats

Thread dumps stop JVM at “safe point”

- You get a point of the nearest safepoint
- Not necessarily the hotspot itself

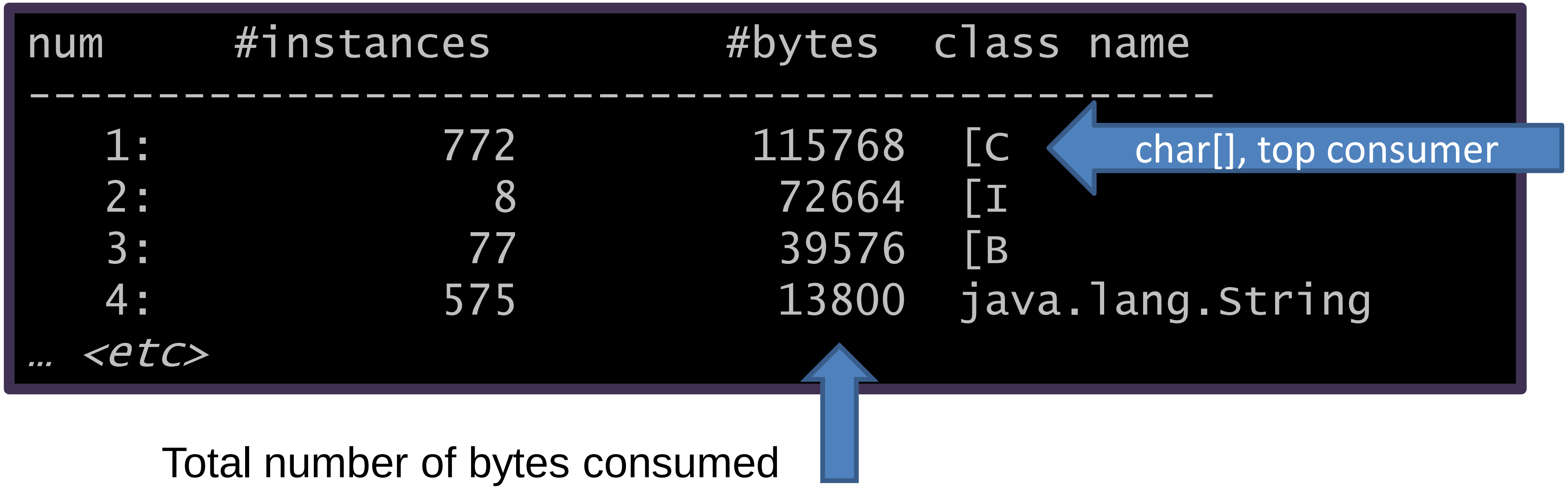
The work-around: Native Profiling

- Works via undocumented “async threadump”
- Hard to get from inside of Java (need native code)
  - That’s where you’d rather use tool like Intel VTune, AMD CodeAnalyst, Oracle Solaris Studio Performance Analyzer

Memory usage profiling

Use “jmap –histo <pid>”

- Use “jps” to find pids of your java processes
- You get something like this:



```
num     #instances         #bytes  class name
----------------------------------------------
   1:          772         115768  [C
   2:            8          72664  [I
   3:           77          39576  [B
   4:          575          13800  java.lang.String
… <etc>
```

char[], top consumer

Total number of bytes consumed

Memory usage profiling caveats

You get *all* objects in heap

- Including garbage
  - Can make a big difference
- Use “jmap -histo:live <pid>”
  - Will do GC before collecting histogram
    - Slow, the process will be suspended
  - Will work only on live process (as GC needs safepoint)

You don’t know where allocation was made

- On fast & DIY solution to this problem later

More useful JVM options

-XX:+PrintClassHistogram

- on Ctrl-Break or “kill -3” gets “jmap -histo”

-XX:+HeapDumpOnOutOfMemoryError

- Produces dump in hprof format
- You can use tools offline on the resulting file
- No need to integrate 3rd party tools into live JVM
  - But still get many of the benefits of modern tools
- Other ways to get HeapDump:
  - Use “jmap –dump:<options> <pid>”
  - Use HotSpotDiagnostic MBean
    - Right from Java via JMX

Memory allocation profiling

You will not see “new MyClass” as a hotspot

- But it will eat your CPU time
- Because time will be spent collecting garbage

Figure out how much you spend in GC

- Use the following options
  - -verbose:gc or -XX:+PrintGC or -XX:+PrintGCDetails
  - -XX:+PrintGCTimeStamps
- Worry if you spend a lot

Memory allocation profiling

Use “-Xaprof” option in your JVM

- Prints something like this *on process termination*:

```
Allocation profile (sizes in bytes, cutoff = 0 bytes):

___________Size__Instances__Average__Class__________________
      555807584   34737974       16  java.lang.Integer
         321112       5844       55  [I
         106104        644      165  [C
          37144         63      590  [B
          13744        325       42  [Ljava.lang.Object;
… <the rest>
```

Top alloc’d

Memory allocation profile

But where is it allocated?

- If you have a clue – just add counting via AtomicLong in the suspect places
- If you don’t have a clue… just add it everywhere
  - Using aspect-oriented programming
  - Using bytecode manipulation

More DIY style

Bytecode manipulation

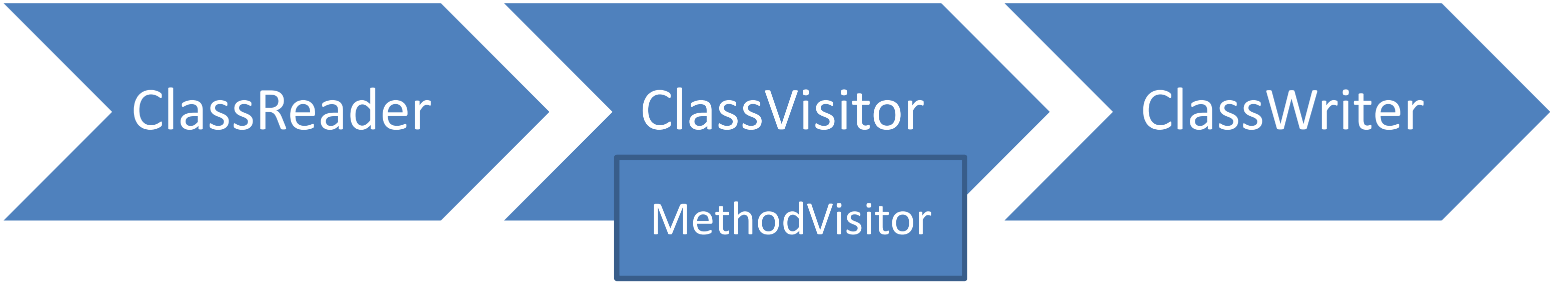
Change bytecode instead of source code for all your profiling needs

- Counting, time measuring
- Decouples profiling from code logic
  - Great if you don’t need it always on
- Can do it ahead-of-time and on-the-fly
- Great for tasks like “profile each place of code where ***new XXX*** is invoked”

Bytecode manipulation

ObjectWeb ASM is an open source lib to help

- Easy to use for bytecode manipulation
- Extremely fast (suited to on-the-fly manipulation)



Bytecode manipulation with ASM

```
class AClassVisitor extends ClassAdapter {
    public MethodVisitor visitMethod(…) {
        return new AMethodVisitor(super.visitMethod(…))
    }
}

class AMethodVisitor extends MethodAdapter {
    public void visitIntInsn(int opcode, int operand) {
        super.visitIntInsn(opcode, operand);
        if (opcode == NEWARRAY) {
            // add new instructions here into this
            // point of class file… Will even preserve
            // original source code line numbers
        }
    }
}
```

To trace each array allocation

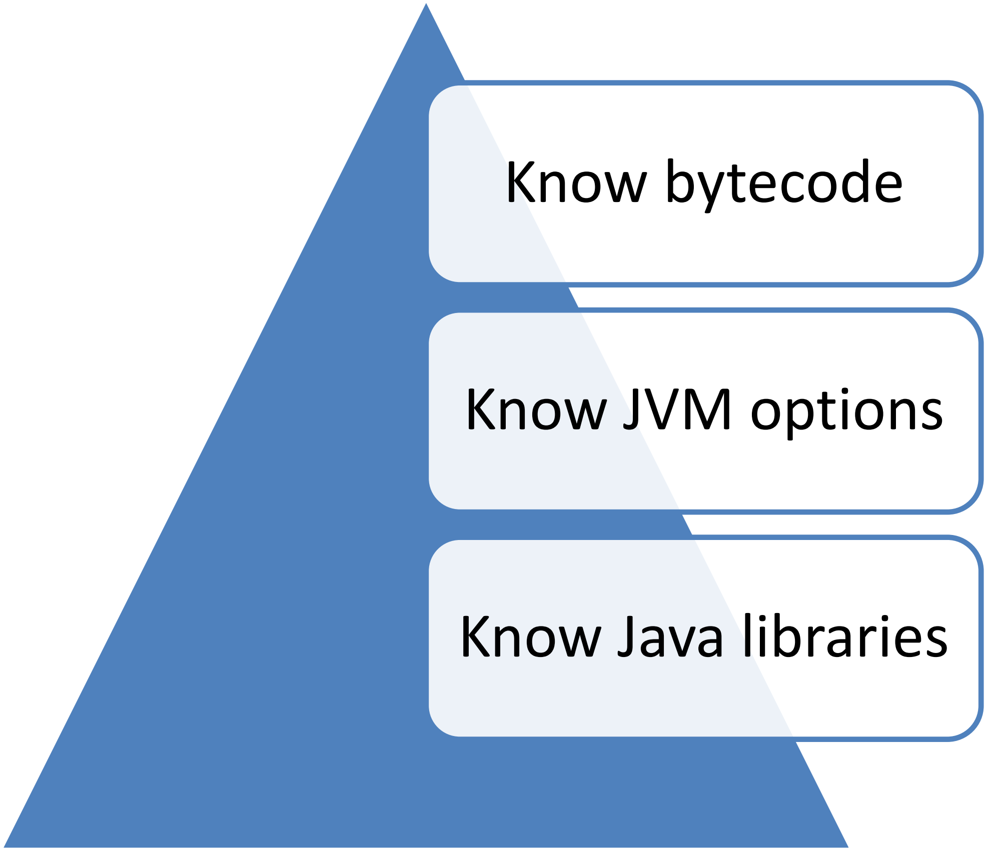
On-the-fly bytecode manipulation

Use java.lang.instrument package

Use “-javaagent:<jarfile>” JVM option

- Will run “premain” method in “Premain-Class” from jar file’s manifest
- Will provide an instance of Instrumentation
  - It lets you install system-wide ClassFileTransformer
    - That transforms even system classes!
  - It has other useful methods like getObjectSize

Conclusion



Know bytecode

Know JVM options

Know Java libraries

Questions?