Performance

History
5 years
Speed
Memory Use
Future?

Currently
Server side -- yes
Client side applets -- not really
Client side applications -- not really
Toasters -- not at all

Sun Wish
Server Side
Client applications
Toasters

Problems
Memory and Speed problems
Distribution -- the "mom" test
Better tools
Better programming culture about usability
Cooperate with JVM vendors better to reduce incompatibility

Double Clickable Jar
This is almost possible today -- java -jar foo.jar
Compile-Time

.java -> .class compiler
Compiles down to standard "bytecode" format in a .class file
class file
Encodes all sorts of info: class names, method names, ivar names and types
Much more info than in C/C++. You can use the "Reflection" language features to access this info at run-time from your code.

bytecode
optimized to be: compact, portable/unambiguous

bytecode = description
describes a computation -- like PDF describes an image
not necessarily optimized for speed/running. Maybe it's more important that it just do a good job of description, and we'll improve the VM implementation strategies to take care of performance over time.

Evolve or Die

Design does not evolve (Inertia)
(As above) the fundamental constraints of say, the .class format (Java) or .o (C/C++), are hard to evolve.
Software inertia makes change hard.

Implementation Speed -- improve over time
With the fundamentally right design, you can evolve and improve the implementation for better performance over time -- just write better and better JIT technology over time.

Steve Jobs Idea
Software develops slower than its hardware
MacOS vs PowerPC
DOS/Windows vs. x86
End up with old, legacy software holding back quickly evolving hardware
Therefore: make the software very ambitious at the start compared to the current state of hardware
Your software decisions will introduce lots of inertia -- be ambitious enough that the software system will be great even a few years out.
Java Performance

JITs
Just In Time compiler
Translate the bytecode into native code -- do a hasty, low quality job of it.
   Big improvement, but uses lots of memory

HotSpot
Watch the code, and figure out what to optimized.
Compile a small amount of the code aggressively.
Do lots of inlining -- enables all sorts of other optimizations

"Plumbing Effect" -- libraries
Much CPU time is spent in library activity such as new, JPEG decompress, file read...
Those libraries may be implemented natively
The Java is left as the plumbing that wire sthings together, so its speed is less important

Future
Cache the compiled version
bytecode is just for distribution, remote RMI, etc.

Optimization Quotes

   Rules of Optimization:
   Rule 1: Don’t do it.
   Rule 2 (for experts only): Don’t do it yet.
   - M.A. Jackson

   "More computing sins are committed in the name of efficiency (without necessarily achieving it) than for any other single reason - including blind stupidity." - W.A. Wulf

   "We should forget about small efficiencies, say about 97% of the time: premature optimization is the root of all evil." - Donald Knuth
Optimization 101

Reality
Hard to predict where the bottlenecks are
It’s not so hard to use tools to measure what the code is doing once it is written.
Therefore, write the code you way you want to be correct and finished first, then worry about optimization.

"Premature Optimization" = evil
Classic advice from Don Knuth
Write the code to be straightforward and correct first
Maybe it's fast enough already
If not, measure to find the bottleneck
Focus optimization there. Use CS161 type optimal algorithms + use language techniques as below

Data Structures
Your data structure will have a profound influence on performance.
This is one bit of "early" design where you might want to think about performance a little.
The choice of data structure (what you store, who has pointers to whom) can be very constraining on the possible algorithms later on.

Proportionality To Caller
Suppose we write a foo() utility in a way which is easy to code but naive -- it currently costs 1 millisecond, but could be sped up drastically. foo() is only called in one place by the bar() method. (If foo() is called multiple times, just add them all up to get the total foo() cost.)
How do you know if this matters?
The key question: how costly is bar()? If bar() takes 20 milliseconds, then foo() just doesn't matter. The smart strategy is to leave foo() in it's slow/naive/correct implementation -- find something else to fix.
If bar() takes 2 milliseconds, then foo() makes a huge difference and should be fixed.

1-1 User Event Rule
If something happens some fixed number of times like 1 or 3, for each single user event, such as a button push, then performance is not too important for that operation.
Watch for operations that happen 100's or thousands of times in relation to each user event.
User events happen very slowly from the computer's point of view.
e.g. We didn't worry about paint() too much for Tetris, but we did worry about place/undo (many times for each piece as the brain plays).
Algorithm Optimization

Pixels Expensive
Laying down pixels is costly
It's worth having an algorithm that is smart enough to only draw what's necessary

Disk Expensive
Getting bytes of the disk or network is expensive

Computing Again and Again
Sometimes all the fancy abstraction and encapsulation can create an algorithm that's pretty stupid: compute foo(x) add it to y. Compute foo(x) again add it to z...
You can use encapsulation here where the client is unaware that the second call to getFoo() is just returning a cached answer.

Java Tips
Using the right data structure and algorithm is the most important. After that we have language feature rules...

1. 1-10-1000 Rule

   assignment (=) : 1 unit of time
   method call : 10 units of time
   similar overhead to C
   new object or array : 1000 units of time

   Newer VMs are making this cheaper, but it's still much more expensive than other operations

2. int getWidth() vs. Dimension getSize()

   getSize() requires a heap allocated object
   getWidth() and getHeight() may just be inlined to move the two ints right into the local vars of the caller code.
   With HotSpot, supposedly short lived objects have been implemented to much faster, so this may be less important in the future.

3. static buffer -- "singleton"
Suppose you need some temporary array in a method.
Instead of calling new char[1000] in every call...
1. allocate a static array just once, and use it every time
2. (better) declare a static array, and allocate it the first time the method is called by checking if it's null -- avoids creating more load-time cost
Note: be careful if the method is executed by multiple threads
Disadvantage: we’re taking up 1000 bytes all the time, even when the method is not running.

4. Clever swapping
108 Tetris board implementation
Allocate two copies of the "board" data structure.
Swap between the two implement the undo feature
Point: rotate between a fixed number of objects, to avoid ever needing to call new
Cache
In this case, the use of cache memory is better as well -- the two copies get "hot" and we just switch between them.

5. Locals Faster Than IVars
Local variables are faster than member variables of any object (the receiver or some other object). Locals are also easier for the optimizer to work with for a variety of optimizations.
This could be a .width variable in some other object, or in this receiver -- they are both slower than a local stack variable.
Inside loops, pull needed values into local variables (int i;).
Suppose we are in a for loop...
1. Slow -- message send
...i < piece.getWidth()
2. Medium -- instance variable -- with a JIT, this case and (1) above are essentially the same.
...i < piece.width
-or-
...i< width (suppose the code is executing against the receiver)
3. Fast -- pull the state into a local (stack) variable, and then use it. This allows the implementation to pull the value into a native register. If the value is in an ivar, the runtime needs to retrieve it from memory every time it is used. It’s hard for the runtime to deduce that .width is not being changed, so it has to reload it from memory. Whereas it’s easy for it to deduce that localWidth is not being changed, so it can just put it in a register and use that value the whole time. (Note theme for the future: we’re sensitive to generating memory traffic.)
int localWidth = piece.getWidth(); // or width if we are the receiver
... i<localWidth...
-or-

// make it even more clear for the JIT...
final int localWidth = piece.getWidth();

6. Avoid Synchronized
Synchronized has a moderate runtime cost -- although this has been reduced as of Java 2
Can have synch and unsynch versions of the same method, and switch between the two based on some other flag.
Use "immutable" (unchangeable) objects to finesse synchronization problems.

7. StringBuffer
Use StringBuffer for multiple append operations -- change to String only once it's not going to change.

Automatic
This case the compiler optimizes for you -- appending together a bunch of strings at one moment into one immutable string.
String s = "a string" + foo.toString() + "some other string";

No
String record;     // ivar

void transaction(String id) {
    record = record + " " + id;     // NO, chews through memory
}

YES
StringBuffer record;
void transaction(String id) {
    record.append(" ");
    record.append(id); + id;
}

8 Don't Parse
Slow: read in XML, ASCII, etc. -- build big data structure
Fast: read it into memory, but leave it as just chars. Do the search, etc. in the chars -- just parse/build what you need on the fly.

9. Avoid Weird Code
The whole stack of VM optimizations added over time will be oriented towards common looking code -- write your code in the most obvious, common way, not some weird way. Ironically, weird code often gets written in the pursuit of optimization.
e.g. for (int i = 0; i<bound; i++) {...}  
Also, realize that obvious method implementations like getWidth()
    {return(width);} will certainly be targeted by HotSpot, so don't worry
about the method overhead.

10. Don't Use Vector  
   It's too synchronized, use the new Collections ArrayList instead.  
   If you can get away with a plain array, even better -- that's the fastest

11. Thread - GUI  
   Use separate threads so the GUI remains responsive. This "feels" fast.

12. Thread -- updating GUI  
   As your threads do things, have them update the GUI now and then with
   progress feedback. This "feels" faster too.

13. Use final for Methods  
   VM optimizers, and hot spot in particular, make aggressive use of inlining
      -- pasting called code into the caller code.  
   Inlining enables many other optimizations.  
   Pro: "final" is a huge aid in enabling inlining  
   Con: subclasses can no longer override your method. If you're just
      compiling all of your own code together, then it's no great loss.
Not Inlined

A() {
    B() {
        C() {
            Inlined
        }
    }
}

Advantages

Data Flow

Values in A() are passed to parameters in B(), passed to C(), where they are used.
Now, the flow of that value through the whole A/B/C sequence can be analyzed -- the value can just live in one variable/register for the whole computation

Other Optimizations

Suffice it to say, many other optimizations become possible in the "collapsed" inlined form