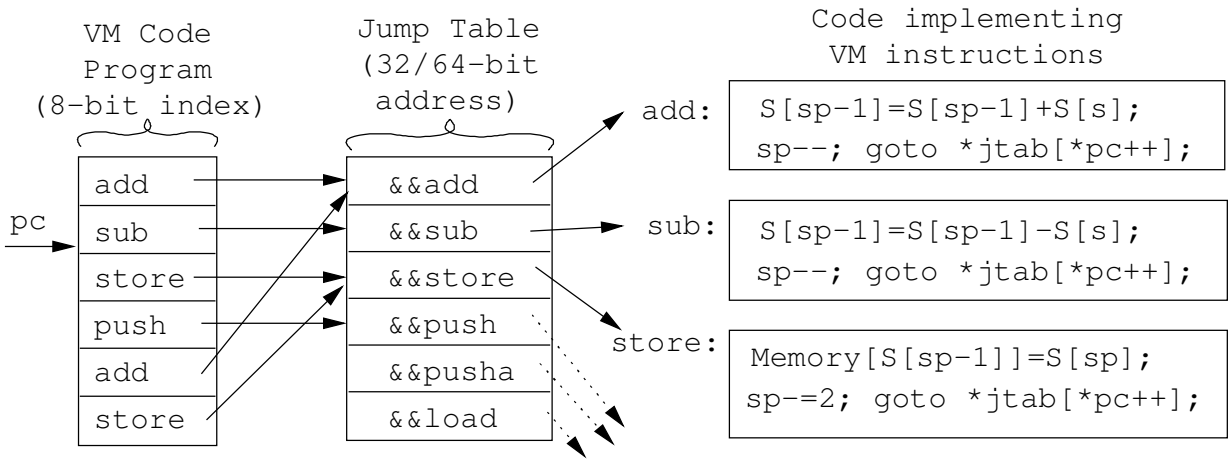
Indirect Threading...



Other Optimizations

Minimizing Stack Accesses

- To reduce the cost of stack manipulation we can keep one or more of the *Top-Of-Stack* elements in registers.
- In the example below, `TOS` holds the top stack element. `Stack[sp]` holds the element second to the top, etc.

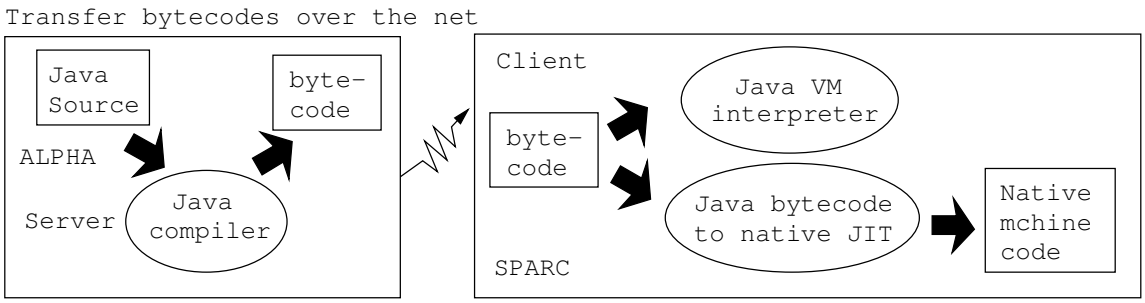
```
void engine() {
  static Inst prog[]={&&add,&&store,···};
  Inst *pc = &prog; int sp; register int TOS;
  goto *pc++;
  add:   TOS+=Stack[sp]; sp--; goto *pc++;
  store: Memory[Stack[sp]]=TOS; TOS=Stack[sp-1]
         sp-=2; goto *pc++;
}
```

Instruction Sets Revisited

- We can (sometimes) speed up the interpreter by being clever when we design the VM instruction set:
  1. Combine often used code sequences into one instruction. E.g. `muladd` a, b, c, d for $a := b * c + d$. This will reduce the number of instructions executed, but will make the VM engine larger.
  2. Reduce the total number of instructions, by making them simple and RISC-like. This will increase the number of instructions executed, but will make the VM engine smaller.
- A small VM engine may fit better in the cache than a large one, and hence yield better overall performance.

Just-In-Time Compilation

- Used to be called *Dynamic Compilation* before the marketing department got their hands on it. Also a verb, *jitting*.
- The VM code is compiled to native code just prior to execution. Gives machine independence (the bytecode can be sent over the net) and speed.
- When? When a class/module is loaded? The first time a method/procedure is called? The 2nd time it's called?



Summary

- Direct threading is the most efficient dispatch method. It cannot be implemented in ANSI C. Gnu C's "labels as values" do the trick.
- Indirect threading is almost as fast as direct threading. It may sometimes even be faster, since the interpreted program is smaller and may hence fits better in the cache.
- Call threading is the slowest method. There is overhead from the jump, save/restore of registers, the return, as well as the fact that VM registers have to be global.