MIPS Procedure Calls
JVM and Assignment 3

CSE 378 – Section AB

JVM and Assignment 3

- JVM is a stack machine
  - Portability
  - Compactness
- Our simplified JVM consists of:
  - Execution Stack
    - Instructions take parameters from the stack
    - Instructions place results onto the stack
  - Pointer to top of the stack
  - Local Storage
    - Just a big array for storing data
  - Java bytecode program
  - Program counter

Emulating JVM

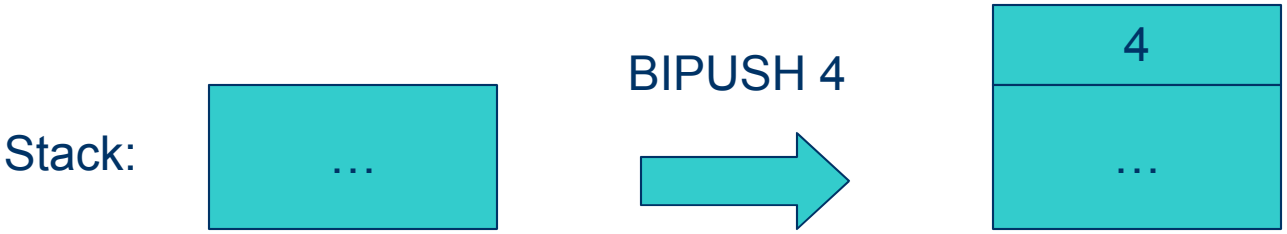
- Interpreter:
  - Get next instruction
  - Decode it
  - Execute
  - Store results
  - Repeat

Emulating JVM

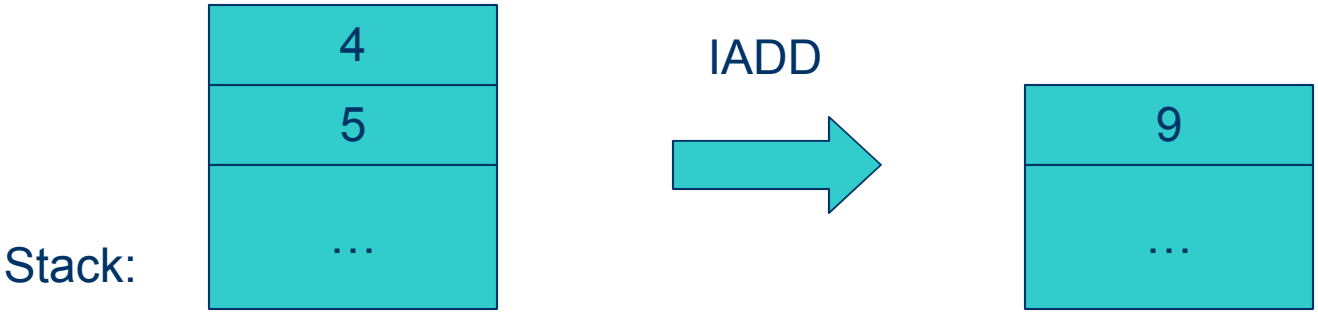
- Probably need SPIM registers for:
  - Pointer to top of JVM stack
  - Pointer to current JVM instruction (PC)
  - Holding a couple of values from the stack (when pushing/popping) – v1, v2
- Use SPIM static data section for:
  - The entire execution stack (1024 bytes maximum)
  - the local storage area
  - The program itself
    - sequence of instruction opcodes and parameters

JVM Instructions

- Load constant (BIPUSH for 8-bit, SIPUSH for 16)

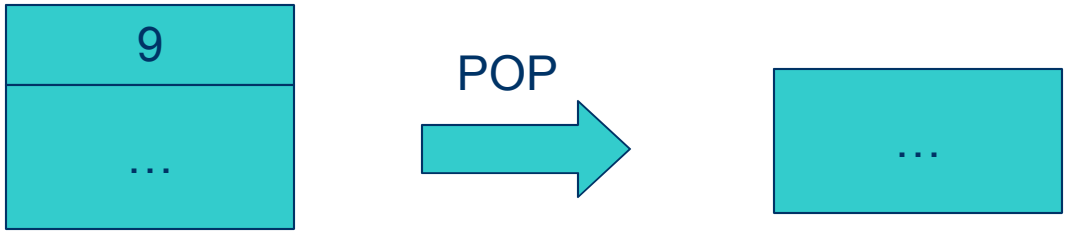


- Arithmetic (IADD, ISUB, IMUL, IDIV)

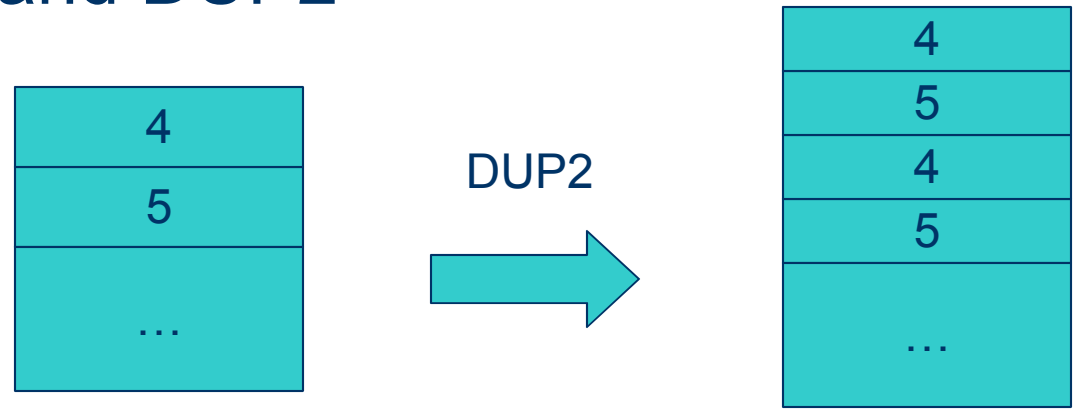


JVM Instructions 2

- POP



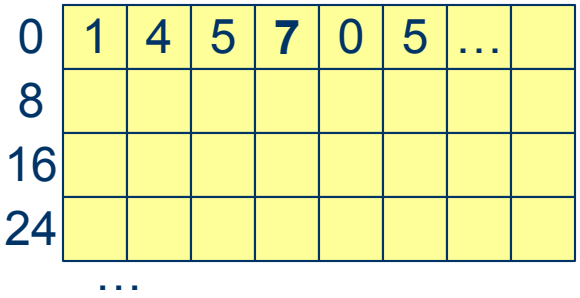
- DUP and DUP2



Loading from local storage

- ILOAD, ISTORE – load/store *32-bit word* using unsigned *8-bit index* into storage

Local storage:

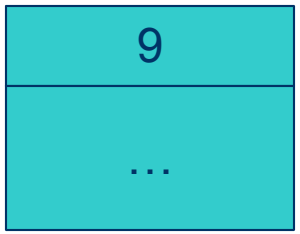


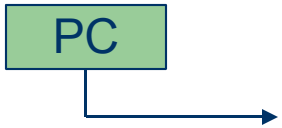
Stack:

ILOAD 3

Branches

- Pop one thing off stack, compare with zero using specified condition, update PC if true
- Take a signed 2-byte offset from current PC
  - No “labels” in bytecodes, just offsets





JVM program:

BIPISH 0x09

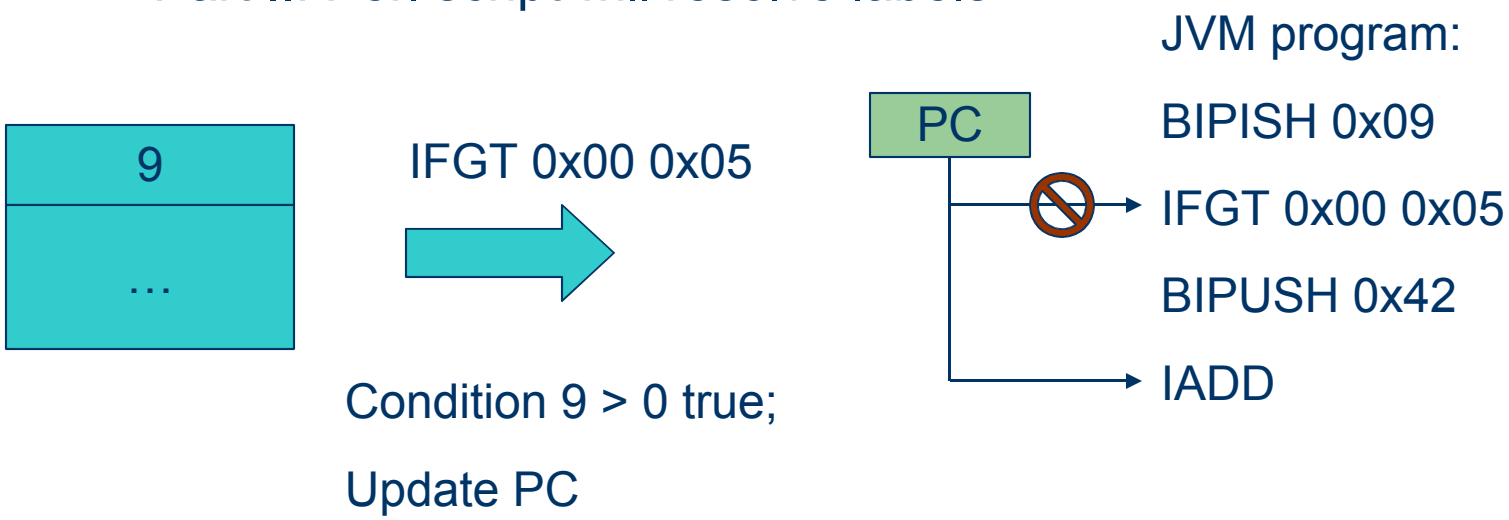
IFGT 0x00 0x05

BIPUSH 0x42

IADD

Branches

- To understand offset destinations, add up opcodes (1 byte), along with any arguments
  - E.g. IFEQ 0x00 0x05 takes 3 bytes, IADD takes 1.
    - Part II: Perl script will resolve labels



Example: a=a+b+c

Add first 3 words in local storage

Store the result into the first local storage word

```
ILOAD 0
ILOAD 1
ILOAD 2
IADD
IADD
ISTORE 0
```

Example:

$$\frac{1}{2\sqrt{\pi}\sqrt{t}}\left(-e^{-\frac{(-1+x)^2}{4t}}\sqrt{t}\left(2\sqrt{t}+e^{\frac{(-1+x)^2}{4t}}\sqrt{\pi}\,x\,\mathrm{Erf}\left[\frac{-1+x}{2\sqrt{t}}\right]\right)+e^{-\frac{x^2}{4t}}\sqrt{t}\left(2\sqrt{t}+e^{\frac{x^2}{4t}}\sqrt{\pi}\,x\,\mathrm{Erf}\left[\frac{x}{2\sqrt{t}}\right]\right)\right)$$

Example 2: if (b==0) a=3; else a=5;

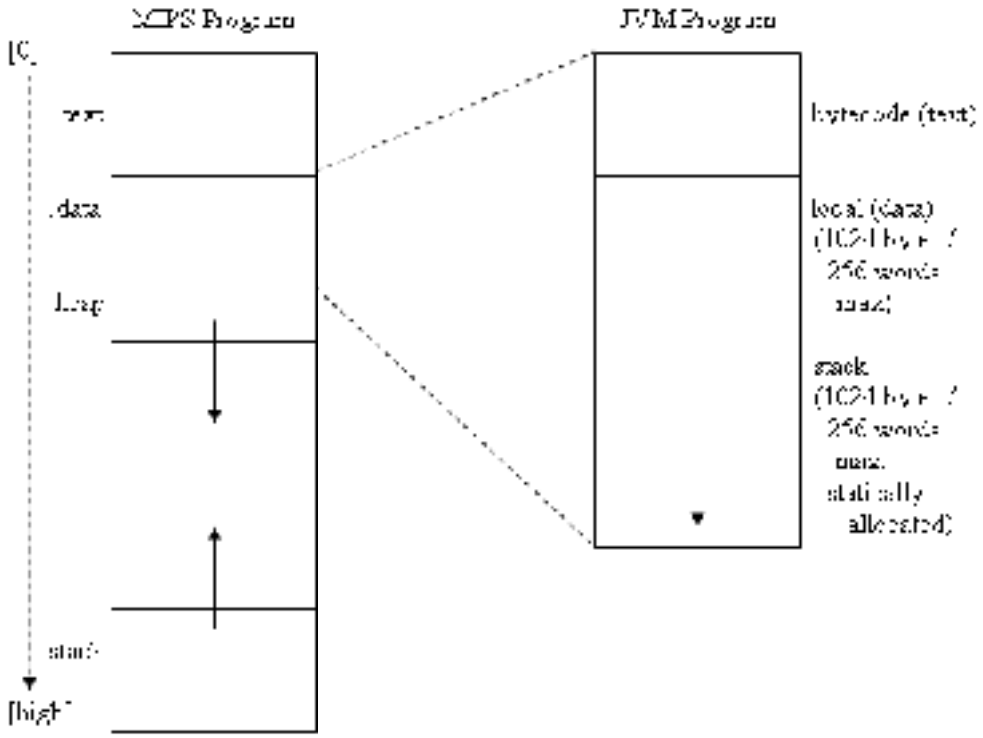
- Assume a is local word 0,
  b is local word 1:

```
                ILOAD 1
                IFEQ skip
                BIPUSH 3
                ISTORE 0
                GOTO endif
skip:           BIPUSH 5
                ISTORE 0
endif:          …
```

To bytecodes
(use perl script)

```
 .align  2
test2:
  .byte   0x15, 0x01        # iload
  .byte   0x99, 0x00, 0x0a  # ifeq
  .byte   0x10, 0x03        # bipush
  .byte   0x36, 0x00        # istore
  .byte   0xa7, 0x00, 0x07  # goto
  .byte   0x10, 0x05        # bipush
  .byte   0x36, 0x00        # istore
  .byte   0x00              #
  .align  2
end_test2:
```

Your Homework



Your Homework (cont.)

- The JVM also has four special-use registers. These are the PCJVM, SPJVM, v1, and v2. Where are you going to “store” these? MIPS t-registers or s-registers are perhaps the best option.
- JVM bytecodes.

Any Questions?

Procedure Call Basics

- Jump to procedure:
  jal <label>
  - Saves return address to $ra
- Return from a procedure:
  jr $ra
- $a0 - $a3 to pass arguments
- $v0 and $v1 to return values
- Save certain registers to preserve across procedure calls.
  - Use the stack
- $t0-$t9, $a0-a3, $v0-v1 – *caller-saved*.
  - Caller's responsibility to save if expects to use these after a call.
- $s0-$s7, $ra, $fp – *callee-saved*.
  - Callee's responsibility to save if callee uses them.
  - Save at beginning of function, restore at end

Calling procedures

To call a procedure:

2. Put arguments into $a0-a3
3. Save caller-saved registers
4. jal <proc>
5. Restore caller-saved registers

Example:

```
<some stuff here, uses $t2>
…
# set up a call to myproc(4)
addi $a0, $0, 4
subu $sp, $sp, 4
sw $t2, 0($sp)
jal myproc
lw $t2, 0($sp)
addiu $sp, $sp, 4
…
<use $t2 again>
```

Setup at the start/end of procedure

Before any procedure starts running, it must:

2. Allocate memory for callee-saved registers
3. Save callee-saved registers
   - If calling another procedure inside, must save $ra! (why?)

At the end of procedure:

5. Place return value into $v0
6. Restore callee-saved regs
7. jr $ra

```
myproc: # wants to use $s0 inside
    subu $sp, $sp, 8
    sw $ra, 4($sp)
    sw $s0, 0($sp)
    …
    <do some computation in $s0>
    …
    addi $v0, $s0, 42
    lw $s0, 0($sp)
    lw $ra, 4($sp)
    addiu $sp, $sp, 8
    jr $ra
```

Miscellaneous

- MIPS stack conventions:
  - $sp double-word aligned
  - Minimum frame size is 24 bytes (fits four arguments and return address)
  - Don't use it for projects
  - Other rules flexible too: have to use common sense for what you need to save
- If >4 arguments, use the stack to pass them
  - Caller, callee must agree on where they go in the stack and who pops them off.

The End