CS212

Java Practicum

Introduction to SaM

What is SaM? Why SaM?

- **From last lecture**:
  - computer stores data and instructions in memory
  - ***fetch-and-decode cycle***:
  - JVM is ________ of computers
  - **bytecodes are _______________**
- ***SaM***:
  - stands for: ______________________
  - see SaM on CS212 for full instruction set
  - gives us legible instruction set
    - your compiler will generate ________
    - BTW, what's a compiler? (last panel...)

Samcode Instructions

- **Low-level instructions**:
  - push and pop values in memory
  - ***mnemonics*** for bit patterns
- **Structure**:

```
opcode
opcode operand
```

- **Areas (watch DIS play w/SaM)**

Structure of Samcode File

- ASCII Text! (What's ASCII?)
- Write instructions on new lines
- `//` indicates single-line comments, which are ignored
- Program ends with ___________
- Program must leave how many items on Stack?

Focus on Stack

- ***Call Stack*** (and other names):
  - function calls function calls ...
  - when last function done, go back, then back, then ...
  - how to picture this structure?
- ***Frame***:
  - each function's portion of Stack
  - variables, data, administrative info
- Cells and addresses
  - **start at 0!**
- Helpful picture?

Useful Registers

- ***Frame Based Register*** (***FBR***)
  - administrative information
  - keeps track of current frame (and thus, function)
- ***Stack Pointer*** (***SP***)
  - uses register
  - store location of next free cell in stack
- Helpful picture?

Some Instructions

- **ALU**:
  - arithmetic, boolean, comparison
  - generally follows ***below op top***
  - usually pops both values and pushes result
- **Stack Manipulation**:
  - pushing
  - swapping, duplicating
  - storing, retrieving
- **Register**
- **Control**
- Descriptions:
  - see on-line documentation
  - see **Chapter 1**

Some Examples

- Notation:
  - Infix: (1 – 2) – 3
  - Postfix: 1 2 – 3 –
- Logical: ~(4 <= 5)
  - Samcode rem: ***below op top***
- Samcode?

Program Storage?

- Main memory model:
  - store programs as ___________
  - so, instructions have patterns of ________
- Where are they in SaM?
  - Samcode read into an array
  - array stores instruction objects
- Want more? See documentation and source code
  - **SaM→Individual Files→Core→Instructions**
  - See next page for example
- How to load your own instructions?
  - recompile everything (a pain)
  - or...use SaM's ***instruction loader***

Example

```
package edu.cornell.cs.sam.core.instructions;
import edu.cornell.cs.sam.core.*;

public class SAM_ADD extends SamInstruction {
      public void exec() throws SystemException {
            int type1 = mem.getType(cpu.get(SP) - 2);
            int type2 = mem.getType(cpu.get(SP) - 1);
            mem.push(higherPrecedence(type1, type2), mem.pop() + mem.pop());
            cpu.inc(PC);
      }
}
```

Variable Scope

- Take an aside... is SaM really useful?
- Example:
  - is the following legal?

```
int x(int x) { return x++; }
int y(int x) { return x(x); }
```

  - why? why not?
- Scope of variable:
  - region of code in which variable represents something
  - how does Java indicate?
- Local and global variables:
  - each function has its own local variables
  - global variables shared
- Does SaM help?

Variables and Frames

- **A way to picture variables in frames...**
  - variable gets cell
  - Aside: SaM shows type of cell
- **Samcode program**:
  - allocate cell
  - fill cell
  - later retrieve/change contents
  - finally deallocate cell (why?)

Allocation and Deallocation

- Pushing:
  - `PUSHIMM`... (see SaM website)
- Allocating:
  - Allocate *v* amount of vars: `ADDSP` *v*
  - Deallocate *v* amount of vars: `ADDSP -`*v*
- Example:

```
ADDSP 3
ADDSP -1
ADDSP -1
ADDSP -1
STOP
// error mesg (why?)
```

How to access a variable?

- **Addressing of variables**:
  - absolute
  - relative
- ***Absolute***:
  - don't worry about your current frame
  - figure out variable address on stack
  - eg) globals
- ***Relative***:
  - do worry about your current frame
  - figure out variable address with respect to FBR value
  - eg) locals

Absolute Address

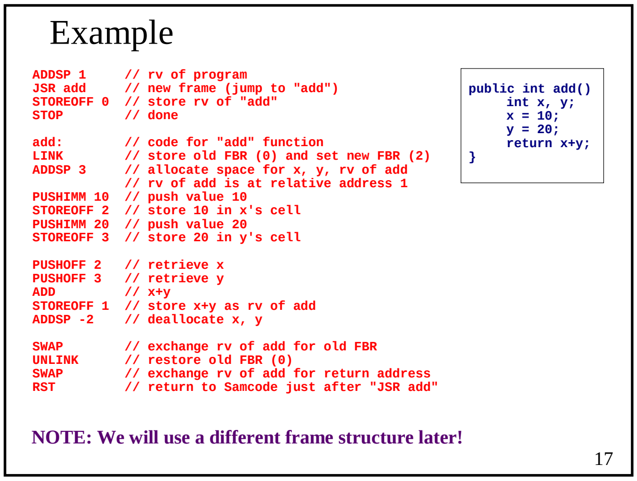
- **Instructions**:
  - To **store** a value *v* at location *i*:
    - `PUSHIMM` *v*: Stack[SP] ← *v*; SP++
    - `STOREABS` *i*: Stack[*i*] ← Stack[SP-1]; SP--
  - To **retrieve** a value *v* from location *k*:
    - `PUSHABS` *k*; Stack[SP] ← Stack[*k*]; SP++
- **Example:**

```
int rv;
int x;
int y;
x = 10;
y = 20;
rv = x + y;
return rv;
```

```
ADDSP 3
PUSHIMM 10
STOREABS 1
PUSHIMM 20
STOREABS 2
PUSHABS 1
PUSHABS 2
ADD
STOREABS 0
ADDSP -2
STOP
```

Relative Address

- Instructions:
  - To store a value *v* at location *i*:
    - `PUSHIMM` *v*: Stack[SP] ← *v*; SP++
    - `STOREOFF` *i*: Stack[*i*+FBR] ← Stack[SP-1]; SP--
  - To retrieve a value *v* from location *k*:
    - `PUSHOFF` *k*: Stack[SP] ← Stack[*k*+FBR]; SP++
- Picture?

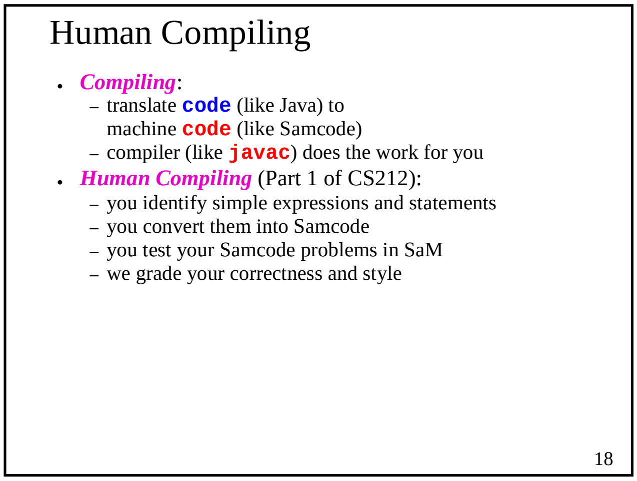


Example

```
ADDSP 1     // rv of program
JSR add     // new frame (jump to "add")
STOREOFF 0  // store rv of "add"
STOP        // done

add:        // code for "add" function
LINK        // store old FBR (0) and set new FBR (2)
ADDSP 3     // allocate space for x, y, rv of add
            // rv of add is at relative address 1
PUSHIMM 10  // push value 10
STOREOFF 2  // store 10 in x's cell
PUSHIMM 20  // push value 20
STOREOFF 3  // store 20 in y's cell

PUSHOFF 2   // retrieve x
PUSHOFF 3   // retrieve y
ADD         // x+y
STOREOFF 1  // store x+y as rv of add
ADDSP -2    // deallocate x, y

SWAP        // exchange rv of add for old FBR
UNLINK      // restore old FBR (0)
SWAP        // exchange rv of add for return address
RST         // return to Samcode just after "JSR add"
```

```
public int add()
     int x, y;
     x = 10;
     y = 20;
     return x+y;
}
```

NOTE: We will use a different frame structure later!



Human Compiling

- *Compiling*:
  - translate `code` (like Java) to machine `code` (like Samcode)
  - compiler (like `javac`) does the work for you
- *Human Compiling* (Part 1 of CS212):
  - you identify simple expressions and statements
  - you convert them into Samcode
  - you test your Samcode problems in SaM
  - we grade your correctness and style