Plan

Schedule update

Code generation for function/method calls and definitions

- Can do MOST of the code generation before having a symbol table
- Analyze what nodes in the AST are affected
- Lots of examples.

RecursiveCount Example in MeggyJava

```
/**
*Recursively put BLUE pixels in (2,0), (1,0), (0,0)
*/
import meggy.Meggy;
class RecursiveCount {
  public static void main(String[] whatever){
    new Foo().count((byte)0);
  }
}
class Foo {
  public void count(byte p) {
    // if haven't reached 2,
      // recursively call count
    // call setPixel at (p,0)
  }
}
```

Recall AVR-GCC Calling Convention

Calling Convention for AVR-GCC

- Pass parameters in registers
  - r24, r25 for parameter 1
  - r22, r23 for parameter 2
  - …
  - r16, r17 for parameter 5
  - …
  - r8, r9 for parameter 9
- Pass return values in register(s), r24, r25
- Call and return instructions implicitly store and use return address on stack
- Push and pop keep track of the stack pointer, which points at next open slot
- Frame pointer is managed internally by each function

Code generation for Function/Method Calls

Already did code generation for

- Meggy.setPixel()
- Meggy.delay()
- Meggy.checkButton()
- Meggy.getPixel()
- How did the above work?

How did we know the types for the actual argument expressions?

How can we know they types for user-defined functions? Return value?

What are the relevant AST nodes for method/function calls?

Outline of Code to Generate at a Function Call

```
# for each actual expression, pop it from the run-time stack into
# appropriate register(s) for parameter pass
        pop r??
        pop r??
        ...

        # call the function
        call classnamefuncname
        → next sequential instruction = return address

        # If we are an expression, then push the return value
        # onto the stack.
        push r25    # only have this if have a 2 byte return value
        push r24
```


call, return, return address

Call and return instructions manipulate the RTS implicitly.

A call instruction:

call clNmfNm

RA:

pushes RA (return address) on the RTS and jumps to clNmfNm.

A return instruction:

ret

pops the return address off the RTS and jumps to it.

Stack Pointer vs Frame Pointer

Stack Pointer is used to evaluate expressions, and thus varies
Points at first available open slot in the Run Time Stack

Frame Pointer is used to address locals, and does not vary during the execution of a function body. Gets updated at the beginning of a method call

Notice that Run Time Stack actually grows Down in memory (in spite of pictures on following slides), so when offsetting off frame pointer use Y+1, Y+2 for this, Y+3 for first parameter if byte, Y+3 and Y+4 if int, etc.

Code Generation at the Method/Function Definitions

Where should the code be generated for method/function definitions?

```
    .text
.global methodname
    .type methodname, @function
methodname:
    # push callers frame pointer
    push r29
    push r28
    # store off parameter(s)
    push r24
    …
    # make callee's frame pointer copy of stack pointer
    in r28, __SP_L__
    in r29, __SP_H__
```

Code Generation at the Method/Function Definitions

Epilogue

```
# handle return value


# pop parameters off stack


# restore the frame pointer


# return
ret
.size methodname, .-methodname
```


Calling convention

Caller:

1. gather actual params on the RTS
- push receiver
  (receiver = "this" in callee)
- eval and push explicit parameters 2,3,…

2. call
- pop actuals in reg (pair)s
- call fname
  (fname = className+funcName)

3. on return
(1) push return value on stack

Callee:

1. push old FP (r28, r29)

2. make space for frame
multiple push 0-s

3. copy SP → FP
in r28, __SP_L__
in r29, __SP_H__

4. populate frame (Reg → Y+offset)

5. execute body
may push return value

6. may get return value into r24(25)

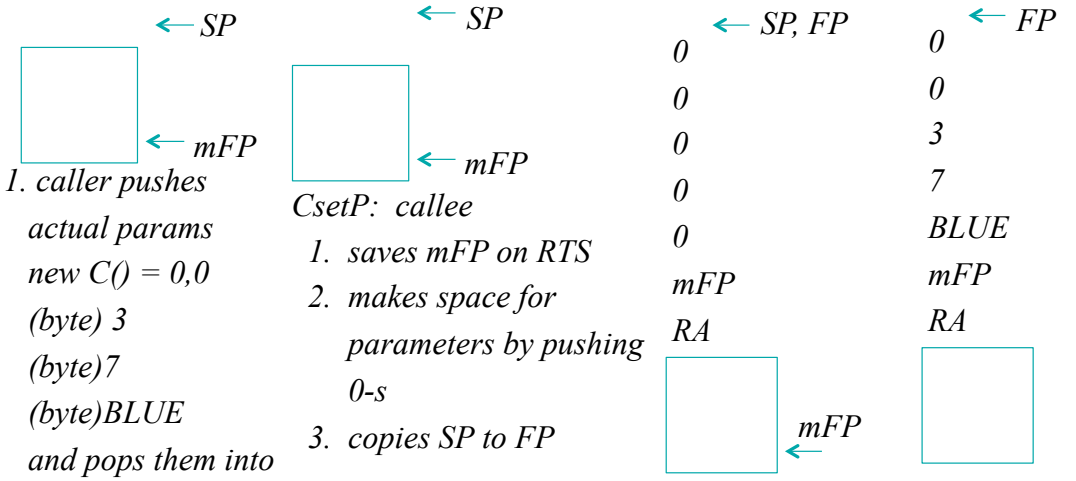
7. clear frame space (undo 2)

8. pop FP into r28,r29

9. ret

PA4simple.java example: call

new C().setP((byte)3 ,(byte)7,Meggy.Color.BLUE);

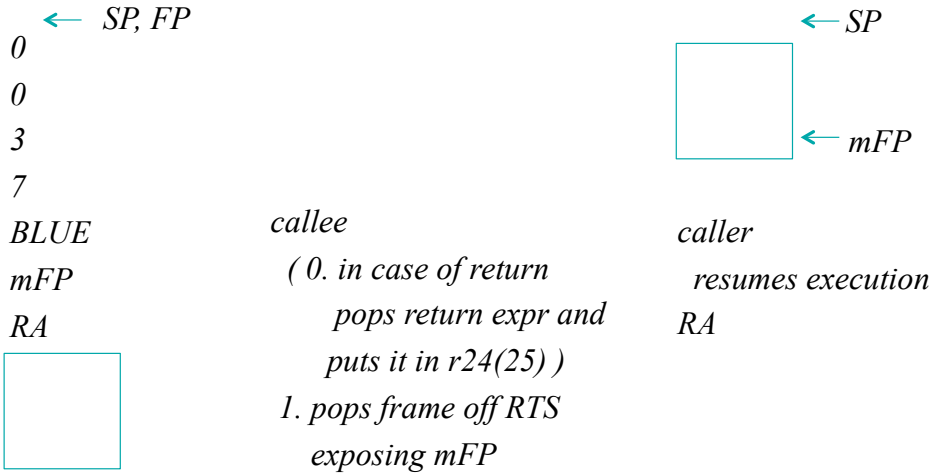


1. caller pushes
actual params
new C() = 0,0
(byte) 3
(byte)7
(byte)BLUE
and pops them into
r18: BLUE r20: 7
r22: 3 r24(25) newC()
2. caller performs
CALL CsetP
RA:

CsetP: callee
1. saves mFP on RTS
2. makes space for parameters by pushing 0-s
3. copies SP to FP

callee
4. populates stack frame
5. executes body
(6. in case of return pops ret expr into r24(25))

PA4simple.java example: return



callee
(0. in case of return pops return expr and puts it in r24(25))
1. pops frame off RTS exposing mFP
2. pops mFP into FP exposing RA
3. executes ret, which pops RA and jumps to it

caller
resumes execution at RA

Visualize RTS, heap

Visualize the run-time stack for RecursiveCount example. Recursively put BLUE pixels in (2,0), (1,0), (0,0). Do it, do it.

Every call has an implicit first parameter this: the receiver object associated with the call. In PA4 this is just a place holder (no instance variables or locals yet). In PA5 heap objects of type C contain instance variables. Heap and RTS:

RTS has locals that may refer to heap objects: C x = new C(init);

Issues you don't need to worry about: RTS overflow, Garbage collection