Code Generation, Continued

How to be a MIPS Master

It's really easy to get confused with assembly

- Try writing a program by hand before having the compiler generate it
- Draw lots of pictures of program flow
- Have your compiler output detailed comments

Get help

- Post on piazza

Roadmap

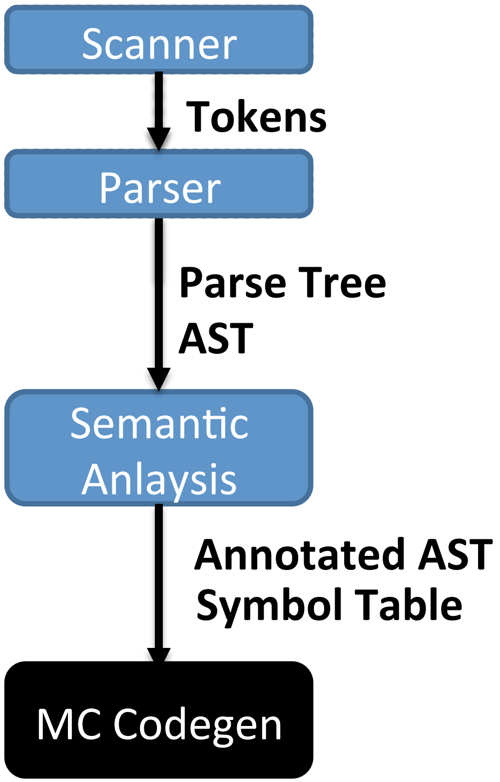
Last time:

– Talked about compiler backend design points

– Decided to go with direct to machine code design for our language

This time:

– Run through what the actual codegen pass will look like



Review: Global Variables

Showed you one way to do declaration last time:

```
.data
.align 2
_name: .space 4
```

Simpler form for primitives:

```
.data
_name: .word <value>
```

Review: Functions

Preamble

– Sort of like the function signature

Prologue

– Set up the function

Body

– Do the thing

Epilogue

– Tear down the function

Function Preambles

```c
int f(int a, int b){
    int c = a + b;
    int d = c - 7;
    return c;
}
```

```
.text
f:
#... Function body ...
```

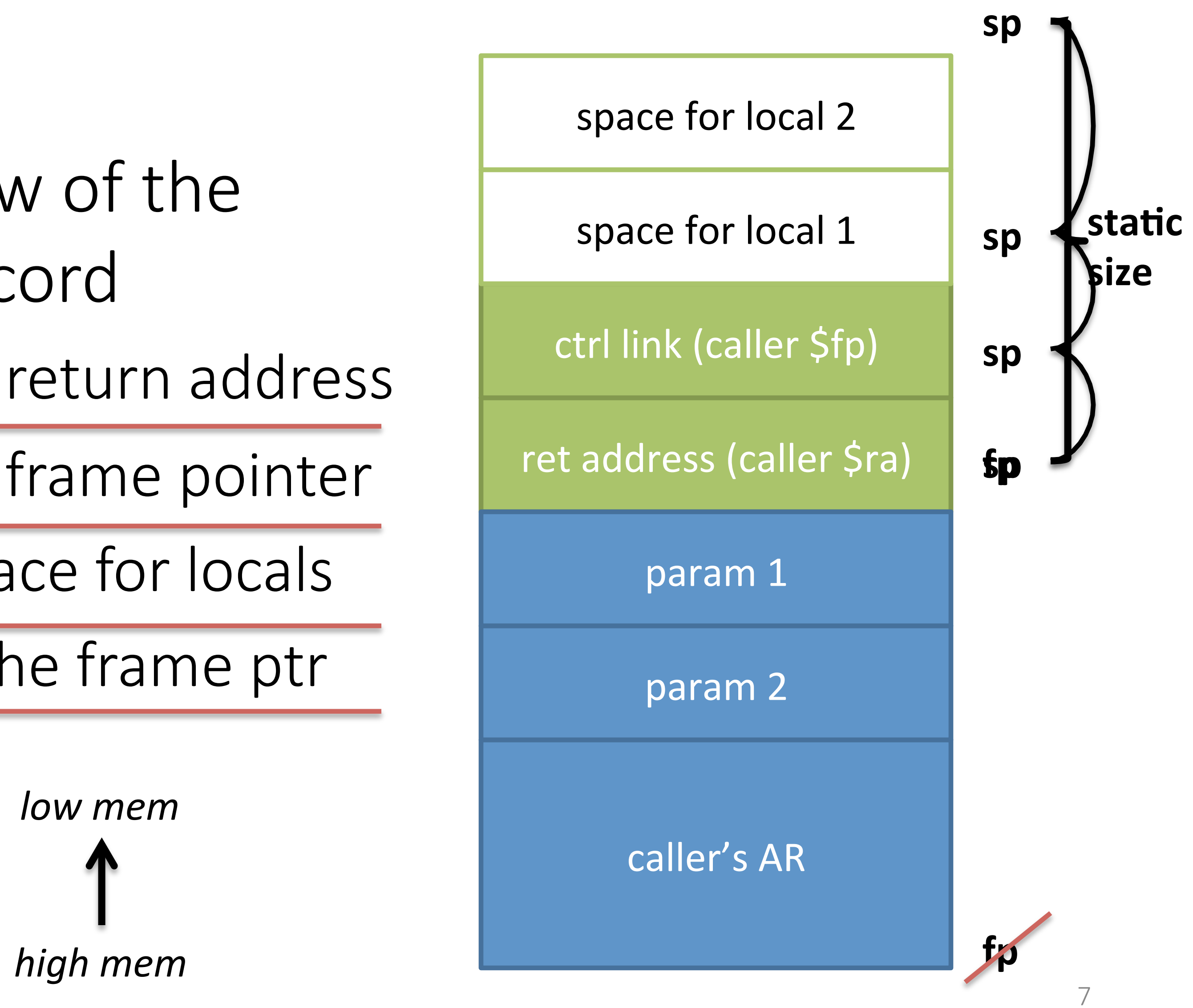
This label gives us something to jump to

```
jal f
```

Function Prologue

Recall our view of the Activation Record

1. save the return address
2. save the frame pointer
3. make space for locals
4. update the frame ptr



Function Prologue: MIPS

Recall our view of the Activation Record

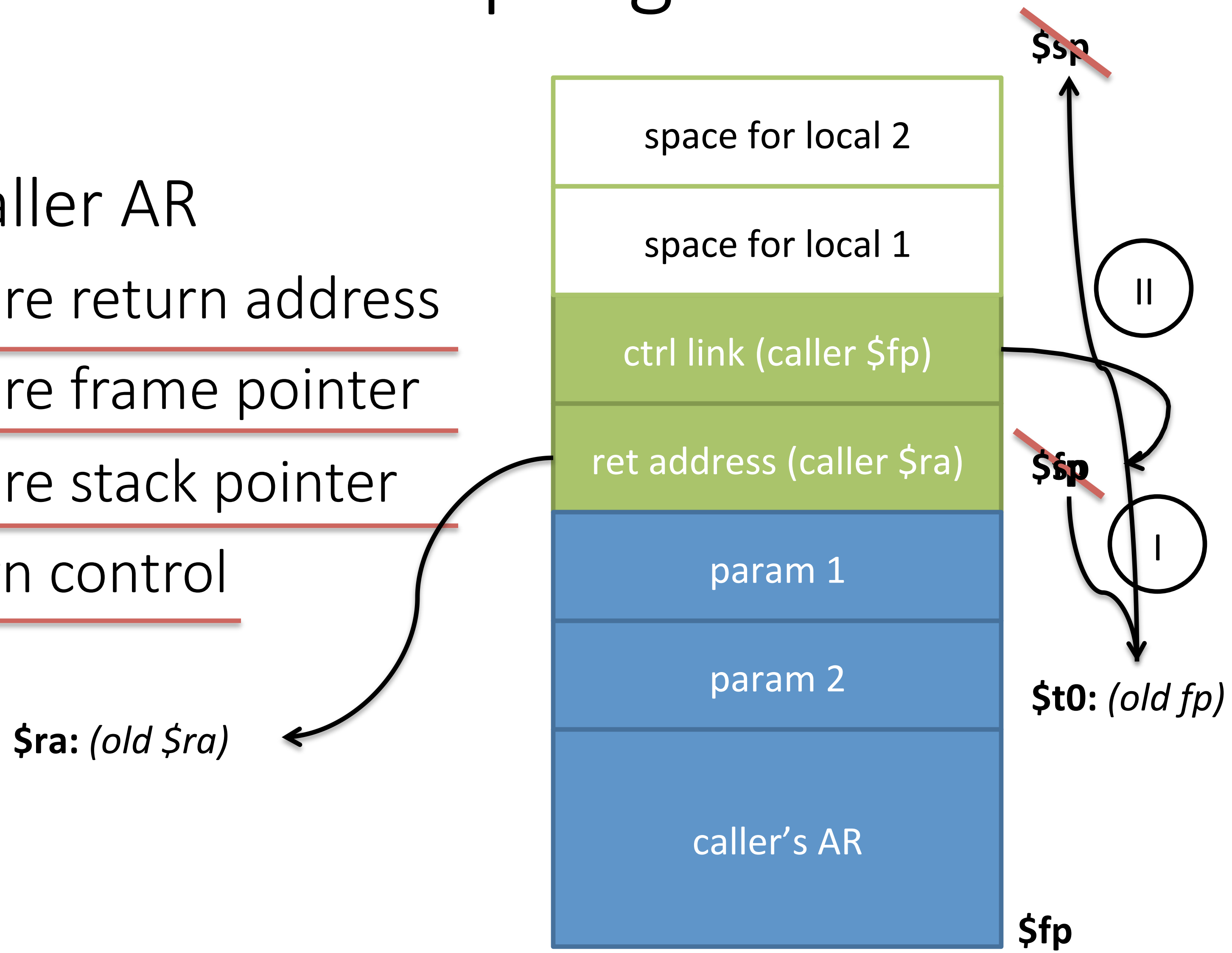
1. save the return address
2. save the frame pointer
3. make space for locals
4. update the frame ptr

```
.text
f:
   sw $ra 0($sp)     #call lnk
   subu $sp $sp 4    # (push)
   sw $fp 0($sp)     #ctrl lnk
   subu $sp $sp 4    # (push)
   subu $sp $sp 8    #locals
   addu $fp $sp 16 #update fp
```

Function Epilogue

Restore Caller AR

1. restore return address
2. restore frame pointer
3. restore stack pointer
4. return control



Function Epilogue: MIPS

Restore Caller AR

1. restore return address
2. restore frame pointer
3. restore stack pointer
4. return control

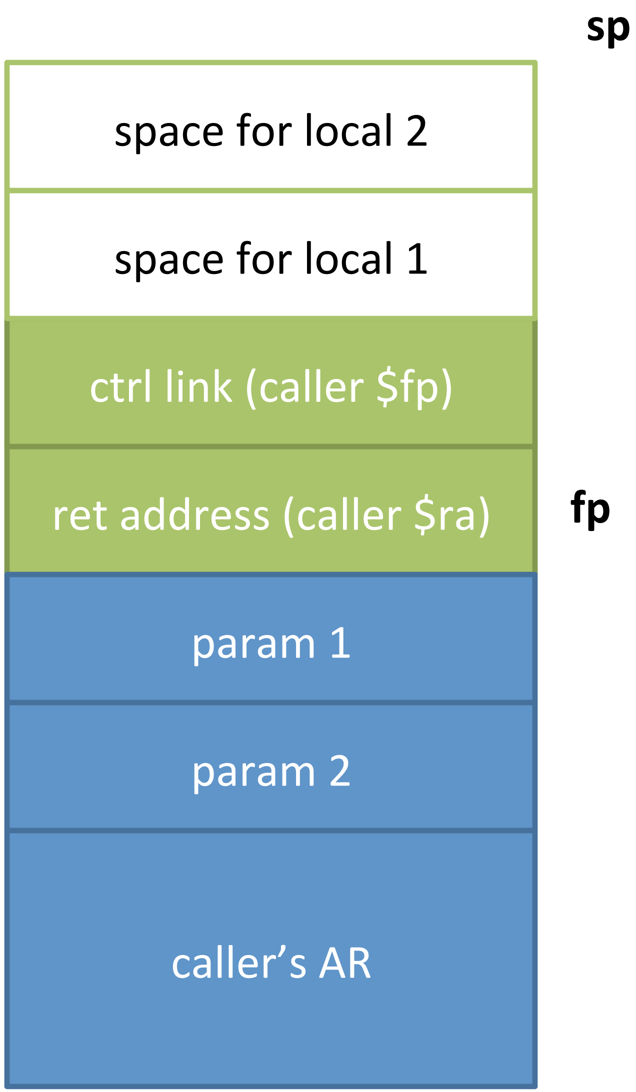
```
.text
f:
  sw $ra 0($sp)
  subu $sp $sp 4
  sw $fp 0($sp)
  subu $sp $sp 4
  subu $sp $sp 8
  addu $fp $sp 16
  #... Function body ...
  lw $ra, 0($fp)
  move $t0, $fp
  lw $fp, -4($fp)
  move $sp, $t0
  jr $ra
```

Function Body

Obviously, quite different based on content

- Higher-level data constructs
  - Loading parameters, setting return
  - Evaluating expressions
- Higher-level control constructs
  - Performing a call
  - Loops
  - Ifs

Function Locals

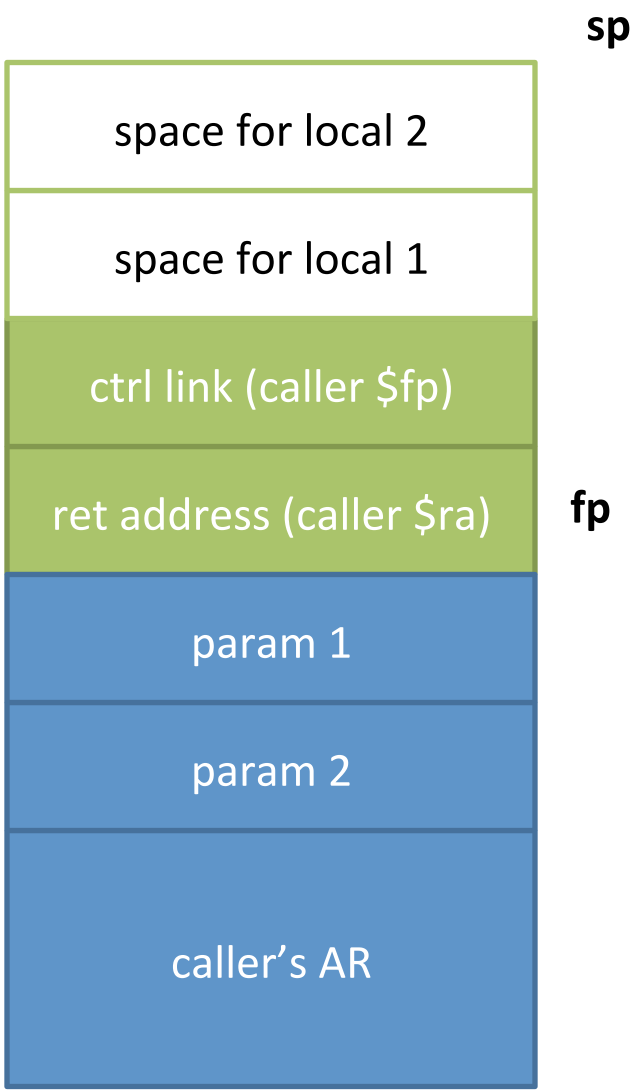



```
.text
f:
    # … prologue … #
    lw $t0, -8($fp)
    lw $t1, -12($fp)



    # … epilogue … #
```

Function Returns




```
.text
f:
    # … prologue … #
    lw $t0, -8($fp)
    lw $t1, -12($fp)
    lw $v0, -8($fp)
    j f_exit
f_exit:
    # … epilogue … #
```

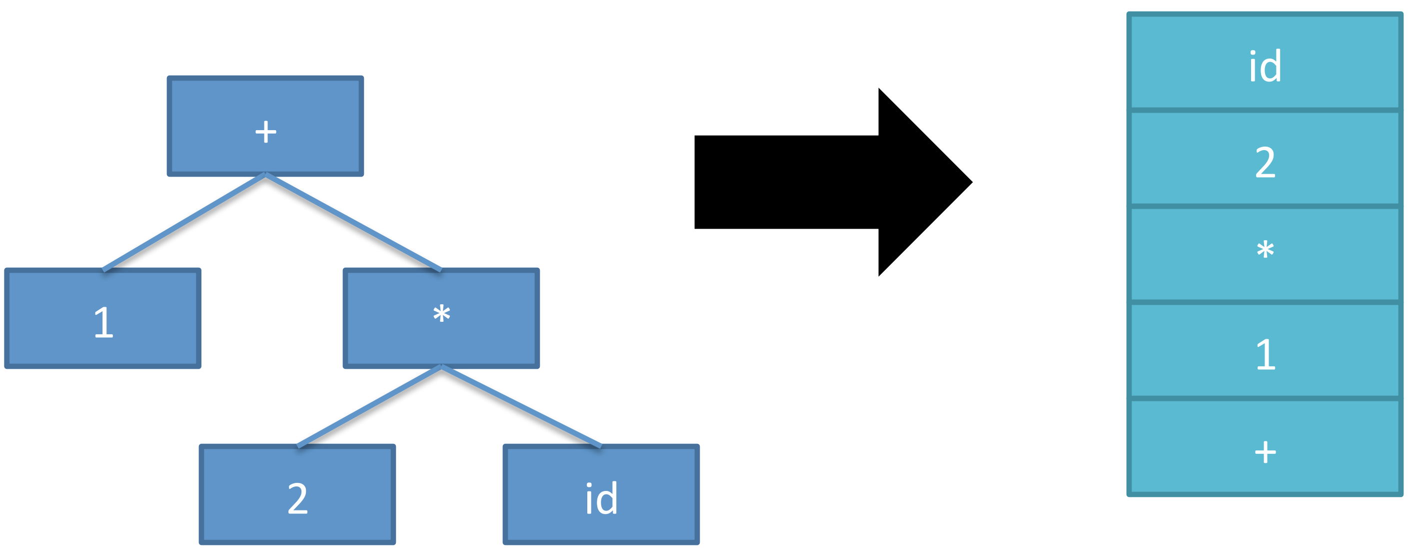
Function Body: Expressions

Goal

– Serialize (“flatten”) an expression tree

Use the same insight as the parser

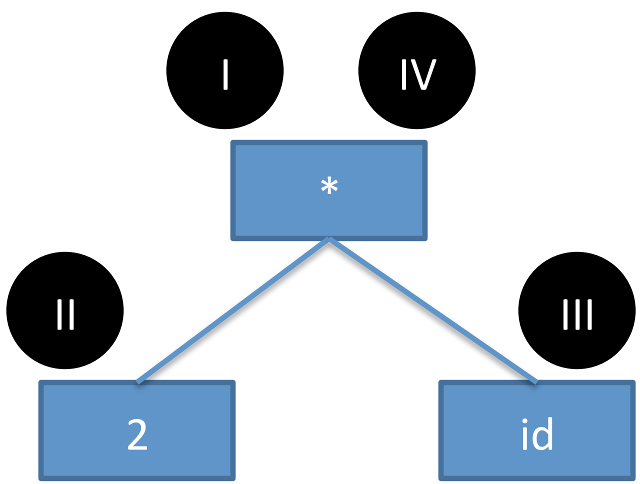
– Use a work stack and a post-order traversal



Serialized Psuedocode

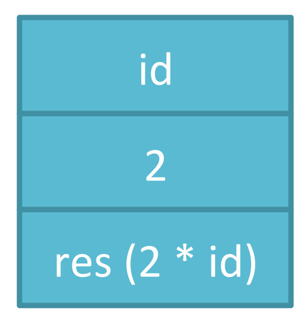
Key insight

- Use the stack pointer location as “scratch space”
- At operands: push value onto the stack
- At operators: pop source values from stack, push result



push 2
push id
pop id into t1
pop 2 into t0
mult t0 * t1 into t0
push t0

$t1 = id
$t0 = ~~2~~ 2 * id



Serialized MIPS

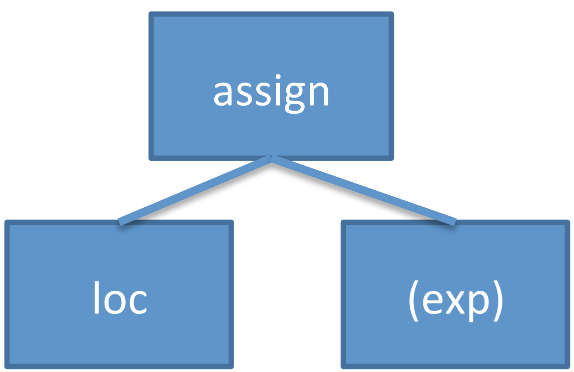
L1: push 2
L2: push id
L3: pop id into t1
L4: pop 2 into t0
L5: mult t0 * t1 into t0
L6: push t0

```
L1: li $t0 2
    sw $t0 0($sp)
    subu $sp $sp 4
L2: lw $t0 id
    sw $t0 0($sp)
    subu $sp $sp 4
L3: lw $t1 4($sp)
    addu $sp $sp 4
L4: lw $t0 4($sp)
    addu $sp $sp 4
L5: mult $t0 $t0 $t1
L6: sw $t0 0($sp)
    subu $sp $sp 4
```

Stmts

By the end of the expression, our stack isn't exactly as we left it

- Contains the result of the expression
- This is by design

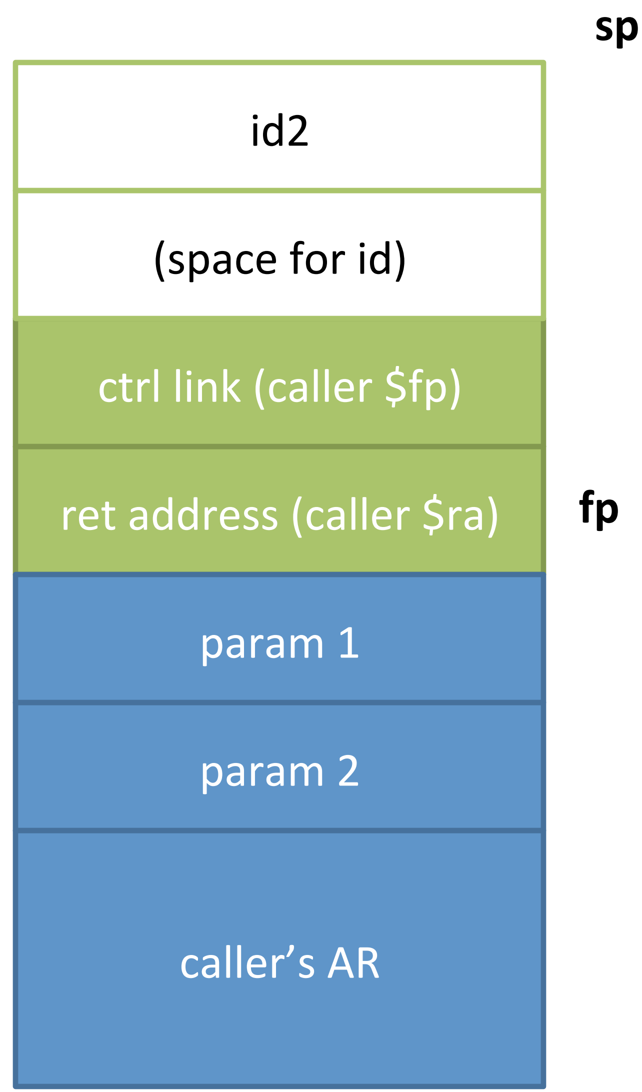


1) Compute RHS expr on stack
2) Compute LHS *location* on stack
3) Pop LHS into $t1
4) Pop RHS into $t0
5) Store value $t0 at address $t1

Simple Assign, You Try

Generate stack-machine style MIPS code for

id = 1 + 2;



Algorithm

1) Compute RHS expr on stack
2) Compute LHS *location* on stack
3) Pop LHS into $t1
4) Pop RHS into $t0
5) Store value $t0 at address $t1

Dot Access

Fortunately, we know the offset from the base of a struct to a certain field statically

- The compiler can do the math for the slot address
- This isn't true for languages with pointers!

```
struct Demo inst;
struct Demo inst2;
inst.b.c = inst2.b.c + 1;
```

load this address

load this value

Dot Access Example

```
void v(){
    struct Inner{
      bool hi;
      int there;
      int c;
    };
    struct Demo{
      struct Inner b;
      int val;
    };
    struct Demo inst;
    inst.b.c = inst.b.c;
}
```

inst is based at -8($fp)

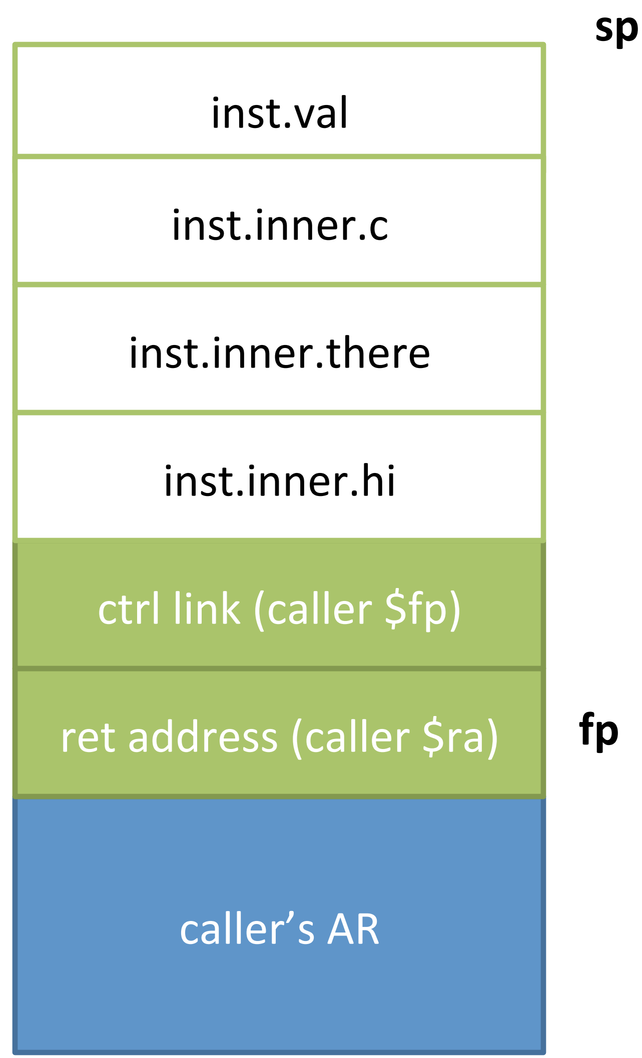
field b.c is -8 off the base

LHS

```
subu $t0 $fp 16
sw $t0 0($sp)
```

RHS

```
lw $t0 -16($fp)
sw $t0 0($sp)
subu $sp $sp 4
```



Control Flow Constructs

Function Calls

Loops

Ifs

We do these next time

Function Call Example

```
int f(int arg1, int arg2){
  return 2;
}
int main(){
  int a;
  a = f(a,4);
}
```

```
li $t0 4            # push arg 2
sw $t0 0($sp)       #
subu $sp $sp 4      #
lw $t0 -8($fp)      # push arg 1
sw $t0 0($sp)       #
subu $sp $sp 4      #
jal f               # goto f
addu $sp $sp 8      # tear down params
sw $v0 -8($fp)      # retrieve result
```

Summary

Today:

– Got the basics of MIPS

– CodeGen for *some* AST node types

Next time:

– Do the rest of the AST nodes

– Introduce control flow graphs

Function Call

Two tasks:

- Put argument *values* on the stack (pass-by-value semantics)
- Jump to the callee preamble label
- Bonus 3rd task: save *live* registers
  - (We don't have any in a stack machine)
- Semi-bonus 4th task: retrieve result value