Programs and Recursion

Class 40

Working with Strings

- QtSpim stores C-strings as bytes within a word
- so to load individual characters from RAM, we want a byte instead of a word
- `lbu` load byte unsigned is specifically provided to make it easy to load one byte of a word location into a register
- because it's unsigned, it's zero-extended for the upper 24 bits

- word addresses (e.g., `lw`) must be even 4-byte values
- but a byte address can be any address in RAM

Example Program

strlen_program.c

Example Program

strlen_program.c

sand: /tmp/strlen_program.s

Recursion

- recursion is a very powerful algorithm design technique
- it is not required; anything that can be computed with recursion can also be computed with iteration instead (and vice versa)
- however, some algorithms are expressed most naturally and easily using recursion

Recursion

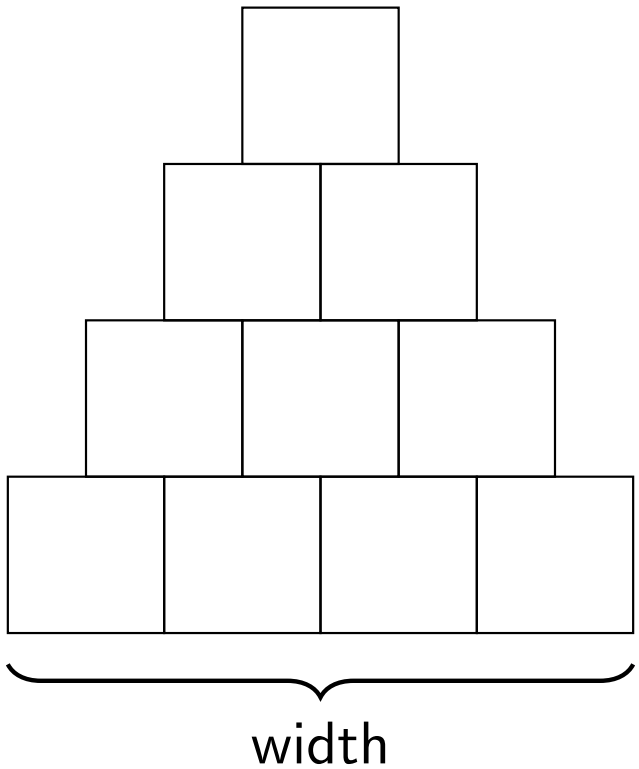
- all recursive algorithms contain the following three elements:
  1. tests and results for one or more base cases
  2. one or more actions that are local work
  3. one or more recursive calls

Recursive Calls

- a recursive function must have at least one parameter
- the value of the actual parameter must differ in subsequent recursive calls
- the value of the actual parameter must make progress toward a base case

Pyramid

- suppose we have a pyramid composed of unit squares
- we know only the width of the base
- we wish to compute the surface area



Thinking Recursively

- this is expressed very easily using recursion

- the area of a pyramid of width zero is zero (base case)
- the widths of two adjacent rows differ by one (recursive case)
- the area of one row is simply its width (local work)

Pyramid

```
 1  unsigned get_area(unsigned width)
 2  {
 3    unsigned result;
 4
 5    if (width == 0)
 6    {
 7      return 0;
 8    }
 9
10    result = get_area(width - 1);
11
12    return result + width;
13  }
```

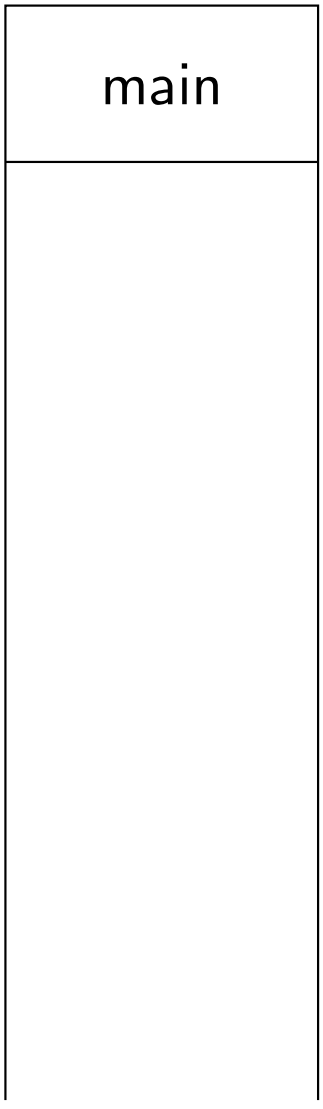
Pyramid in Assembly

see code

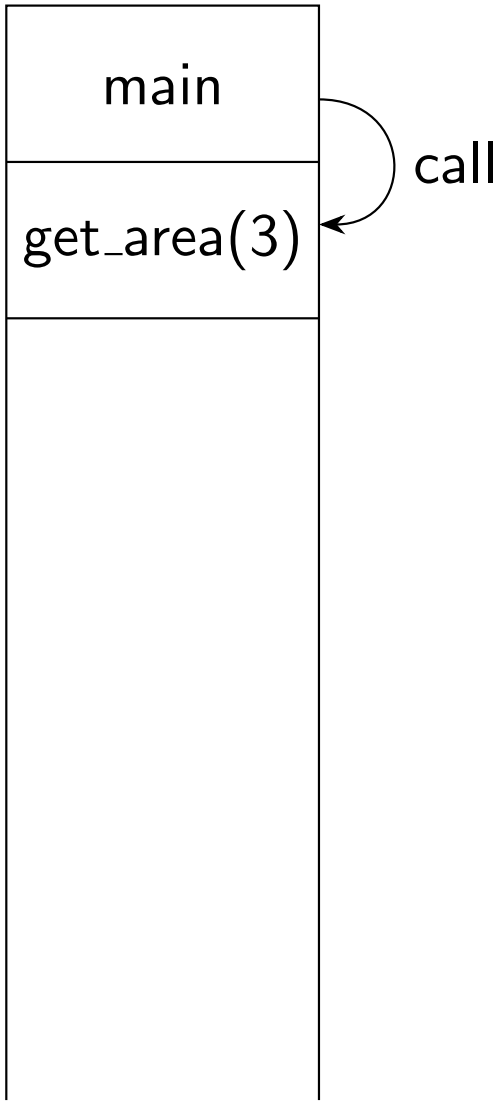
The Stack

- to appreciate recursion, we must consider the stack
- recursion is impossible without a stack

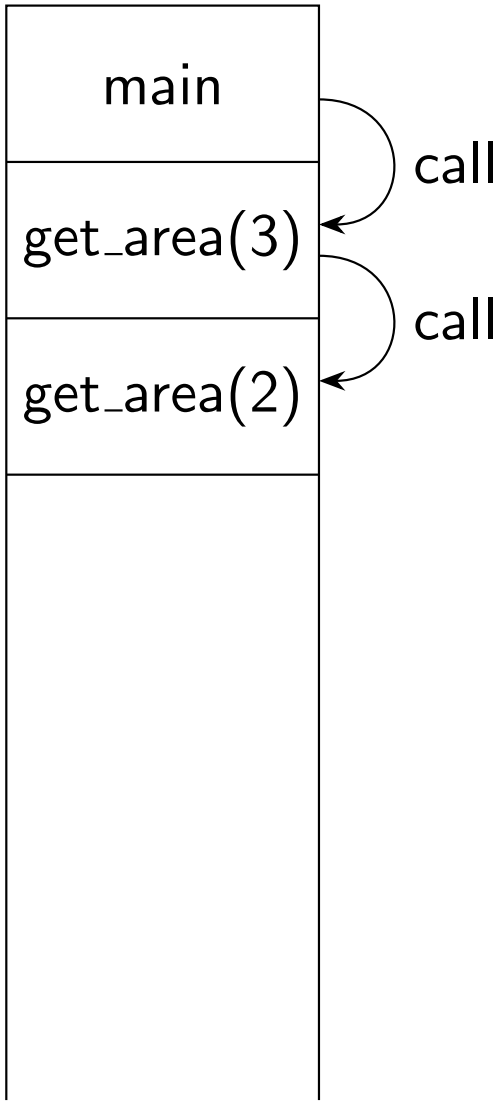
The Stack



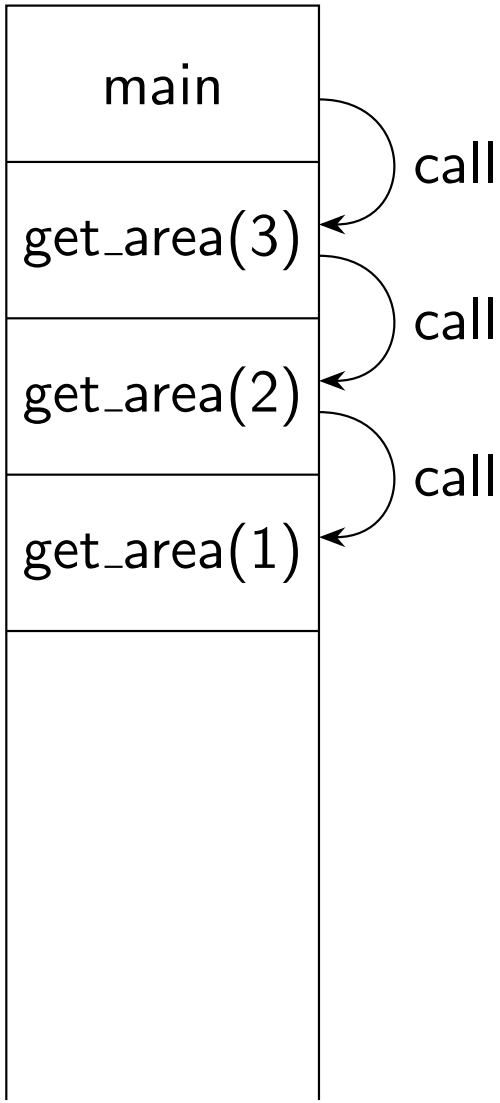
The Stack



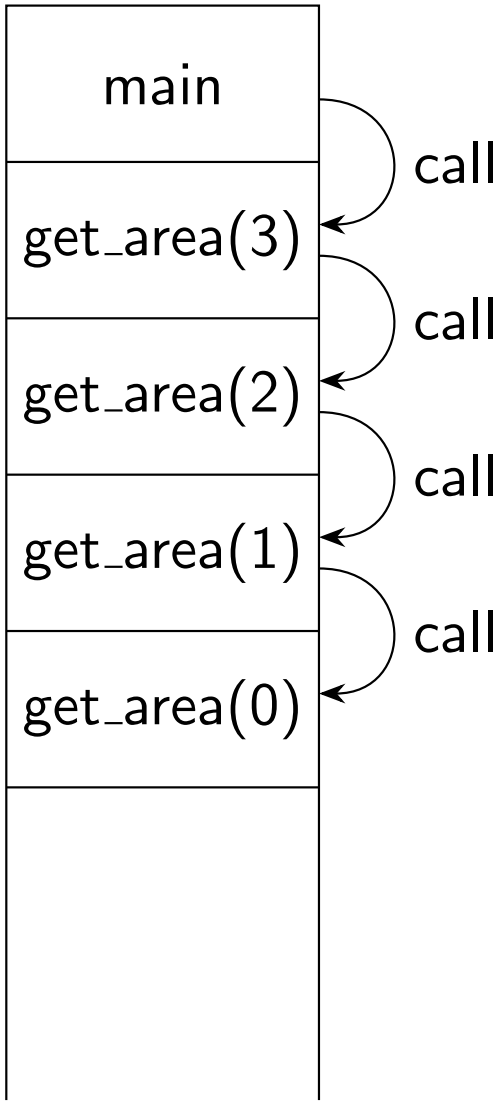
The Stack



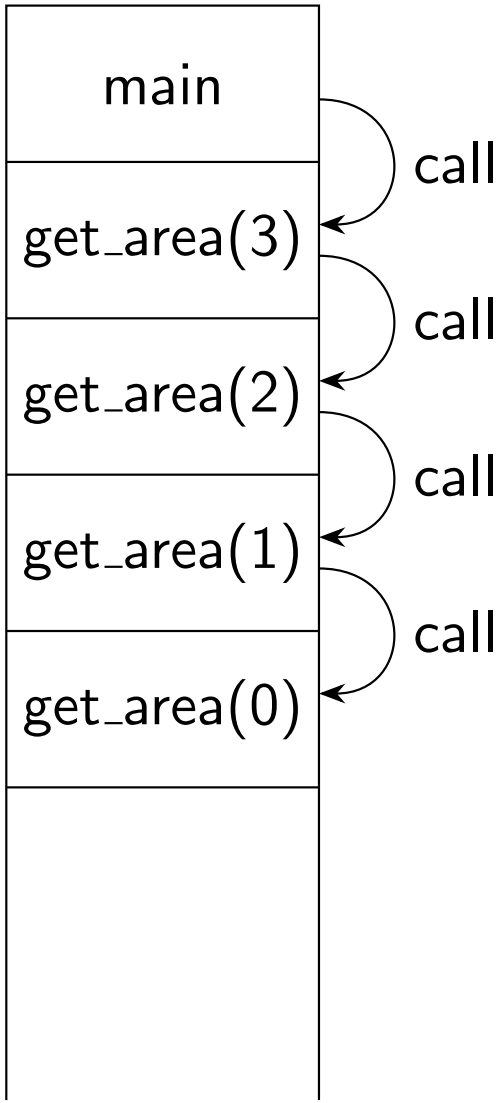
The Stack

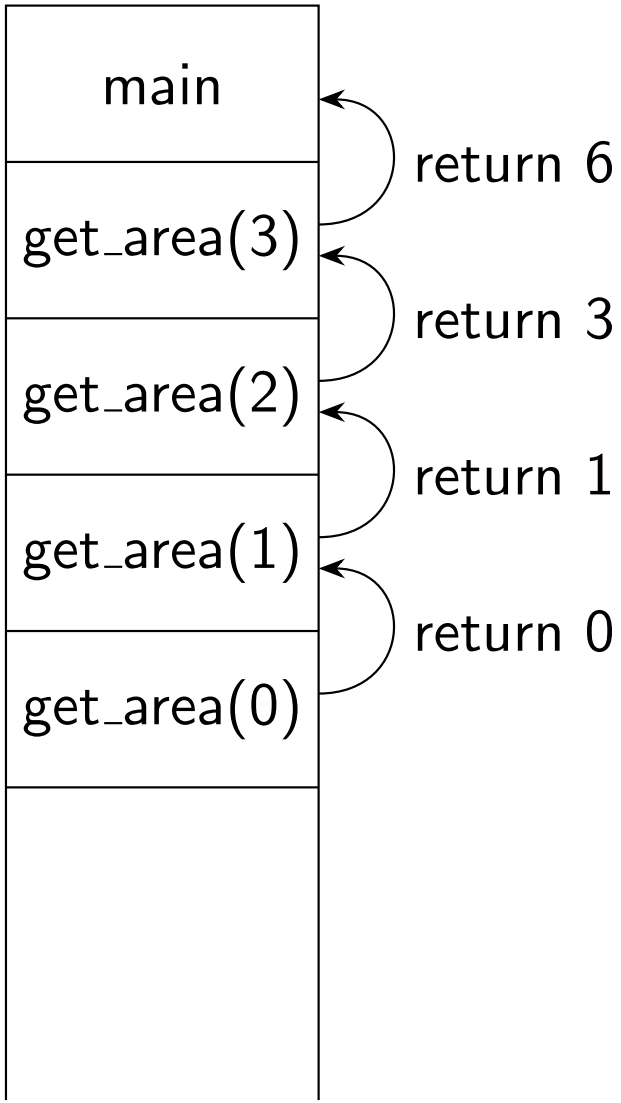


The Stack


main
get_area(3)
get_area(2)
get_area(1)
get_area(0)
call
call
call
call

The Stack


main
get_area(3)
get_area(2)
get_area(1)
get_area(0)
call
call
call
call


main
get_area(3)
get_area(2)
get_area(1)
get_area(0)
return 6
return 3
return 1
return 0

Palindrome

- a palindrome is a phrase which reads the same backwards and forwards
- in the simple case, no spaces, punctuation, or case
- in general, spaces, punctuation, and case are ignored

Madam, I'm Adam