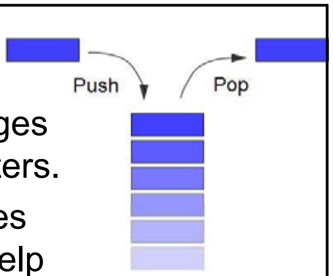
Assembler Functions

COMP375 Computer Architecture
and Organization

Goals

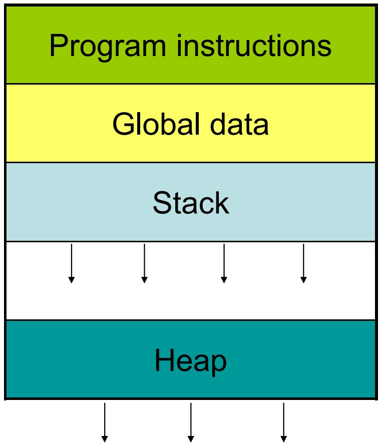
- Understand how function calls are implemented.

Stacks

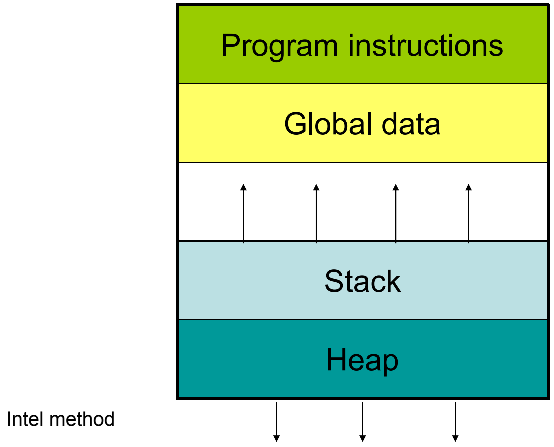


- Many programming languages use stacks to pass parameters.
- Many computer architectures have stack instructions to help implement these programming languages.
- Most architectures have stack pointer register. The stack pointer always points to the top item on the stack.

Program Memory Organization



Program Memory Organization



Pushing and Popping

- A **PUSH** copies the value of a register onto the top of the stack.
  - Decrement the stack pointer
  - Store the register at the address pointed to by the stack pointer.
- A **POP** remove the value on the top of stack and put it in a register.
  - Load the value pointed to by the stack pointer into the register
  - Increment the stack pointer

Push Example

```
// preserve edx and ecx so previous code is
// not disrupted
   push        edx
   push        ecx
// do something using edx and ecx
   pop         ecx
   pop         edx
```

Intel PUSHA and POPA

- The **PUSHA** instruction pushes the contents of all eight of the registers on the stack. *(push all)*.
- The **POPA** instruction pops seven values from the stack and places the values in the registers (in reverse order of PUSHA).
- These instructions provide a quick way to save the state upon function entry.

Function Call Hardware

- All computers have machine language instructions to support function calls.
- The level of hardware support varies with modern computers providing more support.

Intel Call instruction

- The **`CALL`** instruction basically pushes the program counter on the stack and branches to a new location.
- There are many versions of the Intel **`CALL`** instruction to support different addressing modes and changes in privileges.

Intel RET instruction

- The **`RET`** or return instruction pops a value from the stack and places it in the program counter register.
- Since the program counter contains the address of the next instruction to execute, this has the effect of branching back to the calling program.

Steps to perform a function call

- Compute any equations used in the parameters, such as `x=func(a + b);`
- Push the parameter values on the stack.
- Execute a call instruction to push the return address on the stack and start execution at the first address of the function.

Upon function entry

- Store the contents of the registers
- Increase the stack pointer to reserve memory for the local variable.
- Start executing the function code.

Upon function exit

- Reduce the stack by the size of the local variable.
- Pop the register values.
- Execute the return instruction to pop the address from the stack into the program counter.

Example Function Call

- Consider the function

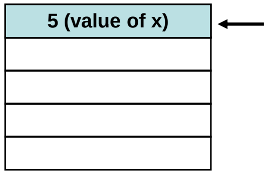
```
    void thefunc( float &b, int a ){
        int r = a;
    }
```

- that is called by the main program

```
int x = 5;
float  y = 7.0;
float *w = &y;
thefunc( w, x );
```

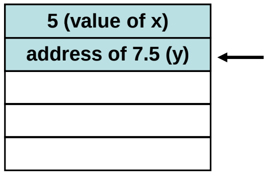
Stack for Call

- push x



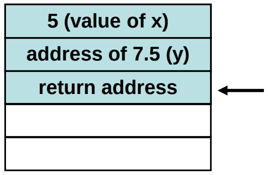
Stack for Call

- push x
- push w


5 (value of x)
address of 7.5 (y)

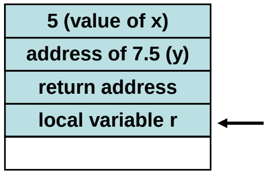
Stack for Call

- push x
- push w
- call thefunc


5 (value of x)
address of 7.5 (y)
return address

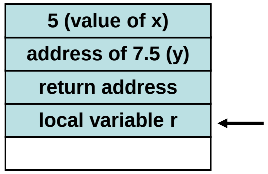
Stack Use by Function

- push x
- push w
- call **thefunc**
- increment stack


5 (value of x)
address of 7.5 (y)
return address
local variable r

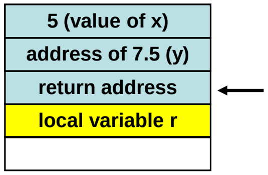
Stack for Call

- push x
- push w
- call **thefunc**
- increment stack
- get R1,12[sp] // param a


5 (value of x)
address of 7.5 (y)
return address
local variable r

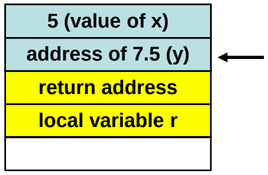
Stack for Return

- push x
- push w
- call **thefunc**
- increment stack
- get R1,12[sp] // param a
- decrement stack



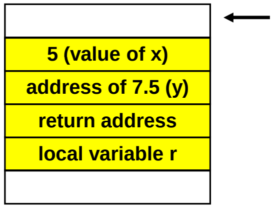
Stack for Return

- push x
- push w
- call **thefunc**
- increment stack
- get R1,12[sp] // param a
- decrement stack
- return



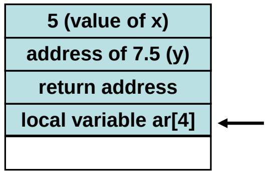
Cleanup Stack

- push x
- push w
- call **thefunc**
- increment stack
- get R1,12[sp] // param a
- decrement stack
- return
- decrement stack by 2



Stack Overflow Attack

- A common security attack is to cause a program to overflow the stack.
- If the program stores a value into ar[4], it will right in the data past ar, the return address.
- Instructions might be loaded in the rest of the stack.



Stack Protection

- Good programs should check all parameters to ensure values are within range.
- Some processors prohibit instructions from being fetched from the stack.

---

020 sub1 *whatever*
…
030 ret
…

100 call sub1
102 *something*

508	
SP → 504	

Stack pointer	504
Program Counter	100

---

020 sub1 *whatever*
…
030 ret
…

100 call sub1
102 *something*

508	
504	
SP → 500	102

Stack pointer	500
Program Counter	020

---

020 sub1 *whatever*
…
030 ret
…

100 call sub1
102 *something*

508	
504	
SP → 500	102

Stack pointer	500
Program Counter	022

```
020 sub1  whatever
          …
030       ret
          …

100       call sub1
102       something
```

508	
SP → 504	
	102

Stack pointer	504
Program Counter	102

Passing Parameters

- Pass by value parameters can be pushed on the stack before calling the function.
- Parameters are usually pushed in a right to left order. The left most parameter is then on top.
- The function can access them using an offset from the stack pointer.
- The stack must be popped or incremented upon return from the function.

`sub1( x, y )`

```
020 sub1  mov  eax,4[esp]
          …
030       ret
          …
100       mov   eax, y
104       push  eax
106       mov   eax, x
10A       push  eax
10C       call  sub1
110       add   esp,8
```

SP → 50C	
508	
504	
500	

x	17
y	43

Stack pointer	50C
Program Counter	100

`sub1( x, y )`

```
020 sub1  mov  eax,4[esp]
          …
030       ret
          …
100       mov   eax, y
104       push  eax
106       mov   eax, x
10A       push  eax
10C       call  sub1
110       add   esp,8
```

SP → 50C	
508	
504	
500	

x	17
y	43

Stack pointer	50C
Program Counter	104

sub1(x, y)

```
020 sub1 mov  eax,4[esp]
         …
030      ret
         …
100      mov   eax, y
104      push  eax
106      mov   eax, x
10A      push  eax
10C      call   sub1
110      add   esp,8
```

	50C	
SP →	508	43
	504	
	500	

x	17
y	43

Stack pointer	508
Program Counter	106

---

sub1(x, y)

```
020 sub1 mov  eax,4[esp]
         …
030      ret
         …
100      mov   eax, y
104      push  eax
106      mov   eax, x
10A      push  eax
10C      call   sub1
110      add   esp,8
```

	50C	
SP →	508	43
	504	
	500	

x	17
y	43

Stack pointer	508
Program Counter	10A

---

sub1(x, y)

```
020 sub1 mov  eax,4[esp]
         …
030      ret
         …
100      mov   eax, y
104      push  eax
106      mov   eax, x
10A      push  eax
10C      call   sub1
110      add   esp,8
```

	50C	
	508	43
SP →	504	17
	500	

x	17
y	43

Stack pointer	504
Program Counter	10C

---

sub1(x, y)

```
020 sub1 mov  eax,4[esp]
         …
030      ret
         …
100      mov   eax, y
104      push  eax
106      mov   eax, x
10A      push  eax
10C      call   sub1
110      add   esp,8
```

	50C	
	508	43
	504	17
SP →	500	110

x	17
y	43

Stack pointer	500
Program Counter	020

sub1(x, y)

```
020 sub1  mov   eax,4[esp]
          …
030       ret
          …
100       mov   eax, y
104       push  eax
106       mov   eax, x
10A       push  eax
10C       call  sub1
110       add   esp,8
```

	50C	
	508	43
	504	17
SP →	500	110

x	17
y	43

Stack pointer	500
Program Counter	024

---

sub1(x, y)

```
020 sub1  mov   eax,4[esp]
          …
030       ret
          …
100       mov   eax, y
104       push  eax
106       mov   eax, x
10A       push  eax
10C       call  sub1
110       add   esp,8
```

	50C	
	508	43
SP →	504	17
	500	110

x	17
y	43

Stack pointer	504
Program Counter	110

---

sub1(x, y)

```
020 sub1  mov   eax,4[esp]
          …
030       ret
          …
100       mov   eax, y
104       push  eax
106       mov   eax, x
10A       push  eax
10C       call  sub1
110       add   esp,8
```

SP →	50C	
	508	43
	504	17
	500	110

x	17
y	43

Stack pointer	50C
Program Counter	112

Returning Function Results

- Simple return types *(i.e. int, char, address, etc.)* are returned in the eax register.
- For more complex data types *(i.e. objects, arrays)* the return value is in memory and the eax register contains the address of the returned value.

Local Variables

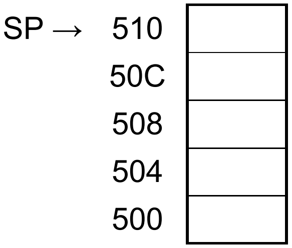
- Local variables (sometimes called automatic variable) are those allocated within a function.
- Local variable are allocated on the stack.
- When a function returns, the stack space is available for other functions.

Example

```
void sub1( int x ) {
  int  a;
  int  b;
  …
  return;
}
int main( ) {
  int x = 17;
  sub1( x );
}
```

`sub1( x )`

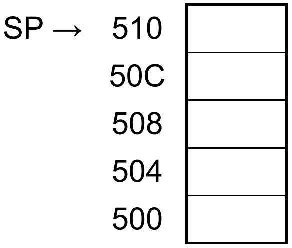
```
020 sub1  mov  eax,-4[esp]
               …
030            ret
               …
100            mov   eax, x
104            push  eax
106            call  sub1
10A            add   esp,4
```



Stack pointer	510
Program Counter	100

`sub1( x )`

```
020 sub1  mov  eax,-4[esp]
               …
030            ret
               …
100            mov   eax, x
104            push  eax
106            call  sub1
10A            add   esp,4
```



Stack pointer	510
Program Counter	104

sub1(x)

```
020 sub1  mov  eax,-4[esp]
          …
030       ret
          …
100       mov   eax, x
104       push  eax
106       call  sub1
10A       add   esp,4
```

	510	
SP →	50C	17
	508	
	504	
	500	

Stack pointer	50C
Program Counter	106

sub1(x)

```
020 sub1  mov  eax,-4[esp]
          …
030       ret
          …
100       mov   eax, x
104       push  eax
106       call  sub1
10A       add   esp,4
```

	510	
	50C	17
SP →	508	10A
	504	
	500	

Stack pointer	508
Program Counter	020

sub1(x)

```
020 sub1  mov  eax,-4[esp]
          …
030       ret
          …
100       mov   eax, x
104       push  eax
106       call  sub1
10A       add   esp,4
```

	510	
	50C	17
SP →	508	10A
	504	a
	500	b

Stack pointer	508
Program Counter	023

sub1(x)

```
020 sub1  mov  eax,-4[esp]
          …
030       ret
          …
100       mov   eax, x
104       push  eax
106       call  sub1
10A       add   esp,4
```

	510	
SP →	50C	17
	508	10A
	504	a
	500	b

Stack pointer	50C
Program Counter	10A

`sub1( x )`

```
020 sub1  mov  eax,-4[esp]
          …
030       ret
          …
100       mov   eax, x
104       push  eax
106       call   sub1
10A       add    esp,4
```

SP →	510	
	50C	17
	508	10A
	504	a
	500	b

Stack pointer	510
Program Counter	10C