Computer Systems Organisation (CS2.201)

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21 June, Monday (Lecture 12) – Procedures

Taught by Prof. Avinash Sharma

Procedures

A procedure call involves passing control as well as data (parameters and return values) from one part of a program to another. This is handled by manipulating the stack. Local variables of the procedure also need to be allocated space.

Stack Frames

The stack frame (or activation record) is the collection of all data on the stack associated with one function call. It generally includes

- the return address
- argument variables
- local variables
- saved copies of registers modified by the function that need to be restored.

A local variable that cannot be stored in the registers is stored in the stack. This can occur because:

- there are not enough registers
- some of the local variables are arrays or structures
- `&` is applied to the variable and therefore it must have an address

The caller function also stores the arguments of the callee in the stack (in the argument build area).

The end of the caller's frame is the return address of the callee, and the callee's frame starts with the saved value of the frame pointer.

However, in x86-64, only the 7th argument onwards is stored in the argument build area. The other aspects of stack composition are similar to IA32.

Transferring Control

The `call` instruction simply pushes the return address on the stack and jumps to the start of the callee. The `ret` instruction pops an address off the stack and jumps to that instruction.

Register Usage Conventions

The callee is free to overwrite the `%eax`, `%ecx` and `%edx` registers (caller-save registers), since they are stored by the caller.

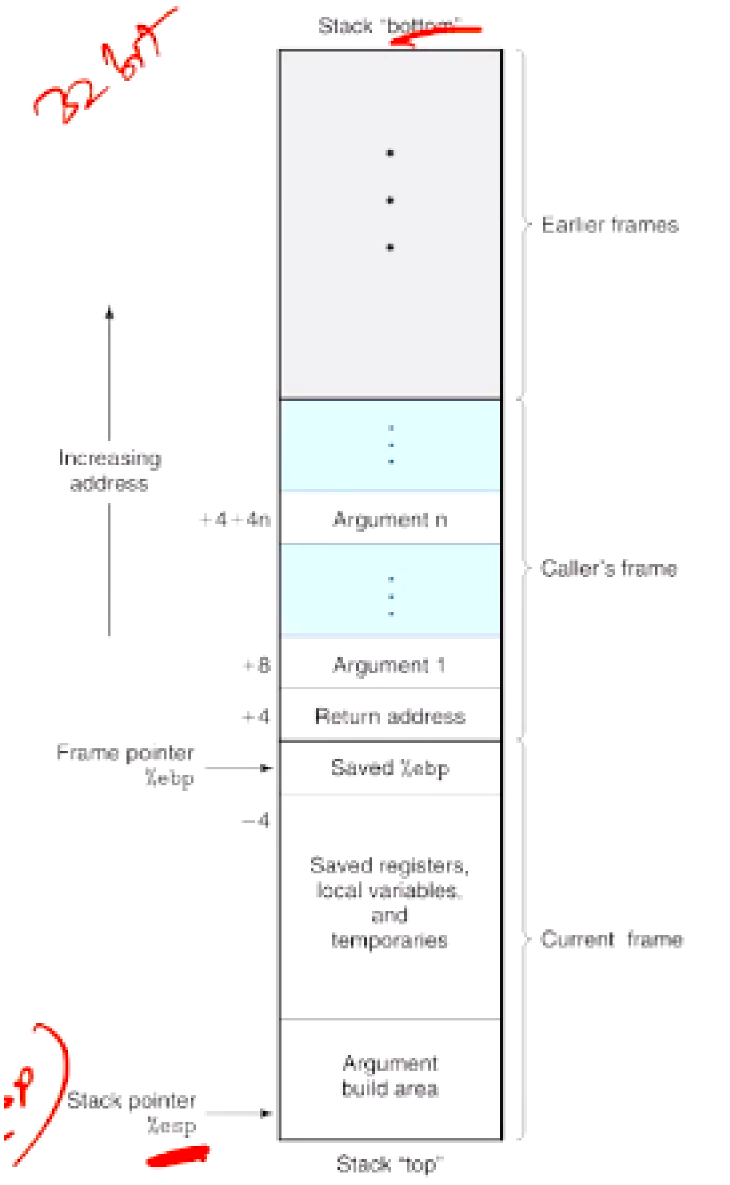


Figure 1: Stack Frames in IA32

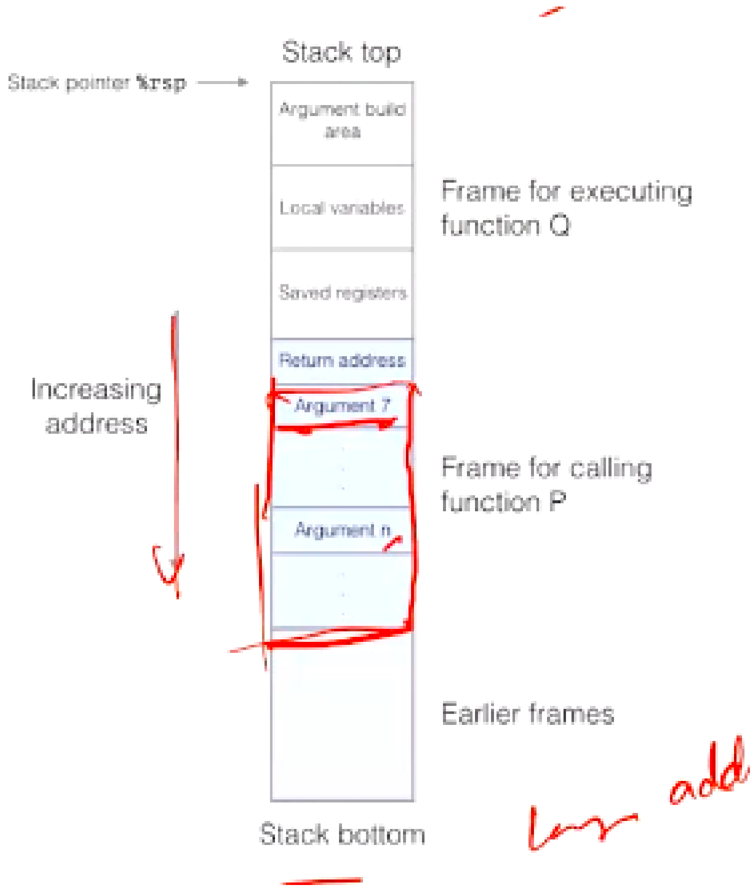
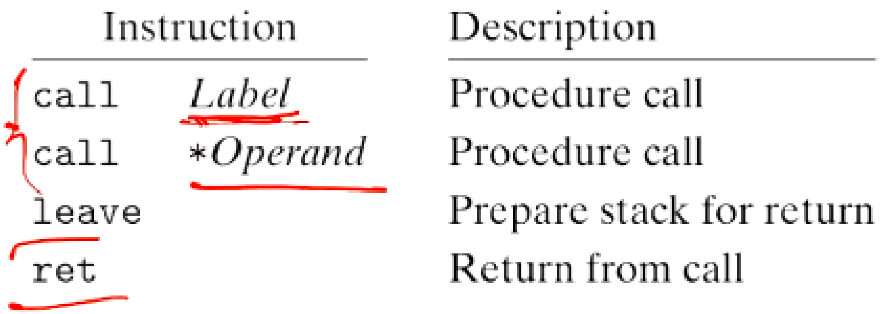


Figure 2: Stack Frames in x86-64



Instruction		Description
call	*Label*	Procedure call
call	**Operand*	Procedure call
leave		Prepare stack for return
ret		Return from call

Figure 3: Control Transfer

However, the callee must store the values of `%ebx`, `%esi` and `%edi` (callee-save registers) before modifying them, because the caller does not store these.

Consider the function

```
int P(int x)
{
int y = x*x;
int z = Q(y);
return y+z;
}
```

`y` must survive after calling Q as well. Therefore P can store `y` either in its own stack frame before calling Q, or in a callee-save register.

Consider the functions

```
int swap_add(int *xp, int *yp)
{
    int x = *xp;
    int y = *yp;
    *xp = y;
    *yp = x;
    return x + y;
}

int caller()
{
    int arg1 = 534;
    int arg2 = 1057;
    int sum = swap_add(&arg1, &arg2);
    int diff = arg1 - arg2;
    return sum * diff;
}
```

The relevant states of the stack are

and the equivalent assembly code is

```
caller:
  push1 %ebp
  movl %esp, %ebp
  subl $24, %esp
  movl %34, -4(%ebp)
  movl $1057, -8(%ebp)
  leal -8(%ebp), %eax
  movl %eax, 4(%esp)
  leal -4(%ebp), %eax
  movl %eax, (%esp)
  call swap_add
```

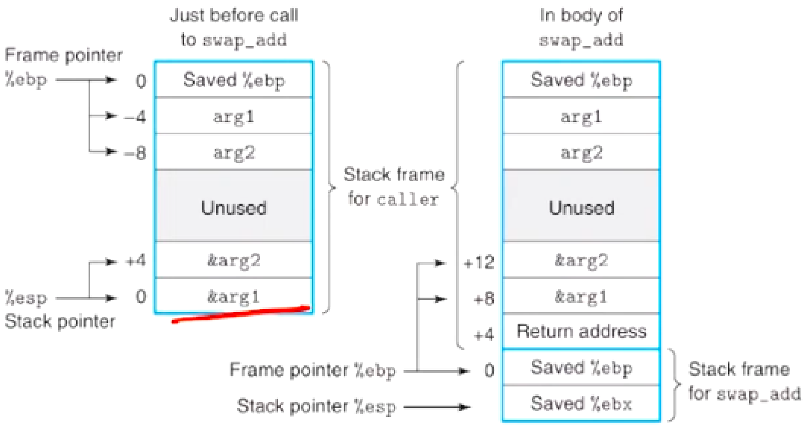


Figure 4: Stack

```
swap_add:
  push1 %ebp
  movl %esp, %ebp
  pushl %ebx
  movl 8(%ebp), %edx
  movl 12(%ebp), %ecx
  movl (%edx), %ebx
  movl (%ecx), %eax
  movl %eax, (%edx)
  movl %ebx, (%ecx)
  addl %ebx, %eax
  popl %ebx
  popl %ebp
  ret
```