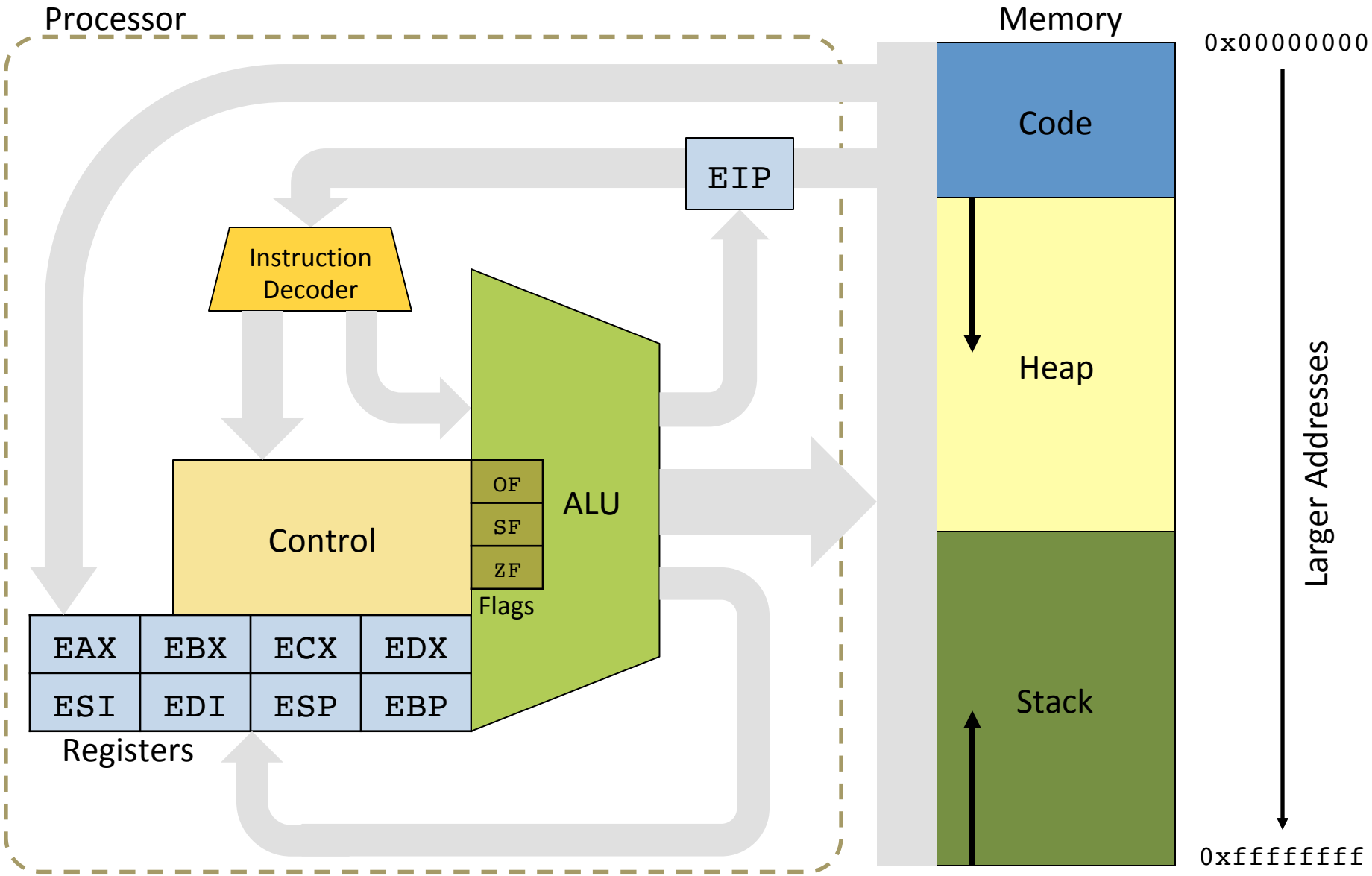
Lecture 4

CIS 341: COMPILERS

CIS 341 Announcements

- HW2: X86lite
  - Available on the course web pages.
  - Due: Weds. Feb. 7th at midnight
  - Pair-programming project

X86 Schematic

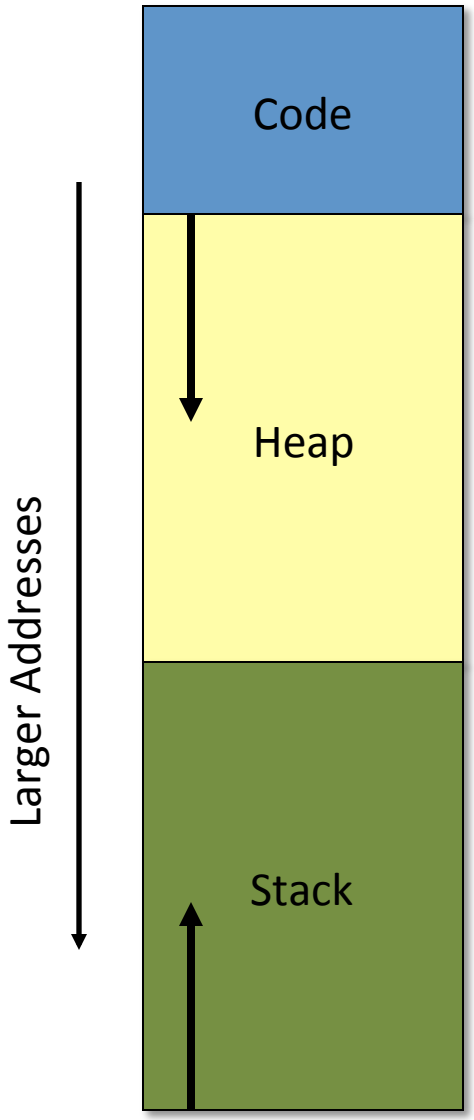


PROGRAMMING IN X86LITE

3 parts of the C memory model

- The code & data (or "text") segment
  - contains compiled code, constant strings, etc.
- The Heap
  - Stores dynamically allocated objects
  - Allocated via "malloc"
  - Deallocated via "free"
  - C runtime system
- The Stack
  - Stores local variables
  - Stores the return address of a function

- In practice, most languages use this model.



Local/Temporary Variable Storage

- Need space to store:
  - Global variables
  - Values passed as arguments to procedures
  - Local variables (either defined in the source program or introduced by the compiler)

- Processors provide two options
  - Registers: fast, small size (32 or 64 bits), very limited number
  - Memory: slow, very large amount of space (2 GB)
    - caching important

- In practice on X86:
  - Registers are limited (and have restrictions)
  - Divide memory into regions including the *stack* and the *heap*

Calling Conventions

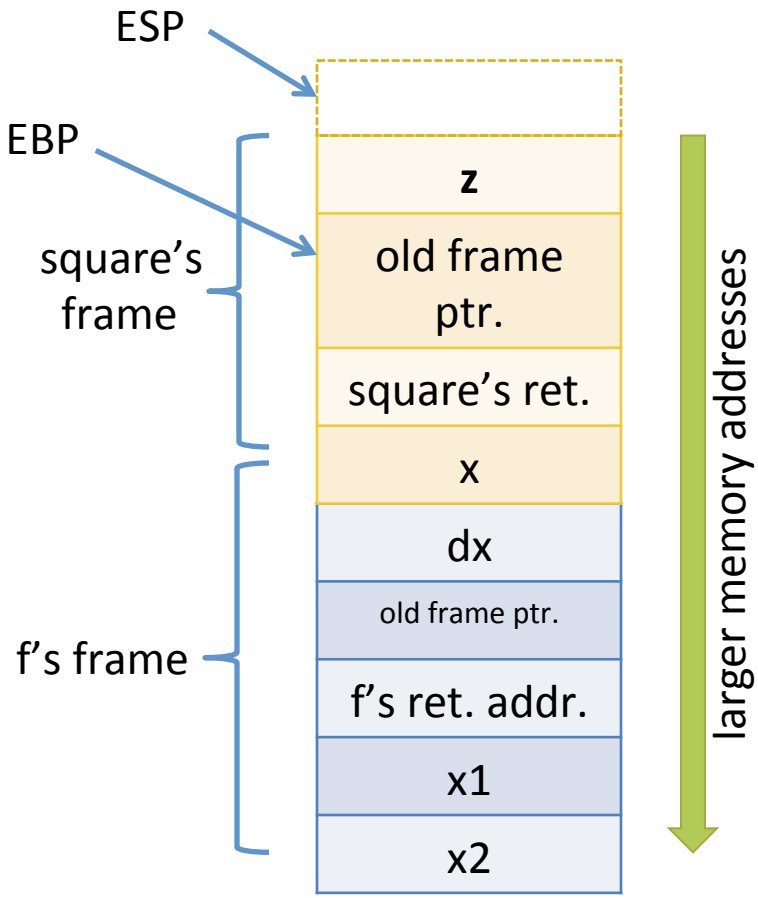
- Specify the locations (e.g. register or stack) of arguments passed to a function and returned by the function
- Designate registers either:
  - Caller Save – e.g. freely usable by the called code
  - Callee Save – e.g. must be restored by the called code
- Define the protocol for deallocating stack-allocated arguments
  - Caller cleans up
  - Callee cleans up (makes variable arguments harder)

32-bit cdecl calling conventions

- "Standard" on X86 for many C-based operating systems (i.e. almost all)
  - Still some wrinkles about return values (e.g. some compilers use `EAX` and `EDX` to return small values)
  - 64 bit allows for packing multiple values in one register
- Arguments are passed on the stack in right-to-left order
- Return value is passed in `EAX`
- Registers `EAX`, `ECX`, `EDX` are caller save
- Other registers are callee save
  - Ignoring these conventions will cause havoc (bus errors or seg faults)

Call Stacks: Example

- Use a stack to keep track of the return addresses:
  - `f` calls `g`, `g` calls `h`
  - `h` returns to `g`, `g` returns to `f`
- Stack frame:
  - Functions arguments
  - Local variable storage
  - Return address
  - Link (or "frame") pointer



Call Stacks: Caller's protocol

- Function call:

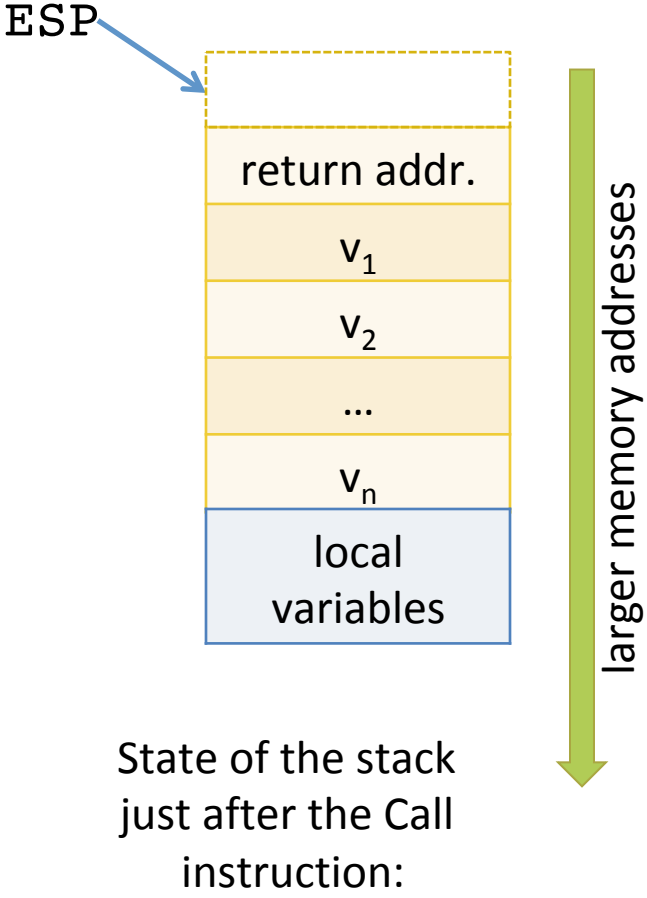
  `f(`e_1`, `e_2`, …, `e_n`);`

1. Save caller-save registers
2. Evaluate e_1 to v_1, e_2 to v_2, … , e_n to v_n
3. Push v_n to v_1 onto the top of the stack.
4. Use `Call` to jump to the code for `f`
   - pushing the return address onto the stack.

- Invariant: returned value passed in `EAX`

- After call:

1. clean up the pushed arguments by popping the stack.
2. Restore caller-saved registers



State of the stack just after the Call instruction:

Call Stacks: Callee's protocol

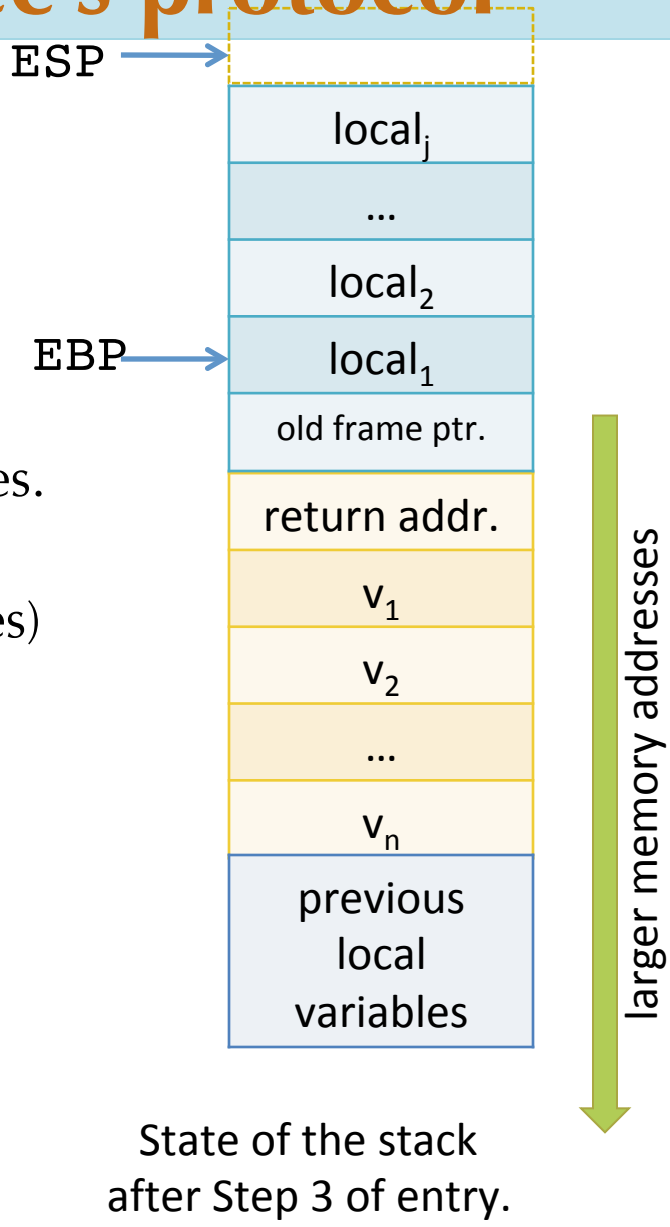
- On entry:

1. Save old frame pointer
   - EBP is callee save
2. Create new frame pointer
   - Mov(Esp, Ebp)
3. Allocate stack space for local variables.

- Invariants: (assuming word-size values)
  - Function argument n is located at:
    EBP + (1 + n) * 4
  - Local variable j is located at:
    EBP – j * 4

- On exit:

1. Pop local storage
2. Restore EBP



State of the stack after Step 3 of entry.

X86-64 SYSTEM V AMD 64 ABI

- More modern variant of C calling conventions
  - used on Linux, Solaris, BSD, OS X

- Callee save: `rbp, rbx, r12-r15`
- Caller save: all others

- Parameters 1 .. 6 go in: `rdi, rsi, rdx, rcx, r8, r9`
- Parameters 7+ go on the stack (in right-to-left order)
  - so: for n > 6, the nth argument is located at ((n-7)+2)*8 + rbp

- Return value: in `rax`

- 128 byte "red zone" – scratch pad for the callee's data

See: handcoding.ml, runtime.c

DEMO: COMPILING EXPRESSIONS