# CS240 Laboratory 9
## Disassembly and Reverse Engineering

### Memory Layout

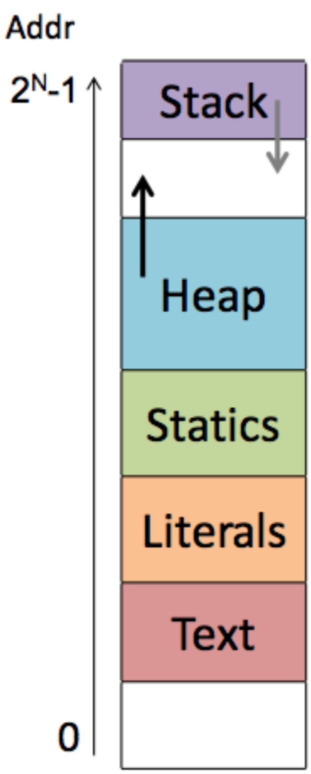
**Kernel**
above 0x7fffffff

**Stack**
below Ox7fffffff
grows down

**Heap**
above Data segment

**Data segment**
statics and literals

**Text segment**
starts at 0x400000




| Perm | Contents | Managed by | Initialized |
|---|---|---|---|
| RW | Procedure context | Compiler | Run-time |
| RW | Dynamic data structures | Programmer, malloc/free, new/GC | Run-time |
| RW | Global variables/ static data structures | Compiler/ Assembler/Linker | Startup |
| R | String literals | Compiler/ Assembler/Linker | Startup |
| X | Instructions | Compiler/ Assembler/Linker | Startup |

# Instructions

## **Moving D**ata

*mov Src,Dest*

Note: the size of the data being referenced is often specified with an additional character:

*b* (byte)
*w* (2 bytes)
*l* (4 bytes), or
*q* (8 bytes).

**Arithmetic/Logical operations** – 2 operands

*add Src,Dest*
*sub Src,Dest*
*imul Src,Dest*

*shr Src,Dest*
*sar Src, Dest*
*shl Src,Dest*
*sal Src, Dest*
*shr Src,Dest*

*xor Src,Dest*
*and Src,Dest*
*or Src,Dest*

*mul* *Src,Dest*
*imul* *Src,Dest*
*div* *Src,Dest*
*idiv* *Src,Dest*

**Arithmetic/Logical operations** – 1 operand

*inc* *Dest*
*del* *Dest*
*neg* *Dest*
*not* *Dest*

**Setting Condition Codes Explicitly** – used for control flow

*cmp* *Src2,Src1* sets flags based on value of Src2 – Src1, discards result
*test* *Src2,Src1* sets flags based on a & b, discards result

# Operand Types

**Immediate** $0x400, $-533

**Register**: %rax,%rbx,%rcx,%rdx,%rsi,%rdi,%rbp,%rsp, %r8,%r9,%r10,%r11,%r12,%r13,%r14,%r15

some have special purpose: **%rsp** is stack pointer, **%rax** always used to return value from functions

**Memory** -0x18(%rsp)

**Most General Form:**

**D(Rb,Ri,S)** **Mem[Reg[Rb] + S*Reg[Ri] + D]**

D: Constant "displacement" value represented in 1, 2, or 4 bytes

Rb: Base register: Any register

Ri: Index register: Any except %esp (or %rsp if 64-bit) ; %ebp unlikely

S: Scale: 1, 2, 4, or 8 (*why these numbers?*)

**Special Cases:** can use any combination of D, Rb, Ri and S

| | | |
|---|---|---|
| **(Rb,Ri)** | **Mem[Reg[Rb]+Reg[Ri]]** | (S=1, D=0) |
| **D(Rb,Ri)** | **Mem[Reg[Rb]+Reg[Ri]+D]** | (S=1) |
| **(Rb,Ri,S)** | **Mem[Reg[Rb]+S*Reg[Ri]]** | (D=0) |

**Control Flow**

Conditional jump instructions in X86 implement the following high-level constructs:

- if (condition) then {...} else {…}
- while (condition) {…}
- do {…} while (condition)
- for (initialization; condition; iterative) {...}

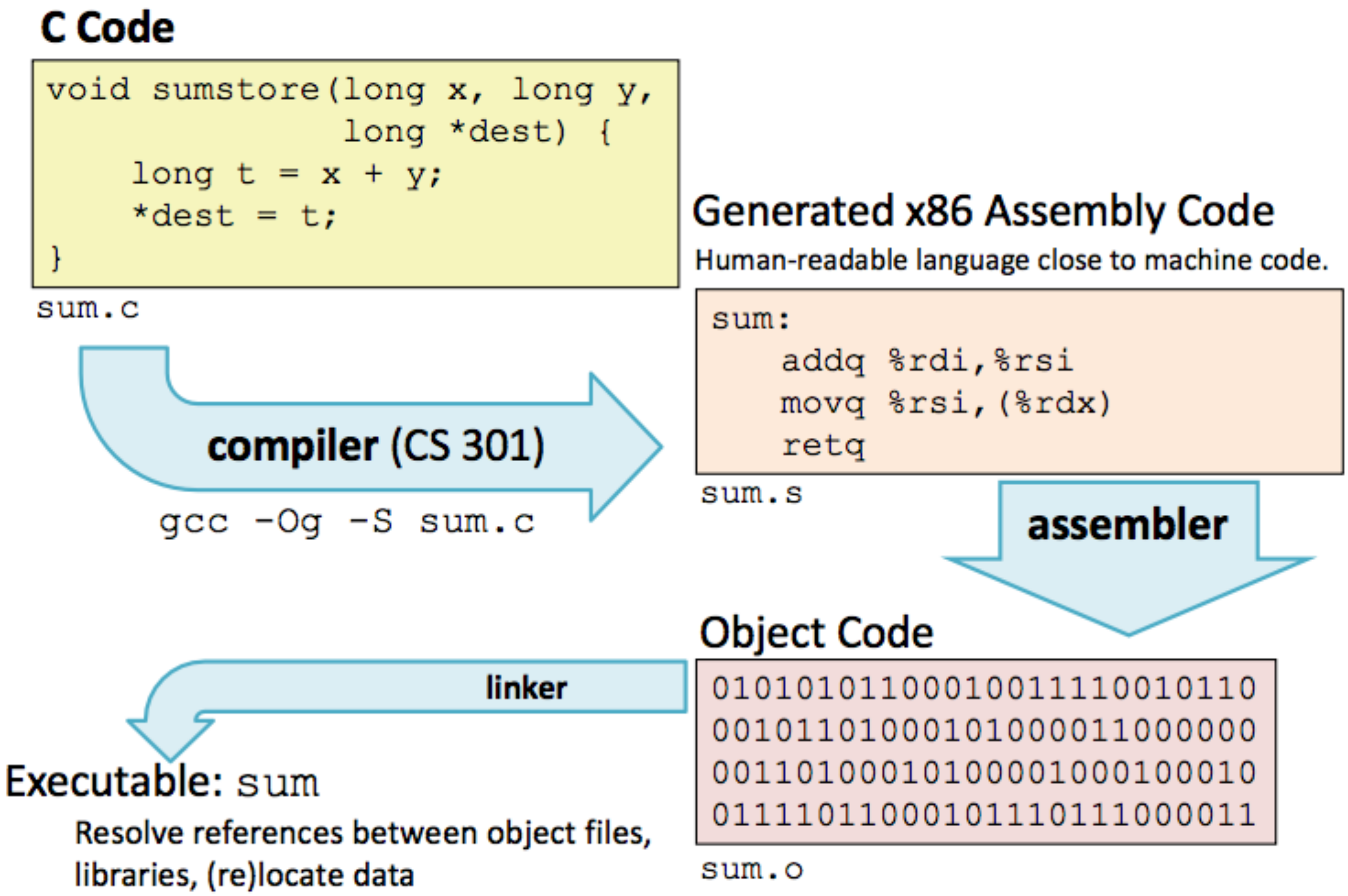
Unconditional jumps are used for high-level constructs such as:

- break
- continue

| jX | Condition | Description |
|---|---|---|
| jmp | 1 | Unconditional |
| je | ZF | Equal / Zero |
| jne | ~ZF | Not Equal / Not Zero |
| js | SF | Negative |
| jns | ~SF | Nonnegative |
| jg | ~(SF^OF)&~ZF | Greater (Signed) |
| jge | ~(SF^OF) | Greater or Equal (Signed) |
| jl | (SF^OF) | Less (Signed) |
| jle | (SF^OF)\|ZF | Less or Equal (Signed) |
| ja | ~CF&~ZF | Above (unsigned) |
| jb | CF | Below (unsigned) |

Jump instructions encode the offset from next instruction to destination PC, instead of the absolute address of the destination (makes it easier to relocate the code)

# Turning C into Machine Code




- X86 instructions can be in different order from C code
- Some C expressions require multiple X86 instructions
- Some X86 instructions can cover multiple C expressions
- Compiler optimization can do some surprising things!
- Local or temporary variables can be stored in registers or on the stack

# Function Calling Conventions

- Arguments for functions are stored in registers, in the following order: arg1 – arg6: %rdi,%rsi,%rdx,%rcx,%r8,%r9
- If there are more than 6 parameters for a function, the rest of the arguments are stored on the stack before the function is called
- Return value from function is always in %rax

The compiler will use only part of a register if the value stored there will fit in less than 64 bits (8 bytes). This is an optimization that makes instructions a bit shorter.

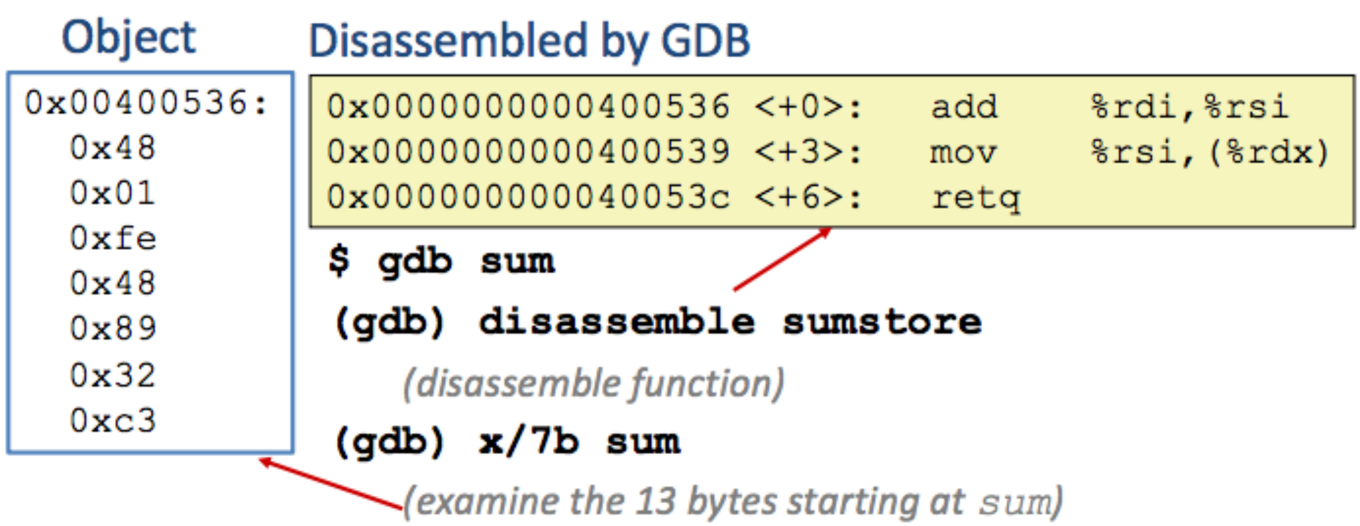
So, in the code, you may see register names of the following form, all of which refer to %rax:

%**r**ax = 8 byte value
%**e**ax = 4 byte value
%ax = 2 byte value
%al = 1 byte value

# Tools

Tools can be used to examine bytes of object code (executable program) and reconstruct (reverse engineer) the assembly source.

**gdb** – disassembles an executable file into the associated assembly language representation, and provides tools for memory and register examination, single step execution, breakpoints, etc.




**objdump**

can also be used to disassemble and display information

$ *objdump –t p*

Prints out the program's symbol table. The symbol table includes the names of all functions and global variables, the names of all the functions the called, and their addresses.

$ *objdump -d p*

| **Object Code** | **Disassembled version** |
|---|---|
| 0x401040 <sum>: | 00401040 <_sum>: |
| 0x55 | 0: 55 push %ebp |
| 0x89 | 1: 89 e5 mov %esp,%ebp |
| 0xe5 | 3: 8b 45 0c mov 0xc(%ebp),%eax |
| 0x8b | 6: 03 45 08 add 0x8(%ebp),%eax |
| 0x45 | 9: 89 ec mov %ebp,%esp |
| 0x0c | b: 5d pop %ebp |
| 0x03 | c: c3 ret |
| 0x45 | |
| 0x08 | |
| 0x89 | |
| 0xec | |
| 0x5d | |
| 0xc3 | |

## strings

$ *strings –t x p*

Displays the printable strings in your program.