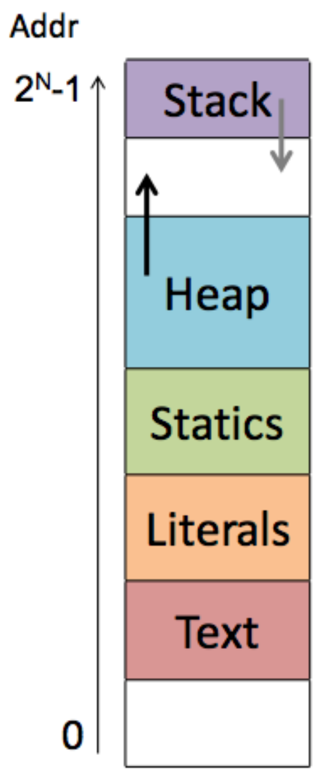
CS240 Laboratory 7
Disassembly and Reverse Engineering

Memory Layout



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

Text Segment
Program instructions can be stored starting at 0x400000 in memory
Grows up into higher addresses in memory with longer programs.

Stack Segment
Top of stack is initially 0x7fffffffff ($2^{47} - 1$).
Grows down into lower addresses in memory as stack fills.

When examining X86 code, addresses or numbers used as displacements or pointers/addresses will have values in the range of the text or stack segments.

Instructions

Moving Data

movl Src,Dest

Load Effective Address - compute address or arithmetic expression of the form x + k*I **(**does not set the condition flags!)

leal Src,Dest

Arithmetic/Logical operations – 2 operands

addl Src,Dest
subl Src,Dest
imull Src,Dest
shrl Src,Dest
sarl Src, Dest
shll Src,Dest
sall Src, Dest
shrl Src,Dest

xorl Src,Dest
andl Src,Dest
orl Src,Dest

mull Src,Dest
imull Src,Dest
divl Src,Dest
idivl Src,Dest

Arithmetic/Logical operations – 1 operand

incl Dest
decl Dest
negl Dest
notl Dest

Zero Extend from Byte to Quad Word

movzbq Src,Dest

Setting Condition Codes Explicitly – used for control flow

cmpl/cmpq Src2,Src1	sets flags based on value of Src2 – Src1, discards result
testl/testq Src2,Src1	sets flags based on a & b, discards result

Operand Types

Immediate

$0x400, $-533

Register: 16 general purpose

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

Memory:

(%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:

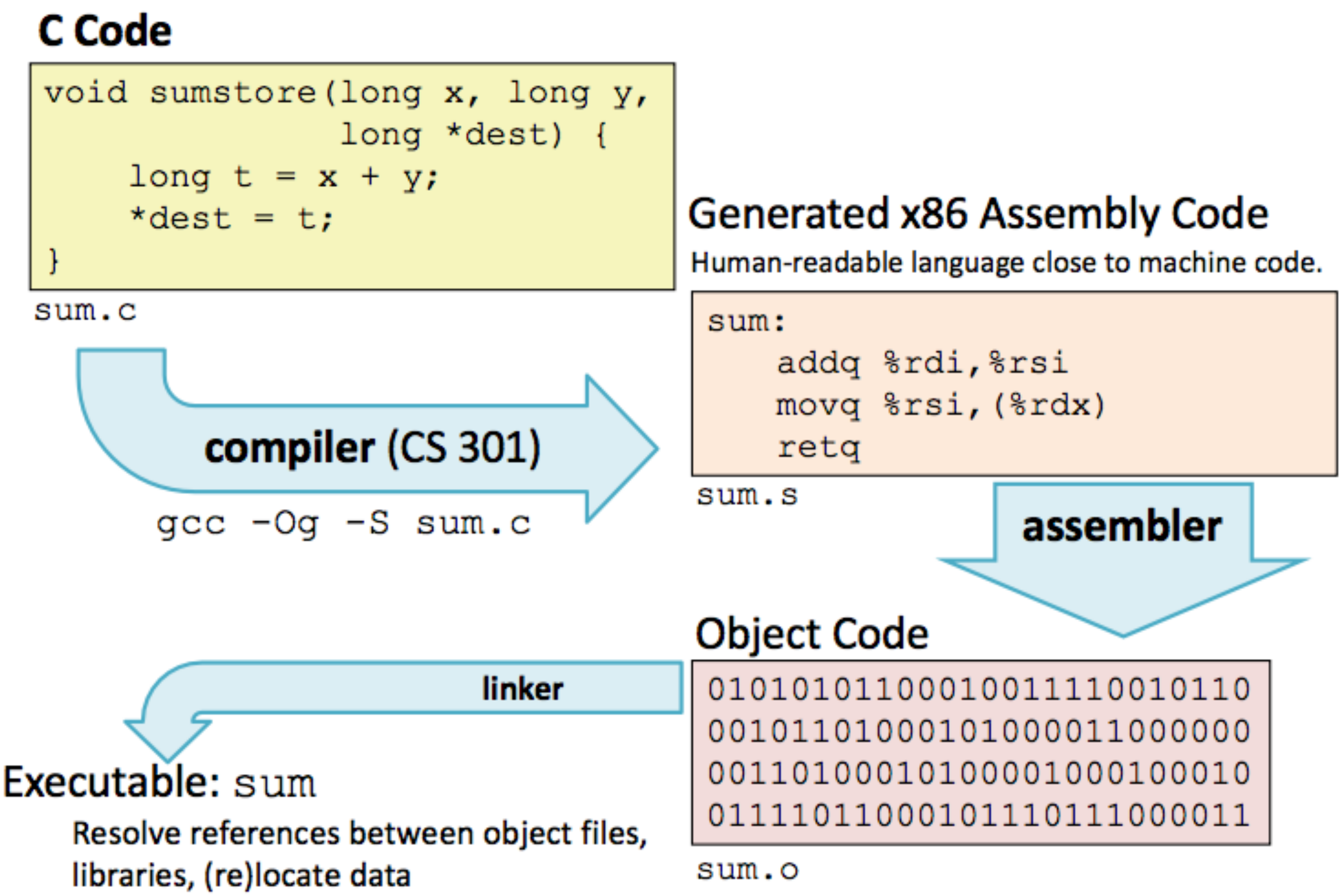
- break
- continue

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)

PC-relative Addressing

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

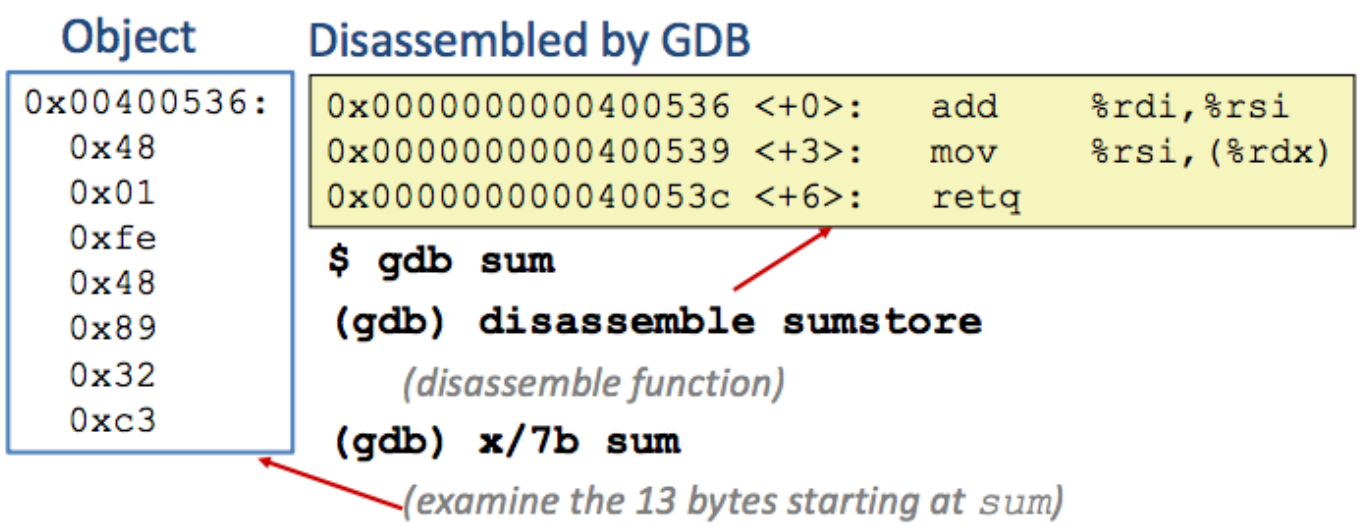
Function Calling Conventions

- Arguments for functions are stored in registers, in the following order: arg1 – arg6: %rdi,%rsi,%rdx,%rcx,%r8,%r9
- Return value from function always in %rax

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

```
0x401040 <sum>:
0x55
0x89
0xe5
0x8b
0x45
0x0c
0x03
0x45
0x08
0x89
0xec
0x5d
0xc3
```

Disassembled version

```
00401040 <_sum>:
 0:   55         push %ebp
 1:   89 e5      mov %esp,%ebp
 3:   8b 45 0c   mov 0xc(%ebp),%eax
 6:   03 45 08   add 0x8(%ebp),%eax
 9:   89 ec      mov %ebp,%esp
 b:   5d pop     %ebp
 c:   c3         ret
```

strings

$ *strings –t x p*

Displays the printable strings in your program.