

Reverse Engineering

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- 3 Quick introduction to C
- 4 Loading a binary
- 5 Some dynamic analysis
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What is reverse engineering?

- Working out what a program does
- Malware analysis
- Finding exploits
- Cracking software
- Cheating in games

Some terms

Static analysis Working out what a program does by looking at the files

Dynamic analysis Working out what a program does by running it and examining and modifying it's memory

Decompiler Attempts to turn machine code or bytecode into a higher level language

Disassembler Attempts to turn machine code or bytecode into an assembly language

Debugger Attaches to a process and allows you to examine and modify it's memory

Setup

- Update r2

```
sudo apt update && sudo apt upgrade radare2
```
- Set up 32 bit

```
dpkg --add-architecture i386
sudo apt update && sudo apt install libc6:i386
libc6-dev-i386
```

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Non native binaries

- Some languages don't compile to native executables.
- They compile to bytecode which is executed in a virtual machine (emulated CPU).
- This is usually done to make the executable run cross platform easily (without needing to recompile).
- These languages include Java, .net (clr), python (.pyc), etc...
- They tend to be easier, and you can usually get something close to the full original source code back, with variable names.
- The generated code is not always perfect though, and sometimes can't be recompiled.

Some tools I

Java

JD-GUI, cfr, jad, Krakatau, Procyon- decompilers
javasnoop - debugger
r2 - can read java bytecode, not much good
documentation though

Android (java)

apktool - disassembles dalvik bytecode to a higher
level format called smali
dex2jar - converts dalvik bytecode to jvm bytecode

.net

dnspy - decompiler

Some tools II

Python

Uncompyle6 - decompiler

Native

radare2 - disassembler and debugger

binaryninja - diassembler, paid, free demo

ida - disassembler and debugger, paid, free demo

gdb - debugger (disassembly isn't great)

objdump - disassembler

snowman - decompiler

hex rays decompiler - decompiler, paid

Obfuscation

- To make these challenges harder the code can be obfuscated
- Replacing variable and function names with nonsense
I recommend looking for meaningful strings assuming they haven't been encoded
Also looking for functions which you recognise e.g. `modexp`, `rsa`, ...
- Having some code in base64 (or other), decoding it, and executing it
Replace the `eval` function with a `print` statement

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Types I

Every variable must have a specific type.

Variable declaration and assignment

```
int a;  
a = 10;  
// can do both at the same time  
int a = 10;
```

Basic types

- `int` \geq 32 bits
- `long` \geq 64 bits
- `char` 1 byte
- `float` \geq 32 bits
- `double` \geq 64 bits
- `bool` true/false 1 byte (should include `stdbool.h`)

Functions

Definitions

```
bool greaterThan10(int num) {  
    return num > 10;  
}
```

Call

```
bool result = greaterThan10(20); // true
```

Every program must have a main function (some exceptions - e.g. libraries)

```
int main(int argc, char** argv) {  
}
```

Basic flow control I

If statement

```
if (1 == 2) {  
    puts("true");  
}  
else {  
    puts("false");  
}
```

While loop

```
int a = 0;  
while (a < 5) {  
    printf("%d", a);  
    a++;  
}
```

Basic flow control II

For loop

```
for(int i=0; a<5; a++) {  
    printf("%d", a)  
}
```


Pointers

- A pointer stores a memory address
- Address-of operator & gets a memory address
- Dereference operator * gets the value at a memory address
- If a pointer doesn't point to anything you can set it to NULL
- On most systems NULL is 0 which isn't a valid address

```
int a = 5;
int* p = &a; // stores address of a in p
int b = *p // b == 5
a++; // a == 6, b == 5
b = *p; // b == 6
```

Why pointers

- Pass by reference
We can't retrun arrays from functions (except some circumstances, e.g. array is on the heap)
- Pointer maths
e.g. array indexing

Arrays

- Need to specify a type and size
- Strings are stored in arrays of characters. Strings end with a nullbyte.
- The variable holds a pointer to the start of the array
- Array elements are stored next to each other in memory

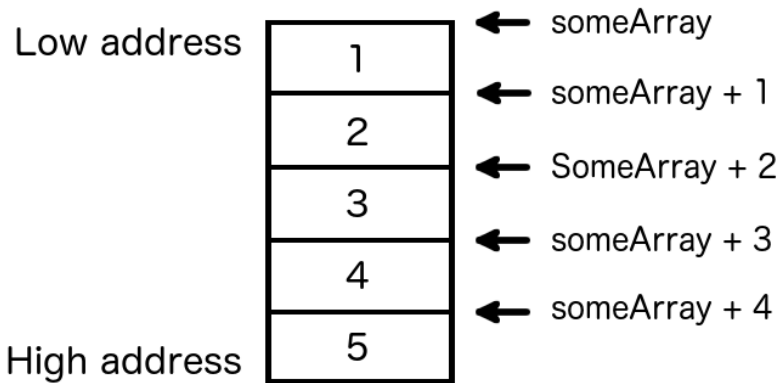
```
int someArray[5] = {1,2,3,4,5};  
char someString[6] = "12345" // size is +1 for nullbyte
```

Array indexing

```
int someArray[5] = {1,2,3,4,5};  
printf("%d\n", someArray[2]); // is equivalent to  
printf("%d\n", *(someArray+2));
```

- adding to a pointer actually adds a multiple of the type size.
- e.g. integers are (probably) 4 bytes, stack memory addresses also decrease towards 0, so `someArray+2` actually adds $2 \times 4 = 8$ to the memory address in `someArray`

Note: In ASM this would be 4, 8, 12, 16
Also note: Like many things, different compilers
may do this differently.



Some string operations

Need to `#include <string.h>`

strlen

Gets the length of a string

Counts the number of characters before a nullbyte -
O(n)

```
int len = strlen("some string");
```

strcmp

Compares strings

Returns 0 if equal

```
if (strcmp("abc", "def") == 0) {  
    puts("equal");  
}
```

Need to `#include <stdio.h>`

puts

Writes a string to stdout followed by a newline

```
puts("Hello, World!");
```

printf

Writes to stdout following a format string

Does not add a newline

```
printf("int: %d float: %f string: %s\n", 1, 2.0, "a string");
```

gets - DO NOT USE

Gets a line from stdin - line does not include newline character(s)

```
char myStr[20];  
gets(myStr);
```

fgets

Gets either n-1 characters from stdin or a line (whichever is shorter)
Includes newline character(s)

```
char myStr[20];  
fgets(mystr, 20, stdin);  
fgets(mystr, sizeof(myStr), stdin); // better
```


A full program (series/1.c)

```
#include <stdio.h>
#include <string.h>
#include <stdbool.h>

char password[] = "password";

bool testPassword(char* attempt) {
    return strcmp(attempt, password) == 0;
}

int main(int argc, char** argv) {
    printf("Enter password: ");

    char buff[200];
    fgets(buff, sizeof(buff), stdin); // get input
    buff[strlen(buff) - 1] = '\0'; // remove the newline

    if (testPassword(buff)) {
        puts("You win!");
    }
    else {
        puts("You fail");
    }
}
```

Command line arguments (codes/args.c)

```
#include <stdio.h>
#include <string.h>
#include <stdbool.h>
#include <stdlib.h>

char password[] = "password";

bool testPassword(char* attempt) {
    return strcmp(attempt, password) == 0;
}

int main(int argc, char** argv) {
    if (argc != 2) {
        puts("Give the password as a command line argument");
        exit(EXIT_FAILURE);
    }
    if (testPassword(argv[1])) { // 0 is name of program/command
        puts("You win!");
    }
    else {
        puts("You fail");
    }
}
```

Compiling

c is a compiled language - it needs to be compiled into a binary to execute

```
gcc mycode.c -o exename
```

If you use math.h

```
gcc mycode.c -lm -o execname
```

Some things I haven't included

- File IO (fopen, fclose, fprintf)
- Heap allocation (malloc, realloc, free)
- Function pointers
- Void pointers
- Undefined behavior

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What is an executable

- Binaries are not just raw machine code
- They are stored in a format which says how to load them
- linux uses binaries in the Executable and Linkable Format (ELF)
- windows uses the portable executable format (PE)
- OSX uses the Mach object file format (Mach-O)

Loading

- The program on linux that links binaries is called ld
- When the kernel is told to run a file with a magic number that matches ELF (0x7F ELF) it gives it to ld

Important things that need to happen

- Load segments of the binary into memory
- Load linked dynamic libraries (LD_LIBRARY_PATH)
- Call the main function

Some segments

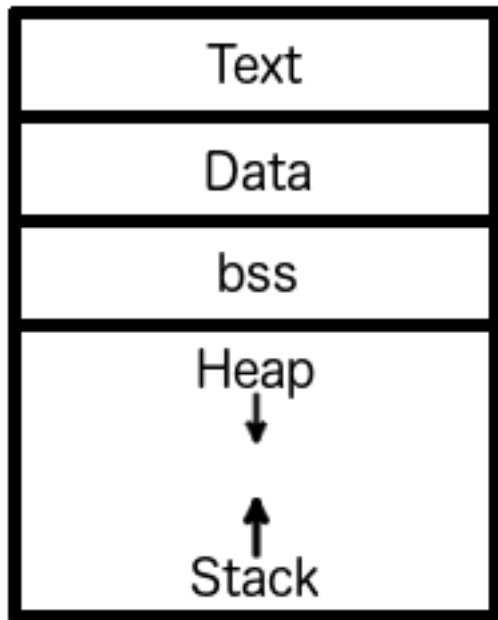
- data - stores initialised global variables
- bss - stores uninitialised global variables (only the length is stored in the binary). Linux and windows initialise it to 0.
- text - stores the machine code

On my mac (Apple LLVM version 9.1.0 (clang-902.0.39.2)) string literals in functions seem to be stored in a data section. - a pointer is put on the stack

On kali (gcc version 7.2.0 (Debian 7.2.0-19)) they seem to be stored in the code as integers (8 bytes in a 64 bit integer) and moved onto the stack.

Other memory locations in a running program

- stack - local variables, stack frames
- heap - malloc, realloc, free



Low address
000...

High address
fff...

```
int a = 1; // data
int b; // bss
char str[5]; // bss

int main(int argc, char **argv) {
    char str2[10]; // stack
    char str3[] = "abcdef"; // data or stack?
    int i = 0; // stack
    for (;i<4;i++) {
        char c = str3[i]; // stack
    }
}
```

```
#include <stdio.h>
#include <string.h>
#include <stdbool.h>

char password[] = "password";

bool testPassword(char* attempt) {
    return strcmp(attempt, password) == 0;
}

int main(int argc, char** argv) {
    printf("Enter password: ");

    char buff[200];
    fgets(buff, sizeof(buff), stdin); // get input
    buff[strlen(buff) - 1] = '\0'; // remove the newline

    if (testPassword(buff)) {
        puts("You win!");
    }
    else {
        puts("You fail");
    }
}
```

Strings

In this code the password string is stored in the binary in the data section. We can just find it with strings

```
root@kali:/m/s/c/R/codes > strings 1
/lib64/ld-linux-x86-64.so.2
libc.so.6
puts
stdin
printf
fgets
strlen
...
%b
=I
5B
AWAVI
AUATL
[]A\A]A^A_
Enter password:
You win!
You fail
;*3$"
password
...
```

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ltrace

ltrace prints all the calls to dynamically linked functions

```
root@kali:~ > ltrace ./1
printf("Enter password: ")
fgets(Enter password:
"\n", 200, 0x7fb1f3b64a00)
strlen("\n")
strcmp("", "password")
puts("You fail"You fail
)
+++ exited (status 0) +++
```

strace

strace prints all the system calls made by the program

```
root@kali:~ > strace ./1
execve("./1", ["/1"], 0x7ffc177e9330 /* 41 vars */) = 0
brk(NULL)                                = 0x5597eb436000
access("/etc/ld.so.nohwcap", F_OK)       = -1 ENOENT (No such file or directory)
access("/etc/ld.so.preload", R_OK)       = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/etc/ld.so.cache", O_RDONLY|O_CLOEXEC) = 3
fstat(3, {st_mode=S_IFREG|0644, st_size=146319, ...}) = 0
mmap(NULL, 146319, PROT_READ, MAP_PRIVATE, 3, 0) = 0x7f780d532000
close(3)                                 = 0
access("/etc/ld.so.nohwcap", F_OK)       = -1 ENOENT (No such file or directory)
openat(AT_FDCWD, "/lib/x86_64-linux-gnu/libc.so.6", O_RDONLY|O_CLOEXEC) = 3
read(3, "\177ELF\2\1\1\3\0\0\0\0\0\0\0\3\0>\0\1\0\0\0\240\33\2\0\0\0\0\0"... , 832) = 832
fstat(3, {st_mode=S_IFREG|0755, st_size=1800248, ...}) = 0
...
fstat(0, {st_mode=S_IFCHR|0620, st_rdev=makedev(136, 2), ...}) = 0
write(1, "Enter password: ", 16Enter password: )    = 16
read(0,
"\n", 1024)                                = 1
write(1, "You fail\n", 9You fail
)                                = 9
exit_group(0)                              = ?
+++ exited with 0 +++
```



```
bool testPassword(char* attempt) {  
    if (strlen(attempt) != 8)  
        return false;  
    if (attempt[0] != 'p')  
        return false;  
    if (attempt[1] != 'a')  
        return false;  
    if (attempt[2] != 's')  
        return false;  
    if (attempt[3] != 's')  
        return false;  
    if (attempt[4] != 'w')  
        return false;  
    if (attempt[5] != 'o')  
        return false;  
    if (attempt[6] != 'r')  
        return false;  
    if (attempt[7] != 'd')  
        return false;  
    return true;  
}
```

On windows you can use procmon from sysinternals as
strace

For ltrace I think I've used API monitor from
rohitab.com

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- Used by Intel and AMD
- Complex instruction set computer (CISC)
- Little endian architecture
least significant byte first - "reverse" order
i.e. 16909060
In big endian: 0x01020304
In little endian: 0x04030201
- Instructions are variable length

Registers

- 64 bit registers extend 32 bit which extend 16 bit which extend 8 bit
- 64 bit also added new registers r8 - r15
- Most registers are general purpose and can be used for anything
- rip is the instruction pointer, it points to the current instruction being executed
- rbp is the stack base pointer, it points the start of the current stack frame
- rsp is the stack pointer, it points to the top of the stack
- the FLAGS/EFLAGS/RFLAGS register holds information about calculations

RAX	Bit 64				Bit 0
RBX		E*X	*X	*H	*L
RCX					
RDX					
RSP		E*P	*P		*PL
RBP					
RSI		E*I	*I		*IL
RDI					
RIP		EIP	IP		
R8-R15		*D	*W		*B

Data types

Bytes are bytes, the only difference between a int, char, bool, etc... is the interpretation.

The size of a word in x86 assembly is 2 bytes (16 bits) (The actual hardware word size has changed, but "word" in assembly still refers to 2 bytes for backwards compatibility)

- byte - 1 byte
- word - 2 bytes
- dword - double word, 4 bytes
- qword - quad word, 8 bytes

Basic syntax

- There are a few different syntaxes. I will use Intel's syntax
- `<instruction> <operand1>, <operand2>, <operand3>`
- The result of the expression is stored in the first argument
`add rax, 1`
- A literal value in an operand (like the above 1) is called an immediate value
- The number of arguments can vary. e.g. no args
`nop`

mov I

- To do things with data we need to move it into registers
- The mov instruction moves (actually copies) data around

```
mov rax, 1 ; put 1 in rax
```

```
mov rax, rbx ; copy what is in rbx into rax
```

Dereferencing pointers

- We can dereference pointers with brackets
- Need to specify the size

```
; copy a byte at the top of the stack into rax
```

```
mov rax, byte [esp]
```

```
; copy dword from ebx to the top of the stack
```

```
mov dword [esp], ebx
```

Array indexing

Assuming start of array is at `rbp - 40` and holds 4 byte ints

```
mov rax, 2 ; index  
mov rax, dword [rbp + rax*4 - 40]
```

Problem - moving smaller data into a larger register
i.e. Can't do

```
mov rax, ebx
```

Signed integers

- We use a format called two's complement
- store negative numbers as $2^N - x$ where N is the number of bits and x is the number to negate
- e.g. for -3 as a 8 bit integer $2^8 - 3$
- This is so that we can just add negative numbers normally
- for $-3 + 4$ adding the first 3 in the 4 overflows the -3 to 0. The last 1 in the 4 makes the result 1
- An equivalent way to calculate 2s complement is to invert all the bits and add 1
- the most significant bit of a signed integer is the sign bit, if it's 1 the number is negative

movsx and movzx

- To extend a smaller number (e.g. 32 bits to 64 bits) we need to know if it's signed or unsigned
- If it's signed we should extend it with the sign bit
- If it's unsigned we should extend it with 0
- `movsx` = move with sign extend
- `movzx` = move with zero extend

lea

Moves the address of data into a register

```
mov rax, 2 ; index  
; move thing at arr[2] into rbx  
mov rbx, dword [rbp + rax*4 - 40]  
; move the address of arr[2] into rbx  
lea rbx, [rbp + rax*4 - 40]
```

Effectively just does the calculation in the brackets, so it can be used for maths

Some basic maths

```
inc rax ; increment rax
dec rax ; decrement rax
neg rax ; negate rax (2s complement)
add rax, rbx ; add rbx into rax
sub rax, rbx ; subtract rbx from rax
xor rax, rbx ; xor rax and rbx
xor rax, rax ; set rax to 0
and rax, rbx ; and rax and rbx
or rax, rbx
...
```

Unsigned Multiplication I

Multiplication is a bit more complicated as the result can be bigger than the register.

How it works depends on the size of the operand

`mul bl ; a byte`

Does $al * bl$ and stores the result in `ax` (note: `ax` is `al` and `ah`)

`mul bx ; a word`

Does $ax * bx$ and stores the result in `dx:ax` (low part in `ax` and high part in `dx`)

Unsigned Multiplication II

```
mul ebx ; a dword
```

Does $\text{eax} * \text{ebx}$ and stores the result in edx:eax

```
mul rbx; a qword
```

Does $\text{rax} * \text{rbx}$ and stores the result in rdx:rax

So in most cases it multiplies the operand with the appropriate sized portion of rax and stores the result in same sized portions of rdx and rax .

Signed Multiplication

- `imul` instead of `mul`
- It can work like `mul`, but it also has another 2 addressing modes
- One lets you specify the destination and the other specifies the destination and the second source

Unsigned Division

- The `div` instruction does not create a floating point number.
- It calculates the quotient and remainder.
- The dividend (thing being divided) has a size twice as large as the divisor (thing divided by)
- 8 bit divisor
dividend is in `AX`, quotient is put in `AL`,
remainder in `AH`
- 16 bit divisor
dividend is in `edx:eax`, quotient put in `AX`,
remainder in `DX`
- 32 bit divisor
dividend is in `edx:eax`, quotient put in `eax`,
remainder in `edx`
- 64bit divisor
dividend in `rdx:rax`, quotient put in `rax`,
remainder in `edx`

Flow control I

- x86 does not have if statements and loops, it has conditional (and unconditional) jumps instead.
- When writing assembly we jump to labels. A disassembler will show memory addressss instead though.

Unconditional jump

```
label:  
    add rax 1  
jmp label
```

Note: this example is an infinite loop

Flow control II

The `cmp` instruction compares two numbers and sets RFLAGS/EFLAGS based on whether the numbers are higher, lower, equal, ... It is usually used before a conditional jump

Conditional jump

```
mov rax, 0
mov rbx, 1
cmp rax, rbx
jeq label ; jump if equal
...
label:
...
```

Flow control III

Some common conditional jumps

`jeq` - equal

`jne` - not equal

`jt` - less than

`jg` - greater than

`jle` - less than or equal to

`jge` - greater than or equal to

note: for signed comparisons `b` (below) is used instead of `l` and `a` (above) is used instead of `g`

If statement I

Note: I'm using .1., .2., etc... as placeholders for code

If

```
if (1 == 2) {  
    .1.  
}
```

.2.

```
mov rax, 1  
; cmp doesn't take 2 immediates  
cmp rax, 2  
jne false  
.1.  
false:  
.2.
```

If statement II

If - Else

```
if (1 == 2) {  
    .1.  
} else {  
    .2.  
}  
.3.
```

```
mov rax, 1  
cmp rax, 2  
jne false  
.1.  
jmp end  
false:  
.2.  
end:  
.3.
```

Loop

```
int i = 0;
while (i < 5) {
    .1.
    i++
}
.2.
```

```
mov rax, 0
jmp test
start:
    .1.
    inc rax
test:
    cmp rax, 5
    jb start
.2.
```


Functions I

Need to deal with a few things

- ① Passing arguments
- ② Jumping to the function
- ③ Storing local variables
- ④ Returning a value
- ⑤ Going back where we came from
- ⑥ Also handling the fact that registers will change in the function

Let's deal with 2 and 5 first

- We handle this by storing information on the stack.

Functions II

- When calling the function it pushes the position of the **next** instruction onto the stack before jumping to it
- When returning it pops it back into the instruction pointer
- If we allocate stack space for local variables we also need to be able to restore the stack pointers
- That can be done by saving the old ebp and using the leave instruction at the end of the function

Functions III

call and ret

`call myfunc`

`push eip`
`jmp myfunc`

`ret`

`pop eip`

`leave`

`mov ebp, esp`
`pop ebp`

Functions IV

- For local variables we will allocate some stack space and store them on the stack
- If we are going to change the stack pointer we also need to either save it on the stack or increment it again later
- We refer to the local variables using `ebp` and keep `ebp` constant. `esp` can change if we push more stuff on the stack.

Functions V

A basic function

myfunc:

push ebp

mov ebp, esp

sub esp 12 ; 3 ints

...

pop ebp

ret

call myfunc

There are different conventions for handling arguments and return values

- Used when compiling 32 bit programs with gcc, is common with 32 bit compilers
- Arguments are pushed onto the stack in right to left order
- Return value is put in eax (usually - different implementations)
- eax,ecx and edx should be saved by the caller (if needed) others should be saved by the callee
- The calling function cleans up the arguments on the stack

cdecl II

cdecl

```
int addNums(int a, int b, int c) {  
    int 11 = 2;  
    int 12 = 3;  
    return a+b+c + 11 + 12;  
}  
addNums(1,2,3);
```

```
addNums:  
    push ebp  
    move ebp, esp  
    sub esp, 8  
    mov dword [ebp - 4], 2  
    mov dword [ebp - 8], 3  
    mov edx, dword [ebp + 8]  
    mov eax, dword [ebp + 12]  
    add edx, eax  
    mov eax, dword [ebp + 16]  
    add edx, eax  
    mov eax, dword [ebp - 4]  
    add edx, eax  
    mov eax, dword [ebp - 8]  
    add eax, edx  
    leave  
    ret
```

```
push 3  
push 2  
push 1  
call addNums
```

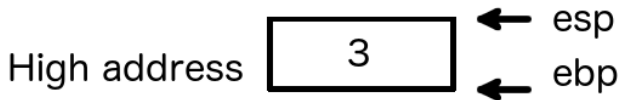
Low address

High address

← esp, ebp

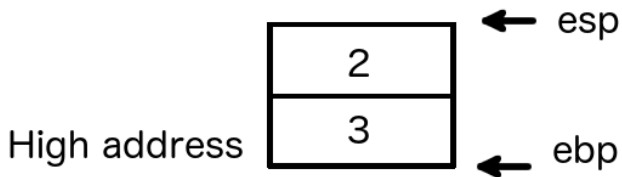
push 3

Low address



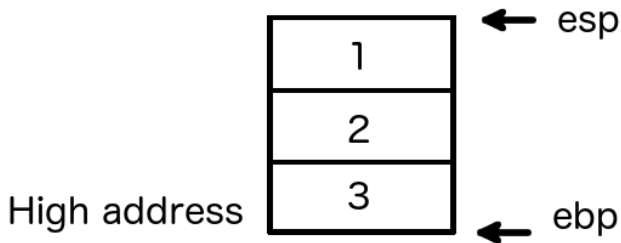
push 2

Low address



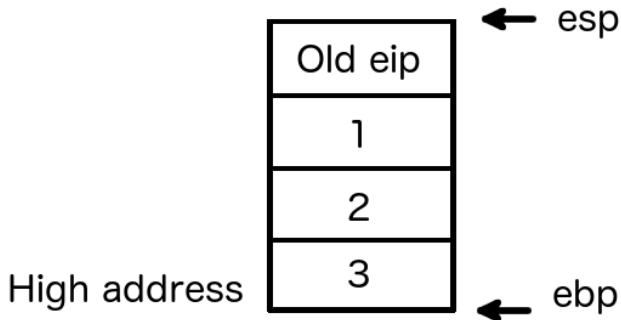
push 1

Low address



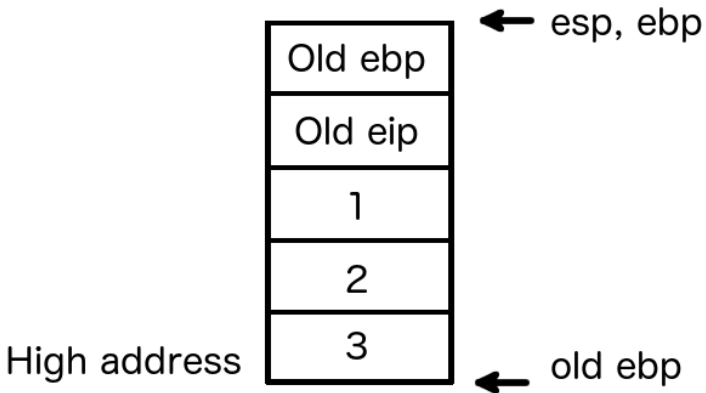
call addNums

Low address

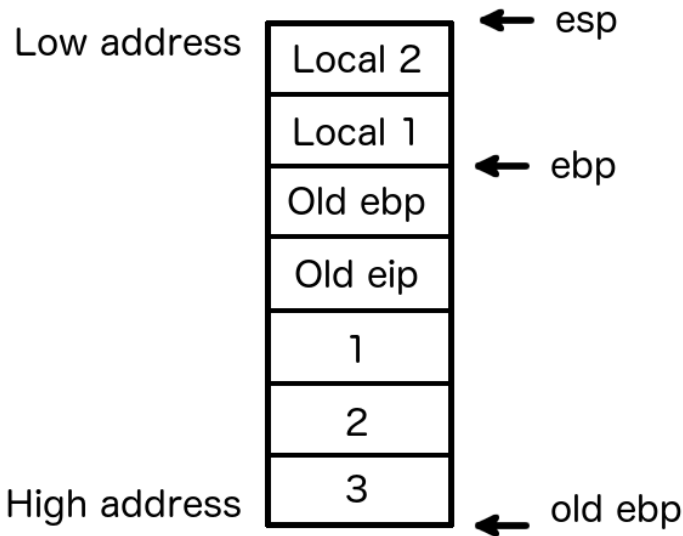


```
push ebp  
mov ebp, esp
```

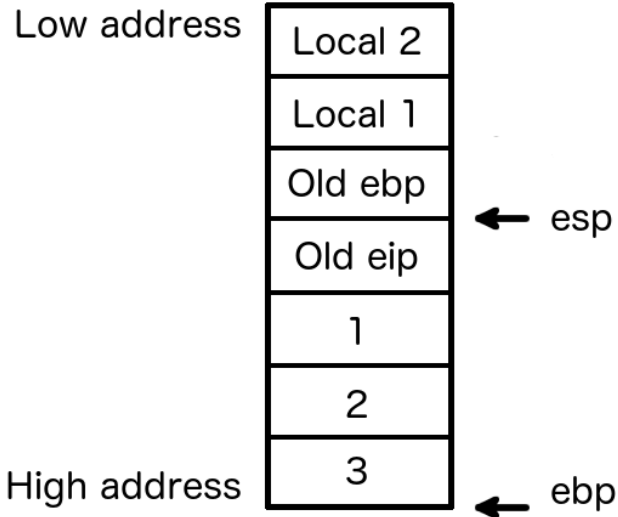
Low address



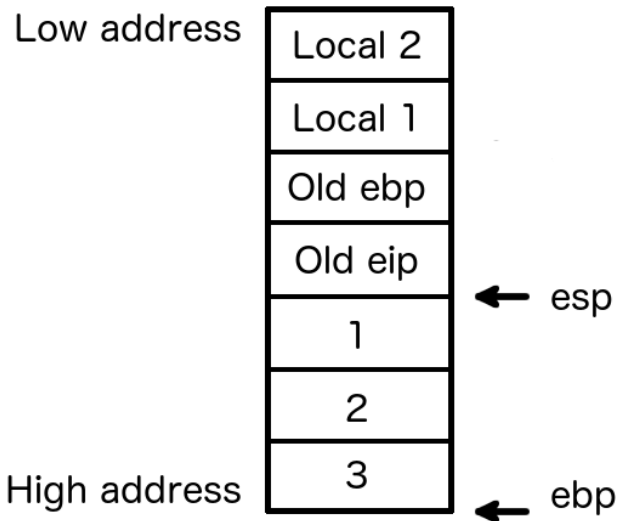
sub esp 8



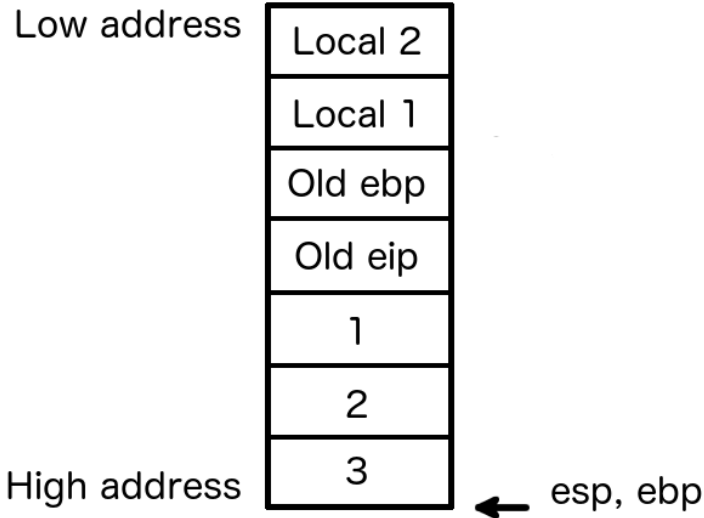
```
leave (mov esp, ebp  
      pop ebp)
```



ret



add esp, 12



System V AMD ABI

- 64 bit calling convention
- Used by linux, freeBSD, MacOS
- Registers are faster than stack memory
- The 64 bit architecture has more registers
- First 6 arguments are stored in rdi, rsi, rdx, rcx, r8 and r9
- Others are put on the stack (RTL)
- Return value in rax
- If the callee uses the registers rbx, rbp, and r12-r15 it needs to save and restore them before returning
- Others need to be saved by the caller

Windows function calls

- for 32 bit windows mostly uses stdcall which is similar to cdecl.
The main difference is that the callee removes the arguments from the stack
This can be done by giving ret an operand e.g.
ret 4
- fastcall and vectorcall are also used sometimes.
They put some of the arguments into registers.
- Microsoft x64 calling convention
 - First four args in rcx, rdx, r8 and r9. Others on stack (RTL)
 - caller must **always** allocate 32 bytes of "shadow space" on the stack before calling the function
 - rax, rcx, rdx, r8, r9, r10, r11 are saved by the caller
 - rbx, rbp, rdi, rsi, rsp, r12, r13, r14, r15 are saved by the callee

Stack alignment

- Variables on the stack may not be directly after each other in memory
- The compiler may put padding in between some variables to align them on certain boundaries
- How it's aligned can depend on compiler version. I think it can also be set to suit your hardware
- This also happens in structs

Syscalls I

- External resources, e.g. files, stdin, stdout, etc... are managed by the kernel
- To use them we need to call a function in the kernel
- `int 80` is a ~~rapper~~ an older way of making syscalls
The syscall number is put in `eax` and the args into `ebx,ecx,edx,esi,edi`
Then `int 80`
The return value is put in `rax`
There are faster methods
- for 32 bit you can use `sysenter`
- for 64 bit you can use `syscall`

Syscalls II

64 bit linux syscall numbers:

<https://filippo.io/linux-syscall-table/>

32 bit linux syscall numbers:

<https://syscalls.kernelgrok.com/>

C programs don't usually make syscalls directly, the standard library wraps them.

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- collection of tools
 - rax2 - expression evaluator
 - rabin2 - shows information about binaries
 - radiff2 - diffs 2 binary files
 - rasm2 - assembler and disassembler
 - ragg2 - compiler
 - rahash2 - hash each block in a file
 - radare2 - main binary that combines all the others
- the -d commandline arg enables debugging
- the -w commandline arg allows binary patching
- commands use memonics
- use the ? command to get help
- ? also evaluates expressions

a - analysis

- aa - analyse all
- aaa - does aa and autonames functions
- af - analyse functions
 - af ([name]) ([addr]) - analyse functions starting at addr
 - afvn [old_name] [new_name] - rename an argument/variable (analyse function variable name)
 - afl - list functions (analyse function list)
- ax - list xrefs
- axt - find references to address

d - debugging

- db - breakpoints
 - db - list breakpoints
 - db <addr> - add breakpoint at addr
 - db -<addr> - remove breakpoint at addr
 - dbd <addr> - disable breakpoint
 - dbe <addr> - enable breakpoint
 - dbs <addr> - Toggle breakpoint
- dc - continue
- ds - step
- ds <num> - step number of instructions
- dso - step over
- dsf - step to end of frame (step out)
- dr - print registers
- dr <register>=<val> - set a register

Visual mode

- V (capital) enters visual mode
- Pressing ? gives some help
- You can change view with p and P
- You can run a command with :
- q quits
- Pressing V again opens the control flow graph (CFG)

Reverse Debugging

- Radare 2 has a reversible debugger, you can revert to a previous state of the program
- use dts+ to save the current state and start recording
- dsb - step back
- dcb - continue back

- Understand xor (probably other binary operations as well)
- Learn to recognize hex numbers in the printable ASCII range
- Step through code you don't understand and look at the changes to the registers and stack
- Maybe do the same to code you do understand to make sure you are correct

- If the password is assembled completely before being compared you can easily pull it from memory
- Try searching for the failure message – the checking code is often close (or has an xref close)
- If you can find the success/failure messages try working backwards from there
- If you can't find an exact password try to reduce the search space and bruteforce
- Write it down

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Anti reversing

- Remove helpful information from the binary
- Make the disassembly a mess
- Stop debuggers attaching to the process
- Stop tools being able to open the file

Stripping the binary (stripped)

- We can tell gcc not to include information about function and vairable names
- `gcc -s -fvisibility=hidden`

Static linking (static)

- The binary still contains information about libraries it is linked to and what it calls in them
- This is needed for dynamic linking
- If we statically link the binary we can remove it
- glibc (GNU's c library implementation) does not support static linking
- We can use musl instead
- `sudo apt install musl-tools musl-dev`
- `musl-gcc -s -fvisibility=hidden -static`

Removing strings (nostrings)

- We (badly) hid the password string earlier so it couldn't be found with strings
- But we didn't hide the success and failure messages
- They can give information about where the checking function may be
- Let's just use a simple xor "encryption"
- This is bad though - it's quick to brute force so someone could compute all 255 versions of the binary and strings them all
- Use something closer to a real encryption algorithm

Fake main function (fakemain)

- The program does not actually start executing at main
- Some other stuff is done first to link dynamic libraries and handle passing command line args to main
- gcc allows you to create a function with `__attribute__((constructor))`
- This function will be called before main
- Put the real code in here and exit before main is called
- Put fake code in main

Stopping ptrace (ptrace)

- ptrace is the syscall debuggers use to interact with the binary
- the linux kernel only allows one process to debug it with ptrace
- so we can just make it ptrace itself
- see: `man ptrace`
- In windows you can check if the process is being debugged. `IsDebuggerPresent` is common
[https://msdn.microsoft.com/en-us/library/windows/desktop/ms680345\(v=vs.85\).aspx](https://msdn.microsoft.com/en-us/library/windows/desktop/ms680345(v=vs.85).aspx)
<https://docs.microsoft.com/en-us/windows-hardware/drivers/devtest/determining-if-a-debugger-is-attached>

SIGTRAP (sigtrap)

- Debuggers use the SIGTRAP signal for breakpoints
- They don't pass the signal on to the program they are debugging
- So we can put important code in a signal handler and SIGTRAP the binary
- The important code will never be called as the debugger intercepted the signal

Jumping into the middle of instructions (instructions)

- The disassembly view can't show overlapping instructions
- This is not normally an issue as instructions don't normally overlap
- But this can be valid code
- See code for an example

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Resources

- These are all **free**
- [RE4B](#)
- [Intel developer manuals](#).
You probably want part 2 of the 4 volume set
- [Programming Linux: Anti-Reversing Techniques](#)
Some of the code samples with this presentation are based on code from this book
- [Radare2 Book](#)
- [Wikibooks x86 assembly](#)
- [Wikibooks x86 disassembly](#)
- [NoREPls](#)
- [Malware Reversing - Burpsuite Keygen](#)
- [crackmes.one](#)