Getting Started with Reverse Engineering [UPDATED]

by offen5ive | 16-06-2022

What is Reverse Engineering?

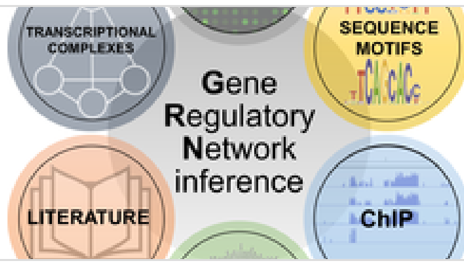
In simple words Reverse Engineering is the Process of taking compiled machine code and retrieving it's code into readable form. The main goal of reverse engineering is to understand how the program is working.

For further reference -

Reverse engineering - Wikipedia

Reverse engineering (also known as backwards engineering or back engineering) is a process or method through the application of which one attempts to understand through deductive reasoning how

W https://en.wikipedia.org/wiki/Reverse_engineering



What is ELF (Executable and Linkable Format)?

The header file <elf.h> defines the format of ELF executable binary files. Amongst these files are normal executable files, relocatable object files,
core files, and shared objects.

An executable file using the ELF file format consists of an ELF header, followed by a program header table or a section header table, or both. The ELF header is always at offset zero of the file. The program header table and the section header table's offset in the file are defined in the ELF header. The two tables describe the rest of the particularities of the file.

This header file describes the above mentioned headers as C structures and also includes structures for dynamic sections, relocation sections and symbol tables.

Ref -

elf(5) - Linux manual page

The header file defines the format of ELF executable binary files. Amongst these files are normal executable files, relocatable object files, core files, and shared objects. An executable file using the

https://man7.org/linux/man-pages/man5/elf.5.html

The x86 Assembly Overview

Assembly is the most popular low level language. The program written in high level language, for example C, The code is compiled into machine code that the CPU can understand.

The Stack

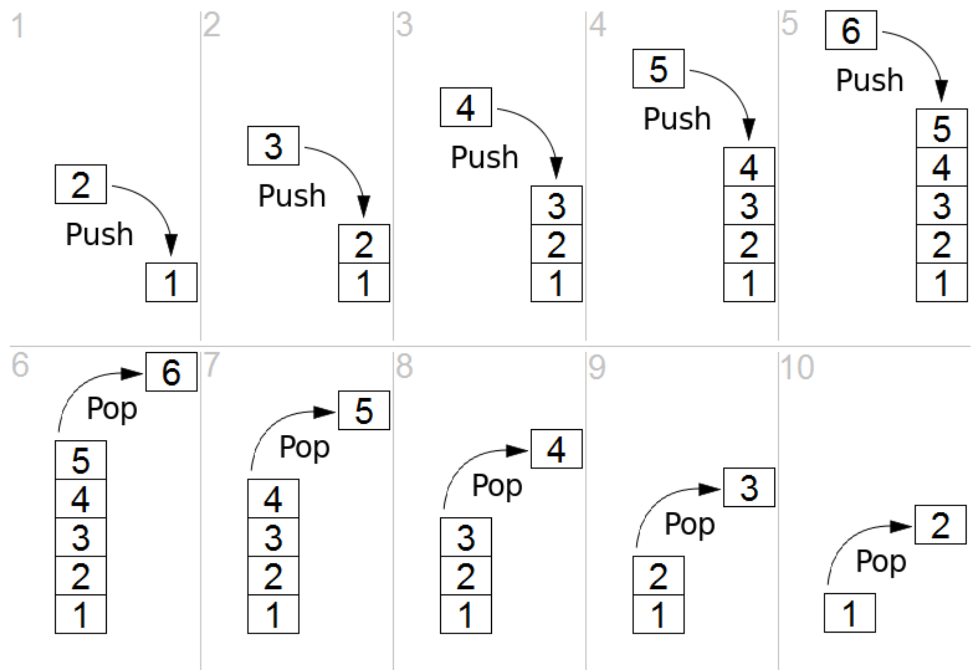
A is an abstract data structure which consists of information in a Last In First Out system. You put arbitrary objects onto the stack and then you take them off again, much like an in/out tray, the top item is always the one that is taken off and you always put on to the top.

A programs stack isn't generally hardware (though it's kept in memory so it can be argued as such), but the Stack Pointer which points to a current area of the Stack is generally a CPU register. This makes it a bit more flexible than a LIFO (Last in First Out) stack as you can change the point at which the stack is addressing.

For example -

PUSH BL / push BL onto the stack and subtract one from the stack pointer.

POP BL / Add one to the stack pointer and POP BL from the stack.



This image makes it easier to understand the Stack last in first out functionality with assembly instructions.

The Registers in x86 Architectures

The register is a small bit of memory inside the CPU used to store and transfer the data and instructions that are being used by the CPU.

- General x86 Resisters - EAX, EBX, ECX, EDX
- Index and Pointers - ESI, EDI, EBP, EIP, ESP
- Indicator - EFLAGS

Instructions in Assembly

- “MOV“: move data from one operand into another
- “ADD/SUB/MUL/DIV“: Add, Subtract, Multiply, Divide one operand with another and store the result in a register
- “AND/OR/XOR/NOT/NEG“: Perform logical and/or/xor/not/negate operations on the operand
- “SHL/SHR“: Shift Left/Shift Right the bits in the operand
- “CMP/TEST“: Compare one register with an operand
- “JMP/JZ/JNZ/JB/JS/etc.”: Jump to another instruction (Jump unconditionally, Jump if Zero, Jump if Not Zero, Jump if Below, Jump if Sign, etc.)
- “PUSH/POP“: Push an operand into the stack, or pop a value from the stack into a register
- “CALL“: Call a function. This is the equivalent of doing a “PUSH %EIP+4” + “JMP”. I’ll get into calling conventions later..
- “RET“: Return from a function. This is the equivalent of doing a “POP %EIP”

Debugger - GDB

To learn GDB (GNU Project Debugger) we will run simple hello_world program binary.

The C hello_world Program -

```
#include <stdio.h>
int main() {
printf("Hello World!");
return 0;
}
```

Compiling C program to obtain Executable

> gcc <example.c> -o <output filename>

→

> gcc hello_world.c -o hello_world

Running the Binary with GDB

Setting Breakpoints

Breakpoints are set to the program for GDB to stop execution and examine the contents of the stack.

For example setting breakpoints to the main function would be

> break main

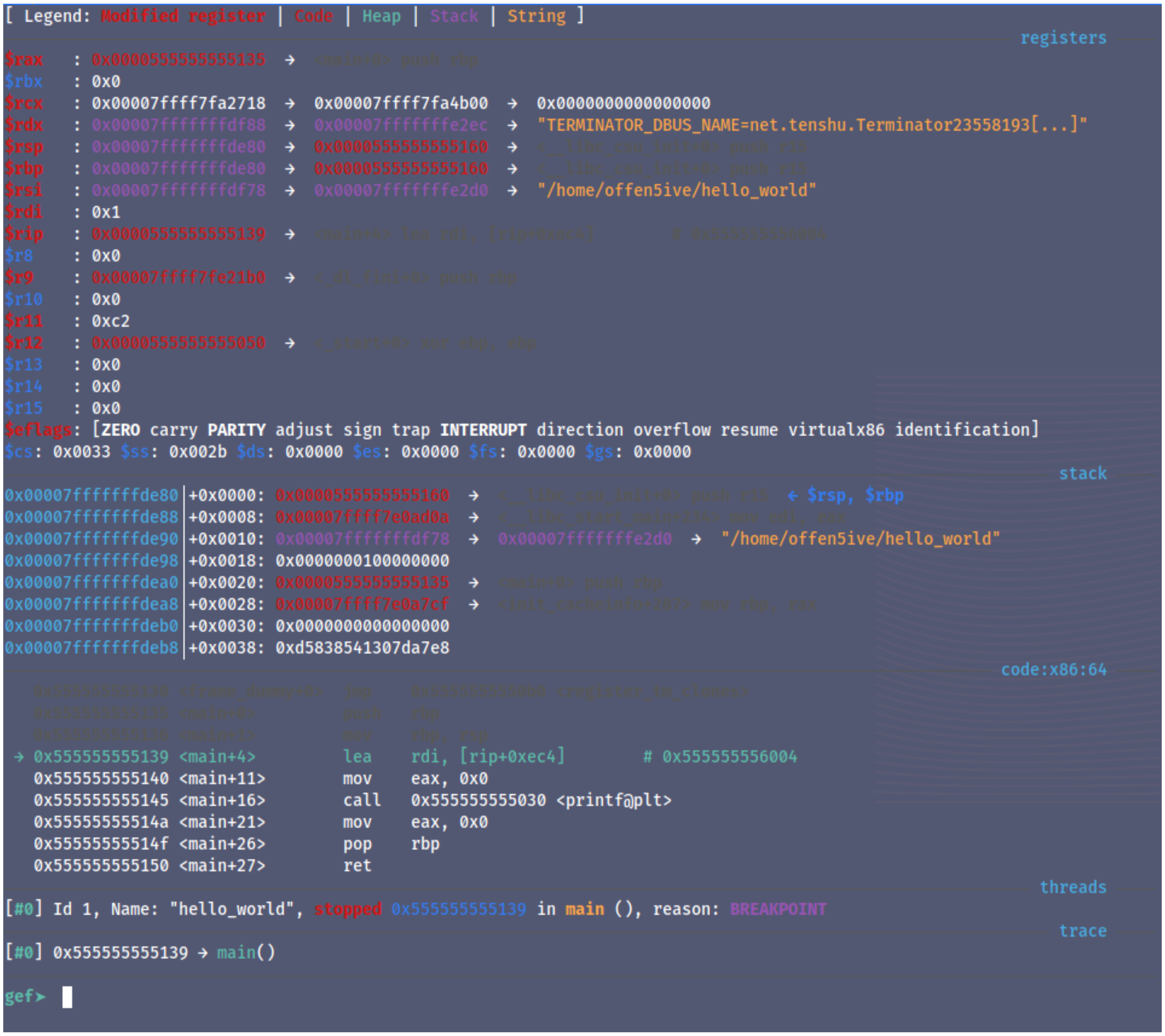
or

> b main

or you can use address of the function to set break point.

```
gef➤  break main
Breakpoint 1 at 0x1139
gef➤
```

Here we have put the breakpoints to the main function now to enter debugging mode we can run the program with 'r'.



after running the program we are in the debugging mode.

To check all the breakpoints we can use use,

> info breakpoints

or 'info b' or 'i b'

```
[#0] 0x555555555139 → main()

gef➤  info b
Num     Type           Disp Enb Address            What
1       breakpoint     keep y   0x0000555555555139 <main+4>
        breakpoint already hit 1 time
gef➤
```

we can see the break point we just set to the main functions.

we can delete the breakpoints with

> del and the num of the break point that is 1 in the image above so

```
gef➤  info b
Num     Type           Disp Enb Address            What
1       breakpoint     keep y   0x0000555555555139 <main+4>
        breakpoint already hit 1 time
gef➤  del 1
gef➤  info b
No breakpoints or watchpoints.
gef➤
```

Analyzing the Binary

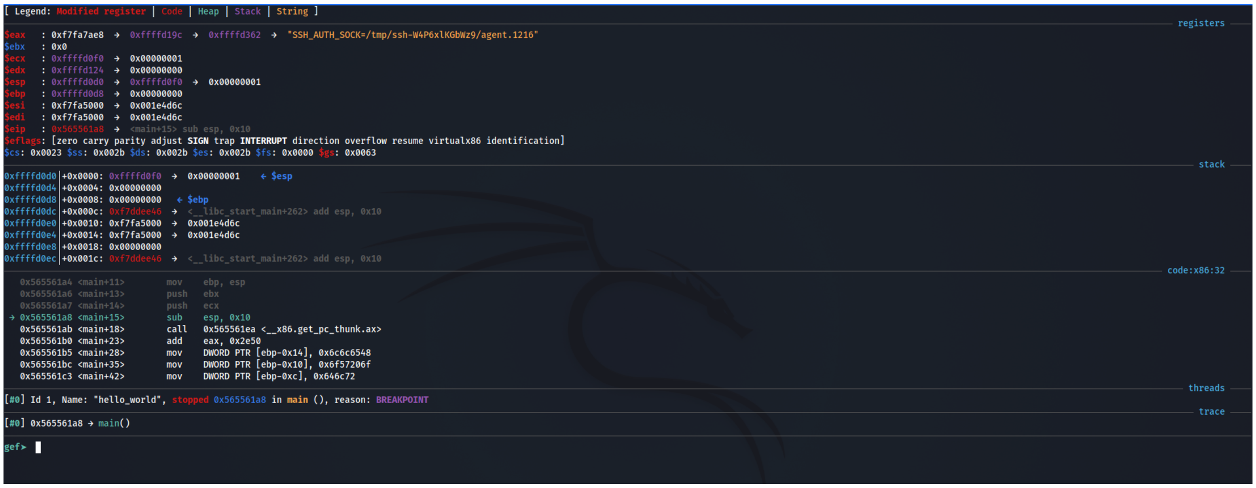
So we will take simple hello world C program binary.

```
#include<stdio.h>
int main()
{
char string[] = "Hello World";
puts(string);
return 0;
}
```

Running Binary with GDB and setting breakpoints to the main function.

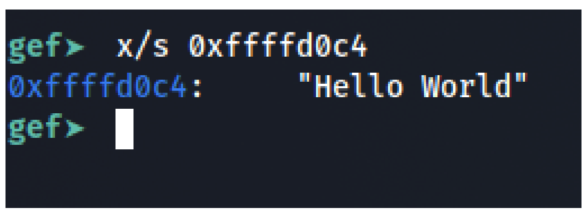
```
┌──(offen5ive㉿kali)-[~]
└─$ gdb hello_world
GNU gdb (Debian 10.1-1.7) 10.1.90.20210103-git
Copyright (C) 2021 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
Type "show copying" and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<https://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
    <http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word"...
GEF for linux ready, type `gef' to start, `gef config' to configure
96 commands loaded for GDB 10.1.90.20210103-git using Python engine 3.9
Reading symbols from hello_world...
(No debugging symbols found in hello_world)
gef➤  disass main
Dump of assembler code for function main:
   0x00001199 <+0>:     lea    ecx,[esp+0x4]
   0x0000119d <+4>:     and    esp,0xfffffff0
   0x000011a0 <+7>:     push   DWORD PTR [ecx-0x4]
   0x000011a3 <+10>:    push   ebp
   0x000011a4 <+11>:    mov    ebp,esp
   0x000011a6 <+13>:    push   ebx
   0x000011a7 <+14>:    push   ecx
   0x000011a8 <+15>:    sub    esp,0x10
   0x000011ab <+18>:    call   0x11ea <__x86.get_pc_thunk.ax>
   0x000011b0 <+23>:    add    eax,0x2e50
   0x000011b5 <+28>:    mov    DWORD PTR [ebp-0x14],0x6c6c6548
   0x000011bc <+35>:    mov    DWORD PTR [ebp-0x10],0x6f57206f
   0x000011c3 <+42>:    mov    DWORD PTR [ebp-0xc],0x646c72
   0x000011ca <+49>:    sub    esp,0xc
   0x000011cd <+52>:    lea    edx,[ebp-0x14]
   0x000011d0 <+55>:    push   edx
   0x000011d1 <+56>:    mov    ebx,eax
   0x000011d3 <+58>:    call   0x1030 <puts@plt>
   0x000011d8 <+63>:    add    esp,0x10
   0x000011db <+66>:    mov    eax,0x0
   0x000011e0 <+71>:    lea    esp,[ebp-0x8]
   0x000011e3 <+74>:    pop    ecx
   0x000011e4 <+75>:    pop    ebx
   0x000011e5 <+76>:    pop    ebp
   0x000011e6 <+77>:    lea    esp,[ecx-0x4]
   0x000011e9 <+80>:    ret
End of assembler dump.
gef➤  b main
Breakpoint 1 at 0x11a8
gef➤
```

To enter Debugging mode press r to run and press enter



As we can see ESP register holds the value 0xffffd0c4

now let's examine pointer.



So we can see that it points to the Hello World....

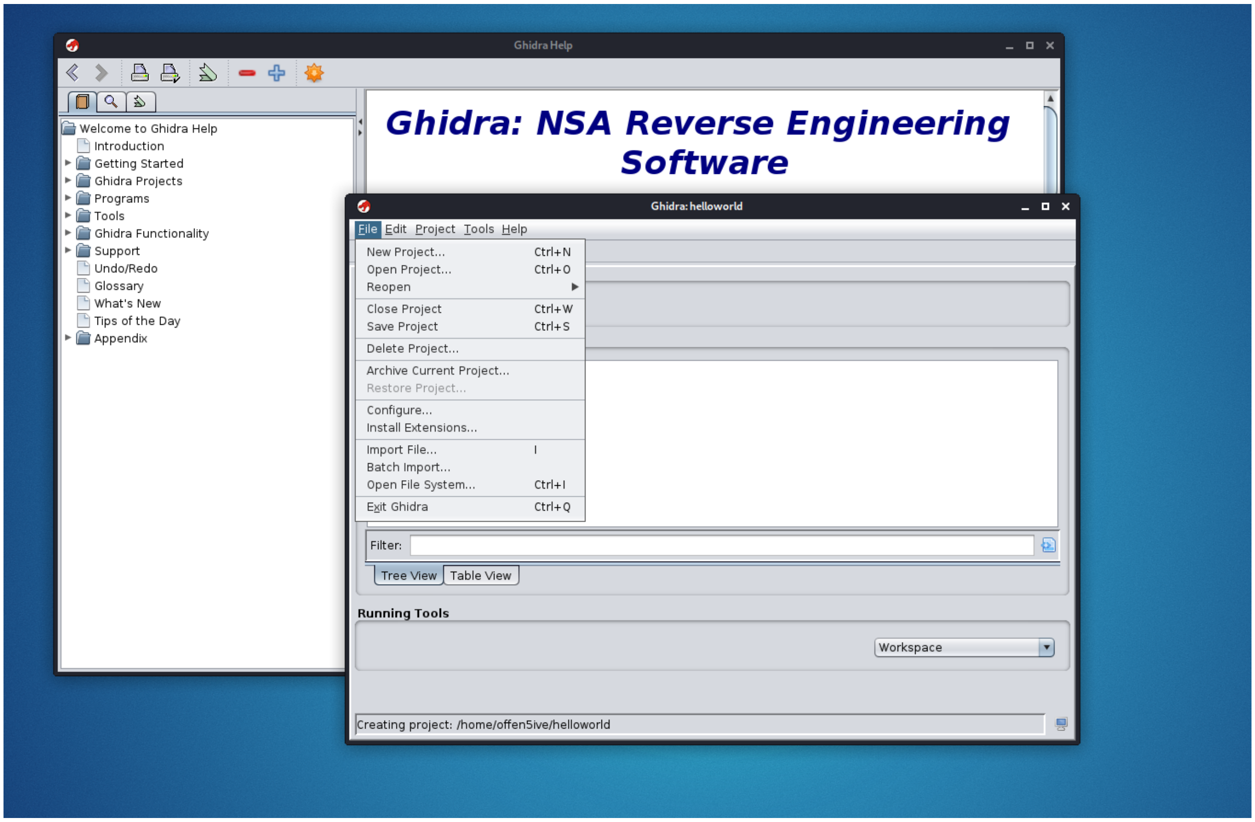
Introduction to Decompiler : Ghidra

Ghidra is a free and open source reverse engineering tool developed by the National Security Agency of the United States. The binaries were released at RSA Conference in March 2019; the sources were published one month later on GitHub. Ghidra is seen by many security researchers as a competitor to IDA Pro.

ref - https://en.wikipedia.org/wiki/Ghidra

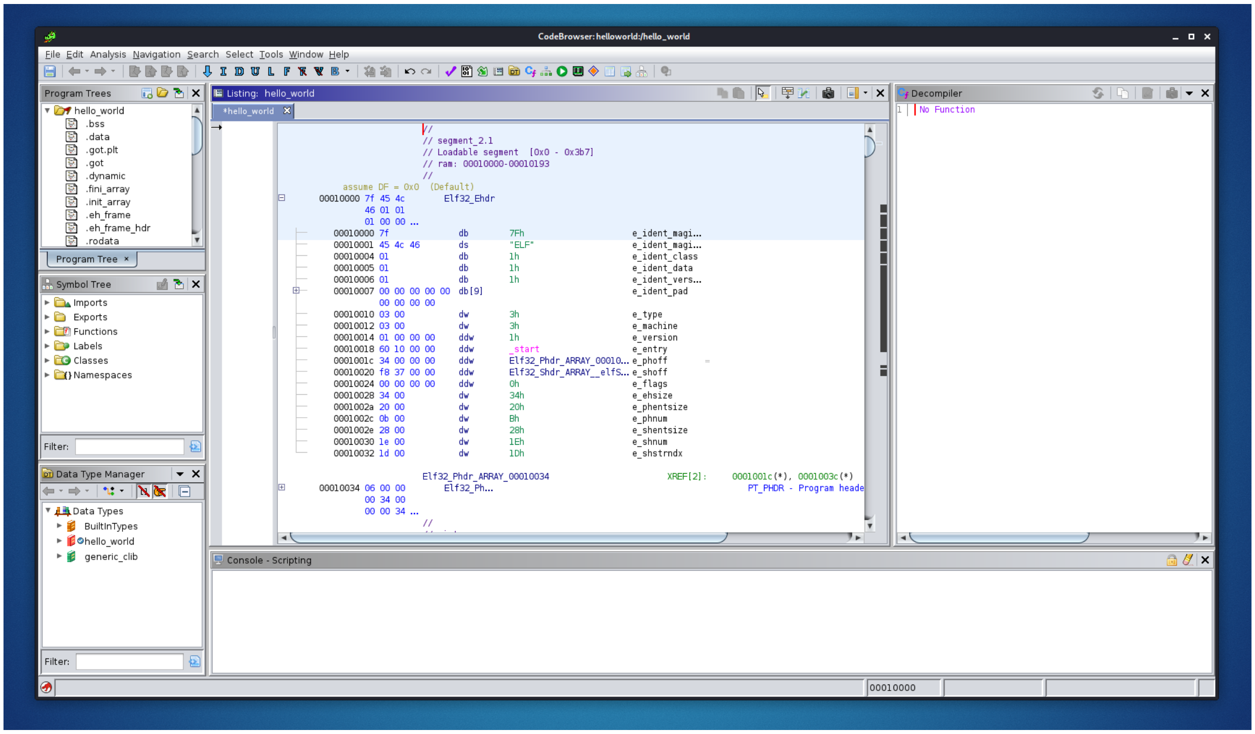
We will take the same hello world program binary and decompile the binary to obtain C program which will be somehow like the binary we compiled.

So open Up ghidra and Create new project and give it a name.



Now under Tool Chest you could see a dragon click on it and your project that you just created will can be seen under Active Projects.

Now click on file tab and open and select the Binary or drag and drop the binary any where on ghidra.



Click on Functions to expand it and all the functions used in the program can be seen.

Click on any function suppose main function once you click on it you'll see the decompiled program on the right most window.

Practical Reverse Engineering

So, I'll be solving a challenge from crackmes.one

So we will start with gathering some information about the binary.

now with this we know that this is 64bit ELF executable and it's a non-stripped binary.

now let's run this with GDB.

```
┌──(offen5ive㉿kali)-[~]
└─$ gdb crackme
GNU gdb (Debian 10.1-1.7) 10.1.90.20210103-git
Copyright (C) 2021 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.
Type "show copying" and "show warranty" for details.
This GDB was configured as "x86_64-linux-gnu".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<https://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
    <http://www.gnu.org/software/gdb/documentation/>.

For help, type "help".
Type "apropos word" to search for commands related to "word"...

GEF for linux ready, type `gef' to start, `gef config' to configure
96 commands loaded for GDB 10.1.90.20210103-git using Python engine 3.9
Reading symbols from crackme...
(No debugging symbols found in crackme)
gef➤
gef➤  disass main
Dump of assembler code for function main:
   0x0000000000001205 <+0>:     push   rbp
   0x0000000000001206 <+1>:     mov    rbp,rsp
   0x0000000000001209 <+4>:     sub    rsp,0x10
   0x000000000000120d <+8>:     mov    DWORD PTR [rbp-0x4],edi
   0x0000000000001210 <+11>:    mov    QWORD PTR [rbp-0x10],rsi
   0x0000000000001214 <+15>:    cmp    DWORD PTR [rbp-0x4],0x1
   0x0000000000001218 <+19>:    je     0x1222 <main+29>
   0x000000000000121a <+21>:    cmp    DWORD PTR [rbp-0x4],0x2
   0x000000000000121e <+25>:    je     0x123f <main+58>
   0x0000000000001220 <+27>:    jmp    0x125e <main+89>
   0x0000000000001222 <+29>:    mov    rax,QWORD PTR [rbp-0x10]
   0x0000000000001226 <+33>:    mov    rax,QWORD PTR [rax]
   0x0000000000001229 <+36>:    mov    rsi,rax
   0x000000000000122c <+39>:    lea    rdi,[rip+0xe36]        # 0x2069
   0x0000000000001233 <+46>:    mov    eax,0x0
   0x0000000000001238 <+51>:    call   0x1050 <printf@plt>
   0x000000000000123d <+56>:    jmp    0x125e <main+89>
   0x000000000000123f <+58>:    lea    rdi,[rip+0xe38]        # 0x207e
   0x0000000000001246 <+65>:    call   0x1030 <puts@plt>
   0x000000000000124b <+70>:    mov    rax,QWORD PTR [rbp-0x10]
   0x000000000000124f <+74>:    add    rax,0x8
   0x0000000000001253 <+78>:    mov    rax,QWORD PTR [rax]
   0x0000000000001256 <+81>:    mov    rdi,rax
   0x0000000000001259 <+84>:    call   0x1155 <check_password>
   0x000000000000125e <+89>:    mov    eax,0x0
   0x0000000000001263 <+94>:    leave
   0x0000000000001264 <+95>:    ret
End of assembler dump.
gef➤
```

Disassembling the main function we can see the assembly of the binary.

```
gef➤  info functions
All defined functions:

Non-debugging symbols:
0x0000000000001000  _init
0x0000000000001030  puts@plt
0x0000000000001040  system@plt
0x0000000000001050  printf@plt
0x0000000000001060  __cxa_finalize@plt
0x0000000000001070  _start
0x00000000000010a0  deregister_tm_clones
0x00000000000010d0  register_tm_clones
0x0000000000001110  __do_global_dtors_aux
0x0000000000001150  frame_dummy
0x0000000000001155  check_password
0x0000000000001205  main
0x0000000000001265  stringCompare
0x0000000000001320  __libc_csu_init
0x0000000000001380  __libc_csu_fini
0x0000000000001384  _fini
gef➤
```

with info functions we can see all the functions used in the program and here as we can see the "check_password" function seems interesting so let's set a break point to the function and see whats happening.

```
gef➤  disass check_password
Dump of assembler code for function check_password:
   0x0000555555555155 <+0>:	push   rbp
   0x0000555555555156 <+1>:	mov    rbp,rsp
   0x0000555555555159 <+4>:	sub    rsp,0x30
   0x000055555555515d <+8>:	mov    QWORD PTR [rbp-0x28],rdi
   0x0000555555555161 <+12>:	mov    BYTE PTR [rbp-0x20],0x73
   0x0000555555555165 <+16>:	mov    BYTE PTR [rbp-0x1f],0x75
   0x0000555555555169 <+20>:	mov    BYTE PTR [rbp-0x1e],0x70
   0x000055555555516d <+24>:	mov    BYTE PTR [rbp-0x1d],0x65
   0x0000555555555171 <+28>:	mov    BYTE PTR [rbp-0x1c],0x72
   0x0000555555555175 <+32>:	mov    BYTE PTR [rbp-0x1b],0x5f
   0x0000555555555179 <+36>:	mov    BYTE PTR [rbp-0x1a],0x73
   0x000055555555517d <+40>:	mov    BYTE PTR [rbp-0x19],0x65
   0x0000555555555181 <+44>:	mov    BYTE PTR [rbp-0x18],0x63
   0x0000555555555185 <+48>:	mov    BYTE PTR [rbp-0x17],0x72
   0x0000555555555189 <+52>:	mov    BYTE PTR [rbp-0x16],0x65
   0x000055555555518d <+56>:	mov    BYTE PTR [rbp-0x15],0x74
   0x0000555555555191 <+60>:	mov    BYTE PTR [rbp-0x14],0x5f
   0x0000555555555195 <+64>:	mov    BYTE PTR [rbp-0x13],0x70
   0x0000555555555199 <+68>:	mov    BYTE PTR [rbp-0x12],0x61
   0x000055555555519d <+72>:	mov    BYTE PTR [rbp-0x11],0x73
   0x00005555555551a1 <+76>:	mov    BYTE PTR [rbp-0x10],0x73
   0x00005555555551a5 <+80>:	mov    BYTE PTR [rbp-0xf],0x5f
   0x00005555555551a9 <+84>:	mov    BYTE PTR [rbp-0xe],0x35
   0x00005555555551ad <+88>:	mov    BYTE PTR [rbp-0xd],0x36
   0x00005555555551b1 <+92>:	mov    BYTE PTR [rbp-0xc],0x31
   0x00005555555551b5 <+96>:	mov    BYTE PTR [rbp-0xb],0x37
   0x00005555555551b9 <+100>:	mov    BYTE PTR [rbp-0xa],0x38
   0x00005555555551bd <+104>:	lea    rdx,[rbp-0x20]
   0x00005555555551c1 <+108>:	mov    rax,QWORD PTR [rbp-0x28]
   0x00005555555551c5 <+112>:	mov    rsi,rdx
   0x00005555555551c8 <+115>:	mov    rdi,rax
   0x00005555555551cb <+118>:	mov    eax,0x0
   0x00005555555551d0 <+123>:	call   0x555555555265 <stringCompare>
   0x00005555555551d5 <+128>:	mov    DWORD PTR [rbp-0x4],eax
   0x00005555555551d8 <+131>:	cmp    DWORD PTR [rbp-0x4],0x1
   0x00005555555551dc <+135>:	jne    0x5555555551f1 <check_password+156>
   0x00005555555551de <+137>:	lea    rdi,[rip+0xe23]        # 0x555555556008
   0x00005555555551e5 <+144>:	mov    eax,0x0
   0x00005555555551ea <+149>:	call   0x555555555040 <system@plt>
   0x00005555555551ef <+154>:	jmp    0x555555555202 <check_password+173>
   0x00005555555551f1 <+156>:	lea    rdi,[rip+0xe56]        # 0x55555555604e
   0x00005555555551f8 <+163>:	mov    eax,0x0
   0x00005555555551fd <+168>:	call   0x555555555050 <printf@plt>
   0x0000555555555202 <+173>:	nop
   0x0000555555555203 <+174>:	leave
   0x0000555555555204 <+175>:	ret
End of assembler dump.
gef➤
```

we can see that values are moved to rbp register and at address 0x00005555555551bd contents of rbp register is moved to rdx register. So viewing the string inside the rdx register will give us the flag.

So set a break point to the check_password function and and run with random argument and analyze the stack.

At address "0x5555555551bd" flag will be in the stack or u can view the content of rdx register at the same address.

```
[ Legend: Modified register | Code | Heap | Stack | String ]
$rax   : 0x00007fffffffe362  →  0x0072727272727262 ("brrrrrr"?)
$rbx   : 0x0
$rcx   : 0x00007ffff7ed2f33  →  0x5577fffff0003d48 ("H="?)
$rdx   : 0x00007fffffffded0  →  "super_secret_pass_56178"
$rsp   : 0x00007fffffffdec0  →  0x000055555555607e  →  "Checking password.."
$rbp   : 0x00007fffffffdef0  →  0x00007fffffffdf10  →  0x0000555555555320  →  <__libc_csu_init+0> push r15
$rsi   : 0x00005555555592a0  →  "Checking password..\n"
$rdi   : 0x00007fffffffe362  →  0x0072727272727262 ("brrrrrr"?)
$rip   : 0x00005555555551c1  →  <check_password+108> mov rax, QWORD PTR [rbp-0x28]
$r8    : 0x14
$r9    : 0x00007ffff7fa2be0  →  0x00005555555596a0  →  0x0000000000000000
$r10   : 0x6e
$r11   : 0x246
$r12   : 0x0000555555555070  →  <_start+0> xor ebp, ebp
$r13   : 0x0
$r14   : 0x0
$r15   : 0x0
$eflags: [zero carry PARITY adjust sign trap INTERRUPT direction overflow resume virtualx86 identification]
$cs: 0x0033 $ss: 0x002b $ds: 0x0000 $es: 0x0000 $fs: 0x0000 $gs: 0x0000

0x00007fffffffdec0│+0x0000: 0x000055555555607e  →  "Checking password.."       ← $rsp
0x00007fffffffdec8│+0x0008: 0x00007fffffffe362  →  0x0072727272727262 ("brrrrrr"?)
0x00007fffffffded0│+0x0010: "super_secret_pass_56178"    ← $rdx
0x00007fffffffded8│+0x0018: "cret_pass_56178"
0x00007fffffffdee0│+0x0020: 0x0038373136355f73 ("s_56178"?)
0x00007fffffffdee8│+0x0028: 0x0000000000000000
0x00007fffffffdef0│+0x0030: 0x00007fffffffdf10  →  0x0000555555555320  →  <__libc_csu_init+0> push r15    ← $rbp
0x00007fffffffdef8│+0x0038: 0x000055555555525e  →  <main+89> mov eax, 0x0

   0x5555555551b5 <check_password+96> mov    BYTE PTR [rbp-0xb], 0x37
   0x5555555551b9 <check_password+100> mov    BYTE PTR [rbp-0xa], 0x38
   0x5555555551bd <check_password+104> lea    rdx, [rbp-0x20]
 → 0x5555555551c1 <check_password+108> mov    rax, QWORD PTR [rbp-0x28]
   0x5555555551c5 <check_password+112> mov    rsi, rdx
   0x5555555551c8 <check_password+115> mov    rdi, rax
   0x5555555551cb <check_password+118> mov    eax, 0x0
   0x5555555551d0 <check_password+123> call   0x555555555265 <stringCompare>
   0x5555555551d5 <check_password+128> mov    DWORD PTR [rbp-0x4], eax

[#0] Id 1, Name: "crackme", stopped 0x5555555551c1 in check_password (), reason: SINGLE STEP

[#0] 0x5555555551c1 → check_password()
[#1] 0x55555555525e → main()

gef➤  x/s $rdx
0x7fffffffded0: "super_secret_pass_56178"
gef➤
```

So we have got the Flag :D

```
┌──(offen5ive㉿kali)-[~]
└─$ ./crackme super_secret_pass_56178
Checking password..
Good job!
```