A Practical Introduction to Reverse Engineering

Workshop

Singapore – December, 3rd 2022

Romain Thomas

Introduction

Workshop Presentation

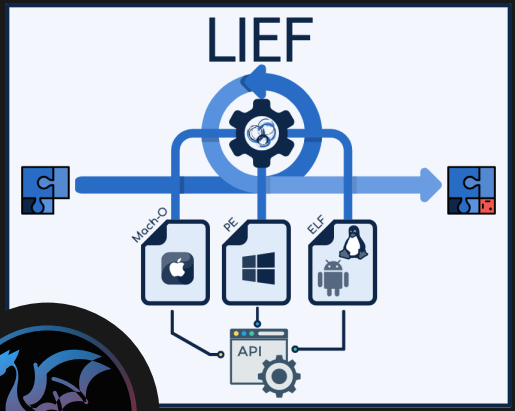
- Introduction to x86-64 Linux reverse engineering.
- 4-hours workshop + 1 hour for 1x1 questions.
- Driven by hands-on.
- A 30 minutes evaluation at the end of the session.

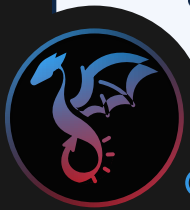
VM

- Ubuntu 22.04
- Login: `re` / Password: `re`
- Ghidra 10.2

About

- Security Engineer
- Enjoy reverse engineering and development
- Mostly doing reverse on mobile (Android & iOS)





Open Obfuscator

Practical Reverse Engineering

Reverse Engineering

The purpose of reverse engineering is to highlight a *functionality* or an *asset* without having access to the original information (e.g. the source code).

Reverse Engineering

Functionalities:

- An algorithm.

Reverse Engineering

Functionalities:

- An algorithm.
- A check.

Reverse Engineering

Functionalities:

- An algorithm.
- A check.
- A structure.

Reverse Engineering

Assets:

- Password.

Reverse Engineering

Assets:

- Password.
- An API Key.

Reverse Engineering

Original information:

- Without the source code.

Reverse Engineering

Original information:

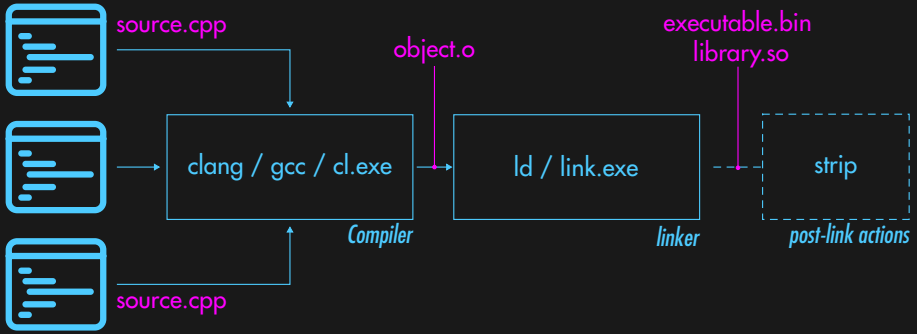
- Without the source code.
- Without the symbols.

Reverse Engineering

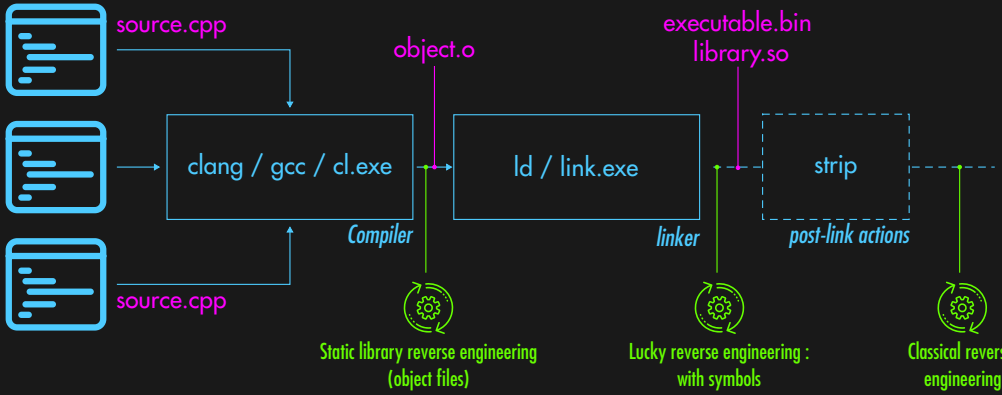
Original information:

- Without the source code.
- Without the symbols.
- With obfuscation.

Reverse Engineering



Reverse Engineering



Linux x86-64 Reverse Engineering

Linux x86-64 Reverse Engineering

Learning reverse engineering is somehow similar to learning a new language:

- Vocabulary

Linux x86-64 Reverse Engineering

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- Vocabulary

- Instructions

Linux x86-64 Reverse Engineering

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- Grammar

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Linux x86-64 Reverse Engineering

Learning reverse engineering is somehow similar to learning a new language:

- Vocabulary
- Grammar

- Instructions
- Addressing Modes/ABI Conventions

Linux x86-64 Reverse Engineering

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- Grammar
- Idioms/Expressions

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Linux x86-64 Reverse Engineering

Learning reverse engineering is somehow similar to learning a new language:

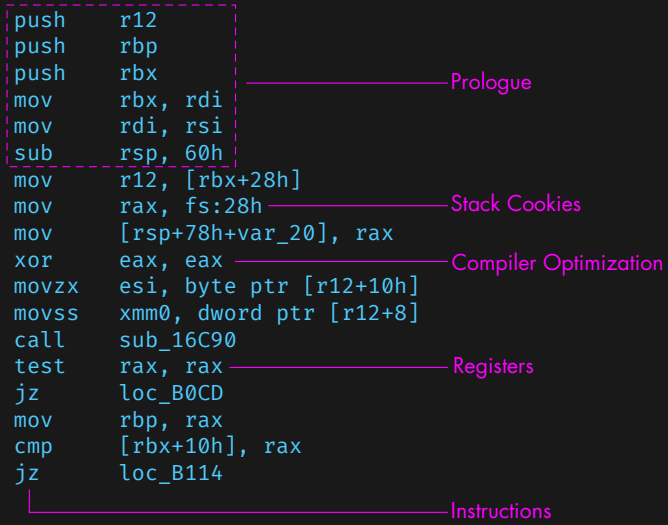
- Vocabulary
- Grammar
- Idioms/Expressions

- Instructions
- Addressing Modes/ABI Conventions
- Compiler Patterns/Optimizations

Linux x86-64 Reverse Engineering

```
push    r12
push    rbp
push    rbx
mov     rbx, rdi
mov     rdi, rsi
sub     rsp, 60h
mov     r12, [rbx+28h]
mov     rax, fs:28h
mov     [rsp+78h+var_20], rax
xor     eax, eax
movzx   esi, byte ptr [r12+10h]
movss   xmm0, dword ptr [r12+8]
call    sub_16C90
test    rax, rax
jz      loc_B0CD
mov     rbp, rax
cmp     [rbx+10h], rax
jz      loc_B114
```

Linux x86-64 Reverse Engineering



x86-64: Registers

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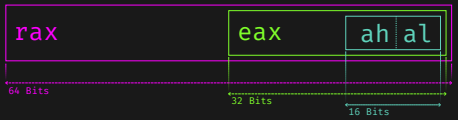

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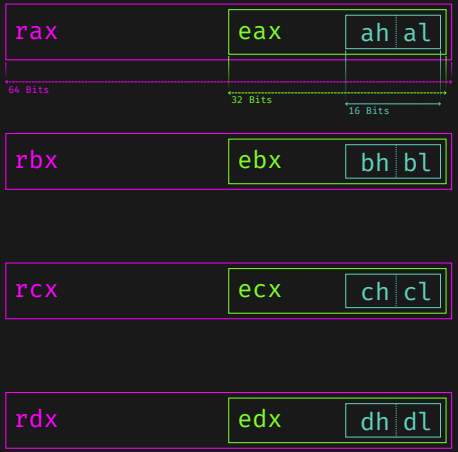

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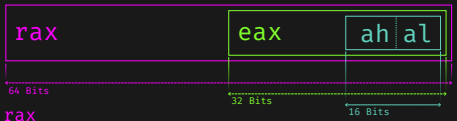

16 General-Purpose Registers

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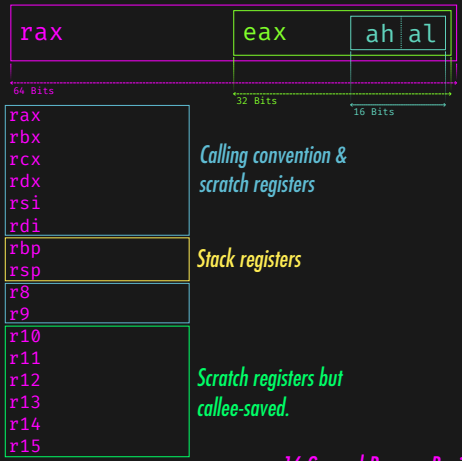

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```

```
mov DST, SRC

mov rax,              rdi
mov ecd,              dl
mov rdi,              qword ptr [rsi + 0×8]
mov byte ptr [rsp], cl
mov rax,              0×123
```

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```

```
push rax
pop  rbb
```

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mov     rbp, rax
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```

```
add rax, rbx
sub rdx, rcx
xor eax, eax
or  rax, rax
( ... )
```

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```

```
jmp loc_2345
jmp rax
jnz rcx

call FUNC_123
call rax
```

Compiler Optimizations

x86-64: Instructions

```
rax = rbx + 2
```

```
mov    rax, rbx
add    rax, 0×2
```

x86-64: Compiler Optimizations

```
rax = rbx + 2
```

```
lea     rax, [rbx + 0×2]
```

x86-64: Compiler Optimizations

```
rax := 0          mov    rax, 0×0  48 c7 c0 00 00 00 00
```

x86-64: Compiler Optimizations

```
rax := 0          xor    rax, rax  48 31 c0
```

x86-64: Compiler Optimizations

```
X % 8
```

```
mov    rax, <X>
mov    rcx, 0×8
idiv   rcx
mov    rax, rdx
```

x86-64: Compiler Optimizations

```
X % 8
```

```
mov rax, <X>
and rax, 7
```

x86-64: Compiler Optimizations

```
X % 26
```

```
mov    rax, <X>     48 8b 45 f8
mov    rcx, 26      b9 1a 00 00 00
div    rcx          48 f7 f1
mov    rax, rdx     48 89 d0
```

x86-64: Compiler Optimizations

```
X % 26
```

```
mov    rax, <X>    48 89 f8
push   26          6a 1a
pop    rcx         59
div    rcx         48 f7 f1
mov    rax, rdx    48 89 d0
```

x86-64: Compiler Optimizations

```
                        movabs rcx, 0×4ec4ec4ec4ec4ec5
                        mov    rax, <X>
                        mul    rcx
                        shr    rdx, 0×3
X % 26                  lea    rax, [rdx+rdx*4]
                        lea    rax, [rax+rax*4]
                        add    rax, rdx
                        sub    <X>, rax
```

x86-64: Compiler Optimizations

$$X \equiv r \mod 26$$

$$X = 26q + r$$

$$X - 26q = r$$

$$X - 26 \left\lfloor \frac{X}{26} \right\rfloor = r$$

```
movabs rcx, 0×4ec4ec4ec4ec4ec5
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mul    rcx
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x86-64: Compiler Optimizations

$$X - 26 \left\lfloor \frac{X}{26} \right\rfloor = r$$

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movabs rcx, 0×4ec4ec4ec4ec4ec5
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Calling Convention

x86-64: Calling Convention

A calling convention defines how registers should be used when calling a function.

This convention depends on:

1. The architecture
2. The operating system

It also defines which registers must be preserved when calling functions.

x86-64: Calling Convention

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```
int x = 1;
int y = 2;
int result = compute(x, y);
```

This convention depends on:

1. The architecture
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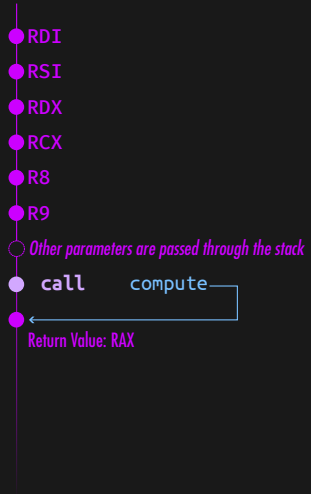
It also defines which registers must be preserved when calling functions.

```
mov     dword ptr [rbp-0Ch], 1
mov     dword ptr [rbp-8],   2
mov     edx, [rbp-8]
mov     eax, [rbp-0Ch]
mov     esi, edx
mov     edi, eax
call    compute
mov     [rbp-4], eax
```

x86-64: Calling Convention

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mov     esi, edx
mov     edi, eax
call    compute
mov     [rbp-4], eax
```

x86-64: Prologue / Epilogue

When calling compute(), the calling convention allows computes() to modify rax, rcx, rdx, r8, r9, r10, r11.

But compute() is not allowed to
modify the values of rbx, rbp, rdi, rsi, rsp, r12, r13, r14, r15.

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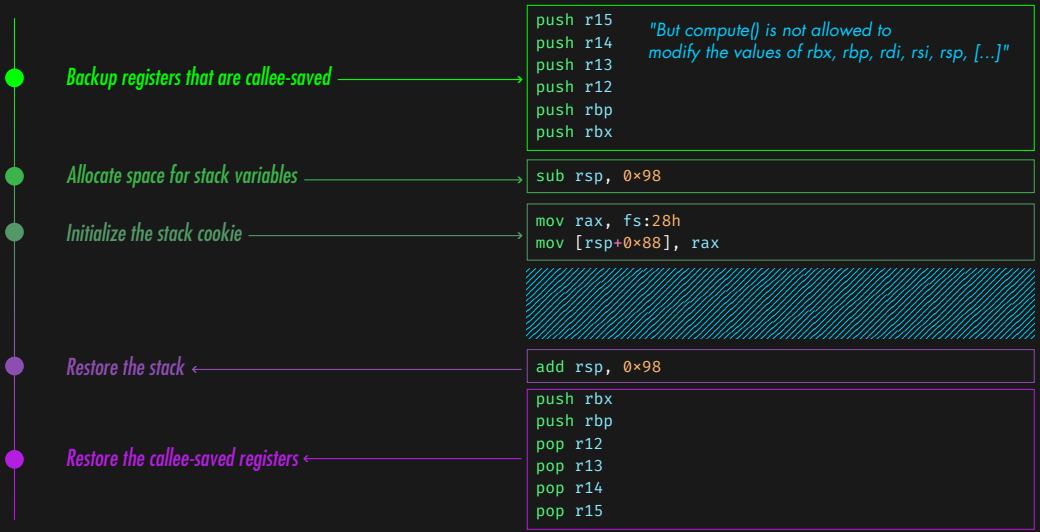
x86-64: Prologue / Epilogue



x86-64: Endianness

```
uintptr_t* memory = ...;
*memory = 0x11223344;
```

44	33	22	11	00	00	00	00

x86-64 is a little-endian architecture which means that the least significant byte is stored at the "highest" memory address.

Basically, the memory representation is reversed compared to the in-register
representation.

12	45	32	AE	E3	00	32	11

```
mov     rax, [rbp+var_8]
```

RAX = 0x113200E3AE324512

x86-64: Optimization

Linux Execution Bootstrapping

Linux Execution Bootstrapping

All executables must define a `main()` function which is the *first* function being executed when the executable starts.

```c
int main(int argc, char** argv) {
  printf("Hello World\n");
  return 0;
}
```

Linux Execution Bootstrapping

```
$ readelf --file-header compiled.bin
ELF Header:
  Magic:   7f 45 4c 46 02 01 01 00 00 00 00 00 00 00 00 00
  Class:                             ELF64
  Data:                              2's complement, little endian
  Version:                           1 (current)
  OS/ABI:                            UNIX - System V
  ABI Version:                       0
  Type:                              DYN (Position-Independent Executable file)
  Machine:                           Advanced Micro Devices X86-64
  Version:                           0x1
  Entry point address:               0x5eb0
  Start of program headers:          64 (bytes into file)
  Start of section headers:          136080 (bytes into file)
  Flags:                             0x0
  Size of this header:               64 (bytes)
  Size of program headers:           56 (bytes)
  Number of program headers:         13
  Size of section headers:           64 (bytes)
  Number of section headers:         26
  Section header string table index: 25
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int main(int argc, char** argv) {
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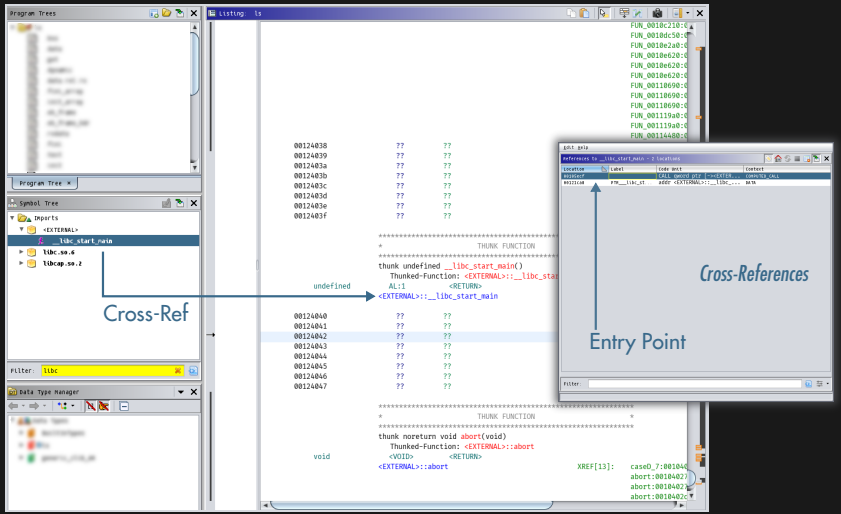
```

```
int main(int argc, char** argv) {
  printf("Hello World\n");
  return 0;
}

__libc_start_main(&main, ...);
```

Linux Execution Bootstrapping



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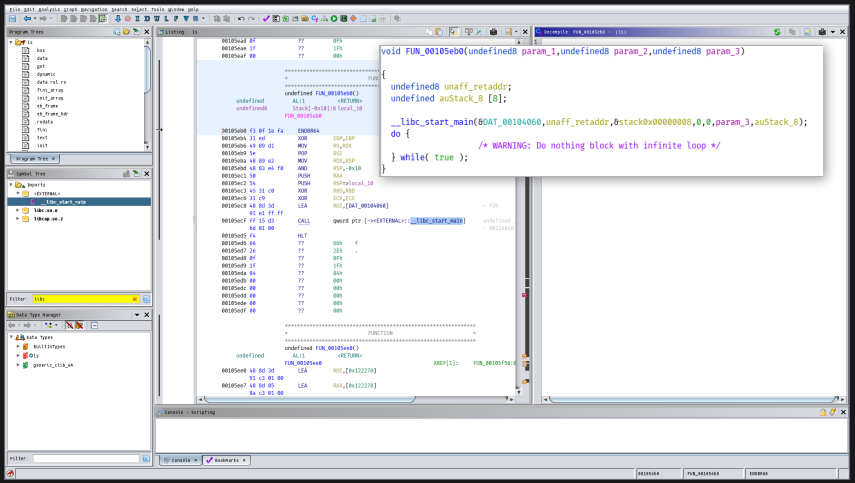


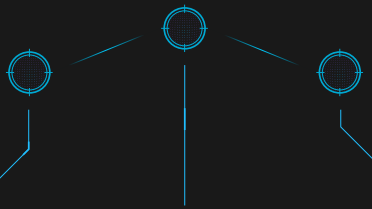
Demo

Hands-on #1: Simple Crackme


```
$ ./crackme.elf foo
Missing login ...
Try again!
$ ********** ./crackme.elf ****
Well done!
```

Level: Easy

Objectives: Getting started with reverse engineering and compiler optimizations.



Hints

- http://flaviojslab.blogspot.com/2008/02/integer-division.html
- The charset of the password is `abcdefghijklmnopqrstuvwxyz` (lower case)
- What is the priority between xor and add ?

Reverse Engineering Structures

Reverse Engineering Structures

Reverse engineering is not always about understanding a function or an algorithm.

It might also involve understanding complex data types like structures or C++ classes.

```
struct PointTy{
  int x;
  int y;
};

int compute(int x, int y) {
  PointTy* P = malloc(sizeof(PointTy));
  P->x = x;
  P->y = y;
  return P->x + P->y;
}
```

Reverse Engineering Structures

```
sub     rsp, 18h
mov     [rsp+18h+var_4], edi
mov     [rsp+18h+var_8], esi
mov     edi, 8
call    _malloc
mov     [rsp+18h+var_10], rax
mov     eax, [rsp+18h+var_4]
mov     rcx, [rsp+18h+var_10]
mov     [rcx], eax
mov     eax, [rsp+18h+var_8]
mov     rcx, [rsp+18h+var_10]
mov     [rcx+4], eax
mov     rax, [rsp+18h+var_10]
mov     eax, [rax]
mov     rcx, [rsp+18h+var_10]
add     eax, [rcx+4]
add     rsp, 18h
retn
```

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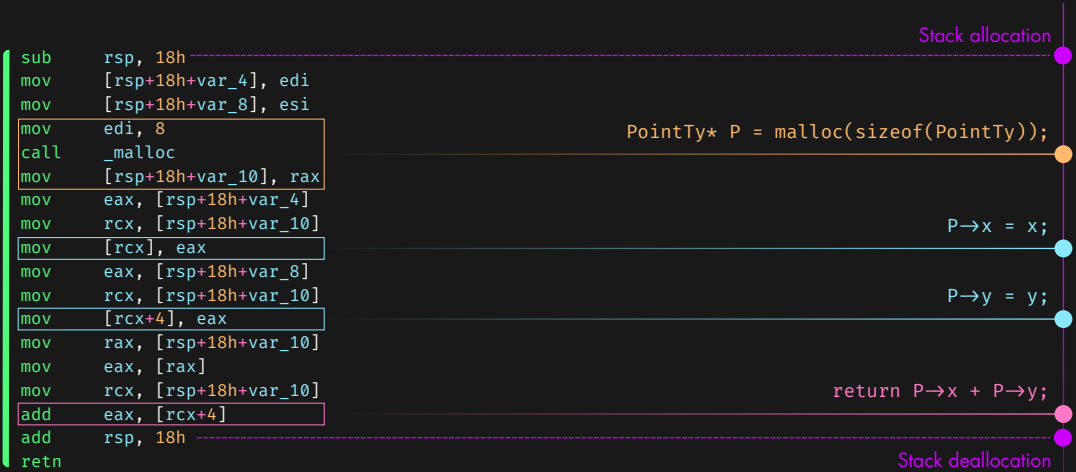
Reverse Engineering Structures



Reverse Engineering Structures

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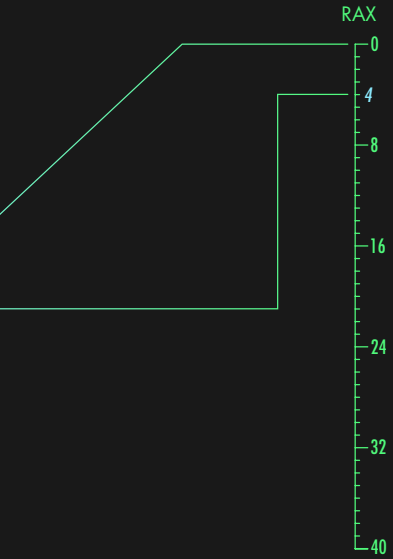
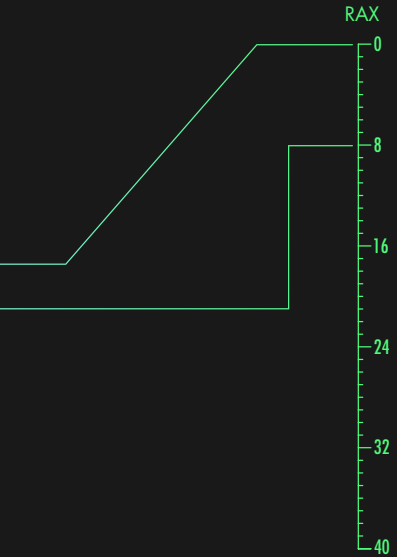


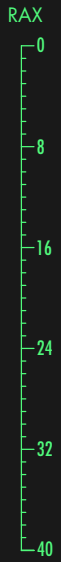
Reverse Engineering Structures

```
struct PointTy {
  void* x;
  void* y;
};
```



Reverse Engineering Structures

```
struct PointTy {
  char  x;
  void* y;
};
```



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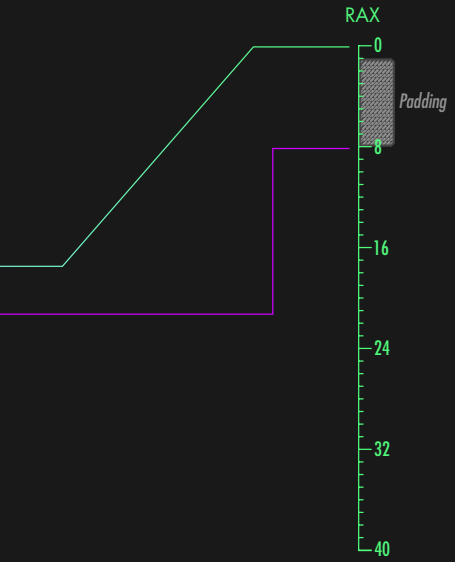
};
```



Reverse Engineering Structures

```
int compute(PointTy* P) {
  P->x = 1;
  P->y = 2;
  return P->x + P->y;
}

int main(int argc, char** argv) {
  PointTy P;
  int value = compute(&P);
  return value;
}
```

Reverse Engineering Structures

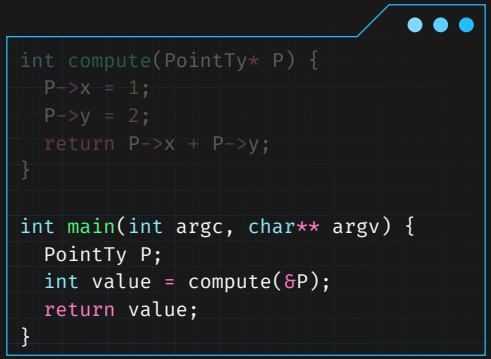
```
int compute(PointTy* P) {
  P->x = 1;
  P->y = 2;
  return P->x + P->y;
}

int main(int argc, char** argv) {
  PointTy P;
  int value = compute(&P);
  return value;
}
```

```
$ clang++ -O0 [ ... ]
```

```
PUSH        RBP
MOV         RBP,RSP
SUB         RSP,0×20
MOV         dword ptr [RBP + local_c],0×0
MOV         dword ptr [RBP + local_10],EDI
MOV         qword ptr [RBP + local_18],RSI
LEA         RDI=>local_20,[RBP + -0×18]
CALL        FUN_00101120
MOV         dword ptr [RBP + local_24],EAX
MOV         EAX,dword ptr [RBP + local_24]
ADD         RSP,0×20
POP         RBP
RET
```

Reverse Engineering Structures



```
int compute(PointTy* P) {
  P->x = 1;
  P->y = 2;
  return P->x + P->y;
}

int main(int argc, char** argv) {
  PointTy P;
  int value = compute(&P);
  return value;
}
```

$ clang++ -O0 [...]

```
// main
undefined4 FUN_00101150(undefined4 param_1, ... ) {
  undefined4 uVar1;
  undefined  local_20 [8];
  undefined8 local_18;
  undefined4 local_10;
  undefined4 local_c;

  local_c = 0;
  local_18 = param_2;
  local_10 = param_1;
  uVar1 = FUN_00101120(local_20);
  return uVar1;
}
```

Reverse Engineering Structures

```
int compute(PointTy* P) {
  P->x = 1;
  P->y = 2;
  return P->x + P->y;
}

int main(int argc, char** argv) {
  PointTy P;
  int value = compute(&P);
  return value;
}
```

```
$ clang++ -O1 [ ... ]
```

```
PUSH        RAX
MOV         RDI,RSP
CALL        FUN_00101120
POP         RCX
RET
```

Reverse Engineering Structures

```
int compute(PointTy* P) {
  P->x = 1;
  P->y = 2;
  return P->x + P->y;
}

int main(int argc, char** argv) {
  PointTy P;
  int value = compute(&P);
  return value;
}
```

```
$ clang++ -O1 [ ... ]
```

```
// main
void FUN_00101150(void) {
  undefined auStack_8[8];

  FUN_00101120(auStack_8);
  return;
}
```

Reverse Engineering Structures

```
int compute(PointTy* P) {
  P->x = 1;
  P->y = 2;
  return P->x + P->y;
}

int main(int argc, char** argv) {
  PointTy P;
  int value = compute(&P);
  return value;
}
```

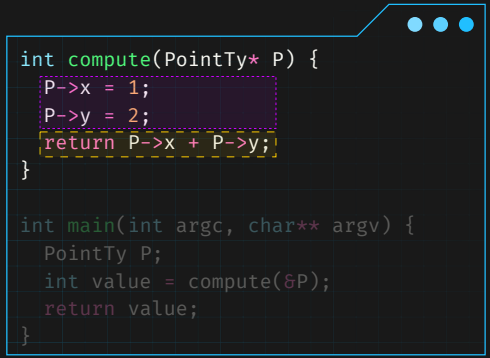
Reverse Engineering Structures

```
int compute(PointTy* P) {
  P->x = 1;
  P->y = 2;
  return P->x + P->y;
}

int main(int argc, char** argv) {
  PointTy P;
  int value = compute(&P);
  return value;
}
```

```
MOV     qword ptr [RSP + local_8],RDI
MOV     RAX,qword ptr [RSP + local_8]
MOV     dword ptr [RAX],0x1
MOV     RAX,qword ptr [RSP + local_8]
MOV     dword ptr [RAX + 0x4],0x2
MOV     RAX,qword ptr [RSP + local_8]
MOV     EAX,dword ptr [RAX]
MOV     RCX,qword ptr [RSP + local_8]
ADD     EAX,dword ptr [RCX + 0x4]
RET
```

Reverse Engineering Structures



```
int compute(PointTy* P) {
  P->x = 1;
  P->y = 2;
  return P->x + P->y;
}

int main(int argc, char** argv) {
  PointTy P;
  int value = compute(&P);
  return value;
}
```

```
// compute
int FUN_00101120(int *param_1) {
  *param_1 = 1;
  param_1[1] = 2;
  return *param_1 + param_1[1];
}
```

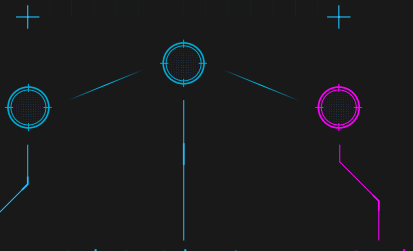
Demo

Hands-on #2: Structures


```
$ ./crackme_medium.elf 01020304
Try again!
$ ./crackme_medium.elf ********
Well done!
```

Level: Medium

Objectives: Identify and reverse structures



Reverse Engineering Large Binaries

Reverse Engineering Large Binaries

Most of the programs relies on third-party libraries that can be dynamically or statically linked.

Reverse Engineering Large Binaries

MD5 Computation with OpenSSL

```c
void do_md5(const char* input) {
  uint8_t H[MD5_DIGEST_LENGTH];
  MD5_CTX ctx;

  MD5_Init(&ctx);
  MD5_Update(&ctx, input, strlen(input));
  MD5_Final(H, &ctx);

  char H_str[MD5_DIGEST_LENGTH * 2];
  for (size_t i = 0; i < MD5_DIGEST_LENGTH; ++i) {
    sprintf(&H_str[i * 2], "%02x", H[i]);
  }
  printf("md5('%s'): %s\n", input, H_str);
}
```

Reverse Engineering Large Binaries

MD5 Computation with OpenSSL

```
void do_md5(const char* input) {
  uint8_t H[MD5_DIGEST_LENGTH];
  MD5_CTX ctx;

  MD5_Init(&ctx);
  MD5_Update(&ctx, input, strlen(input));
  MD5_Final(H, &ctx);

  char H_str[MD5_DIGEST_LENGTH * 2];
  for (size_t i = 0; i < MD5_DIGEST_LENGTH; ++i) {
    sprintf(&H_str[i * 2], "%02x", H[i]);
  }
  printf("md5('%s'): %s\n", input, H_str);
}
```

```
$ clang -O0 main.cpp -o main -lcrypto
```

Dynamic link with OpenSSL

Reverse Engineering Large Binaries

MD5 Computation with OpenSSL

```c
void do_md5(const char* input) {
  uint8_t H[MD5_DIGEST_LENGTH];
  MD5_CTX ctx;

  MD5_Init(&ctx);
  MD5_Update(&ctx, input, strlen(input));
  MD5_Final(H, &ctx);

  char H_str[MD5_DIGEST_LENGTH * 2];
  for (size_t i = 0; i < MD5_DIGEST_LENGTH; ++i) {
    sprintf(&H_str[i * 2], "%02x", H[i]);
  }
  printf("md5('%s'): %s\n", input, H_str);
}
```

```c
void FUN_001011a0(char *param_1) {
  char *data;
  size_t len;
  ulong local_b0;
  char local_a8 [32];
  MD5_CTX local_88;
  byte local_28 [24];
  char *local_10;

  local_10 = param_1;
  MD5_Init(&local_88);
  data = local_10;
  len = strlen(local_10);
  MD5_Update(&local_88,data,len);
  MD5_Final(local_28,&local_88);
  for (local_b0 = 0; local_b0 < 0x10; local_b0 = local_b0 + 1) {
    sprintf(local_a8 + local_b0 * 2,"%02x",(ulong)local_28[local_b0]);
  }
  printf("md5(\'%s\'): %s\n",local_10,local_a8);
  return;
```

Dynamically imported functions

Reverse Engineering Large Binaries

MD5 Computation with OpenSSL

```c
void do_md5(const char* input) {
  uint8_t H[MD5_DIGEST_LENGTH];
  MD5_CTX ctx;

  MD5_Init(&ctx);
  MD5_Update(&ctx, input, strlen(input));
  MD5_Final(H, &ctx);

  char H_str[MD5_DIGEST_LENGTH * 2];
  for (size_t i = 0; i < MD5_DIGEST_LENGTH; ++i) {
    sprintf(&H_str[i * 2], "%02x", H[i]);
  }
  printf("md5('%s'): %s\n", input, H_str);
}
```

```c
void FUN_001011a0(char *param_1) {
  char *data;
  size_t len;
  ulong local_b0;
  char local_a8 [32];
  MD5_CTX local_88;
  byte local_28 [24];
  char *local_10;

  local_10 = param_1;
  MD5_Init(&local_88);
  data = local_10;
  len = strlen(local_10);
  MD5_Update(&local_88,data,len);
  MD5_Final(local_28,&local_88);
  for (local_b0 = 0; local_b0 < 0x10; local_b0 = local_b0 + 1) {
    sprintf(local_a8 + local_b0 * 2,"%02x",(ulong)local_28[local_b0]);
  }
  printf("md5('%s'): %s\n",local_10,local_a8);
  return;
```

Dynamically imported functions

Can't be stripped

Reverse Engineering Large Binaries

MD5 Computation with OpenSSL

```
void do_md5(const char* input) {
  uint8_t H[MD5_DIGEST_LENGTH];
  MD5_CTX ctx;

  MD5_Init(&ctx);
  MD5_Update(&ctx, input, strlen(input));
  MD5_Final(H, &ctx);

  char H_str[MD5_DIGEST_LENGTH * 2];
  for (size_t i = 0; i < MD5_DIGEST_LENGTH; ++i) {
    sprintf(&H_str[i * 2], "%02x", H[i]);
  }
  printf("md5('%s'): %s\n", input, H_str);
}
```

```
$ clang -O0 main.cpp -o main libcrypto.a
```

Static link with OpenSSL

Reverse Engineering Large Binaries

MD5 Computation with OpenSSL

```c
void do_md5(const char* input) {
  uint8_t H[MD5_DIGEST_LENGTH];
  MD5_CTX ctx;

  MD5_Init(&ctx);
  MD5_Update(&ctx, input, strlen(input));
  MD5_Final(H, &ctx);

  char H_str[MD5_DIGEST_LENGTH * 2];
  for (size_t i = 0; i < MD5_DIGEST_LENGTH; ++i) {
    sprintf(&H_str[i * 2], "%02x", H[i]);
  }
  printf("md5('%s'): %s\n", input, H_str);
}
```

```c
void FUN_0013d0f0(undefined8 param_1) {
  undefined8 uVar1;
  undefined8 uVar2;
  ulong uStack_b0;
  undefined auStack_a8 [32];
  undefined auStack_88 [96];
  undefined auStack_28 [24];
  undefined8 uStack_10;

  uStack_10 = param_1;
  FUN_0028ffa0(auStack_88);
  uVar1 = uStack_10;
  uVar2 = strlen(uStack_10);
  FUN_0028f940(auStack_88,uVar1,uVar2);
  FUN_0028fb80(auStack_28,auStack_88);
  for (uStack_b0 = 0; uStack_b0 < 0x10; uStack_b0 = uStack_b0 + 1) {
    sprintf(auStack_a8 + uStack_b0 * 2,&DAT_003a1ed1,auStack_28[uStack_b0]);
  }
  printf(&DAT_00363004,uStack_10,auStack_a8);
  return;
```

Statically imported functions

Reverse Engineering Large Binaries

Dynamic Link

```
void FUN_001011a0(char *param_1) {
  char *data;
  size_t len;
  ulong local_b0;
  char local_a8 [32];
  MD5_CTX local_88;
  byte local_28 [24];
  char *local_10;

  local_10 = param_1;
  MD5_Init(&local_88);
  data = local_10;
  len = strlen(local_10);
  MD5_Update(&local_88,data,len);
  MD5_Final(local_28,&local_88);
  for (local_b0 = 0; local_b0 < 0x10; local_b0 = local_b0 + 1) {
    sprintf(local_a8 + local_b0 * 2,"%02x",(ulong)local_28[local_b0]);
  }
  printf("md5(\'%s\'): %s\n",local_10,local_a8);
  return;
}
```

Static Link (and stripped)

```
void FUN_0013d0f0(undefined8 param_1) {
  undefined8 uVar1;
  undefined8 uVar2;
  ulong uStack_b0;
  undefined auStack_a8 [32];
  undefined auStack_88 [96];
  undefined auStack_28 [24];
  undefined8 uStack_10;

  uStack_10 = param_1;
  FUN_0028ffa0(auStack_88);
  uVar1 = uStack_10;
  uVar2 = strlen(uStack_10);
  FUN_0028f940(auStack_88,uVar1,uVar2);
  FUN_0028fb80(auStack_28,auStack_88);
  for (uStack_b0 = 0; uStack_b0 < 0x10; uStack_b0 = uStack_b0 + 1) {
    sprintf(auStack_a8 + uStack_b0 * 2,&DAT_003a1ed1,auStack_28[uStack_b0]);
  }
  printf(&DAT_00363004,uStack_10,auStack_a8);
  return;
}
```

Reverse Engineering Large Binaries

When a library is statically linked and the program correctly stripped[1], the reverse engineering of the whole binary can be challenging.

[1] this step is error prone

Reverse Engineering Large Binaries

When a library is statically linked and the program correctly stripped[1], the reverse engineering of the whole binary can be challenging.

$\Rightarrow$ We can quickly get lost while trying to analyse the binary.

[1] this step is error prone

Reverse Engineering Large Binaries

Dynamic Link

- Smaller binary size
- Require that the user has the library with the correct version
- Easier to reverse

Static Link (and stripped)

```
void FUN_0013d0f0(undefined8 param_1) {
  undefined8 uVar1;
  undefined8 uVar2;
  ulong uStack_b0;
  undefined auStack_a8 [32];
  undefined auStack_88 [96];
  undefined auStack_28 [24];
  undefined8 uStack_10;

  uStack_10 = param_1;
  FUN_0028ffa0(auStack_88);
  uVar1 = uStack_10;
  uVar2 = strlen(uStack_10);
  FUN_0028f940(auStack_88,uVar1,uVar2);
  FUN_0028fb80(auStack_28,auStack_88);
  for (uStack_b0 = 0; uStack_b0 < 0x10; uStack_b0 = uStack_b0 + 1) {
    sprintf(auStack_a8 + uStack_b0 * 2,&DAT_003a1ed1,auStack_28[uStack_b0]);
  }
  printf(&DAT_00363004,uStack_10,auStack_a8);
  return;
}
```

Reverse Engineering Large Binaries

Dynamic Link

- Smaller binary size
- Require that the user has the library with the correct version
- Easier to reverse

Static Link (and stripped)

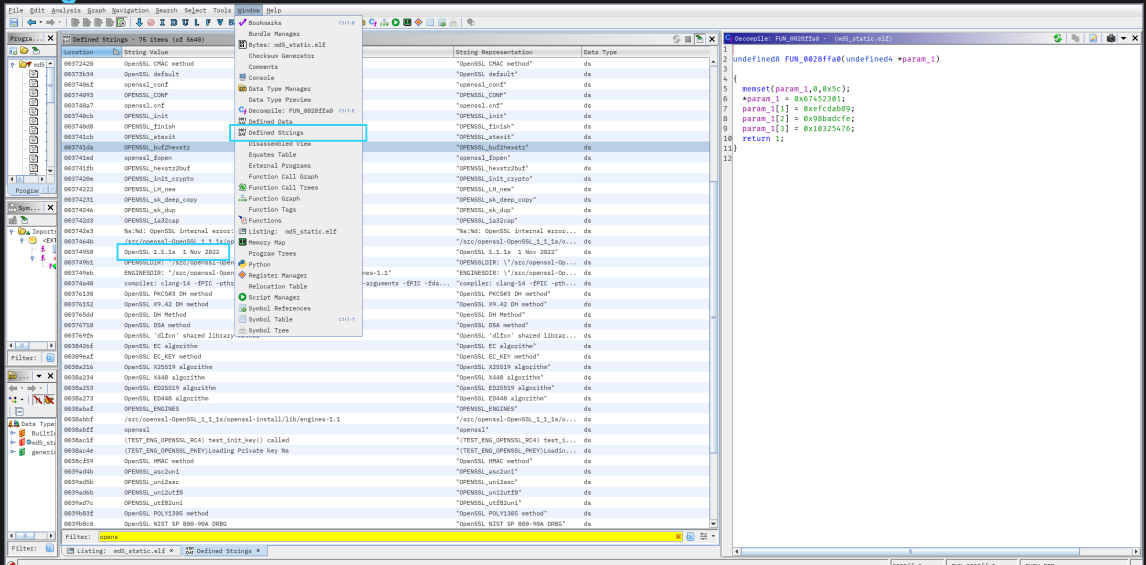
- Larger binary size
- The library is embedded in the binary
- Can be challenging to reverse

Reverse Engineering Large Binaries

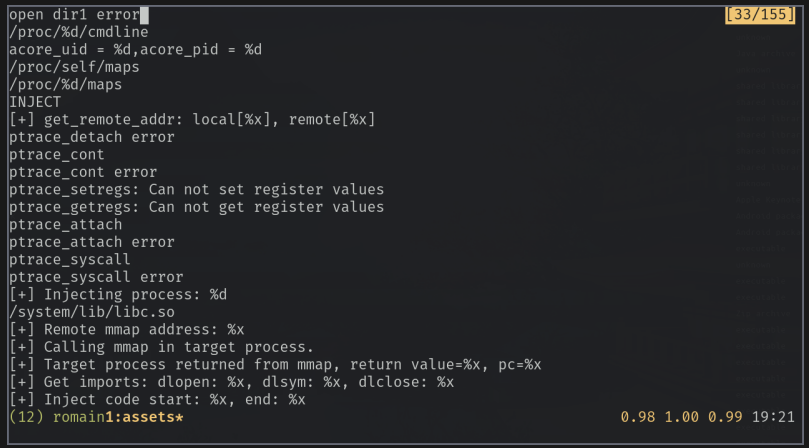
- Strings, logs
- Constants
- Functions relative position

1. Strings

Strings


File Edit Analysis Graph Navigation Search Select Tools Window Help
Bookmarks
Bundle Manager
Bytes: md5_static.elf
Checksum Generator
Comments
Console
Data Type Manager
Data Type Preview
Decompile: FUN_0028ffa0
Defined Data
Defined Strings
Disassembled View
Equates Table
External Programs
Function Call Graph
Function Call Trees
Function Graph
Function Tags
Functions
Listing: md5_static.elf
Memory Map
Program Trees
Python
Register Manager
Relocation Table
Script Manager
Symbol References
Symbol Table
Symbol Tree
Defined Strings - 75 items (of 5640)
Location
String Value
String Representation
Data Type
Decompile: FUN_0028ffa0 - (md5_static.elf)
undefined8 FUN_0028ffa0(undefined4 *param_1)
{
memset(param_1,0,0x5c);
*param_1 = 0x67452301;
param_1[1] = 0xefcdab89;
param_1[2] = 0x98badcfe;
param_1[3] = 0x10325476;
return 1;
}
Filter: opens
Listing: md5_static.elf
Defined Strings
0028ffa0
FUN_0028ffa0
PUSH RBP

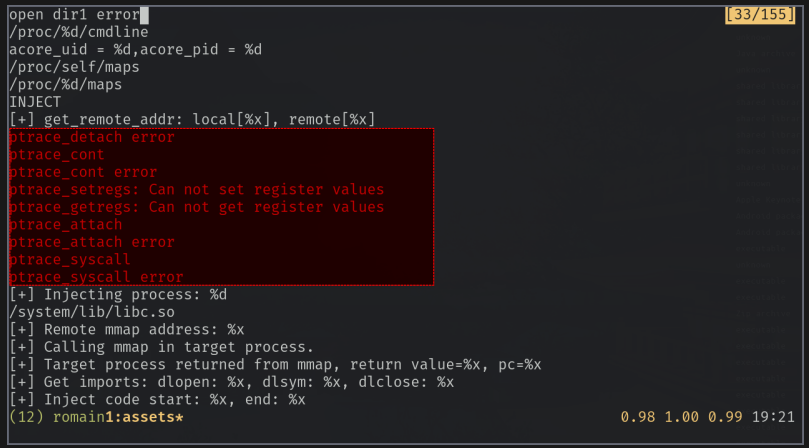
Strings



assets/injectso_arm

List of strings in one of the libraries used in the Android Pegasus spyware.

Strings

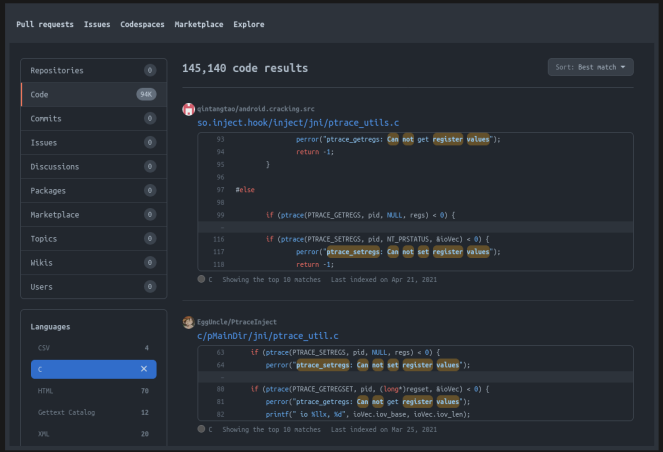


assets/injectso_arm

List of strings in one of the libraries used in the Android Pegasus spyware.

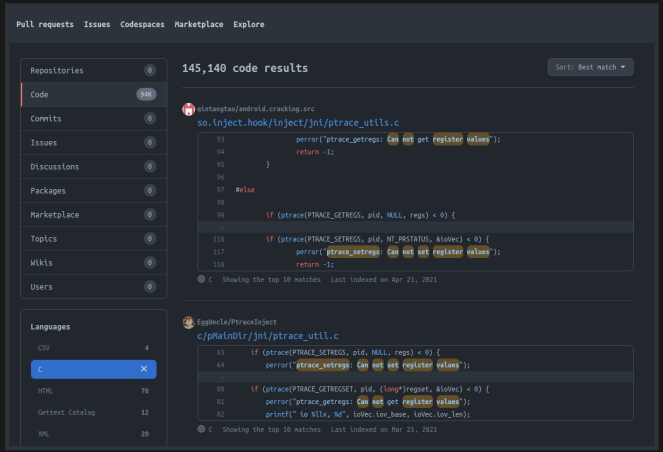
Strings

```
ptrace_detach error
ptrace_cont
ptrace_cont error
ptrace_setregs: Can not set register values
ptrace_getregs: Can not get register values
ptrace_attach
ptrace_attach error
ptrace_syscall
ptrace_syscall error
```



Strings

```
ptrace_detach error
ptrace_cont
ptrace_cont error
ptrace_setregs: Can not set register values
ptrace_getregs: Can not get register values
ptrace_attach
ptrace_attach error
ptrace_syscall
ptrace_syscall error
```



Don't spend time on reversing open-source code!

2. Constants

Constants

```
void FUN_0013d0f0(undefined8 param_1) {
  undefined8 uVar1;
  undefined8 uVar2;
  ulong uStack_b0;
  undefined auStack_a8 [32];
  undefined auStack_88 [96];
  undefined auStack_28 [24];
  undefined8 uStack_10;

  uStack_10 = param_1;
  FUN_0028ffa0(auStack_88);
  uVar1 = uStack_10;
  uVar2 = strlen(uStack_10);
  FUN_0028f940(auStack_88,uVar1,uVar2);
  FUN_0028fb80(auStack_28,auStack_88);
  for (uStack_b0 = 0; uStack_b0 < 0x10; uStack_b0 = uStack_b0 + 1) {
    sprintf(auStack_a8 + uStack_b0 * 2,&DAT_003a1ed1,auStack_28[uStack_b0]);
  }
  printf(&DAT_00363004,uStack_10,auStack_a8);
  return;
```

Decompile: FUN_0028ffa0 - (md5_static.elf)

```
1
2  undefined8 FUN_0028ffa0(undefined4 *param_1)
3
4  {
5    memset(param_1,0,0x5c);
6    *param_1 = 0x67452301;
7    param_1[1] = 0xefcdab89;
8    param_1[2] = 0x98badcfe;
9    param_1[3] = 0x10325476;
10   return 1;
11 }
12
```

Constants

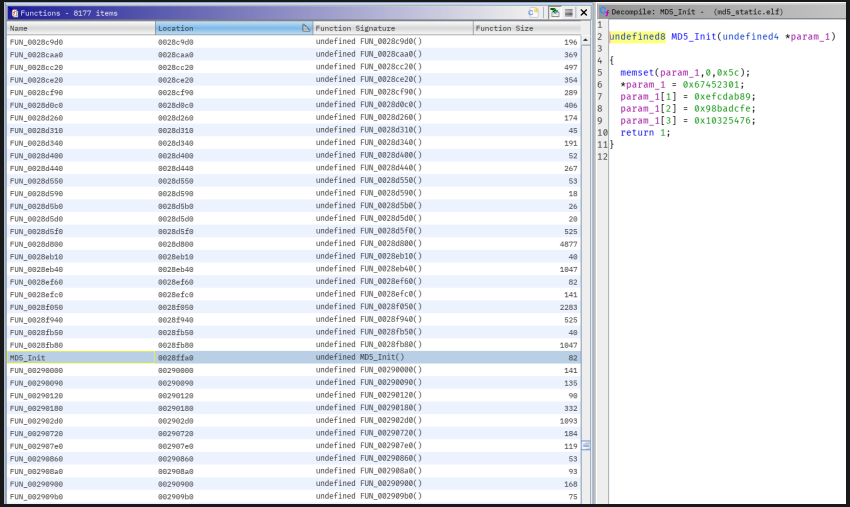
```
void FUN_0013d0f0(undefined8 param_1) {
  undefined8 uVar1;
  undefined8 uVar2;
  ulong uStack_b0;
  undefined auStack_a8 [32];
  undefined auStack_88 [96];
  undefined auStack_28 [24];
  undefined8 uStack_10;

  uStack_10 = param_1;
  FUN_0028ffa0(auStack_88);
  uVar1 = uStack_10;
  uVar2 = strlen(uStack_10);
  FUN_0028f940(auStack_88,uVar1,uVar2);
  FUN_0028fb80(auStack_28,auStack_88);
  for (uStack_b0 = 0; uStack_b0 < 0x10; uStack_b0 = uStack_b0 + 1) {
    sprintf(auStack_a8 + uStack_b0 * 2,&DAT_003a1ed1,auStack_28[uStack_b0]);
  }
  printf(&DAT_00363004,uStack_10,auStack_a8);
  return;
```

Decompile: FUN_0028ffa0 - (md5_static.elf)

```
1
2  undefined8 FUN_0028ffa0(undefined4 *param_1)
3
4  {
5    memset(param_1,0,0x5c);
6    *param_1 = 0x67452301;
7    param_1[1] = 0xefcdab89;
8    param_1[2] = 0x98badcfe;
9    param_1[3] = 0x10325476;
10   return 1;
11 }
12
```

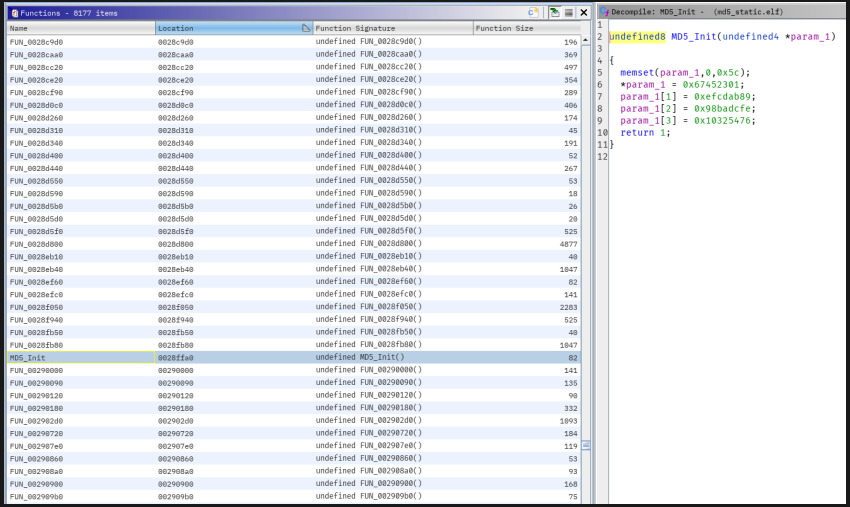
MD5 Constants

Constants


Functions - 8177 items
Name
Location
Function Signature
Function Size
FUN_0028c9d0 0028c9d0 undefined FUN_0028c9d0() 196
FUN_0028caa0 0028caa0 undefined FUN_0028caa0() 369
FUN_0028cc20 0028cc20 undefined FUN_0028cc20() 497
FUN_0028ce20 0028ce20 undefined FUN_0028ce20() 354
FUN_0028cf90 0028cf90 undefined FUN_0028cf90() 289
FUN_0028d0c0 0028d0c0 undefined FUN_0028d0c0() 406
FUN_0028d2e0 0028d2e0 undefined FUN_0028d260() 174
FUN_0028d310 0028d310 undefined FUN_0028d310() 45
FUN_0028d340 0028d340 undefined FUN_0028d340() 191
FUN_0028d400 0028d400 undefined FUN_0028d400() 52
FUN_0028d440 0028d440 undefined FUN_0028d440() 267
FUN_0028d550 0028d550 undefined FUN_0028d550() 53
FUN_0028d590 0028d590 undefined FUN_0028d590() 18
FUN_0028d5b0 0028d5b0 undefined FUN_0028d5b0() 26
FUN_0028d5d0 0028d5d0 undefined FUN_0028d5d0() 20
FUN_0028d5f0 0028d5f0 undefined FUN_0028d5f0() 525
FUN_0028d800 0028d800 undefined FUN_0028d800() 4877
FUN_0028eb10 0028eb10 undefined FUN_0028eb10() 40
FUN_0028eb40 0028eb40 undefined FUN_0028eb40() 1047
FUN_0028ef60 0028ef60 undefined FUN_0028ef60() 82
FUN_0028efc0 0028efc0 undefined FUN_0028efc0() 141
FUN_0028f050 0028f050 undefined FUN_0028f050() 2283
FUN_0028f940 0028f940 undefined FUN_0028f940() 525
FUN_0028fb50 0028fb50 undefined FUN_0028fb50() 48
FUN_0028fb80 0028fb80 undefined FUN_0028fb80() 1047
MD5_Init 0028ffa0 undefined MD5_Init() 82
FUN_00290000 00290000 undefined FUN_00290000() 141
FUN_00290090 00290090 undefined FUN_00290090() 135
FUN_00290120 00290120 undefined FUN_00290120() 90
FUN_00290180 00290180 undefined FUN_00290180() 332
FUN_002902d0 002902d0 undefined FUN_002902d0() 1093
FUN_00290720 00290720 undefined FUN_00290720() 184
FUN_002907e0 002907e0 undefined FUN_002907e0() 119
FUN_00290860 00290860 undefined FUN_00290860() 53
FUN_002908a0 002908a0 undefined FUN_002908a0() 93
FUN_00290900 00290900 undefined FUN_00290900() 168
FUN_002909b0 002909b0 undefined FUN_002909b0() 75
Decompile: MD5_Init - (md5_static.elf)
undefined8 MD5_Init(undefined4 *param_1)
{
memset(param_1,0,0x5c);
*param_1 = 0x67452301;
param_1[1] = 0xefcdab89;
param_1[2] = 0x98badcfe;
param_1[3] = 0x10325476;
return 1;
}

3. Relative Positioning

Constants


Functions - 8177 items
Name
Location
Function Signature
Function Size
FUN_0028c9d0 0028c9d0 undefined FUN_0028c9d0() 196
FUN_0028caa0 0028caa0 undefined FUN_0028caa0() 369
FUN_0028cc20 0028cc20 undefined FUN_0028cc20() 497
FUN_0028ce20 0028ce20 undefined FUN_0028ce20() 354
FUN_0028cf90 0028cf90 undefined FUN_0028cf90() 289
FUN_0028d0c0 0028d0c0 undefined FUN_0028d0c0() 406
FUN_0028d260 0028d260 undefined FUN_0028d260() 174
FUN_0028d310 0028d310 undefined FUN_0028d310() 45
FUN_0028d340 0028d340 undefined FUN_0028d340() 191
FUN_0028d400 0028d400 undefined FUN_0028d400() 52
FUN_0028d440 0028d440 undefined FUN_0028d440() 267
FUN_0028d550 0028d550 undefined FUN_0028d550() 53
FUN_0028d590 0028d590 undefined FUN_0028d590() 18
FUN_0028d5b0 0028d5b0 undefined FUN_0028d5b0() 26
FUN_0028d5d0 0028d5d0 undefined FUN_0028d5d0() 20
FUN_0028d5f0 0028d5f0 undefined FUN_0028d5f0() 525
FUN_0028d800 0028d800 undefined FUN_0028d800() 4877
FUN_0028eb10 0028eb10 undefined FUN_0028eb10() 40
FUN_0028eb40 0028eb40 undefined FUN_0028eb40() 1047
FUN_0028ef60 0028ef60 undefined FUN_0028ef60() 82
FUN_0028efc0 0028efc0 undefined FUN_0028efc0() 141
FUN_0028f050 0028f050 undefined FUN_0028f050() 2283
FUN_0028f940 0028f940 undefined FUN_0028f940() 525
FUN_0028fb50 0028fb50 undefined FUN_0028fb50() 48
FUN_0028fb80 0028fb80 undefined FUN_0028fb80() 1047
MD5_Init 0028ffa0 undefined MD5_Init() 82
FUN_00290000 00290000 undefined FUN_00290000() 141
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FUN_00290120 00290120 undefined FUN_00290120() 98
FUN_00290180 00290180 undefined FUN_00290180() 332
FUN_002902d0 002902d0 undefined FUN_002902d0() 1093
FUN_00290720 00290720 undefined FUN_00290720() 184
FUN_002907e0 002907e0 undefined FUN_002907e0() 119
FUN_00290860 00290860 undefined FUN_00290860() 53
FUN_002908a0 002908a0 undefined FUN_002908a0() 93
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Decompile: MD5_Init - (md5_static.elf)
undefined8 MD5_Init(undefined4 *param_1)
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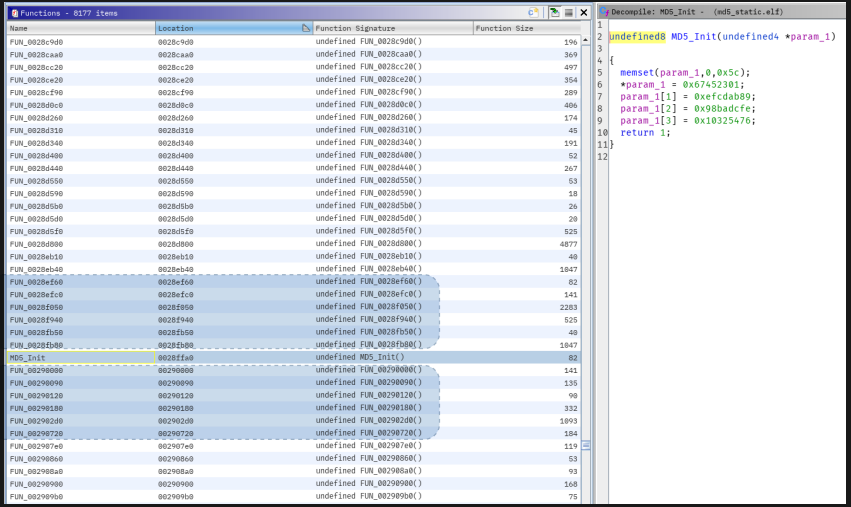
param_1[2] = 0x98badcfe;
param_1[3] = 0x10325476;
return 1;
}

Relative Positioning



Likely MD5-related functions

Likely MD5-related functions

Relative Positioning

```c
#include <stdio.h>
#include "md5_local.h"
#include <openssl/opensslv.h>

/*
 * Implemented from RFC1321 The MD5 Message-Digest Algorithm
 */

#define INIT_DATA_A (unsigned long)0x67452301L
#define INIT_DATA_B (unsigned long)0xefcdab89L
#define INIT_DATA_C (unsigned long)0x98badcfeL
#define INIT_DATA_D (unsigned long)0x10325476L

int MD5_Init(MD5_CTX *c)
{
    memset(c, 0, sizeof(*c));
    c->A = INIT_DATA_A;
    c->B = INIT_DATA_B;
    c->C = INIT_DATA_C;
    c->D = INIT_DATA_D;
    return 1;
}
```

- MD5_Update(...)
- MD5_Transform(...)
- MD5_Final(...)

OpenSSL_1_1_1s/crypto/md5/md5_dgst.c

Relative Positioning

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#include <stdio.h>
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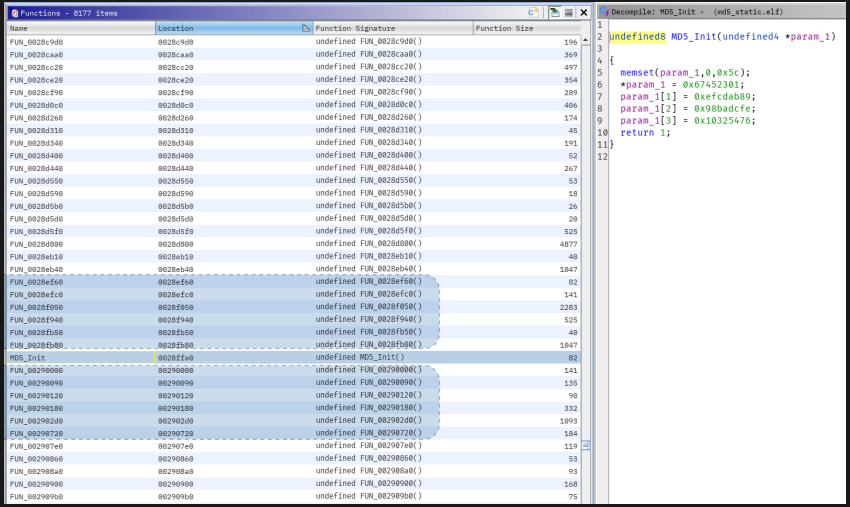
    c->A = INIT_DATA_A;
    c->B = INIT_DATA_B;
    c->C = INIT_DATA_C;
    c->D = INIT_DATA_D;
    return 1;
}
```

- MD5_Update(...)
- MD5_Transform(...)
- MD5_Final(...)

```
$ readelf -SW ./md5_dgst.o
Section Headers:
  [Nr] Name              Type      Off    Size   ES Flg Lk Inf Al
  [ 3] .text.MD5_Update  PROGBITS  000040 00020d 00  AX  0   0 16
  [ 5] .text.MD5_Transform PROGBITS 000250 000028 00  AX  0   0 16
  [ 7] .text.MD5_Final   PROGBITS  000280 000417 00  AX  0   0 16
  [ 9] .text.MD5_Init    PROGBITS  0006a0 000052 00  AX  0   0 16
```

OpenSSL_1_1_1s/crypto/md5/md5_dgst.c

Relative Positioning

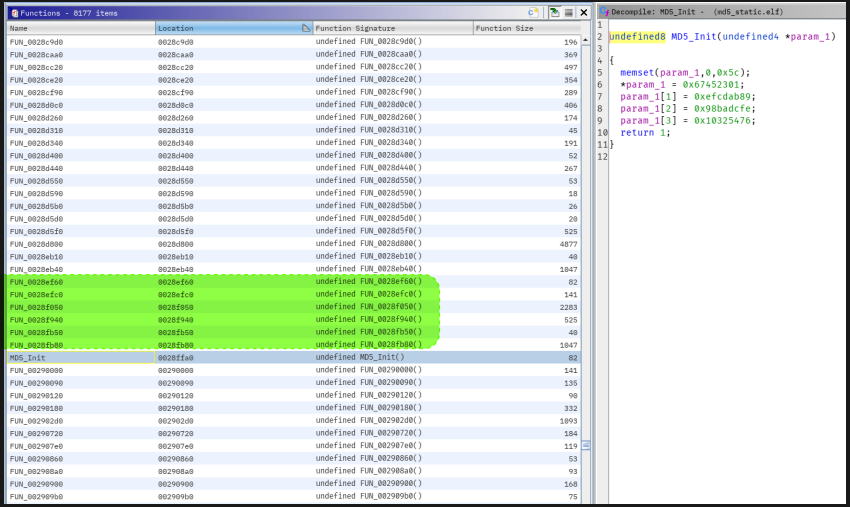


Likely MD5-related functions

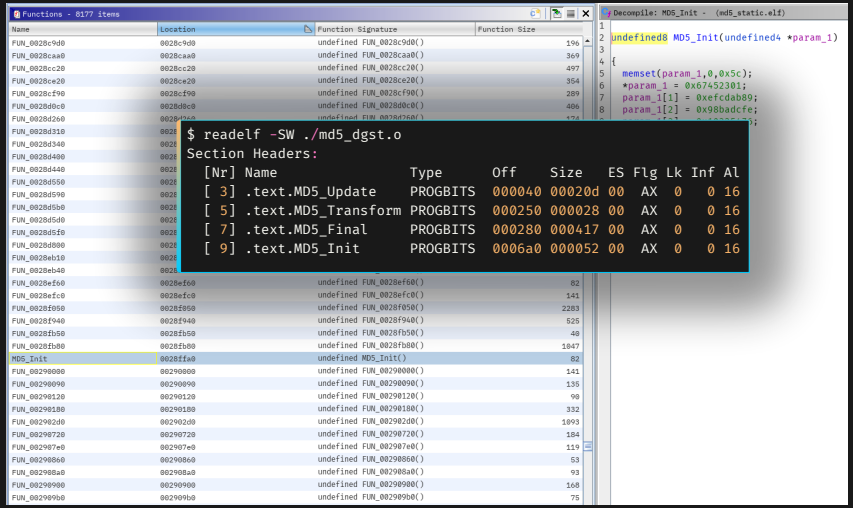
Likely MD5-related functions

Relative Positioning

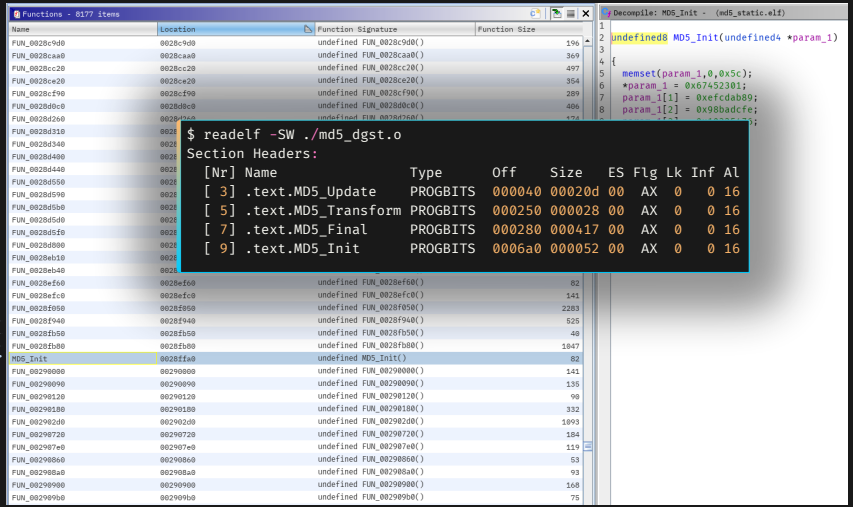
Likely MD5-related functions



Relative Positioning



Relative Positioning



Relative Positioning

As a rule of thumb:
Functions that are close each other in the source file (or compilation unit), are likely close in the compiled binary.

In particular, the relative order in the source code is preserved in the final binary[1].

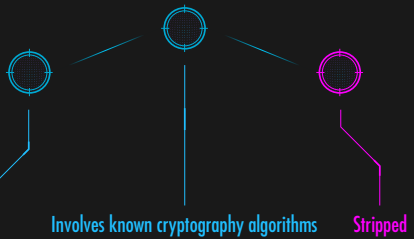
[1]This can be mitigated: *https://github.com/open-obfuscator/o-mvll/blob/main/src/core/utils.cpp#L231-L257*

Hands-on #3: Embedded Library


```
$ ./crackme_hard.elf "azertyw"
Try again!
$ ./crackme_hard.elf "***************"
Well done!
```

Level: Hard

Objectives: Reverse engineering a large binary with cryptography functions.



Guidelines

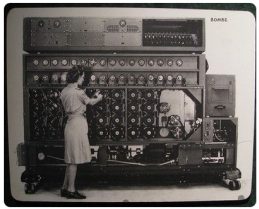
- Statically linked against an open-source cryptography library
- The API for cryptographic functions follows this sequence:
  1. `init()`
  2. `update()`
  3. `finalize()`

Closing Remarks

Closing Remarks

An opinionated guide on how to reverse engineer software, part 1

by Ryan Stortz Nov 2, 2021



This is the first post in a series meant to help improve your static reverse engineering skills. The target audience are folks who have dipped their toes into reverse engineering but found themselves feeling lost. Ideally, readers will have acquired an interactive disassembler such as **Binary Ninja**, **IDA Pro**, or **Ghidra** and have a bit of experience with the C or C++ programming languages. Throughout this series, I'll include links to functions disassembled with **Binary Ninja Cloud**, which offers a free interactive disassembler.

This is an opinionated guide. After 12 years of reverse engineering professionally, I have developed strong beliefs on how to get good at RE.

A highly recommended reading:

1. https://margin.re/2021/11/an-opinionated-guide-on-how-to-reverse-engineer-software-part-1/

2. https://margin.re/2021/11/an-opinionated-guide-on-how-to-reverse-engineer-software-part-2/

Closing Remarks

Closing Remarks

https://www.root-me.org

Thank You!