SCUx401CTF2021 逆向部分 WriteUp

RE1-ez_fps

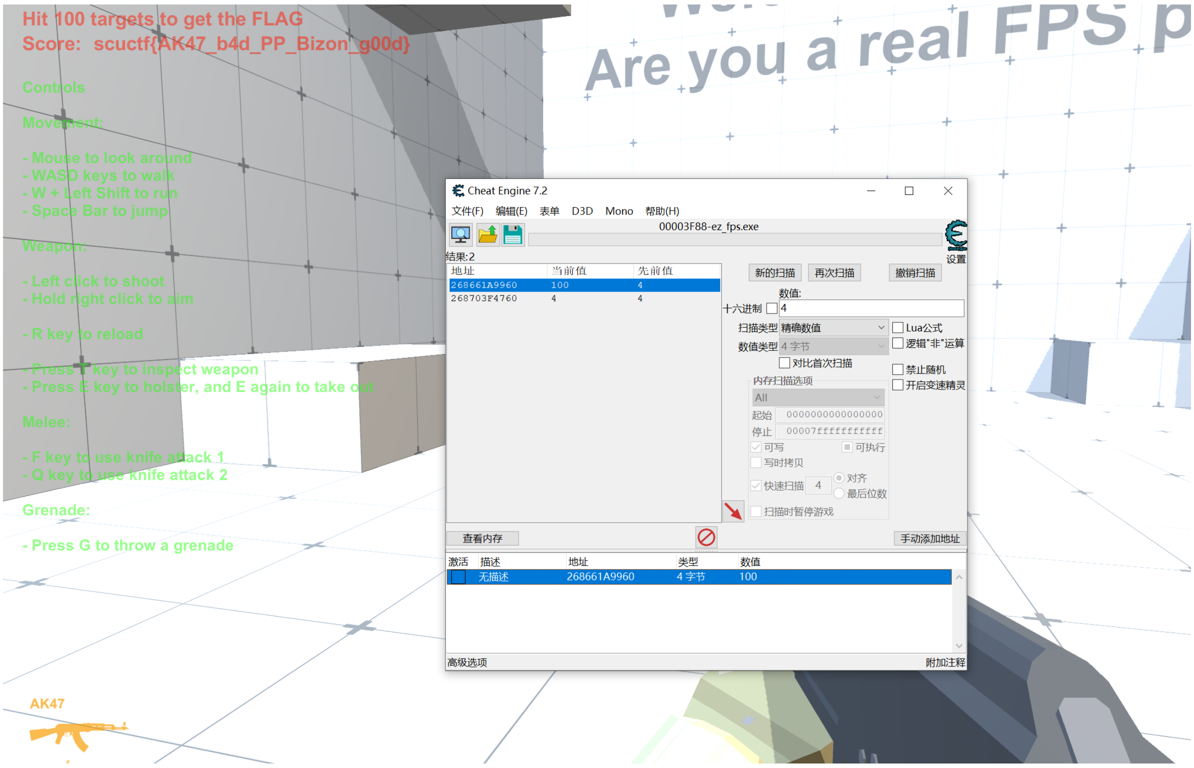
非常简单的 Unity3D 逆向，点进去之后是一个枪战游戏，解题方法有很多。

解法一

根据题目左上角的提示，打够100个靶子即可获得flag，嗯打：

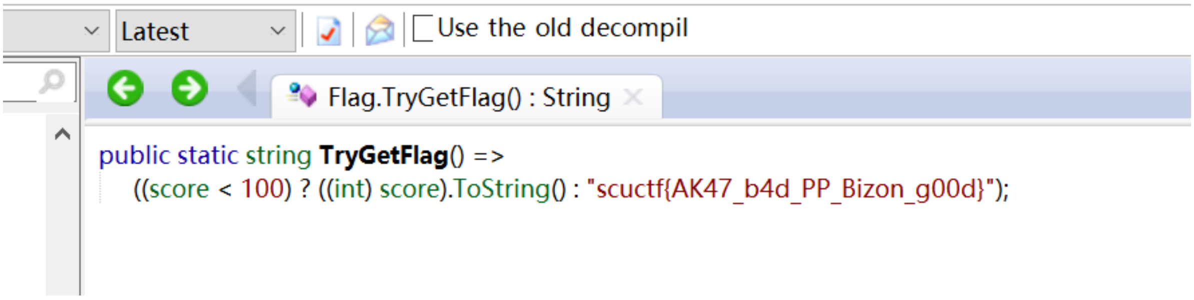
解法二

用 Cheat Engine 修改内存拿到flag：



解法三

使用 .Net Reflector 反编译 ez_fps_Data/Managed 目录下的 Assembly-CSharp.dll文件：



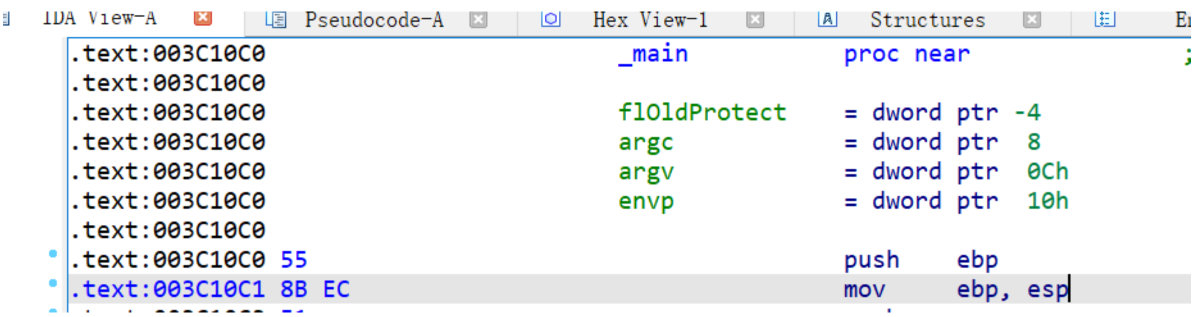
RE2-pixpix

GetPixel获取坐标(401, 401)处像素的RGB值，可以看到有一个函数被加密了，需要在运行时解密，解密需要用到之前获取的RGB值。也就是说我们要求出正确的RGB值才能拿到flag：

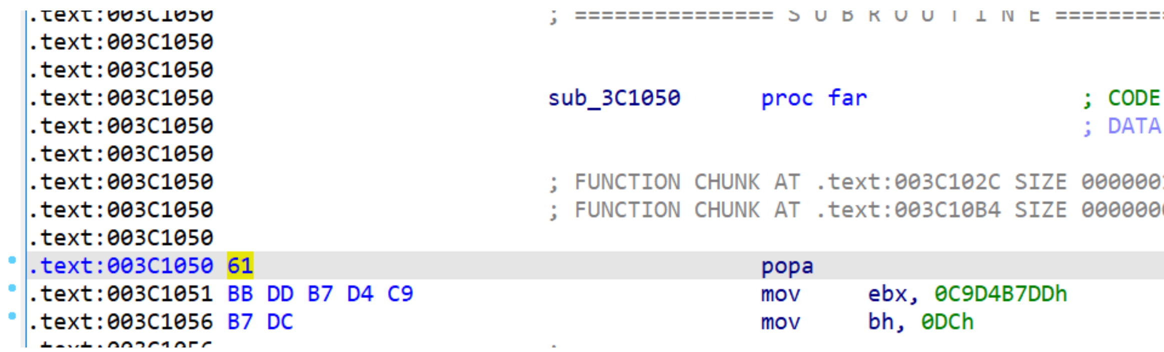
```
  DWORD flOldProtect; // [esp+8h] [ebp-4h] BYREF

  v3 = GetDC(0);
  v4 = GetPixel(v3, 401, 401);
  word_3C3384 = v4;
  byte_3C3386 = BYTE2(v4);
  VirtualProtect(sub_3C1050, (char *)nullsub_1 - (char *)sub_3C1050, 0x40u, &flOldProtect);
  v5 = 0;
  if ( (char *)nullsub_1 != (char *)sub_3C1050 )
  {
    do
    {
      v6 = v5;
      v7 = v5++;
      *((_BYTE *)sub_3C1050 + v7) ^= *((_BYTE *)&word_3C3384 + v6 % 3);
    }
    while ( v5 < (char *)nullsub_1 - (char *)sub_3C1050 );
  }
  VirtualProtect(sub_3C1050, (char *)nullsub_1 - (char *)sub_3C1050, flOldProtect, &flOldProtect);
  sub_3C1050(v9);
  return 0;
}
```

一般来说函数开头的汇编代码是固定的：

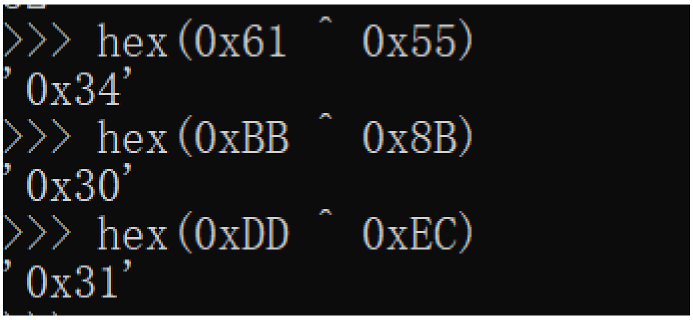
```
push    ebp
mov     ebp, esp
```



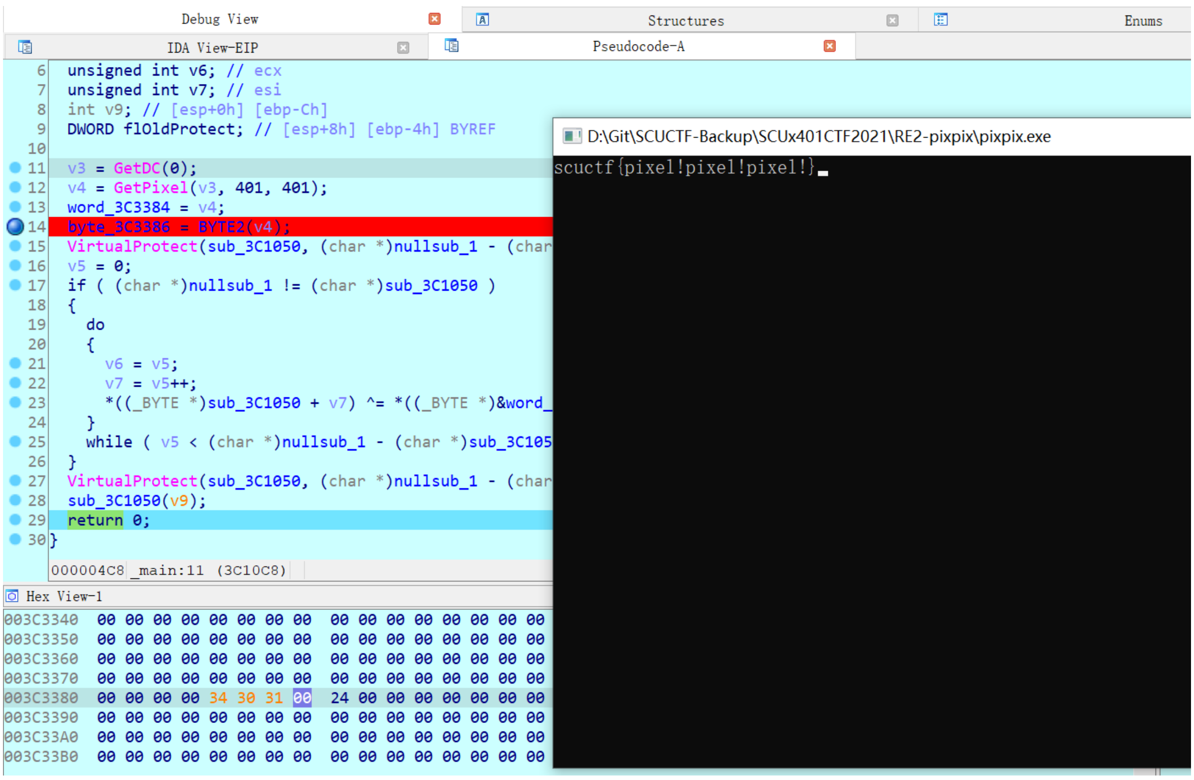
被加密的函数：



根据这个特征我们就能解出正确的RGB值为(0x34, 0x30, 0x31)：



动态调试修改内存得到flag：



RE3-rvm

简单的ruby逆向，是一个很简单的虚拟机，分析起来也很简单，只需要分析出每个opcode对应的指令格式即可。灵感来自国赛初赛一道很恶心的ruby逆向题，但难度要低很多。

直接在源码的基础上进行修改，解析shellcode：

```ruby
class RVM
    def initialize(shellcode)
        @PC = 0
        @FLAG = 1
        @shellcode = shellcode
        @reg = Array.new(27, 0)
    end

    def run
        begin
            op = @shellcode[@PC]
            #ADD reg, imm
            op == "1" ? (puts "@reg[#{@shellcode[(@PC + 1)..(@PC + 2)].to_i}] += 
#{@shellcode[(@PC + 3)..(@PC + 4)].to_i}";@PC += 5) :
            #XOR reg, imm
            op == "2" ? (puts "@reg[#{@shellcode[(@PC + 1)..(@PC + 2)].to_i}] ^= 
#{@shellcode[(@PC + 3)..(@PC + 4)].to_i}";@PC += 5) :
            #SUB reg, imm
            op == "3" ? (puts "@reg[#{@shellcode[(@PC + 1)..(@PC + 2)].to_i}] -= 
#{@shellcode[(@PC + 3)..(@PC + 4)].to_i}";@PC += 5) :
            #WRITE imm.chr
            op == "4" ? (puts "STDOUT<<#{@shellcode[(@PC + 1)..(@PC + 
3)].to_i.chr}";@PC += 4) :
            #CMP
            op == "5" ? (puts "((@reg[#{@shellcode[(@PC + 1)..(@PC + 2)].to_i}] 
== #{@shellcode[(@PC + 3)..(@PC + 5)].to_i}) ? @FLAG &= 1 : @FLAG = 0)";@PC += 
6) :
            #READ reg
            op == "6" ? (puts "READ reg";@PC += 1) :
            #JNZ 1
            op == "7" ? (puts "JNZ 1";@PC += 2) : ()
        end while @PC < @shellcode.length
    end

    def printreg
        puts @reg.inspect
    end

    def printflag
        puts @FLAG
    end

end

#scuctf{ruby_1s_y0ur_fr13nd}
```

```
rvm = RVM.new
"4073411041124117411640586100011010210203103041040510506106071070810809109101101
1111121121311131411141511151611161711171811181911920120211212212223123241242512526126
7200412016120276203342045820514206052079820839209842106421163212692131421452215
8621613217782187521987220802216522279223692247622502226765000935010885020525030
69504067505098506135507024508089509056510196511084512123513143514090515223516076
517201518206519036520043521201522007523014524203525124526212784079407 5"
rvm.run
```

得到:

```
STDOUT<<I
STDOUT<<n
STDOUT<<p
STDOUT<<u
STDOUT<<t
STDOUT<<:
READ reg
@reg[0] += 1
@reg[1] += 2
@reg[2] += 3
@reg[3] += 4
@reg[4] += 5
@reg[5] += 6
@reg[6] += 7
@reg[7] += 8
@reg[8] += 9
@reg[9] += 10
@reg[10] += 11
@reg[11] += 12
@reg[12] += 13
@reg[13] += 14
@reg[14] += 15
@reg[15] += 16
@reg[16] += 17
@reg[17] += 18
@reg[18] += 19
@reg[19] += 20
@reg[20] += 21
@reg[21] += 22
@reg[22] += 23
@reg[23] += 24
@reg[24] += 25
@reg[25] += 26
@reg[26] += 27
@reg[0] ^= 41
@reg[1] ^= 61
@reg[2] ^= 76
@reg[3] ^= 34
@reg[4] ^= 58
@reg[5] ^= 14
@reg[6] ^= 5
@reg[7] ^= 98
@reg[8] ^= 39
@reg[9] ^= 84
@reg[10] ^= 64
@reg[11] ^= 63
```

```
@reg[12] ^= 69
@reg[13] ^= 14
@reg[14] ^= 52
@reg[15] ^= 86
@reg[16] ^= 13
@reg[17] ^= 78
@reg[18] ^= 75
@reg[19] ^= 87
@reg[20] ^= 80
@reg[21] ^= 65
@reg[22] ^= 79
@reg[23] ^= 69
@reg[24] ^= 76
@reg[25] ^= 2
@reg[26] ^= 76
((@reg[0] == 93) ? @FLAG &= 1 : @FLAG = 0)
((@reg[1] == 88) ? @FLAG &= 1 : @FLAG = 0)
((@reg[2] == 52) ? @FLAG &= 1 : @FLAG = 0)
((@reg[3] == 69) ? @FLAG &= 1 : @FLAG = 0)
((@reg[4] == 67) ? @FLAG &= 1 : @FLAG = 0)
((@reg[5] == 98) ? @FLAG &= 1 : @FLAG = 0)
((@reg[6] == 135) ? @FLAG &= 1 : @FLAG = 0)
((@reg[7] == 24) ? @FLAG &= 1 : @FLAG = 0)
((@reg[8] == 89) ? @FLAG &= 1 : @FLAG = 0)
((@reg[9] == 56) ? @FLAG &= 1 : @FLAG = 0)
((@reg[10] == 196) ? @FLAG &= 1 : @FLAG = 0)
((@reg[11] == 84) ? @FLAG &= 1 : @FLAG = 0)
((@reg[12] == 123) ? @FLAG &= 1 : @FLAG = 0)
((@reg[13] == 143) ? @FLAG &= 1 : @FLAG = 0)
((@reg[14] == 90) ? @FLAG &= 1 : @FLAG = 0)
((@reg[15] == 223) ? @FLAG &= 1 : @FLAG = 0)
((@reg[16] == 76) ? @FLAG &= 1 : @FLAG = 0)
((@reg[17] == 201) ? @FLAG &= 1 : @FLAG = 0)
((@reg[18] == 206) ? @FLAG &= 1 : @FLAG = 0)
((@reg[19] == 36) ? @FLAG &= 1 : @FLAG = 0)
((@reg[20] == 43) ? @FLAG &= 1 : @FLAG = 0)
((@reg[21] == 201) ? @FLAG &= 1 : @FLAG = 0)
((@reg[22] == 7) ? @FLAG &= 1 : @FLAG = 0)
((@reg[23] == 14) ? @FLAG &= 1 : @FLAG = 0)
((@reg[24] == 203) ? @FLAG &= 1 : @FLAG = 0)
((@reg[25] == 124) ? @FLAG &= 1 : @FLAG = 0)
((@reg[26] == 212) ? @FLAG &= 1 : @FLAG = 0)
JNZ 1
STDOUT<<O
STDOUT<<K
```

还原成C语言的格式：

```
unsigned char bv[27] =
{41,61,76,34,58,14,5,98,39,84,64,63,69,14,52,86,13,78,75,87,80,65,79,69,76,2,76}
;
unsigned char enc[27] = {93, 88, 52, 69, 67, 98, 135, 24, 89, 56, 196, 84, 123,
143, 90, 223, 76, 201, 206, 36, 43, 201, 7, 14, 203, 124, 212};
unsigned char input[28] = {0};

scanf("%s", input);
for(int i = 0;i < 27;i ++){
    input[i] += i + 1;
    input[i] ^= bv[i];
}
if(!memcmp(input, bv)){
    printf("OK\n");
}
```

exp:

```
#include <cstdio>
#include <cstring>

unsigned char bv[27] =
{41,61,76,34,58,14,5,98,39,84,64,63,69,14,52,86,13,78,75,87,80,65,79,69,76,2,76}
;
unsigned char enc[27] = {93, 88, 52, 69, 67, 98, 135, 24, 89, 56, 196, 84, 123,
143, 90, 223, 76, 201, 206, 36, 43, 201, 7, 14, 203, 124, 212};

int main(){
    for(int i = 0;i < 27;i ++){
        enc[i] ^= bv[i];
        enc[i] -= i + 1;
    }
    printf("flag: %s\n", enc);
}
```

输出:

```
flag: scuctf{ruby_1s_y0ur_fr13nd}
```

RE4-overflow

main函数的流程还是比较清晰的，输入经过了一个加密函数加密后再进行比较:

```c
__int64 __fastcall main(int a1, char **a2, char **a3)
{
  scanf("%s", s1);
  if ( strlen(s1) != 32 )
  {
    puts("?");
    exit(0);
  }
  sub_401EF1();
  if ( !memcmp(s1, &unk_4022F0, 0x20uLL) )
    puts("Right!");
  else
    puts("??");
  return 0LL;
}
```

一个很明显的TEA：

```c
__int64 __fastcall sub_400878(_DWORD *a1, unsigned int *a2)
{
  __int64 result; // rax
  unsigned int i; // [rsp+30h] [rbp-10h]
  int v4; // [rsp+34h] [rbp-Ch]
  unsigned int v5; // [rsp+38h] [rbp-8h]
  unsigned int v6; // [rsp+3Ch] [rbp-4h]

  v6 = *a2;
  v5 = a2[1];
  v4 = 0;
  for ( i = 0; i <= 0x1F; ++i )
  {
    v4 -= 0x61C88647;
    v6 += (v5 + v4) ^ (16 * v5 + *a1) ^ ((v5 >> 5) + a1[1]);
    v5 += (v6 + v4) ^ (16 * v6 + a1[2]) ^ ((v6 >> 5) + a1[3]);
  }
  *a2 = v6;
  result = v5;
  a2[1] = v5;
  return result;
}
```

拷贝TEA的key，这里把32个字节拷贝到了16字节的数组里，rbp和函数返回地址被覆盖，因此会导致**栈溢出**：

```
  char key[16]; // [rsp+80h] [rbp-10h] BYREF

  memcpy(key, &unk_4022A8, 0x20uLL);
  v2[0] = *(_QWORD *)input;
  v2[1] = qword_6029A8;
  v2[2] = qword_6029B0;
  v2[3] = qword_6029B8;
  v2[4] = qword_6029C0;
  v2[5] = qword_6029C8;
  v2[6] = qword_6029D0;
  v2[7] = qword_6029D8;
  v2[8] = qword_6029E0;
  v2[9] = qword_6029E8;
  v2[10] = qword_6029F0;
  v2[11] = qword_6029F8;
  v3 = dword_602A00;
  TEAInit(v1, key);
  return TEAEncrypt(v1, input, v2, 32LL);
}
```

覆盖后的返回地址，在该函数结束后不会返回main函数，而是会跳转到sub_400DE3函数：

```
.rodata:00000000004022A7                 db    0
.rodata:00000000004022A8 key_            db  94h                    ; DAT
.rodata:00000000004022A9                 db 0FAh
.rodata:00000000004022AA                 db  3Eh ; >
.rodata:00000000004022AB                 db  55h ; U
.rodata:00000000004022AC                 db  38h ; 8
.rodata:00000000004022AD                 db 0D5h
.rodata:00000000004022AE                 db  7Fh ;
.rodata:00000000004022AF                 db  71h ; q
.rodata:00000000004022B0                 db  93h
.rodata:00000000004022B1                 db  7Ah ; z
.rodata:00000000004022B2                 db  85h
.rodata:00000000004022B3                 db    7
.rodata:00000000004022B4                 db  6Eh ; n
.rodata:00000000004022B5                 db  96h
.rodata:00000000004022B6                 db 0FBh
.rodata:00000000004022B7                 db 0C5h
.rodata:00000000004022B8                 db 0C0h
.rodata:00000000004022B9                 db  0Fh
.rodata:00000000004022BA                 db  8Fh
.rodata:00000000004022BB                 db 0DDh
.rodata:00000000004022BC                 db 0BBh
.rodata:00000000004022BD                 db 0CBh
.rodata:00000000004022BE                 db 0B8h
.rodata:00000000004022BF                 db 0B4h
.rodata:00000000004022C0                 dq offset sub_400DE3
.rodata:00000000004022C8                 db    0
```

一个很明显的RC4：

```
__int64 __fastcall sub_400C78(_QWORD *a1, __int64 a2, __int64 a3, int a4)
{
  __int64 result; // rax
  unsigned int i; // [rsp+24h] [rbp-Ch]
  int v8; // [rsp+28h] [rbp-8h]
  int v9; // [rsp+2Ch] [rbp-4h]

  v9 = 0;
  v8 = 0;
  for ( i = 0; ; ++i )
  {
    result = i;
    if ( (int)i >= a4 )
      break;
    v9 = (v9 + 1) % 256;
    v8 = (v8 + *(unsigned __int8 *)(*a1 + v9)) % 256;
    sub_400D94(*a1 + v9, v8 + *a1);
    *(_BYTE *)((int)i + a2) = *(_BYTE *)(*a1 + (unsigned __int8)(*(_BYTE *)(*a1 + v9) + *(_BYTE *)(*a1 + v8))) ^ *(_BYTE *)((int)i + a3);
  }
  return result;
}
```

sub_400DE3函数的流程是先把TEA加密后的结果进行RC4加密，随后进行很多次两两交换（100次）：

```
__int64 sub_400DE3()
{
  __int64 result; // rax
  _QWORD v1[2]; // [rsp+0h] [rbp-90h] BYREF
  char buffer[96]; // [rsp+10h] [rbp-80h] BYREF
  int v3; // [rsp+70h] [rbp-20h]
  char key[16]; // [rsp+80h] [rbp-10h] BYREF

  memcpy(key, &RC4key, 0x20uLL);
  *(_QWORD *)buffer = *(_QWORD *)input;
  *(_QWORD *)&buffer[8] = *(_QWORD *)&input[8];
  *(_QWORD *)&buffer[16] = *(_QWORD *)&input[16];
  *(_QWORD *)&buffer[24] = *(_QWORD *)&input[24];
  *(_QWORD *)&buffer[32] = *(_QWORD *)&input[32];
  *(_QWORD *)&buffer[40] = *(_QWORD *)&input[40];
  *(_QWORD *)&buffer[48] = *(_QWORD *)&input[48];
  *(_QWORD *)&buffer[56] = *(_QWORD *)&input[56];
  *(_QWORD *)&buffer[64] = *(_QWORD *)&input[64];
  *(_QWORD *)&buffer[72] = *(_QWORD *)&input[72];
  *(_QWORD *)&buffer[80] = *(_QWORD *)&input[80];
  *(_QWORD *)&buffer[88] = *(_QWORD *)&input[88];
  v3 = *(_DWORD *)&input[96];
  RC4Init(v1, key, 16LL);
  RC4(v1, (__int64)input, (__int64)buffer, 32);
  t = input[15];
  input[15] = input[4];
  input[4] = t;
  t = input[1];
  input[1] = input[21];
  input[21] = t;
  t = input[4];
  input[4] = input[8];
  input[8] = t;
  t = input[31];
  input[31] = input[3];
  input[3] = t;
  t = input[21];
  input[21] = input[5];
  input[5] = t;
```

RC4很常规，至于两两交换的话有很多种解法：

1. 动态调试：交换前将input改为1..32的数字，查看交换后的数字分布得到交换前与交换后的映射关系。
2. angr/unicorn：符号执行/模拟执行这一段交换代码，得到映射关系

3. 直接把这一段伪代码复制之后执行

方法一得先去掉反调试：

在Ubuntu中用strace指令查看系统函数调用栈，发现在退出前调用了getppid这个函数：

```
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f28d2be1000
arch_prctl(ARCH_SET_FS, 0x7f28d2be1d80) = 0
mprotect(0x7f28d2633000, 16384, PROT_READ) = 0
mprotect(0x7f28d1eac000, 4096, PROT_READ) = 0
mprotect(0x7f28d224a000, 4096, PROT_READ) = 0
mmap(NULL, 8192, PROT_READ|PROT_WRITE, MAP_PRIVATE|MAP_ANONYMOUS, -1, 0) = 0x7f28d2bdf000
mprotect(0x7f28d29b6000, 40960, PROT_READ) = 0
mprotect(0x7f28d2bef000, 4096, PROT_READ) = 0
munmap(0x7f28d2be5000, 38917)           = 0
brk(NULL)                               = 0xd54000
brk(0xd75000)                           = 0xd75000
getppid()                               = 2381
openat(AT_FDCWD, "/proc/2381/cmdline", O_RDONLY) = 3
read(3, "strace\0./overflow\0", 1024)   = 18
exit_group(0)                           = ?
+++ exited with 0 +++
ubuntu@VM-12-8-ubuntu:~/workspace/RE4-overflow/build$
```

于是在IDA中通过getppid函数的交叉引用找到反调试代码，patch掉之后可以正常进行动态调试：

```c
int sub_4020B9()
{
  int result; // eax
  char s1[1036]; // [rsp+0h] [rbp-410h] BYREF
  unsigned int v2; // [rsp+40Ch] [rbp-4h]

  v2 = getppid();
  memset(s1, 0, 0x400uLL);
  sub_401FF6(v2, s1);
  result = strcmp(s1, "/bin/bash");
  if ( result )
  {
    result = strcmp(s1, "bash");
    if ( result )
      exit(0);
  }
  return result;
}
```

第二种方法是通过angr求出映射关系：

```python
import angr
import claripy

proj = angr.Project('./overflow', load_options={'auto_load_libs': False})
input_addr = 0x6029A0

table = claripy.BVS('table', 32 * 8)
state = proj.factory.blank_state(addr=0x400EEA)
for i in range(32):
    state.mem[input_addr + i].byte = i
simgr = proj.factory.simgr(state)
simgr.explore(find=0x401EF0)
found = simgr.found[0]
```

```python
table = '['
for i in range(32):
    table += str(found.mem[input_addr + i].byte.concrete)
    table += ', ' if i != 31 else ']'
print(table)
```

求得映射关系：

```
[24, 12, 18, 15, 11, 30, 27, 1, 19, 9, 23, 28, 22, 20, 4, 6, 26, 3, 31, 14, 25,
5, 0, 13, 8, 17, 7, 10, 2, 29, 16, 21]
```

完整exp：

```python
from Crypto.Cipher import ARC4
from binascii import a2b_hex, b2a_hex
from pytea import *

table = [24, 12, 18, 15, 11, 30, 27, 1, 19, 9, 23, 28, 22, 20, 4, 6, 26, 3, 31,
14, 25, 5, 0, 13, 8, 17, 7, 10, 2, 29, 16, 21]
enc =
a2b_hex('7DB937E43FF10A83F555CA5C32D47D47180C21130D15F15B138B357B725D6237')
flag = bytearray()
for i in range(len(table)):
    flag.append(enc[table.index(i)])
flag = ARC4.new(key=a2b_hex('26148D621EF74844918AF182D63976B6')).decrypt(flag)
flag = TEA(key=a2b_hex('94FA3E5538D57F71937A85076E96FBC5')).Decrypt(flag)
print(flag)
```

flag：scuctf{y0u_4r3_r34l_pwn_y3y3!!!}

RE5-baby_maze

根据提示，总共要解出100个迷宫，flag为100个迷宫路径的md5：

```
  maze_83();
  printf("Maze-84\nPlease input the escape route: ");
  maze_84();
  printf("Maze-85\nPlease input the escape route: ");
  maze_85();
  printf("Maze-86\nPlease input the escape route: ");
  maze_86();
  printf("Maze-87\nPlease input the escape route: ");
  maze_87();
  printf("Maze-88\nPlease input the escape route: ");
  maze_88();
  printf("Maze-89\nPlease input the escape route: ");
  maze_89();
  printf("Maze-90\nPlease input the escape route: ");
  maze_90();
  printf("Maze-91\nPlease input the escape route: ");
  maze_91();
  printf("Maze-92\nPlease input the escape route: ");
  maze_92();
  printf("Maze-93\nPlease input the escape route: ");
  maze_93();
  printf("Maze-94\nPlease input the escape route: ");
  maze_94();
  printf("Maze-95\nPlease input the escape route: ");
  maze_95();
  printf("Maze-96\nPlease input the escape route: ");
  maze_96();
  printf("Maze-97\nPlease input the escape route: ");
  maze_97();
  printf("Maze-98\nPlease input the escape route: ");
  maze_98();
  printf("Maze-99\nPlease input the escape route: ");
  maze_99();
  printf("Maze-100\nPlease input the escape route: ");
  maze_100();
  puts("Great!");
  puts("Here is your flag(lower case in format): scuctf{MD5(1500 bytes of your input)}");
  return 0;
}
000A71C9 main:168 (A71C9)
```

每个迷宫都经过了混淆，并且还插入了神奇的**rdrand rax**指令：

```
v321[603] = -21;
__asm { rdrand  rax }
v321[604] = 62;
__asm { rdrand  rax }
v321[605] = -127;
v321[606] = 126;
v321[607] = 96;
v321[608] = -110;
v321[609] = 12;
v321[610] = 32;
__asm { rdrand  rax }
v321[611] = -65;
__asm { rdrand  rax }
v321[612] = -95;
__asm { rdrand  rax }
v321[613] = 62;
__asm { rdrand  rax }
v321[614] = -19;
__asm { rdrand  rax }
v321[615] = 6;
v321[616] = 13;
v321[617] = 95;
__asm { rdrand  rax }
v321[618] = -13;
v321[619] = 44;
__asm { rdrand  rax }
v321[620] = 58;
__asm { rdrand  rax }
v321[621] = 93;
v321[622] = 53;
v321[623] = -9;
qmemcpy(v322, "kgMp9", sizeof(v322));
qmemcpy(v332, &unk_A7420, 0x9C4uLL);
v331 = v321;
v324 = 4;
v325 = 24;
```

要人工解100个迷宫显然不可能，所以我们考虑使用angr求解。首先angr无法解析rdrand指令，编写idapython脚本去除rdrand指令：

```python
import idautils
from ida_bytes import patch_bytes
from idc import *

maze_list = []  #100个迷宫函数的地址
avoid_list = [] #100个迷宫函数中call exit的地址
retn_list = [] #100个迷宫函数的返回地址

for func_addr in idautils.Functions():
    func = idaapi.get_func(func_addr)
    ea = func_addr
    func_name = get_func_name(ea)
    if 'maze' in func_name:
        avoid = []
        while ea < func.end_ea:
            disasm = idc.GetDisasm(ea)
            if 'rdrand' in disasm:
                patch_bytes(ea - 1, b'\x90\x90\x90\x90\x90\x90') #去除rdrand指令
```

```
            if 'call' in disasm and 'exit' in disasm: #将call exit指令的地址添加到avoid_list
                avoid.append(ea + 0x400000)
            ea = idc.next_head(ea)
        maze_list.append(func.start_ea + 0x400000)
        avoid_list.append(avoid)
        retn_list.append(func.end_ea + 0x400000 - 1) #注意这里func.end_ea的值实际上是函数末尾地址+1，所以需要-1得到真正的末尾地址

print(f'maze_list={maze_list}\navoid_list={avoid_list}\nretn_list={retn_list}\n')
```

顺便把100个迷宫函数的地址、迷宫中**call exit**指令的地址、以及迷宫的返回地址求出来。

使用angr进行逐个迷宫求解，最后MD5得到flag：

```
import angr
import claripy
from hashlib import md5
from binascii import b2a_hex

proj = angr.Project('./baby_maze', load_options={'auto_load_libs': False}) #加载二进制文件，auto_load_libs一定设置为False

all_route = b'' #记录所有的输入，最终为15 * 1000=1500个字节

maze_list=[4196234, 4203087, 4209886, 4216655, 4223358, 4230097, 4236842, 4243545, 4250494, 4257185, 4263972, 4270549, 4277276, 4284063, 4290826, 4297607, 4304478, 4311289, 4318124, 4324953, 4331908, 4338719, 4345530, 4352407, 4359152, 4365861, 4372648, 4379375, 4386216, 4393051, 4399868, 4406661, 4413466, 4420247, 4427052, 4433821, 4440626, 4447407, 4454206, 4460981, 4467786, 4474603, 4481342, 4488147, 4494910, 4501901, 4508640, 4515397, 4522184, 4528989, 4535914, 4542677, 4549524, 4556413, 4563128, 4569933, 4576678, 4583543, 4590312, 4597021, 4603766, 4610499, 4617370, 4624241, 4631058, 4637923, 4644872, 4651677, 4658446, 4665317, 4672086, 4678957, 4685858, 4692765, 4699606, 4706447, 4713348, 4720075, 4726730, 4733631, 4740490, 4747289, 4754118, 4760965, 4767680, 4774455, 4781320, 4788179, 4794984, 4801909, 4808756, 4815525, 4822384, 4829057, 4835868, 4842787, 4849592, 4856421, 4863322, 4870265]
```

```python
avoid_list=[[4202842, 4203023], [4209641, 4209822], [4216410, 4216591],
[4223113, 4223294], [4229852, 4230033], [4236597, 4236778], [4243300, 4243481],
[4250249, 4250430], [4256940, 4257121], [4263727, 4263908], [4270304, 4270485],
[4277031, 4277212], [4283818, 4283999], [4290581, 4290762], [4297362, 4297543],
[4304233, 4304414], [4311044, 4311225], [4317879, 4318060], [4324708, 4324889],
[4331663, 4331844], [4338474, 4338655], [4345285, 4345466], [4352162, 4352343],
[4358907, 4359088], [4365616, 4365797], [4372403, 4372584], [4379130, 4379311],
[4385971, 4386152], [4392806, 4392987], [4399623, 4399804], [4406416, 4406597],
[4413221, 4413402], [4420002, 4420183], [4426807, 4426988], [4433576, 4433757],
[4440381, 4440562], [4447162, 4447343], [4453961, 4454142], [4460736, 4460917],
[4467541, 4467722], [4474358, 4474539], [4481097, 4481278], [4487902, 4488083],
[4494665, 4494846], [4501656, 4501837], [4508395, 4508576], [4515152, 4515333],
[4521939, 4522120], [4528744, 4528925], [4535669, 4535850], [4542432, 4542613],
[4549279, 4549460], [4556168, 4556349], [4562883, 4563064], [4569688, 4569869],
[4576433, 4576614], [4583298, 4583479], [4590067, 4590248], [4596776, 4596957],
[4603521, 4603702], [4610254, 4610435], [4617125, 4617306], [4623996, 4624177],
[4630813, 4630994], [4637678, 4637859], [4644627, 4644808], [4651432, 4651613],
[4658201, 4658382], [4665072, 4665253], [4671841, 4672022], [4678712, 4678893],
[4685613, 4685794], [4692520, 4692701], [4699361, 4699542], [4706202, 4706383],
[4713103, 4713284], [4719830, 4720011], [4726485, 4726666], [4733386, 4733567],
[4740245, 4740426], [4747044, 4747225], [4753873, 4754054], [4760720, 4760901],
[4767435, 4767616], [4774210, 4774391], [4781075, 4781256], [4787934, 4788115],
[4794739, 4794920], [4801664, 4801845], [4808511, 4808692], [4815280, 4815461],
[4822139, 4822320], [4828812, 4828993], [4835623, 4835804], [4842542, 4842723],
[4849347, 4849528], [4856176, 4856357], [4863077, 4863258], [4870020, 4870201],
[4876723, 4876904]]
retn_list=[4203086, 4209885, 4216654, 4223357, 4230096, 4236841, 4243544,
4250493, 4257184, 4263971, 4270548, 4277275, 4284062, 4290825, 4297606, 4304477,
4311288, 4318123, 4324952, 4331907, 4338718, 4345529, 4352406, 4359151, 4365860,
4372647, 4379374, 4386215, 4393050, 4399867, 4406660, 4413465, 4420246, 4427051,
4433820, 4440625, 4447406, 4454205, 4460980, 4467785, 4474602, 4481341, 4488146,
4494909, 4501900, 4508639, 4515396, 4522183, 4528988, 4535913, 4542676, 4549523,
4556412, 4563127, 4569932, 4576677, 4583542, 4590311, 4597020, 4603765, 4610498,
4617369, 4624240, 4631057, 4637922, 4644871, 4651676, 4658445, 4665316, 4672085,
4678956, 4685857, 4692764, 4699605, 4706446, 4713347, 4720074, 4726729, 4733630,
4740489, 4747288, 4754117, 4760964, 4767679, 4774454, 4781319, 4788178, 4794983,
4801908, 4808755, 4815524, 4822383, 4829056, 4835867, 4842786, 4849591, 4856420,
4863321, 4870264, 4876967]
for i in range(100):
    addr = maze_list[i]
    print(i + 1)
    route = claripy.BVS('route', 15 * 8) #将输入长度约束为15字节
    state = proj.factory.blank_state(addr=addr, stdin=route)
    for j in range(15):
        b = route.get_byte(j)
        state.solver.add(b >= 33) #将输入约束为可见的ascii字符
        state.solver.add(b <= 126)
    simgr = proj.factory.simgr(state)
    simgr.explore(find=retn_list[i], avoid = avoid_list[i]) #开始符号执行
    single_route = simgr.found[0].posix.dumps(0)
    all_route += single_route
    print(f'Found route: {single_route.decode()}')

print(all_route)
digest = b2a_hex(md5(all_route).digest()).decode()
print(f'scuctf{{{digest}}}')
```

其实angr脚本可以不这么复杂，更简单的版本参考**马猴烧酒**战队的WP。

大概十分钟左右能跑完一百个迷宫：

scuctf{60e925573e0c31236eb1c57005fc0655}

RE6-twin

RE6主要考察选手对Linux进程调度、进程通信的理解，以及AES中一些简单的矩阵运算和有限域下的矩阵方程求解。

首先创建了两个pipe，用于父进程和子进程的通信。pipe[0]是读管道，pipe[1]是写管道，所以要实现父进程和子进程的互相通信必须创建两个管道：

```
__int64 v10; // [rsp+18h] [rbp-48h]
int pipedes[2]; // [rsp+20h] [rbp-40h] BYREF
int v12[2]; // [rsp+28h] [rbp-38h] BYREF
__int64 buf; // [rsp+30h] [rbp-30h] BYREF
__int64 v14; // [rsp+38h] [rbp-28h]
char s[8]; // [rsp+40h] [rbp-20h] BYREF
__int64 v16; // [rsp+48h] [rbp-18h]
char v17; // [rsp+50h] [rbp-10h]
unsigned __int64 v18; // [rsp+58h] [rbp-8h]

v18 = __readfsqword(0x28u);
if ( pipe(pipedes) == -1 || pipe(v12) == -1 )
  puts("??");
```

随后通过fork函数创建子进程，在父进程中，fork函数的返回值为子进程ppid，子进程中fork函数的返回值为0，以此区分父子进程：

```
v8 = fork();
if ( v8 >= 0 )
{
  if ( v8 <= 0 )
  {
    *(_QWORD *)s = 0LL;
    v16 = 0LL;
    v17 = 0;
    v9 = operator new[](0x20uLL);
    for ( i = 0; i <= 3; ++i )
      *(_QWORD *)(8LL * i + v9) = &s[4 * i];
    close(pipedes[1]);
    read(pipedes[0], s, 0x10uLL);
    sub_B9B(v9);
    for ( j = 0; j <= 15; ++j )
    {
      s[j] = (8 * s[j]) | ((int)(unsigned __int8)s[j] >> 5);
      s[j] ^= j;
    }
    close(v12[0]);
    write(v12[1], s, 0x10uLL);
    exit(0);
  }
  *(_QWORD *)s = 0LL;
```

首先看到父进程逻辑，父进程读取长度为16的输入：

```
}
*(_QWORD *)s = 0LL;
v16 = 0LL;
v17 = 0;
buf = 0LL;
v14 = 0LL;
v10 = operator new[](0x20uLL);
for ( k = 0; k <= 3; ++k )
  *(_QWORD *)(8LL * k + v10) = (char *)&buf + 4 * k;
scanf("%s", s);
if ( strlen(s) != 16 )
{
  puts("Wrong length.");
  exit(0);
}
```

经过sub_A8A函数加密后将加密结果通过pipe和write函数传给子进程，调用wait函数等待子进程执行完毕：

```
sub_A8A(v10);
close(pipedes[0]);
write(pipedes[1], &buf, 0x10uLL);
wait(0LL);
```

sub_A8A函数中是一个很简单的字节替换，对应AES中的SubBytes，S_BOX为AES中的S_BOX，因此在求逆时可以直接把AES中的INV_S_BOX复制下来：

IDA View-A | Pseudocode-A | Hex View-1 | Structures | Enums

```
__int64 __fastcall sub_A8A(__int64 a1)
{
  __int64 result; // rax
  int i; // [rsp+10h] [rbp-8h]
  int j; // [rsp+14h] [rbp-4h]

  for ( i = 0; i <= 3; ++i )
  {
    for ( j = 0; j <= 3; ++j )
    {
      result = S_BOX[*(unsigned __int8 *)(*(_QWORD *)(8LL * i + a1) + j)];
      *(_BYTE *)(j + *(_QWORD *)(8LL * i + a1)) = result;
    }
  }
  return result;
}
```

```
.rodata:0000000000001340 S_BOX           db 63h, 7Ch, 77h, 7Bh, 0F2h, 6Bh, 6Fh, 0C5h, 30h, 1, 67h
.rodata:0000000000001340                                         ; DATA XREF: sub_A8A+6B↑o
.rodata:0000000000001340                 db 2Bh, 0FEh, 0D7h, 0ABh, 76h, 0CAh, 82h, 0C9h, 7Dh, 0FAh
.rodata:0000000000001340                 db 59h, 47h, 0F0h, 0ADh, 0D4h, 0A2h, 0AFh, 9Ch, 0A4h, 72h
.rodata:0000000000001340                 db 0C0h, 0B7h, 0FDh, 93h, 26h, 36h, 3Fh, 0F7h, 0CCh, 34h
.rodata:0000000000001340                 db 0A5h, 0E5h, 0F1h, 71h, 0D8h, 31h, 15h, 4, 0C7h, 23h
.rodata:0000000000001340                 db 0C3h, 18h, 96h, 5, 9Ah, 7, 12h, 80h, 0E2h, 0EBh, 27h
.rodata:0000000000001340                 db 0B2h, 75h, 9, 83h, 2Ch, 1Ah, 1Bh, 6Eh, 5Ah, 0A0h, 52h
.rodata:0000000000001340                 db 3Bh, 0D6h, 0B3h, 29h, 0E3h, 2Fh, 84h, 53h, 0D1h, 0
.rodata:0000000000001340                 db 0EDh, 20h, 0FCh, 0B1h, 5Bh, 6Ah, 0CBh, 0BEh, 39h, 4Ah
.rodata:0000000000001340                 db 4Ch, 58h, 0CFh, 0D0h, 0EFh, 0AAh, 0FBh, 43h, 4Dh, 33h
.rodata:0000000000001340                 db 85h, 45h, 0F9h, 2, 7Fh, 50h, 3Ch, 9Fh, 0A8h, 51h, 0A3h
.rodata:0000000000001340                 db 40h, 8Fh, 92h, 9Dh, 38h, 0F5h, 0BCh, 0B6h, 0DAh, 21h
.rodata:0000000000001340                 db 10h, 0FFh, 0F3h, 0D2h, 0CDh, 0Ch, 13h, 0ECh, 5Fh, 97h
.rodata:0000000000001340                 db 44h, 17h, 0C4h, 0A7h, 7Eh, 3Dh, 64h, 5Dh, 19h, 73h
.rodata:0000000000001340                 db 60h, 81h, 4Fh, 0DCh, 22h, 2Ah, 90h, 88h, 46h, 0EEh
.rodata:0000000000001340                 db 0B8h, 14h, 0DEh, 5Eh, 0Bh, 0DBh, 0E0h, 32h, 3Ah, 0Ah
.rodata:0000000000001340                 db 49h, 6, 24h, 5Ch, 0C2h, 0D3h, 0ACh, 62h, 91h, 95h, 0E4h
.rodata:0000000000001340                 db 79h, 0E7h, 0C8h, 37h, 6Dh, 8Dh, 0D5h, 4Eh, 0A9h, 6Ch
.rodata:0000000000001340                 db 56h, 0F4h, 0EAh, 65h, 7Ah, 0AEh, 8, 0BAh, 78h, 25h
.rodata:0000000000001340                 db 2Eh, 1Ch, 0A6h, 0B4h, 0C6h, 0E8h, 0DDh, 74h, 1Fh, 4Bh
.rodata:0000000000001340                 db 0BDh, 8Bh, 8Ah, 70h, 3Eh, 0B5h, 66h, 48h, 3, 0F6h, 0Eh
.rodata:0000000000001340                 db 61h, 35h, 57h, 0B9h, 86h, 0C1h, 1Dh, 9Eh, 0E1h, 0F8h
.rodata:0000000000001340                 db 98h, 11h, 69h, 0D9h, 8Eh, 94h, 9Bh, 1Eh, 87h, 0E9h
.rodata:0000000000001340                 db 0CEh, 55h, 28h, 0DFh, 8Ch, 0A1h, 89h, 0Dh, 0BFh, 0E6h
.rodata:0000000000001340                 db 42h, 68h, 41h, 99h, 2Dh, 0Fh, 0B0h, 54h, 0BBh, 16h
```

随后进入子进程，子进程从管道中读取数据后调用sub_B9B函数进行加密：

```
    v9 = operator new[](0x20uLL);
    for ( i = 0; i <= 3; ++i )
      *(_QWORD *)(8LL * i + v9) = &s[4 * i];
    close(pipedes[1]);
    read(pipedes[0], s, 0x10uLL);
    sub_B9B(v9);
    for ( j = 0; j <= 15; ++j )
    {
      s[j] = (8 * s[j]) | ((int)(unsigned __int8)s[j] >> 5);
      s[j] ^= j;
    }
    close(v12[0]);
    write(v12[1], s, 0x10uLL);
    exit(0);
  }
```

sub_B9B函数对应AES中的行移位变换，即ShiftRows，将4*4矩阵的第i行循环左移i-1：

```
__int64 __fastcall sub_B9B(__int64 a1)
{
  __int64 result; // rax
  int i; // [rsp+1Ch] [rbp-4h]

  for ( i = 0; i <= 3; ++i )
    result = sub_B11(*(_QWORD *)(8LL * i + a1), (unsigned int)i);
  return result;
}
```

```c
unsigned __int64 __fastcall sub_B11(_DWORD *a1, int a2)
{
  int i; // [rsp+10h] [rbp-10h]
  int v4; // [rsp+14h] [rbp-Ch]
  unsigned __int64 v5; // [rsp+18h] [rbp-8h]

  v5 = __readfsqword(0x28u);
  v4 = 0;
  for ( i = 0; i <= 3; ++i )
    *((_BYTE *)&v4 + i) = *((_BYTE *)a1 + (a2 + i + 4) % 4);
  *a1 = v4;
  return __readfsqword(0x28u) ^ v5;
}
```

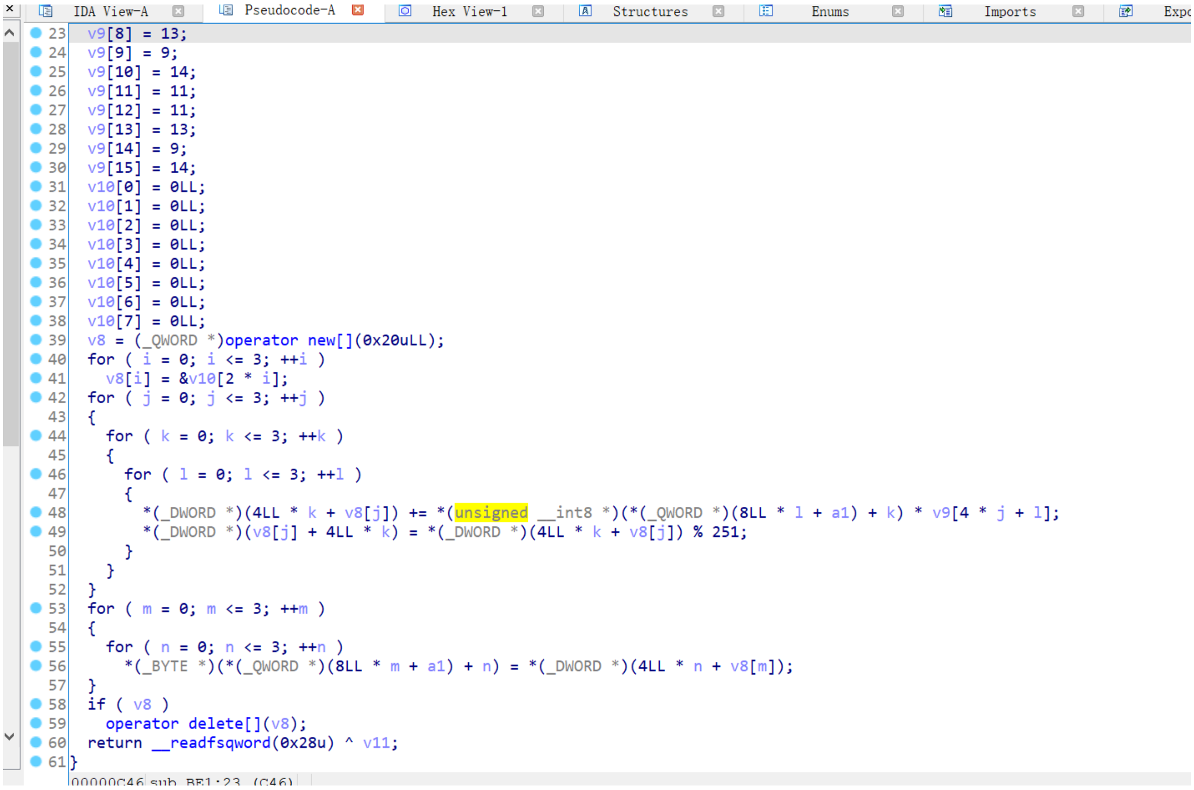
再进行一个简单的加密后将加密结果写入管道，子进程结束：

```c
    sub_B9B(v9);
    for ( j = 0; j <= 15; ++j )
    {
      s[j] = (8 * s[j]) | ((int)(unsigned __int8)s[j] >> 5);
      s[j] ^= j;
    }
    close(v12[0]);
    write(v12[1], s, 0x10uLL);
```

继续返回父进程执行，父进程从管道中读取子进程加密结果，随后经过sub_BE1函数进行加密，最后与密文进行比较：

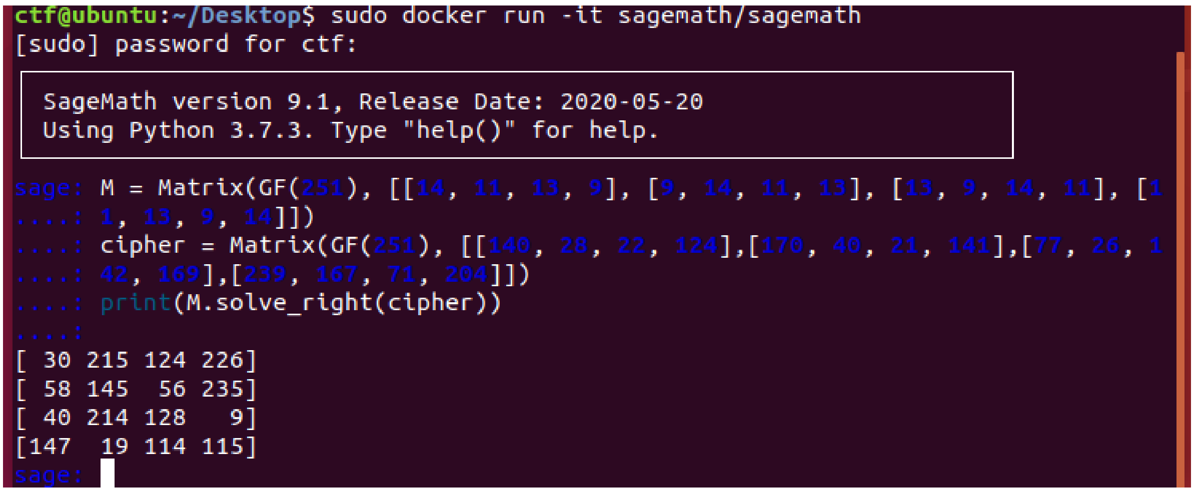
```c
    read(v12[0], &buf, 0x10uLL);
    sub_BE1(v10);
    if ( !memcmp(&buf, &unk_1458, 0x10uLL) )
    {
      puts("Right!");
      printf("Here is your flag: scuctf{%s}\n", s);
    }
    else
    {
      puts("Sorry, try again~");
    }
```

sub_BE1函数是一个模251的矩阵乘法，即有限域GF(251)下的矩阵乘法：



有限域下的矩阵方程可以通过sagemath求解，在Ubuntu中安装sagemath/sagemath Docker，使用以下代码求解矩阵方程：

```
M = Matrix(GF(251), [[14, 11, 13, 9], [9, 14, 11, 13], [13, 9, 14, 11], [11, 13, 9, 14]])
cipher = Matrix(GF(251), [[140, 28, 22, 124],[170, 40, 21, 141],[77, 26, 142, 169],[239, 167, 71, 204]])
print(M.solve_right(cipher))
```



随后用C++写出exp：

```
#include <cstdio>
#include <cstring>
#define BYTE unsigned char

const BYTE INV_S_BOX[] = {
    0x52, 0x09, 0x6a, 0xd5, 0x30, 0x36, 0xa5, 0x38, 0xbf, 0x40, 0xa3, 0x9e,
0x81, 0xf3, 0xd7, 0xfb,
    0x7c, 0xe3, 0x39, 0x82, 0x9b, 0x2f, 0xff, 0x87, 0x34, 0x8e, 0x43, 0x44,
0xc4, 0xde, 0xe9, 0xcb,
```

```
    0x54, 0x7b, 0x94, 0x32, 0xa6, 0xc2, 0x23, 0x3d, 0xee, 0x4c, 0x95, 0x0b,
0x42, 0xfa, 0xc3, 0x4e,
    0x08, 0x2e, 0xa1, 0x66, 0x28, 0xd9, 0x24, 0xb2, 0x76, 0x5b, 0xa2, 0x49,
0x6d, 0x8b, 0xd1, 0x25,
    0x72, 0xf8, 0xf6, 0x64, 0x86, 0x68, 0x98, 0x16, 0xd4, 0xa4, 0x5c, 0xcc,
0x5d, 0x65, 0xb6, 0x92,
    0x6c, 0x70, 0x48, 0x50, 0xfd, 0xed, 0xb9, 0xda, 0x5e, 0x15, 0x46, 0x57,
0xa7, 0x8d, 0x9d, 0x84,
    0x90, 0xd8, 0xab, 0x00, 0x8c, 0xbc, 0xd3, 0x0a, 0xf7, 0xe4, 0x58, 0x05,
0xb8, 0xb3, 0x45, 0x06,
    0xd0, 0x2c, 0x1e, 0x8f, 0xca, 0x3f, 0x0f, 0x02, 0xc1, 0xaf, 0xbd, 0x03,
0x01, 0x13, 0x8a, 0x6b,
    0x3a, 0x91, 0x11, 0x41, 0x4f, 0x67, 0xdc, 0xea, 0x97, 0xf2, 0xcf, 0xce,
0xf0, 0xb4, 0xe6, 0x73,
    0x96, 0xac, 0x74, 0x22, 0xe7, 0xad, 0x35, 0x85, 0xe2, 0xf9, 0x37, 0xe8,
0x1c, 0x75, 0xdf, 0x6e,
    0x47, 0xf1, 0x1a, 0x71, 0x1d, 0x29, 0xc5, 0x89, 0x6f, 0xb7, 0x62, 0x0e,
0xaa, 0x18, 0xbe, 0x1b,
    0xfc, 0x56, 0x3e, 0x4b, 0xc6, 0xd2, 0x79, 0x20, 0x9a, 0xdb, 0xc0, 0xfe,
0x78, 0xcd, 0x5a, 0xf4,
    0x1f, 0xdd, 0xa8, 0x33, 0x88, 0x07, 0xc7, 0x31, 0xb1, 0x12, 0x10, 0x59,
0x27, 0x80, 0xec, 0x5f,
    0x60, 0x51, 0x7f, 0xa9, 0x19, 0xb5, 0x4a, 0x0d, 0x2d, 0xe5, 0x7a, 0x9f,
0x93, 0xc9, 0x9c, 0xef,
    0xa0, 0xe0, 0x3b, 0x4d, 0xae, 0x2a, 0xf5, 0xb0, 0xc8, 0xeb, 0xbb, 0x3c,
0x83, 0x53, 0x99, 0x61,
    0x17, 0x2b, 0x04, 0x7e, 0xba, 0x77, 0xd6, 0x26, 0xe1, 0x69, 0x14, 0x63,
0x55, 0x21, 0x0c, 0x7d
};

void InvSubBytes(BYTE **state){
    for(int i = 0;i < 4;i ++){
        for(int j = 0;j < 4;j ++){
            state[i][j] = INV_S_BOX[state[i][j]];
        }
    }
}

void ShiftRow(BYTE *row, int n){
    BYTE temp[4] = {0};
    for(int i = 0;i < 4;i ++){
        temp[i] = row[(i + 4 + n) % 4];
    }
    memcpy(row, temp, 4);
}

void InvShiftRows(BYTE **state){
    for(int i = 0;i < 4;i ++){
        ShiftRow(state[i], -i);
    }
}

/*
M = Matrix(GF(251), [[14, 11, 13, 9], [9, 14, 11, 13], [13, 9, 14, 11], [11, 13,
9, 14]])
cipher = Matrix(GF(251), [[140, 28, 22, 124],[170, 40, 21, 141],[77, 26, 142,
169],[239, 167, 71, 204]])
print(M.solve_right(cipher))
```

```
[ 30 215 124 226]
[ 58 145  56 235]
[ 40 214 128   9]
[147  19 114 115]
*/
int main(){
    BYTE encFlag[17] = {30, 215, 124, 226, 58, 145, 56, 235, 40, 214, 128, 9,
147, 19, 114, 115, 0};
    BYTE **state = new BYTE*[4];
    for(int i = 0;i < 4;i ++){
        state[i] = encFlag + 4 * i;
    }
    for(int i = 0;i < 16;i ++){
        encFlag[i] ^= i;
        encFlag[i] = (encFlag[i] >> 3) | (encFlag[i] << 5);
    }
    InvShiftRows(state);
    InvSubBytes(state);
    printf("flag: scuctf{%s}\n", encFlag);
}
```

运行得到flag：scuctf{3z_mu1t1pr0c3ss~}