FINDING VULNERABILITIES THROUGH BINARY DIFFING

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BIO

- Lee SeungJin (aka beist) from Korea University
- Principle security consultant at GrayHash
- SECUINSIDE organizer
- Consulting for big companies
- 5 times DEFCON CTF quals
- Over 10 times CTF win and run
- Hunting bugs is my favorite hobby

About this talk

- 50% - Technical
- 50% - 0day and demo
- Hunting security bugs through binary diffing
- Analyzing an 0-day of popular online game module
- Exploiting and demonstrating

What is binary diffing

- Comparing a binary to another binary
- Getting results that say the differences
- Very useful especially for reversers and exploiters
  - And I hope to find it useful for 0-day hunters as well

Binary diffing tools

- Bindiff of Zynamics (Acquired by google)
- DarunGrim2
- Patchdiff
- Turbodiff
- EBDS
- IDACompare

Advantages of diffing

- Binary diffing is used for
  - Patch analysis (1day)
  - Identifying symbols (static compiled)
  - Platform-independent difference analysis (ARM vs x86)
  - Malware detection (VxClass)

Advantages of diffing

- Binary diffing can be used for
  - License check (open source licenses issues)
  - Bug hunting (Via finding vulnerable functions)

License check

- Some big companies in Korea are having trouble in open source licenses issues
- Developers often make mistakes that they don't realize they are using open source licenses
- Would be very bad if they don't mention it
  - I've heard they need a solution for this

License check

- Because the license check team can't access code, they need a solution on binary-level
- Binary diffing can be a solution
  - Even it works well for different platforms like ARM vs x86

Finding vulnerable functions

- This idea popped up when I was preparing a lecture about diffing different arch-binaries
  - BinDiff was working really well for that
- And, I was thinking like
  - "Oh, it even says *Similarity*, what about we make a set of vulnerable functions and just compare it to binaries?"

Idea

- This idea relies on binary diffing
  - Especially, CFG(Control Flow Graph) based diffing
  - But, home-made sauce needed (And will be more)
- The idea is simple
  - It's possible to make patterns of vulnerable functions
  - Then, comparing them with binaries and finding similar functions by binary diffing

Goal

- Better than "*b dangerous_functions*" like "***b strcpy***" or "***b memcpy***"
- Better than just some heuristic methods like loop-detection
- Pattern matching for both code level and binary level

Bug hunting on binary-level

- Two general approaches
  - Fuzzing
    - Can be extremely sophisticated (smart fuzzing)
    - Popular way for bug hunters these days
  - Dynamic + static analysis
    - Pure reversing or dynamic test
    - Still, static reversers find awesome bugs which fuzzers won't find usually

Binary diffing for bug-hunting

- This idea could be a new approach for finding security bugs
- But it's very naive yet
- Let's tour technical stuff

More about diffing

- This talk is not about binary diffing itself
- But we should know some basic stuff
- Many of diffing tools are based on CFG
  - Also, instructions matching, basic blocks fingerprinting

BinDiff

- We chose BinDiff, because
  - Didn't want to waste time to know how to use tools
  - It's commercial which means they support customers
  - Most popular diffing program in the field
- BinDiff
  - From zynamics acquired by Google now
  - Only $200 USD (Reasonable price)
  - BinDiff can compare binaries supported by IDA
    - Using IDA to get CFG

How bindiff works

- BinDiff doesn't care about the concrete assembly-level instructions
  - Except for generating hash on basic block level
- It's more based on "Structural matching"

How bindiff works

- Structural matching
  - It makes fixedpoints between two binaries
  - Then tries to find more fixedpoints iteratively
  - When matching functions is done, it goes for basic blocks

How bindiff works

- Function matching strategy
  - hash matching (very good quality)
  - prime signature matching (SPP) (good quality)
  - string references (medium quality)
  - loop count matching (poor quality)
  - call sequence matching (ver poor quality)
  - etc

[According to zynamics manual]

How bindiff works

- Basic block matching strategy
  - hash matching (very good quality)
  - edges MD index and the other series (good quality)
  - loop entry matching (poor quality)
  - instruction count matching (very poor quality)
  - etc

[According to zynamics manual]

How to implement our idea

- It's not easy to implement the idea
- Again, this project is still naive
  - But we'll see progress at least
- We'll explain step-by-step

Very basic example

- This code is vulnerable obviously

```
void vuln_sample1(char *str) {
  char buf[256];
  strcpy(buf, str);
  printf(“%s\n”, buf);
}
```

- Let’s compare the code with this code

```
void vuln_sample3(char *str) {
    char buf[256];
    printf("test\n");
    strcpy(buf, str);
    printf("%s\n", buf);
}
```

BinDiff result

- It seems BinDiff works well
- It says “0.69” similarity and “0.95” Confidence
  - Similarity is from 0 to 1
  - Confidence means which method it used to diff

	0.69	0.95	00401020	_vuln_sample1	Normal	00401020	_vuln_sample3
	1.00	0.99	00406420	_wctomb	Normal	00406430	_wctomb
	1.00	0.97	0040B708	_WideCharToMult...	Thunk	0040B718	_WideCharToMu...
	1.00	0.97	0040B6C0	_WriteFile@20	Thunk	0040B6D0	_WriteFile@20
	1.00	0.99	00405360	CheckBytes	Normal	00405370	CheckBytes

[BinDiff result]

BinDiff result

```
00401020   _vuln_sample1
00401020   push     ebp                          // _vuln_sample1
00401021   mov      ebp, esp
00401023   sub      esp, 0x140
00401029   push     ebx
0040102A   push     esi
0040102B   push     edi
0040102C   lea      edi, ss:[ebp+var_140]
00401032   mov      ecx, 0x50
00401037   mov      eax, 0xCCCCCCCC
0040103C   rep stosd



0040103E   mov      eax, ss:[ebp+Source]
00401041   push     eax                          // Source
00401042   lea      ecx, ss:[ebp+Dest]
00401048   push     ecx                          // Dest
00401049   call     _strcpy
0040104E   add      esp, 8
00401051   lea      edx, ss:[ebp+Dest]
00401057   push     edx
00401058   push     Format                       // Format
0040105D   call     _printf
00401062   add      esp, 8
00401065   pop      edi
00401066   pop      esi
00401067   pop      ebx
00401068   add      esp, 0x140
0040106E   cmp      ebp, esp
00401070   call     __chkesp
00401075   mov      esp, ebp
00401077   pop      ebp
00401078   retn
```

```
00401020   _vuln_sample3
00401020   push     ebp                          // _vuln_sample3
00401021   mov      ebp, esp
00401023   sub      esp, 0x140
00401029   push     ebx
0040102A   push     esi
0040102B   push     edi
0040102C   lea      edi, ss:[ebp+var_140]
00401032   mov      ecx, 0x50
00401037   mov      eax, 0xCCCCCCCC
0040103C   rep stosd
0040103E   push     Format                       // Format
00401043   call     _printf
00401048   add      esp, 4
0040104B   mov      eax, ss:[ebp+Source]
0040104E   push     eax                          // Source
0040104F   lea      ecx, ss:[ebp+Dest]
00401055   push     ecx                          // Dest
00401056   call     _strcpy
0040105B   add      esp, 8
0040105E   lea      edx, ss:[ebp+Dest]
00401064   push     edx
00401065   push     aS                           // aS
0040106A   call     _printf
0040106F   add      esp, 8
00401072   pop      edi
00401073   pop      esi
00401074   pop      ebx
00401075   add      esp, 0x140
0040107B   cmp      ebp, esp
0040107D   call     __chkesp
00401082   mov      esp, ebp
00401084   pop      ebp
00401085   retn
```

Another example (problem #1)

- What about this code

```
void vuln_sample2(char *str) {
    char buf[256];
    char *p;
    printf("this is a vuln_sample2\n");
    strcpy(buf, str);
    p=strstr(buf, "beist\n");
    if(p)
        printf("beer\n");
    else
        printf("crying\n");
}
```

- BinDiff says “0.21” similarity and “0.38” confidence
  - But we know it’s still vulnerable, this is the first huddle

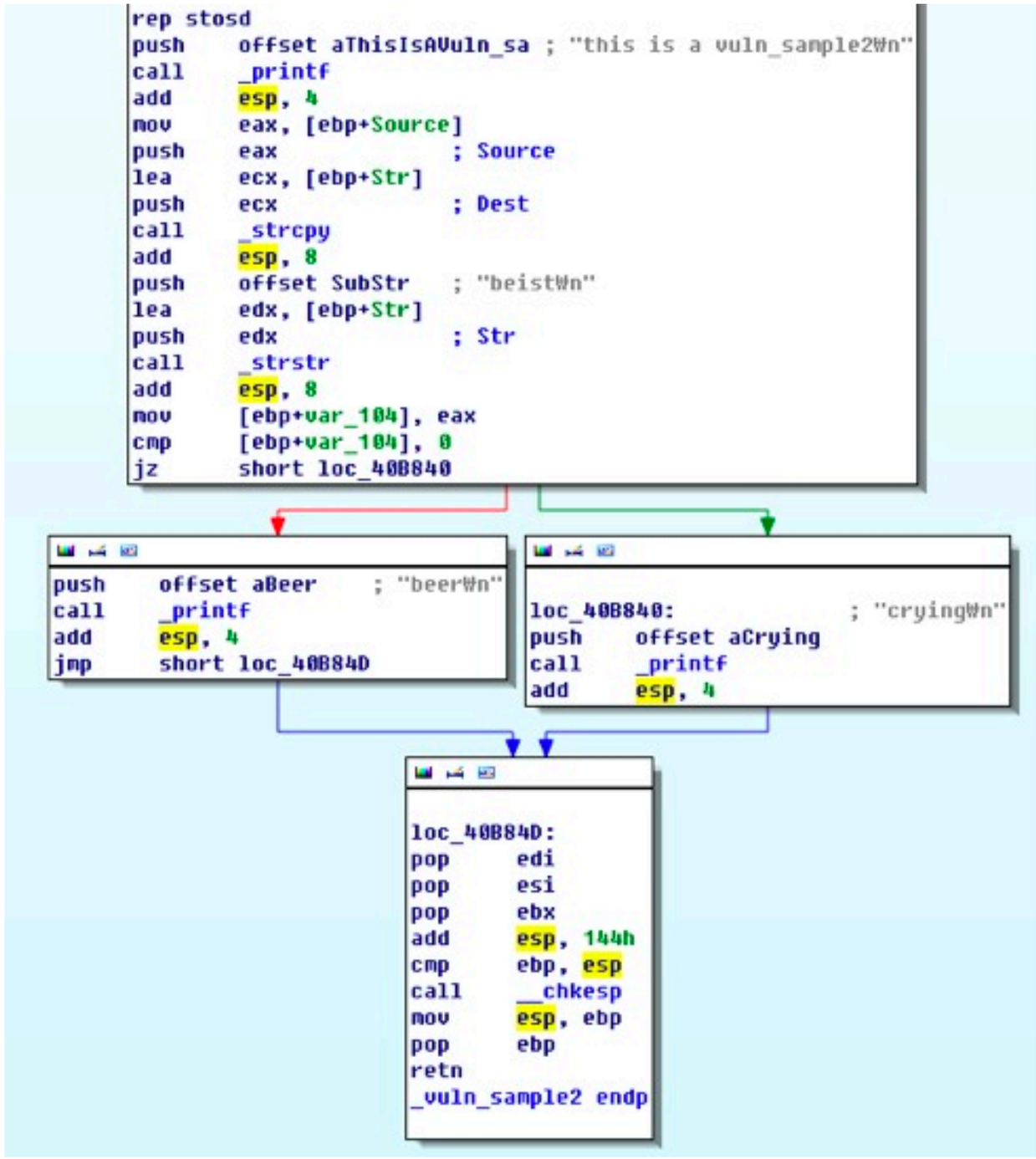
What happens

- Disassembly of sample1

```
; Attributes: bp-based frame

; int __cdecl vuln_sample1(char *Source)
_vuln_sample1 proc near

var_140= byte ptr -140h
Dest= byte ptr -100h
Source= dword ptr  8

push    ebp
mov     ebp, esp
sub     esp, 140h
push    ebx
push    esi
push    edi
lea     edi, [ebp+var_140]
mov     ecx, 50h
mov     eax, 0CCCCCCCCh
rep stosd
mov     eax, [ebp+Source]
push    eax             ; Source
lea     ecx, [ebp+Dest]
push    ecx             ; Dest
call    _strcpy
add     esp, 8
lea     edx, [ebp+Dest]
push    edx
push    offset Format   ; "%s\n"
call    _printf
add     esp, 8
pop     edi
pop     esi
pop     ebx
add     esp, 140h
cmp     ebp, esp
call    __chkesp
mov     esp, ebp
pop     ebp
retn
_vuln_sample1 endp
```

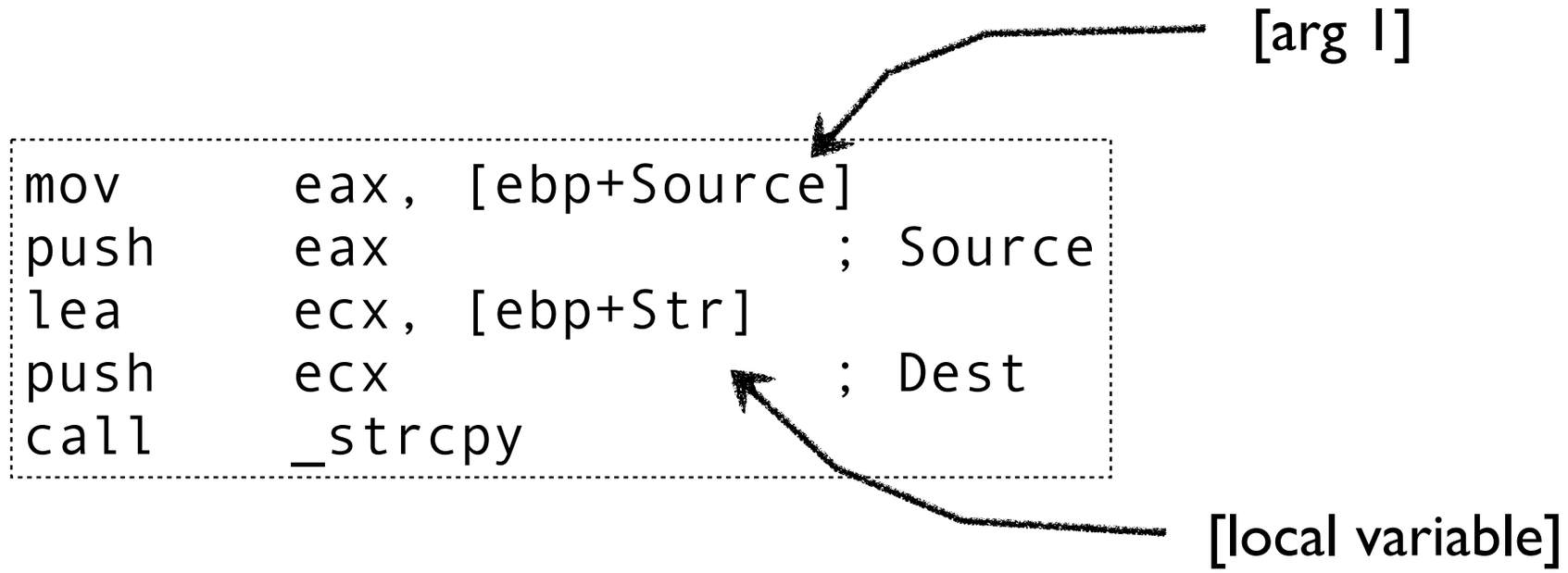
What happens

- Disassembly of sample 2
- Branch/function calls are the problem



What happens

- Looks those graphs are different each other
- But if we see them as a view of a bug hunter, it's the same flow semantically



An idea to solve

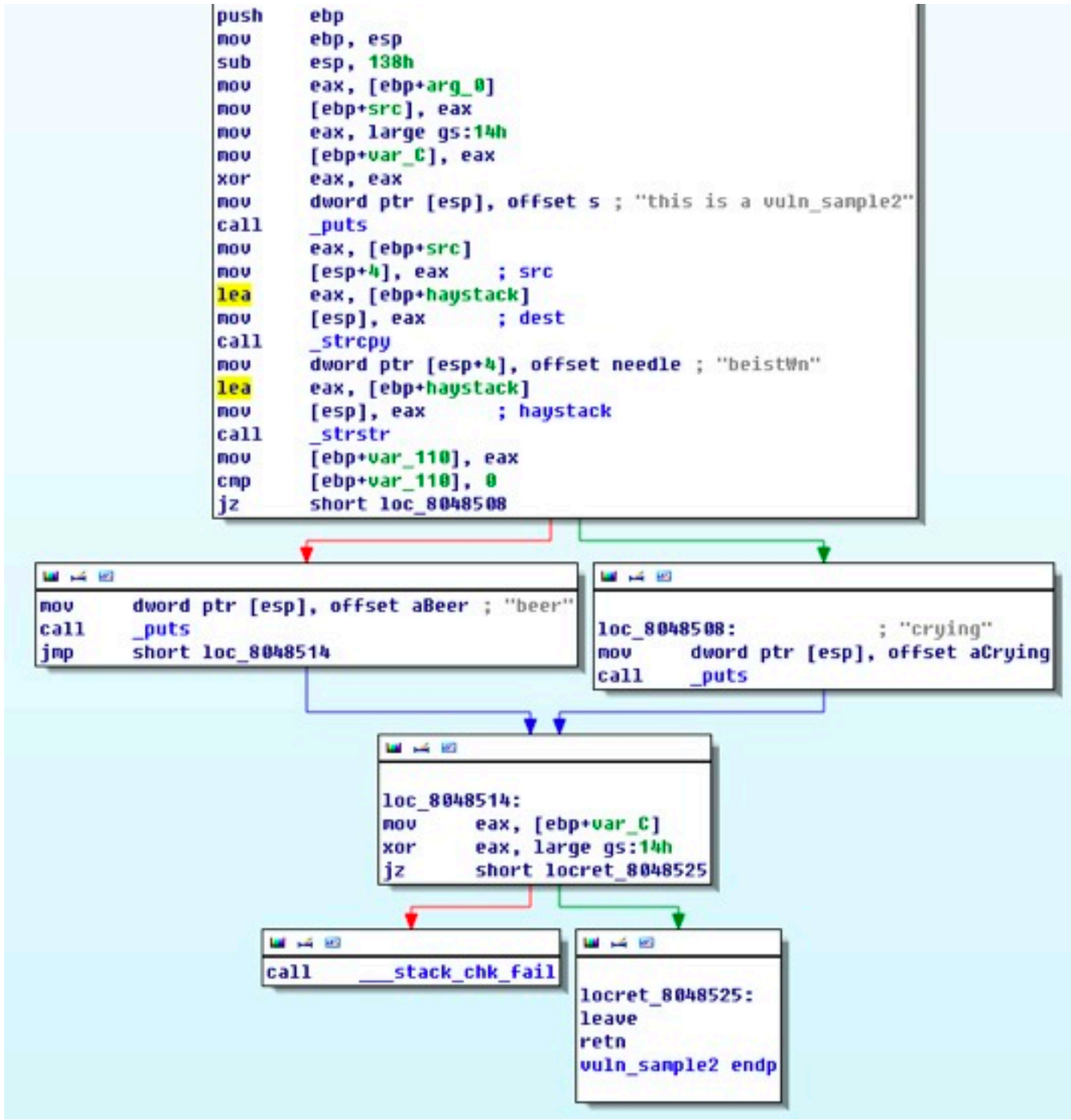
- We try to remove instructions that don't affect control flows
- In vuln_sample2(), We don't need to count
  - *printf()*
  - *strstr()*
    - Should be counted in some situations
    - Like if the returned pointer is referenced for some string routines later

An idea to solve

- We only implemented a script that replace calls to NOP
  - But should be improved as below
- Implementation idea
  - Find non-interesting calls
  - Kill them
  - Adjust offsets
- Implement won’t be easy for complex routines
  - How to remove branches?

Complier dependency (problem #2)

- What if it's compiled by a different complier?
- Disassembly of sample 2 by GCC 4.6



Complier dependency (problem #2)

```
push    ebp
mov     ebp, esp
sub     esp, 144h
push    ebx
push    esi
push    edi
lea     edi, [ebp+var_144]
mov     ecx, 51h
mov     eax, 0CCCCCCCCh
rep stosd
push    offset aThisIsAVuln_sa ; "this is
call    _printf
add     esp, 4
mov     eax, [ebp+Source]
push    eax             ; Source
lea     ecx, [ebp+Str]
push    ecx             ; Dest
call    _strcpy
add     esp, 8
push    offset SubStr   ; "beist\n"
lea     edx, [ebp+Str]
push    edx             ; Str
call    _strstr
```

VS

```
sub     esp, 100h
push    esi
push    edi
push    offset Format   ; "this is a vuln_sample2\n"
call    _printf
mov     edi, [esp+10Ch+arg_0]
or      ecx, 0FFFFFFFFh
xor     eax, eax
lea     edx, [esp+10Ch+Str]
repne scasb
not     ecx
sub     edi, ecx
push    offset SubStr   ; "beist\n"
mov     eax, ecx
mov     esi, edi
mov     edi, edx
shr     ecx, 2
rep movsd
mov     ecx, eax
and     ecx, 3
rep movsb
lea     ecx, [esp+110h+Str]
push    ecx             ; Str
call    _strstr
```

An idea to solve

- Detect which compiler was used
  - Heuristic (Code generating style, etc)
  - Signature matching (raw bytes)
  - We used "*EXEINFO PE*"
- Optimization level could be known
  - Function prologue/epilogue analysis
  - Or we just can compile our subset for every optimization level

Same class bugs (problem #3)

```
void vuln_sample1(char *str) {
  char buf[256];
  strcpy(buf, str);
  printf("%s\n", buf);
}
```

VS

```
void vuln_sample4(char *str) {
  char buf[256];
  memcpy(buf, str, strlen(str));
  printf("%s\n", buf);
}
```

- This can be solved somewhat easily
  - by grouping them
  - example) group *copy_api* = {strcpy, memcpy, gets, ++}
- IDAPython will be helpful
  - Changing call functions in force
  - But we have not been able to implement it yet

More, more, more problems

- Should we ignore operands?
- What about different architecture?
- How to group loop code and copy APIs together?
- etc

Categorize problems

- Most problems can be categorized into 2 groups
  - 1 - Different codebase: coding style, uninteresting functions, etc
  - 2 - Which compiler, version, optimization, etc

Patterns

- We've implemented around 20 patterns
  - dangerous APIs
  - loop
  - off-by-one
  - no null check
  - etc
- All of them are memory corruptions related
- Future work: patterns for other class bugs
  - use-after-free style would be hard

Case study

- We tried to find 0days from online game
- Why online game?
  - Because it has not been security-evaluated
  - Vendors don’t care user to user security
  - User to user hacking is much more dangerous
    - And more difficult than speed-hack hacking
  - Imagine that you get hacked because you just play online games

Case study

- Our target is a module by *Kamuse* company that does p2p file transmission
  - Users download install files from other users
  - This is reasonable since some games' filesize > 10GB
- Almost NCSOFT games use the module
- **What we got**: remote memory corruption bugs

Our strategy

- As this project is naive yet, we first try to find 0days by fuzzing
- Figure out of the bugs
- Compare the vulnerable functions with the binary
- To see if there are similar functions (or more bugs) that can be found via binary diffing

The kamuse module

- The module uses multiple ports
  - For p2p operation and transmission
- It does UPNP
  - So users can be reached by other users even if they are in home-routers

Fuzzing

- We set up a network fuzzer for the module
- Captured operation packets to get proper payload
- Manipulated the payload
- Got some 0days
  - Only took a look at one bug which is exploitable

Quick analysis

- Basic buffer overflow (No-bound-check)
  - But attackers have to have proper payload to reach the vulnerable function
- We can fully control EIP
  - Even we can use null-byte
- Let's take a look at IDA
  - The vulnerable function is 0x00471d40

Diffing strategy

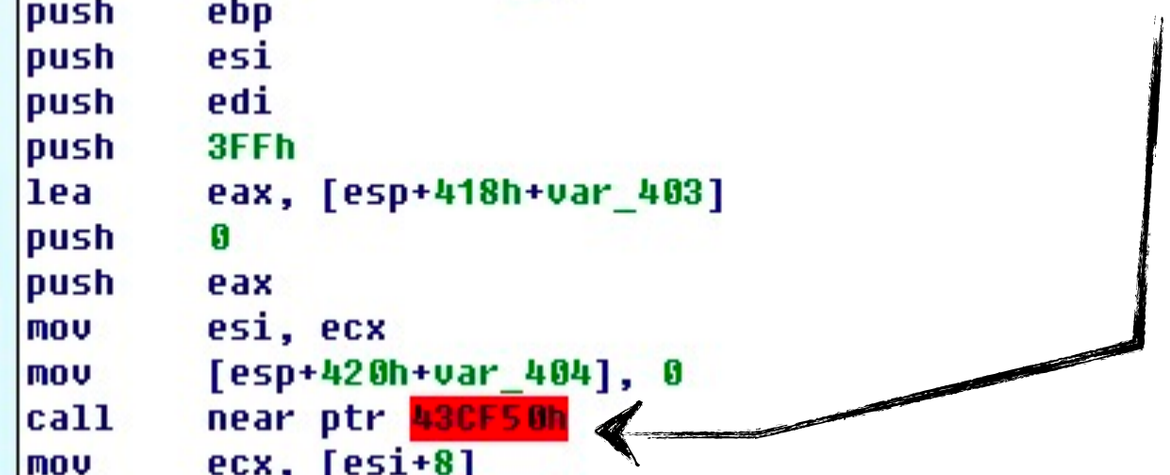
- Let's say we have "target.exe" and *sub_a*() is a vulnerable function
- Looks BinDiff doesn't show us more than 1 matching function
  - If there are 90% and 70% matching functions, BinDiff only shows 90% function

Diffing strategy

- Copying just row bytes of *sub_a*() won't work
  - Because all calls will be broken unless we adjust every offset - but would be not easy

- If our calls are broken, diffing score would be very low

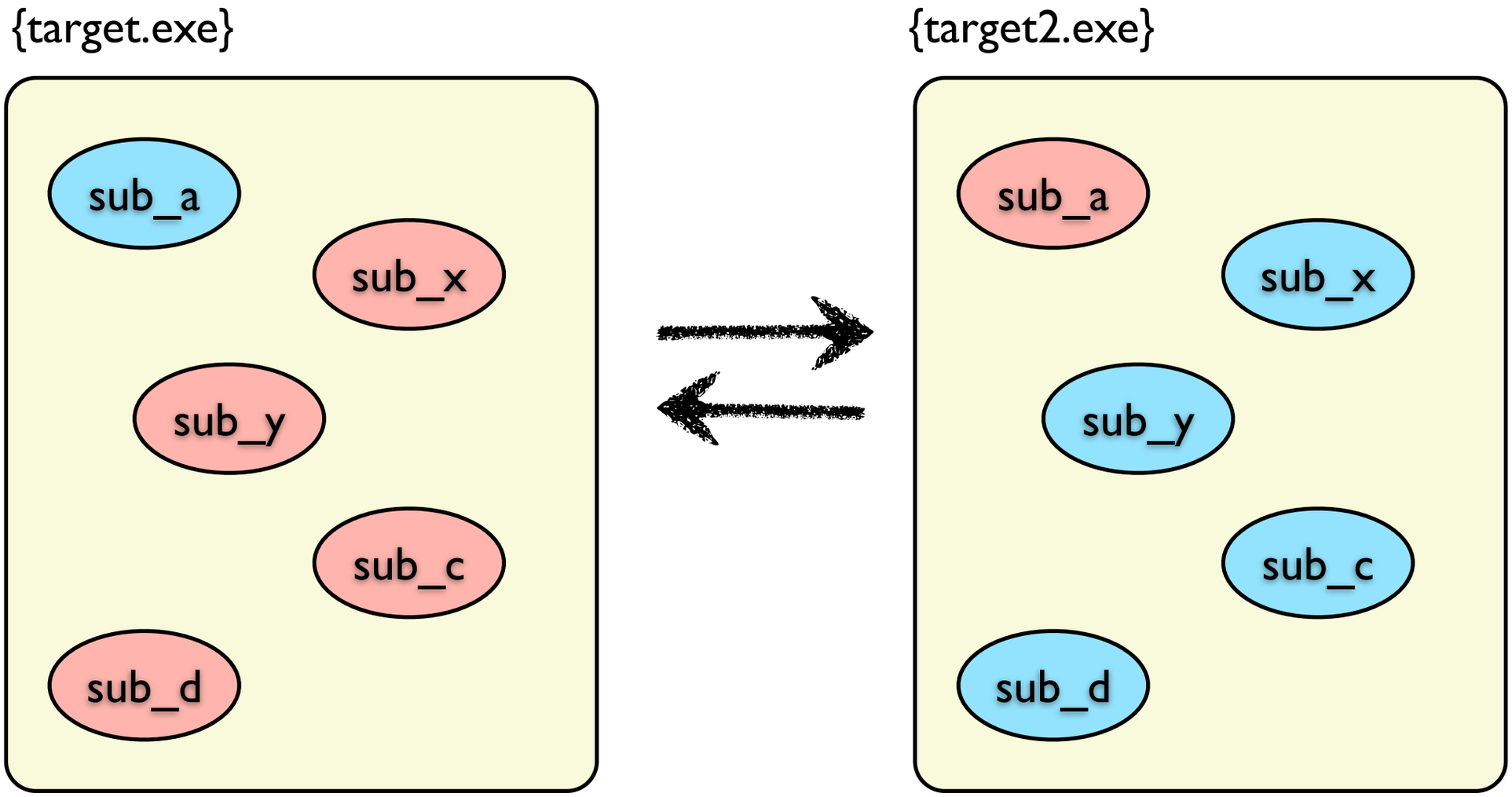
```
sub     esp, 408h
mov     eax, ds:5011BCh
xor     eax, esp
mov     [esp+408h+var_4], eax
push    ebp
push    esi
push    edi
push    3FFh
lea     eax, [esp+418h+var_403]
push    0
push    eax
mov     esi, ecx
mov     [esp+420h+var_404], 0
call    near ptr 43CF50h
mov     ecx, [esi+8]
xor     ebp, ebp
```



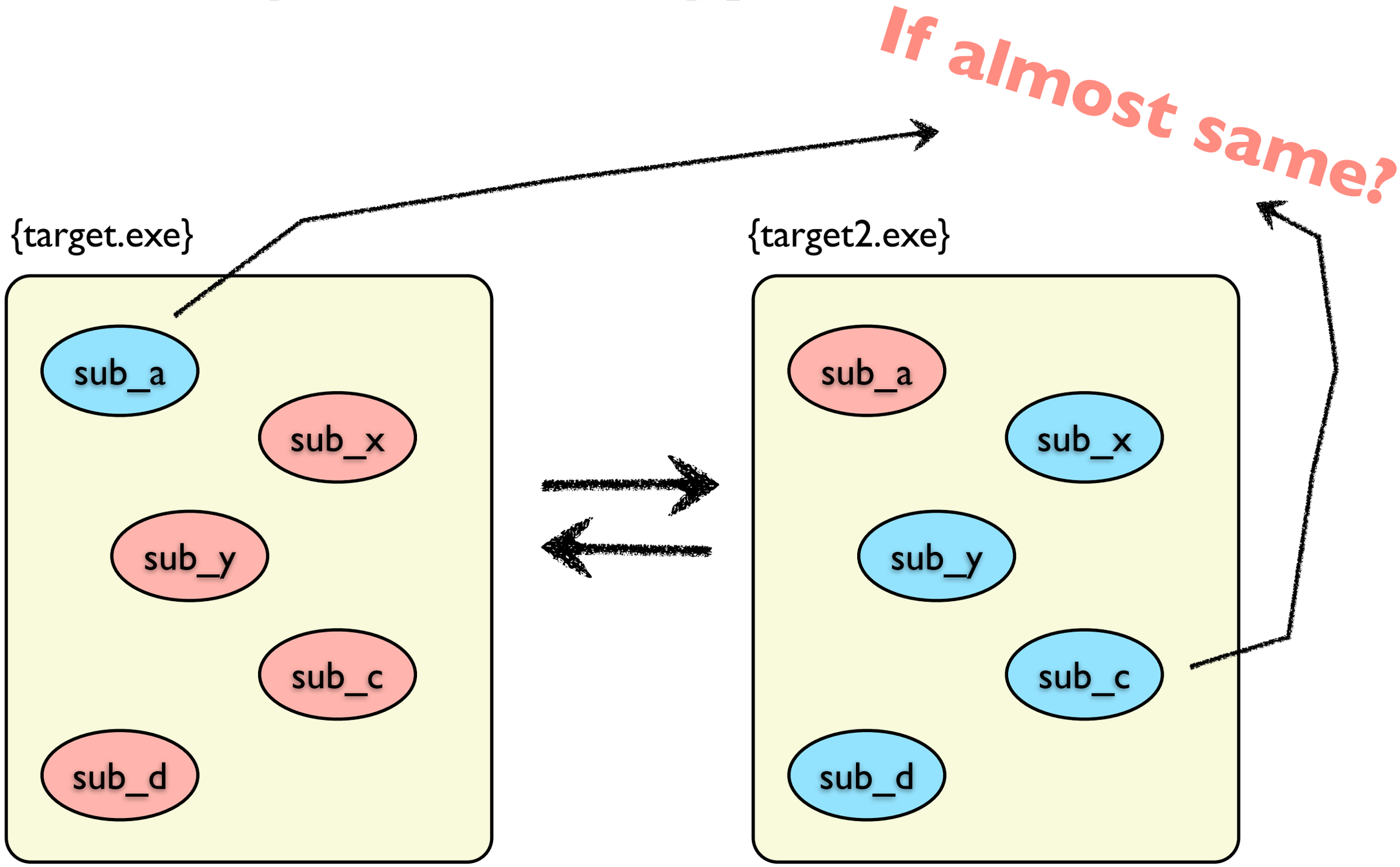
Diffing strategy

- Idea
  - copy target.exe (now we have target2.exe)
  - delete all functions of target.exe that start with "*sub_*"
    - except *sub_a*()
  - delete sub_a() of target2.exe
  - compare target.exe and target2.exe
- Limitations
  - What about if functions don't start with "*sub_*"?
  - If we kill functions, cross references will be gone too

Diffing strategy



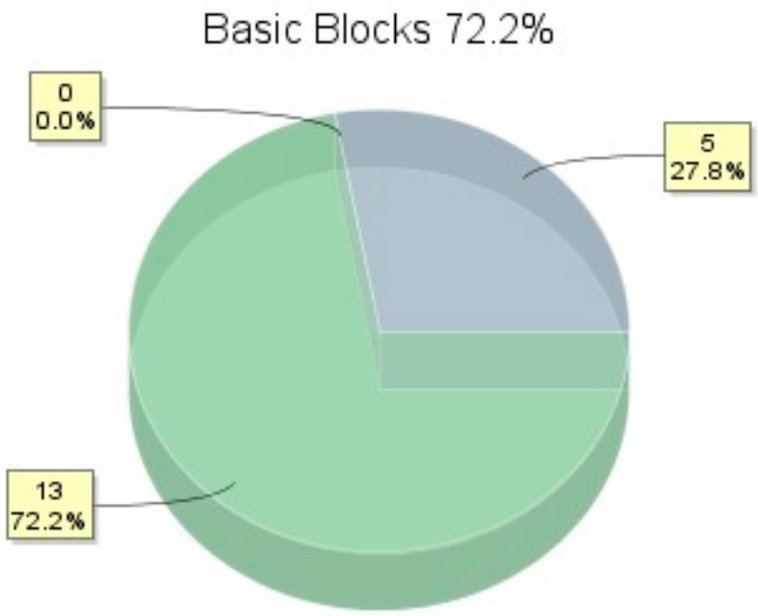
Diffing strategy

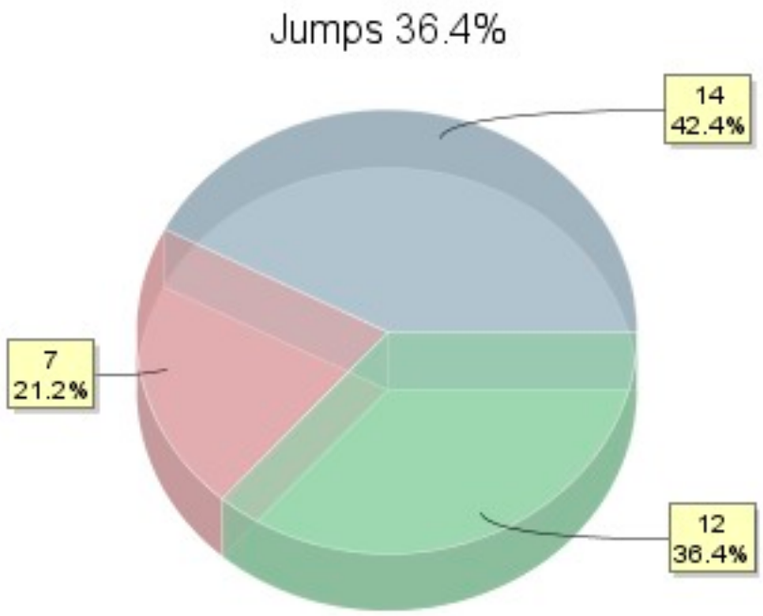


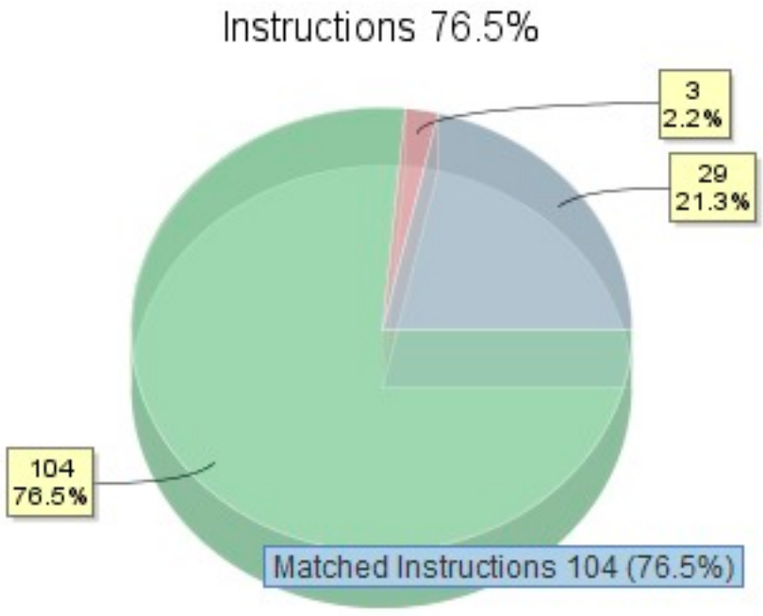
Result

- Found an interesting function
- Remember, 0x00471d40 is the vulnerable function
- 0x00471f60 is “0.77” similarity according to BinDiff

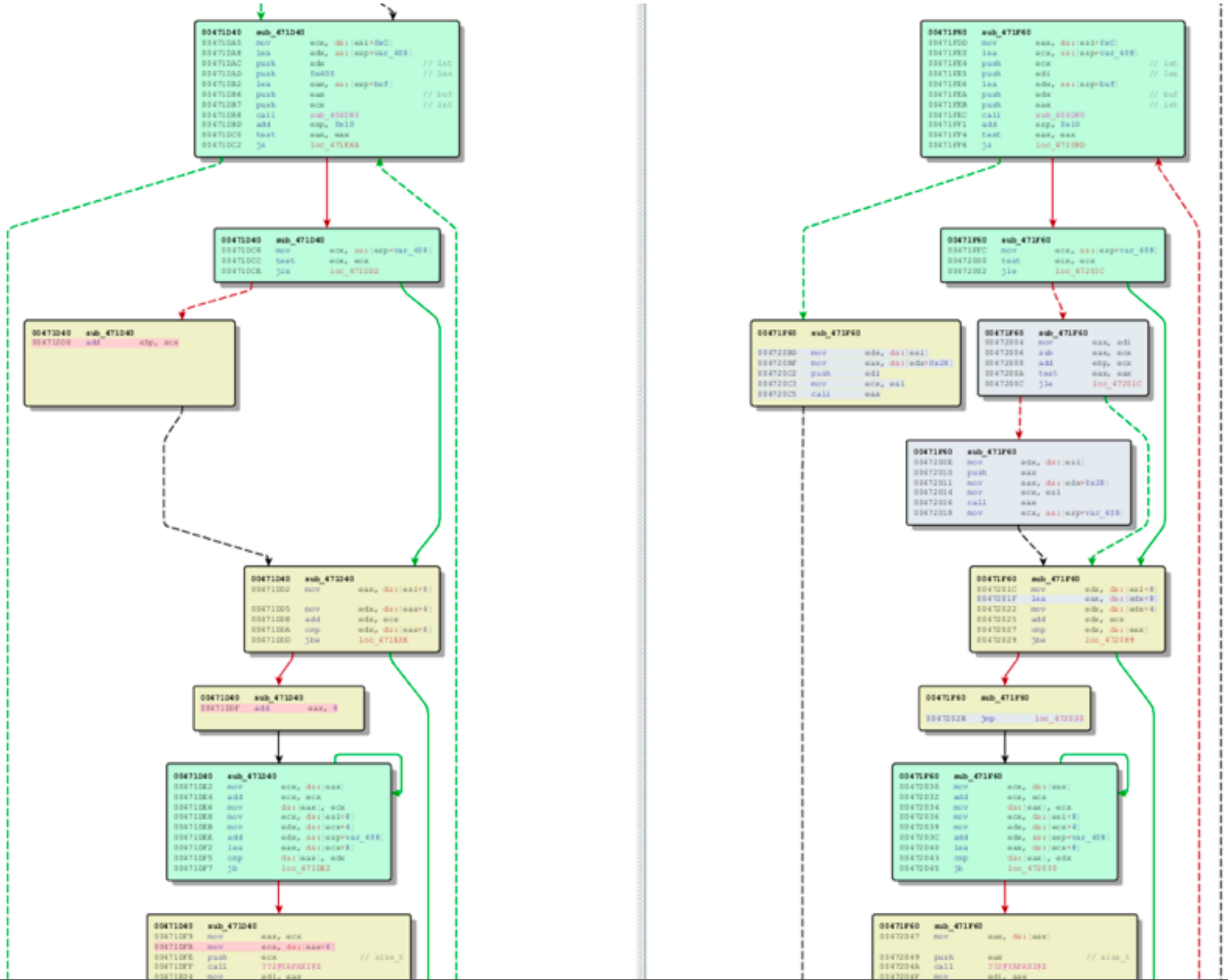
Similarity	Confidence	Address	Primary Name	Type	Address	Secondary Name
0.77	**0.96**	**00471D40**	**sub_471D40**	**Normal**	**00471F60**	**sub_471F60**







Result



Demo

- The kamuse module attack
  - Proof of concept code pops up an image if it works

Conclusion part 1

- Diffing for hunting bug is far away yet from the real world
- Many things to do
  - Very complex reversing works
  - Solving uninteresting instructions / branches problems
  - Compiler issues
  - Integration with code coverage, etc

Conclusion part 1

- We're not saying we have to use BinDiff or specific approach to diff
  - Any way about diffing art would be helpful
- We've seen that it is possible
  - MS08-067 could have been revealed before ;)

Conclusion part 2

- Many NCSOFT games use the module
  - When you download over 10GB files, you are ***very*** vulnerable
  - And, soooo many users
  - Scanning million ports in an hour is reality (Check out Immunity's new service)
  - Thought "*If a module is vulnerable which NCSOFT didn't make, NCSOFT doesn't have any responsibility?*"
    - Hint - google pays for webkit bugs.
    - And.. there would be bugs in modules by NCSOFT too

Q & A

- Thanks to ISEC 2012!
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