Structural Signature and Structuring Signature

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Contents

- Graph theory in binary files comparision
- Patched code affects assembly structure
- Isomorphism on three levels
- Handling compiler optimization
- Demo
- Problems

Graph Theory In Binary Files Comparison

- Isomorphism
  - Different from Isomorphism in Graph Theory
- Structure Assembly Graphs
  - Related
    - Control Flow Graph Analysis
    - Data Flow Analysis

Patched Code Affects Assembly Structure

- Additional “validation” function
  - MS04-022 Task Schedule BOF
- Additional “if” construct to validate string length
  - MS04-011 IIS PCT BOF

Isomorphism In Three Levels

- Three Levels
  - Call Graph Level
  - Control Flow Graph Level
  - Instruction Level
- Each level includes Two phrases
  - Initialization of fixed points
  - Propagation of fixed points

Call Graph Level

- Signature
  - basic information
    - Basic Blocks
    - Links
    - Subcalls
  - structure information
    - Prime product of assigned primes of all schemas
- Constraint Properties
  - Same name
  - Unique signature
  - Same indegree(number of references)
  - Same strings reference
  - Recursive function
  - Same prime product

Same Name

- If two functions have the same name, they will be added as a matched pair.
- We must exclude situations, when
  - the library name is unknown
  - sub_xxxxxxxx

Unique Signature

- Calculate Euclid distance between each two function's signatures.
- for each x that belongs to Graph B, if

$$\exists a \in A, \forall b \in A, b \neq a, 0 = |x-a| < |x-b|$$

  - add the (x,a) as a matched pair

Same number of references

- When two functions which have the same number of references
- Calculate their signature's Euclid distance
- When they satisfy following condition:

$$x \in B, \exists a \in A, \forall b \in A, b \neq a, 0 = |x-a| < |x-b|$$

- add (x,a) as a matched pair

Same String Reference

- Time consuming
- Convert strings to md5 value

Same Prime Product

This is very time consuming! How we do it?

Function A's Prime Product can be represented by

$$\Pi A = K \cdot 2^{64} + b$$

Function B's Prime Product can be looked as

$$\Pi B = j \cdot 2^{64} + c$$

if b != c, $\prod A \neq \prod B$

If b== c, we can assume $\prod A = \prod B$ **, correct?**

Total number $l = C_{n+m-1}^{n}$ **, here** $\prod c_1 \neq \prod c_2 \ldots \neq \prod c_l$

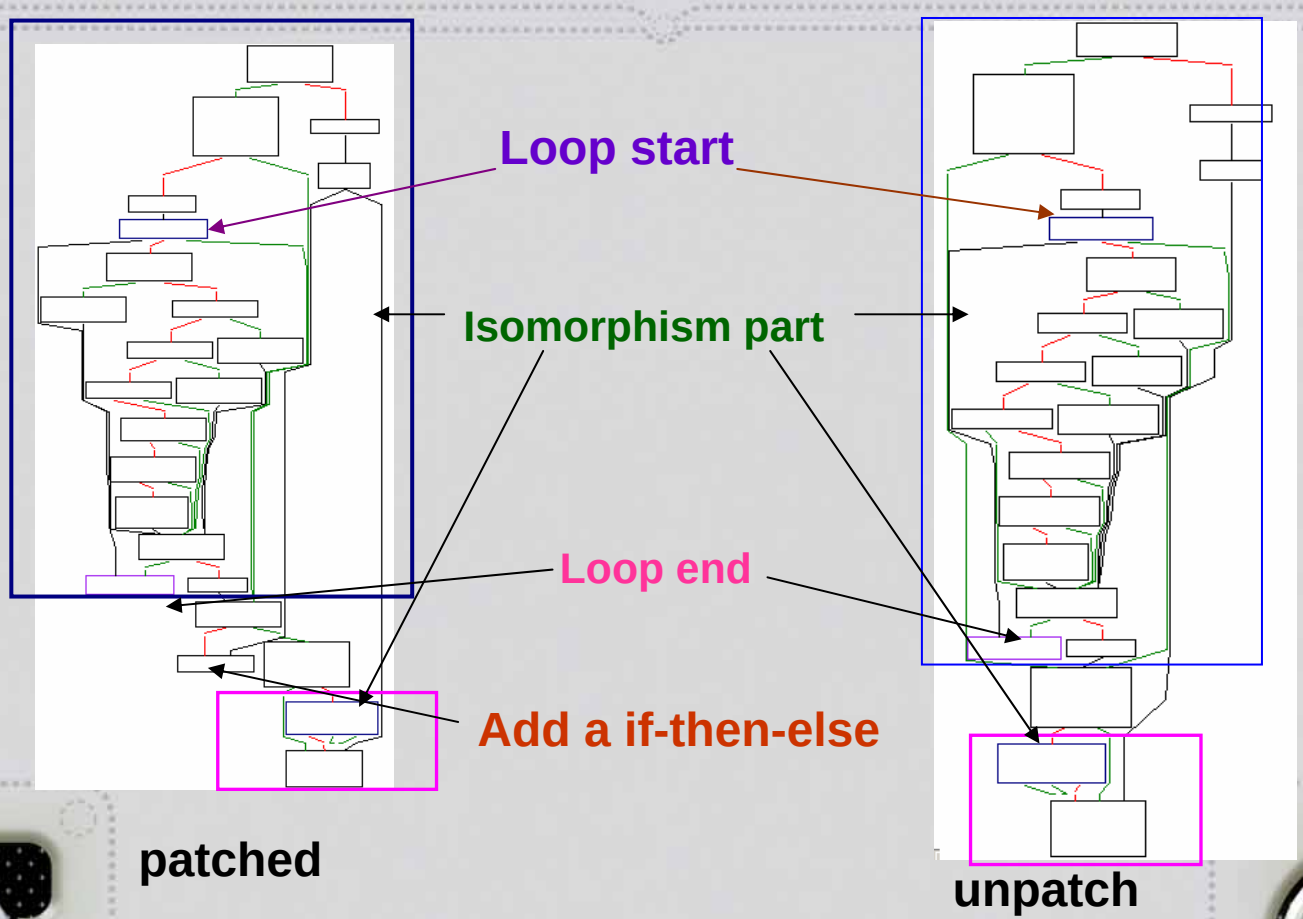
$\prod A \equiv \prod B \bmod 2^{64}$ **Is less or equal to**

$$\left(\frac{P_m^n}{2^{64}} - 1 \right) / C_{n+m-1}^{n}$$

Control Flow Graph Level

- Signature
  - basic information
    - Number of basic blocks on the shortest path from function entry to itself
    - Number of basic blocks on the shortest path from itself to function exit
    - Subcalls
  - Structure information
    - Structure level
- Constraint properties
  - Same Prime products
  - Same strings reference
  - Same subcalls

MS04-011 Pct1SrvHandleUniHello



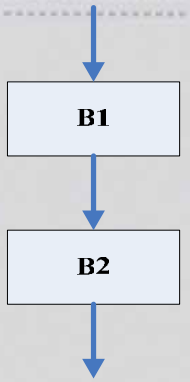
Structure information

- Structural analysis
  - Structural Schema
    - Sequence schema
    - Conditionals schema
      - If-then, if-then-else,switch-case
    - Loop schema
      - Self loop, While loop,Endless loop,multiexit loop
  - Unstructured Schema
    - Unstructured loops
    - Unstructured conditionals
- Add structure information to signature

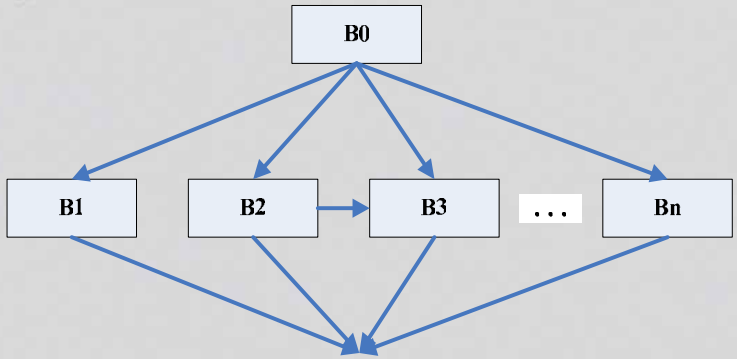
Structure Analysis

- Time consuming!
- But, when we need “visualization of differencies between two flow graphs”, this can be very useful.
  - Isomorphism in control flow graph

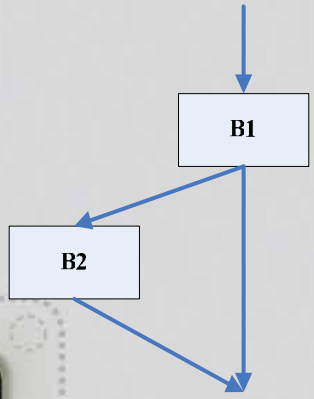
Sequence and conditional Schema



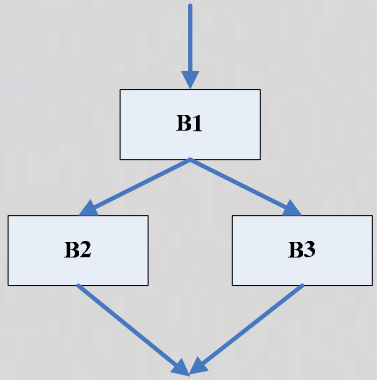
Sequence, can be obsoleted



Switch-case

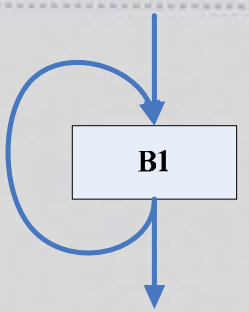


If-then

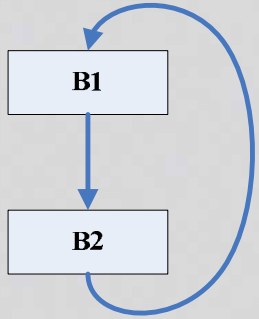


If-then-else

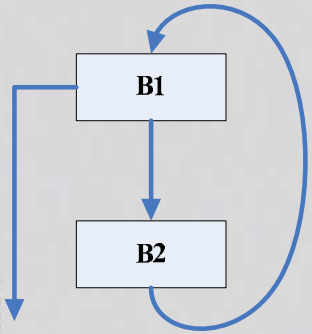
Loop Schema



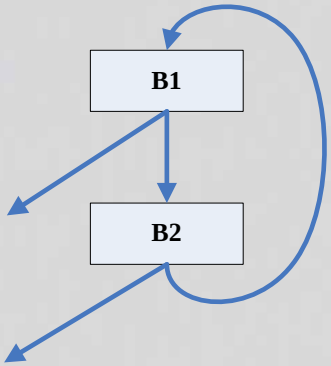
Self loop



Endless loop

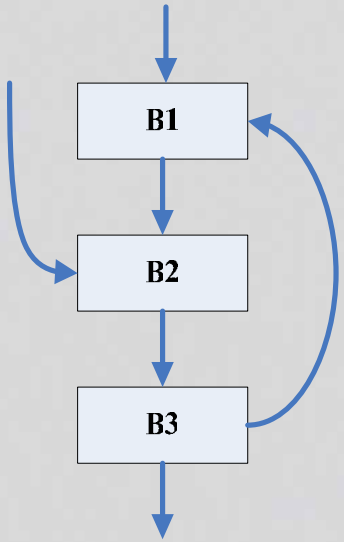


While loop

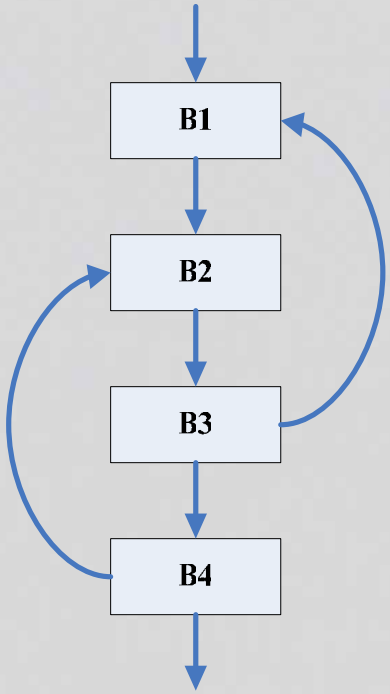


Multi exit

Unstructured Loops

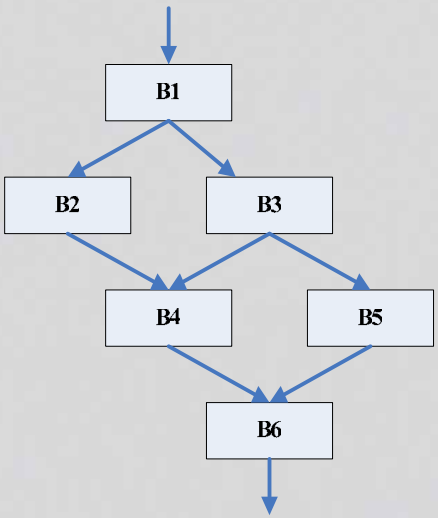


Multi entry

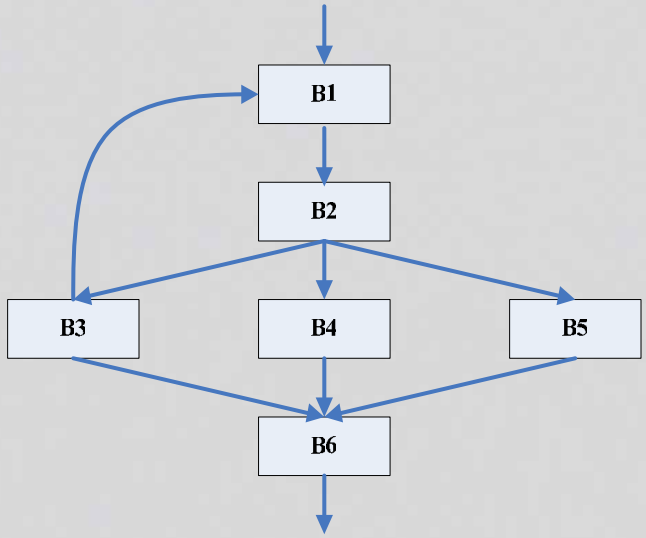


Overlapping

Unstructured conditionals(1)



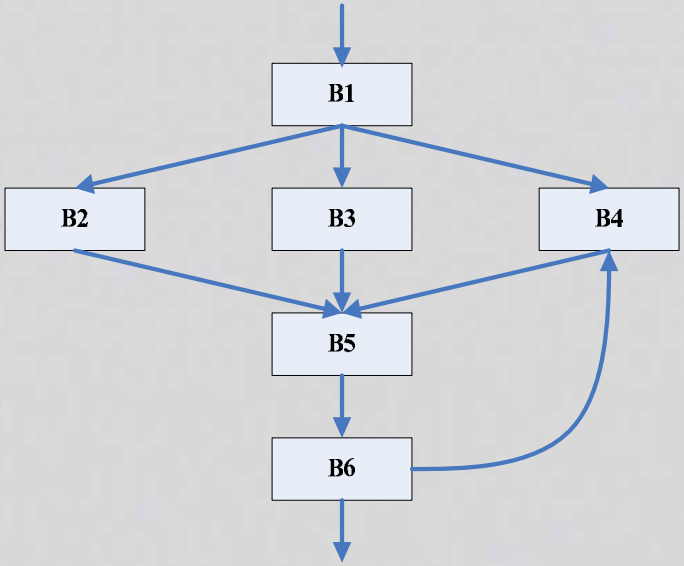
Unstructured 2-way conditionals



Unstructured N-way conditionals

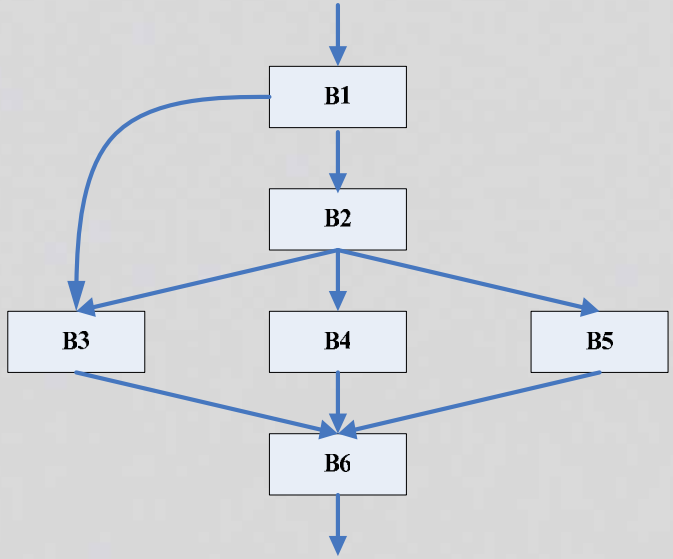
(1)

Unstructured conditionals(2)



Unstructured N-way conditionals

(2)

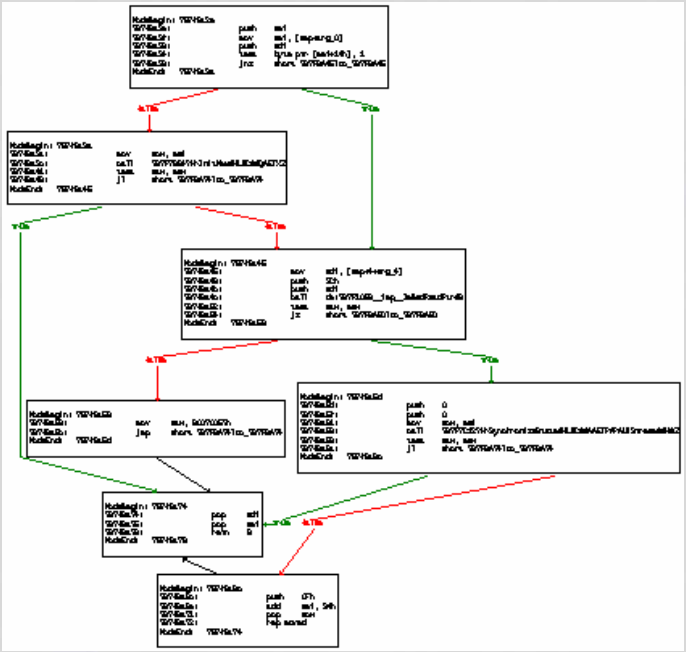


Unstructured N-way conditionals

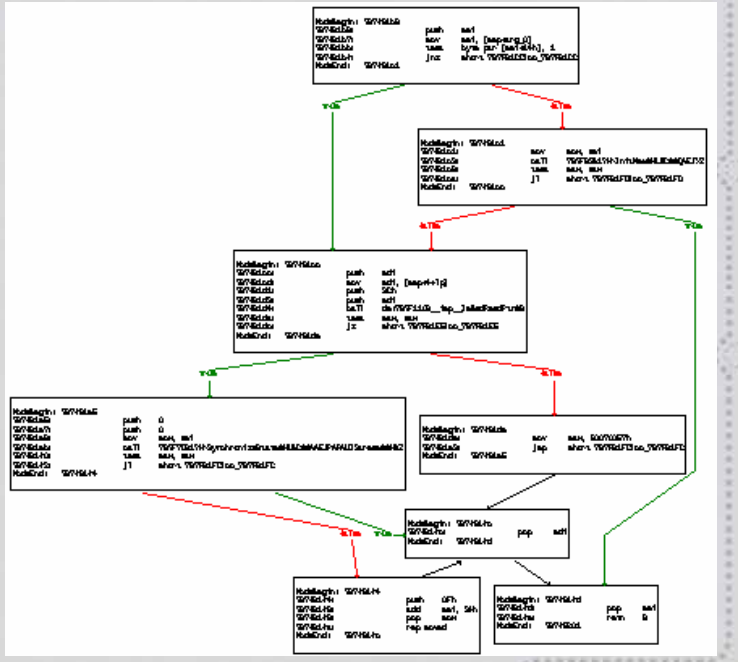
(3)

Example

MS 05-011 HLBC::GetBrowseWindowInfo

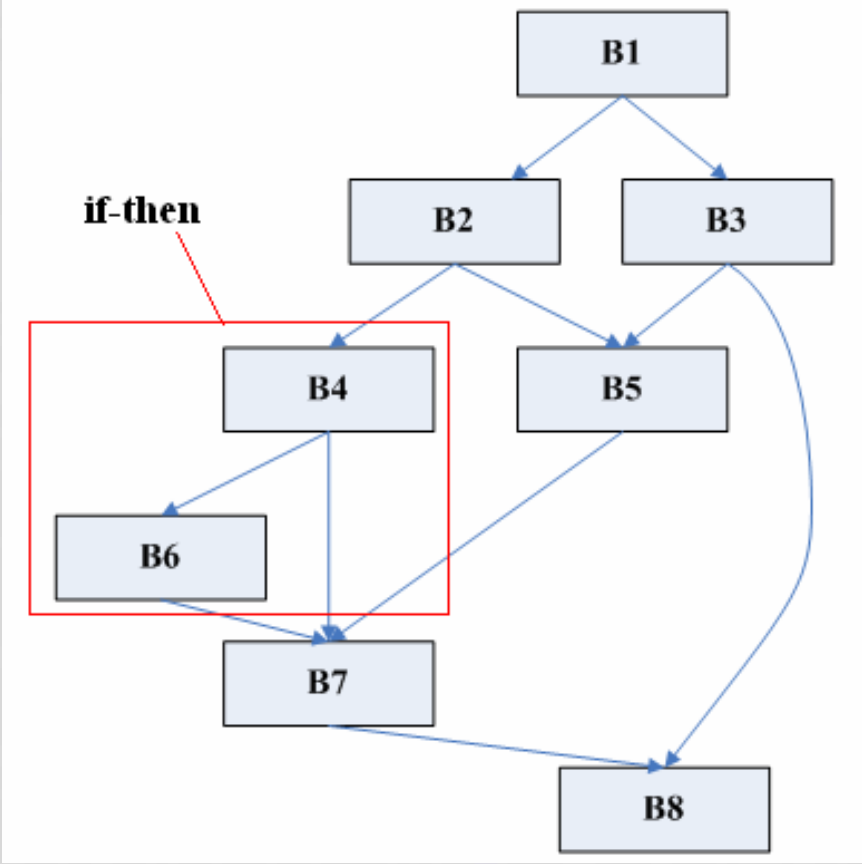


Unpatch Sig = 3::6::3

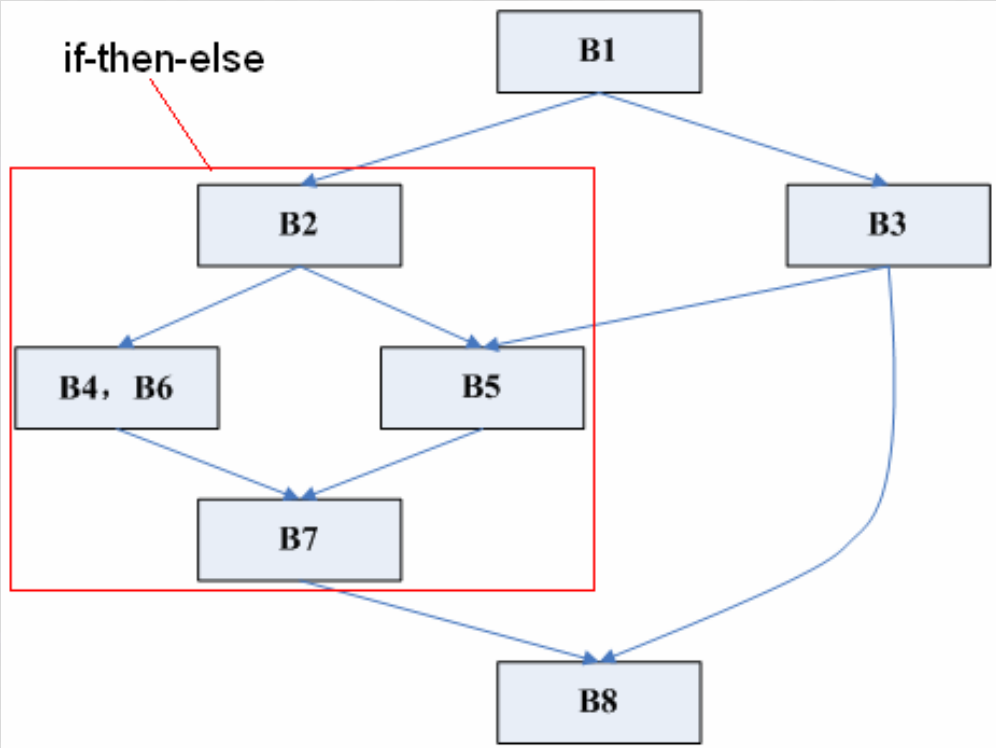


Patched Sig = 4::7::3

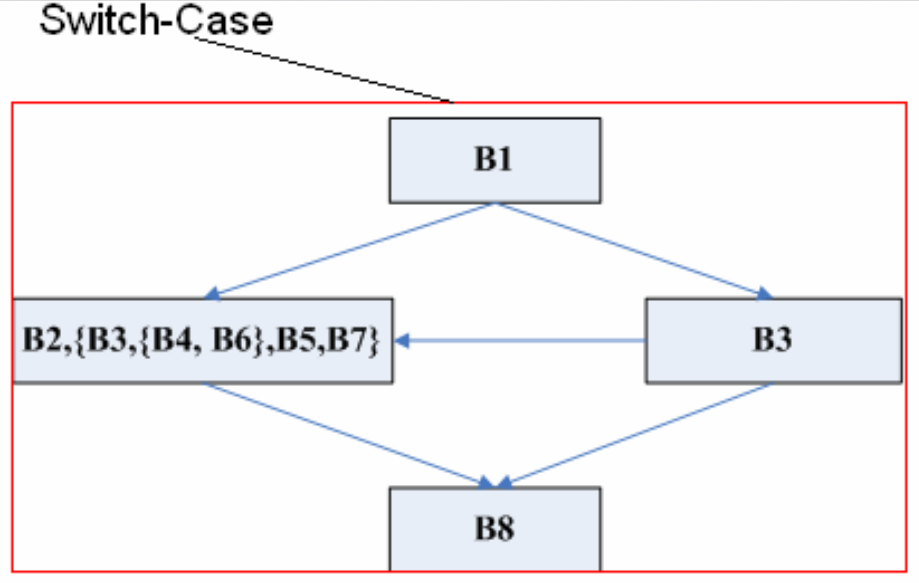
If-then reduce



If-then-else reduce



Switch-case reduction



The other's reduction process is the same

So, the two functions are the same

Assume:

If-then := Prime 2

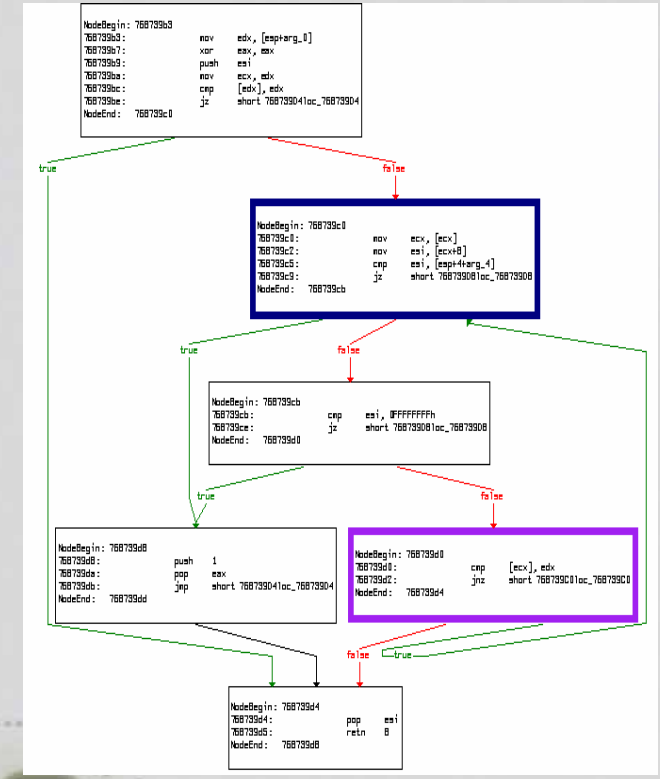
If-then-else := Prime 3

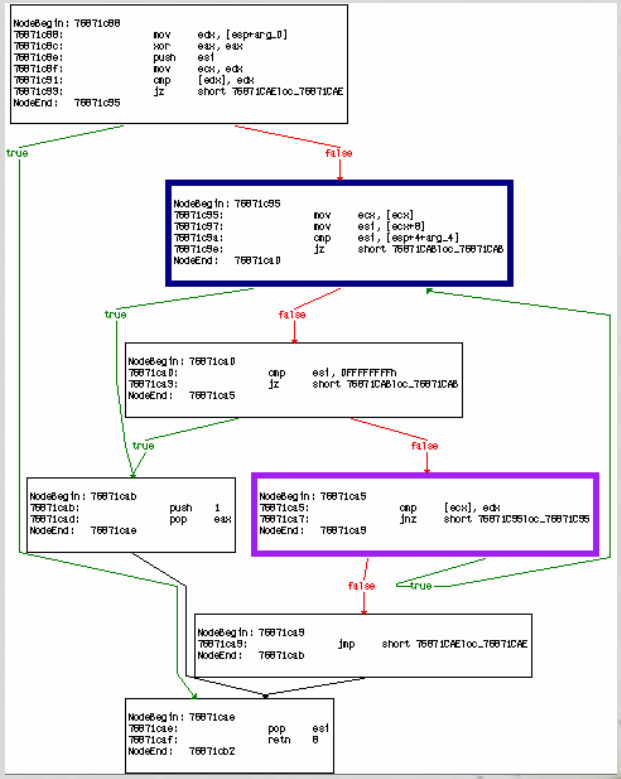
Switch-case := Prime 11

The two structure information sigs = 66

Handling Compiler optimization

Example 1: MsgIsSessionInList





Sig = 6::9::0

Sig = 7::10::0

Optimization Handling Algorithm 1.0

In control flow graph G1， for each node whose number of references is 1, its in edge is (y, x)， out edges are :

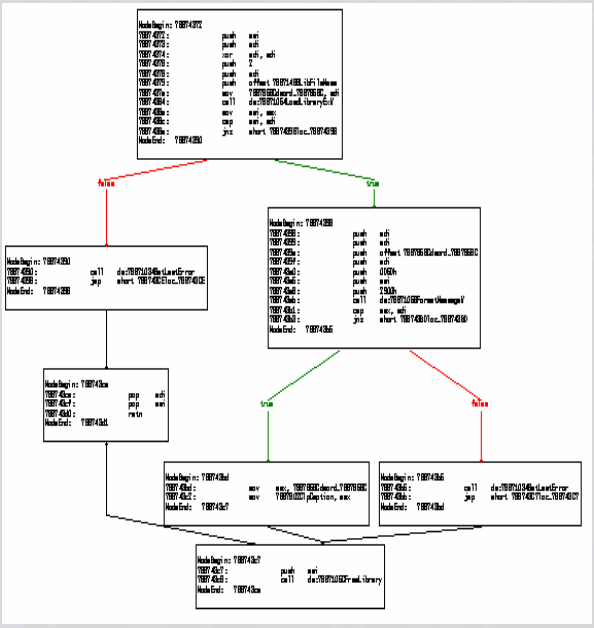
$$\varphi = \{< x, z_1 >, < x, z_2 >, ... < x, z_n >\}$$

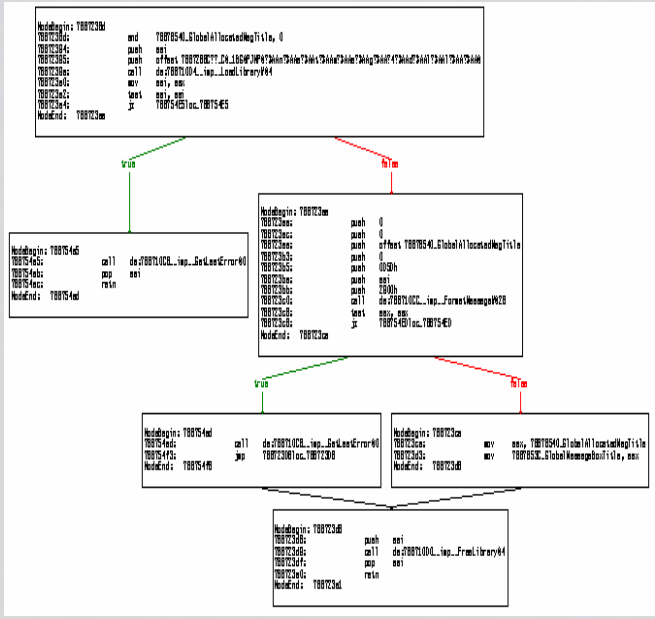
Delete node x, edge (y, x) and all out edges of node x, add edge from y to x's children.

After using algorithm 1.0 example 1's two sigs both are 4::7::0

More Than One Return Node, After Using Algorithm 1.0

Example 2



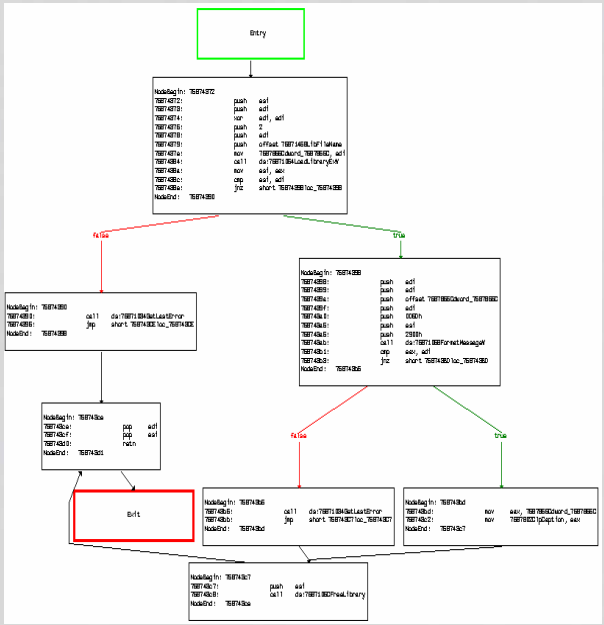


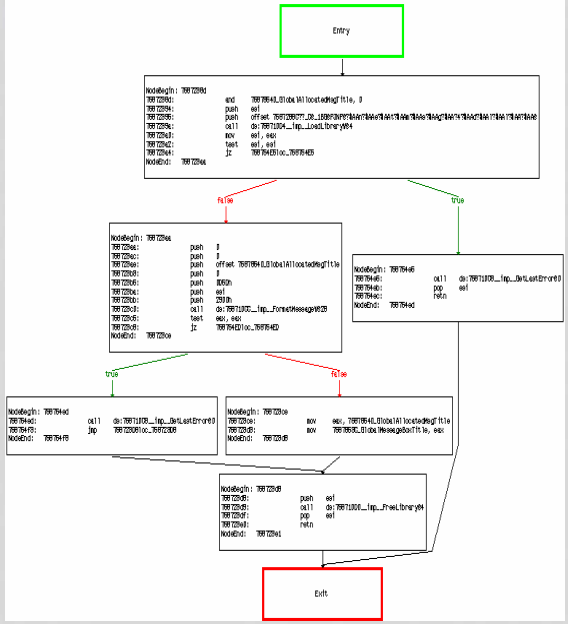
sig3 = 3::4::5

Sig = 3::3::5

Add Virtual Entry and Exit Node

Sig = 3::4::5





Advantage: 1、can unify optimization handling process

2、useful in loop detection

Demo

Problems

- Problems with complete call graph
- Problems with structural comparison
- Problems with instruction isomorphism

Problems with Complete Call Graph

- When we encounter
  - call esi
  - call [ebx+0x4]
- Some cases can be solved by:
  - Finding last definition in one function
  - Vtbl functions and runtime binding
  - Function Pointers Simulation Table
- Some cases too hard to resolve:
  - When definition comes from another module's function
  - When definition comes from Global Uninitialized Variables space
- Call in loop, each time can produce different value

Finding Last Definition In One Function

```
7C80B7FC ; BOOL __stdcall UnmapViewOfFile(LPCVOID lpBaseAddress)
7C80B7FC                  public UnmapViewOfFile
7C80B7FC UnmapViewOfFile proc near               ; CODE XREF: su
7C80B7FC                                         ; BaseInitAppco
7C80B7FC
7C80B7FC lpBaseAddress   = dword ptr  4
7C80B7FC arg_4           = dword ptr  8
7C80B7FC
7C80B7FC                 mov     edi, edi
7C80B7FE                 push    ebp
7C80B7FF                 mov     ebp, esp
7C80B801                 push    esi
7C80B802                 mov     esi, ds:NtUnmapViewOfSection
7C80B808                 push    edi
7C80B809                 push    [ebp+arg_4]
7C80B80C                 push    0FFFFFFFFh
7C80B80E                 call    esi ; NtUnmapViewOfSection
7C80B810                 mov     edi, eax
```

usually, when we use function pointer or load dll function in run-time…

Vtbl Function and Runtime Binding

```
0040100F                mov     dword ptr [eax], offset base_vtbl
00401015                mov     esi, eax
00401017                jmp     short loc_40101B
00401019 ;
00401019
00401019 loc_401019:                             ; CODE XREF: _main+
00401019                xor     esi, esi
0040101B
0040101B loc_40101B:                             ; CODE XREF: _main+
0040101B                mov     eax, [esi]
0040101D                mov     ecx, esi
0040101F                call    dword ptr [eax]
00401021                mov     edx, [esi]
00401023                mov     ecx, esi
00401025                call    dword ptr [edx+4]
```

```
004050B0 base_vtbl      dd offset demo_1
004050B4                dd offset demo_2
004050B8 unk_4050B8     db 0FFh
```

Function Pointers Simulation Table

```
00401020 Demo            proc near               ;
00401020
00401020 arg_0           = dword ptr  8
00401020
00401020                 push    esi
00401021                 mov     esi, [esp+arg_0]
00401025                 call    dword ptr [esi]
00401027                 call    dword ptr [esi+4]
```

```
00401030 _main           proc near               ; C
00401030                 push    offset simul_vtble
00401035                 call    Demo
0040103A                 pop     ecx
```

```
00407030 simul_vtble     dd offset Demo_1
00407034                 dd offset Demo_2
00407038 aDemo1          db 'Demo 1',0Ah,0
00407040 aDemo2          db 'Demo 2',0Ah,0
```

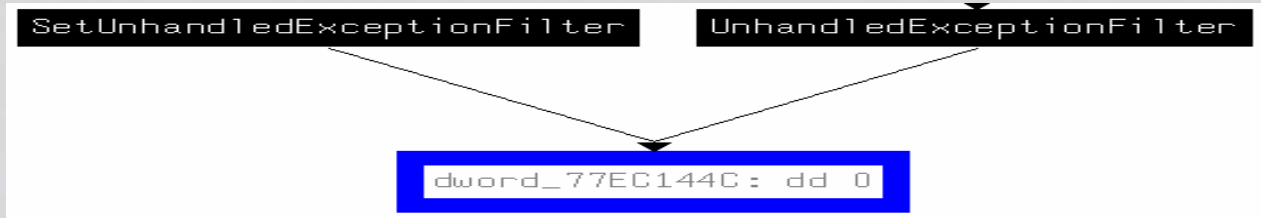
When Definition Comes From another module's function

```
7C862CC1                                        ; UnhandledExceptionFilter+9B↑j
7C862CC1                push    Target
7C862CC7                call    RtlDecodePointer
7C862CCC                cmp     eax, edi
7C862CCE                jz      short loc_7C862CE5
7C862CD0                push    ebx
7C862CD1                call    eax
7C862CD3                cmp     eax, 1
7C862CD6                jz      loc_7C863458
```

Eax is defined by a return value of another module's function

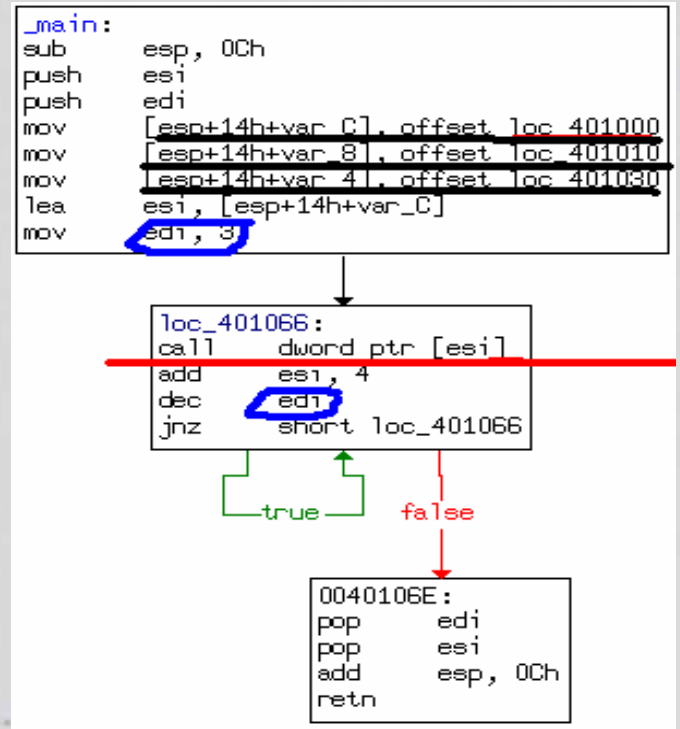
When Definition Comes From Global Uninitialized Var

```
77E9BDB1 loc_77E9BDB1:                                  ; CODE X
77E9BDB1                        mov     eax, dword 77EC144C
77E9BDB6                        cmp     eax, ebx
77E9BDB8                        jz      short loc_77E9BDC7
77E9BDBA                        push    esi
77E9BDBB                        call    eax
77E9BDBD                        cmp     eax, 1
```




```
77E6BC57 SetUnhandledExceptionFilter proc near
77E6BC57
77E6BC57 lpTopLevelExceptionFilter= dword ptr  4
77E6BC57
77E6BC57                        mov     ecx, [esp+lpTopLevelExceptionFilter]
77E6BC5B                        mov     eax, dword_77EC144C
77E6BC60                        mov     dword_77EC144C, ecx
77E6BC66                        retn    4
```

Call in Loop, each time can produce a different value



Loop three times

Firstly we should trace edi's D-U chain

Each time, a different subcall

We can add three functions as its children in call graph for fixed points propagation.

Problems with Structural Comparison

- Mismatching
- In-deep optimizations
- Inline functions
- change of constant values
- Substitute secure function for unsecure function
- The different versions of C compiler

Mismatching

- We can not prove mismatching will not happen.
- May be influenced by many factors

Substitute secure function for unsecure function

MS04-011 LSASS BOF

patched

```
785A0B58        push    [ebp+arg_8]
785A0B5B        mov     eax, 7FFh
785A0B60        sub     eax, esi
785A0B62        push    [ebp+arg_4]
785A0B65        push    eax
785A0B66        lea     eax, [ebp+esi+Buffer]
785A0B6D        push    eax
785A0B6E        call    ds: vsnprintf
785A0B74        add     esp, 10h
```

unpatch

```
7859EE5B        push    [ebp+arg_8]
7859EE5E        lea     eax, [ebp+esi+Buffer]
7859EE65        push    [ebp+arg_4]
7859EE68        push    eax
7859EE69        call    ds:vsprintf
7859EE6F        add     esp, 0Ch
```

Inline Functions

Will change the caller's subcalls number. Lead to mismatch

1、Inline prefix

```
__inline int max(int a, int b)
{
        if (a > b) return a;
        return b;
}
```

2、member function's body in a class definition

Problems with Instruction Isomorphism

- Instruction reorder
- Registers reallocation
- Data flow analysis

References

- [1] Compare, Port, Navigate
- http://www.blackhat.com/presentations/bh-europe-05/BH_EU_05-Flake.pdf
- [2]structural comparison of executale objects
- http://www.sabre-security.com/files/dimva_paper2.pdf
- [3]Graph-based comparison of Executable Objects
- http://www.sabre-security.com/files/BinDiffSSTIC05.pdf

The End