



# HexRaysCodeXplorer: object oriented RE for fun and profit

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# Agenda

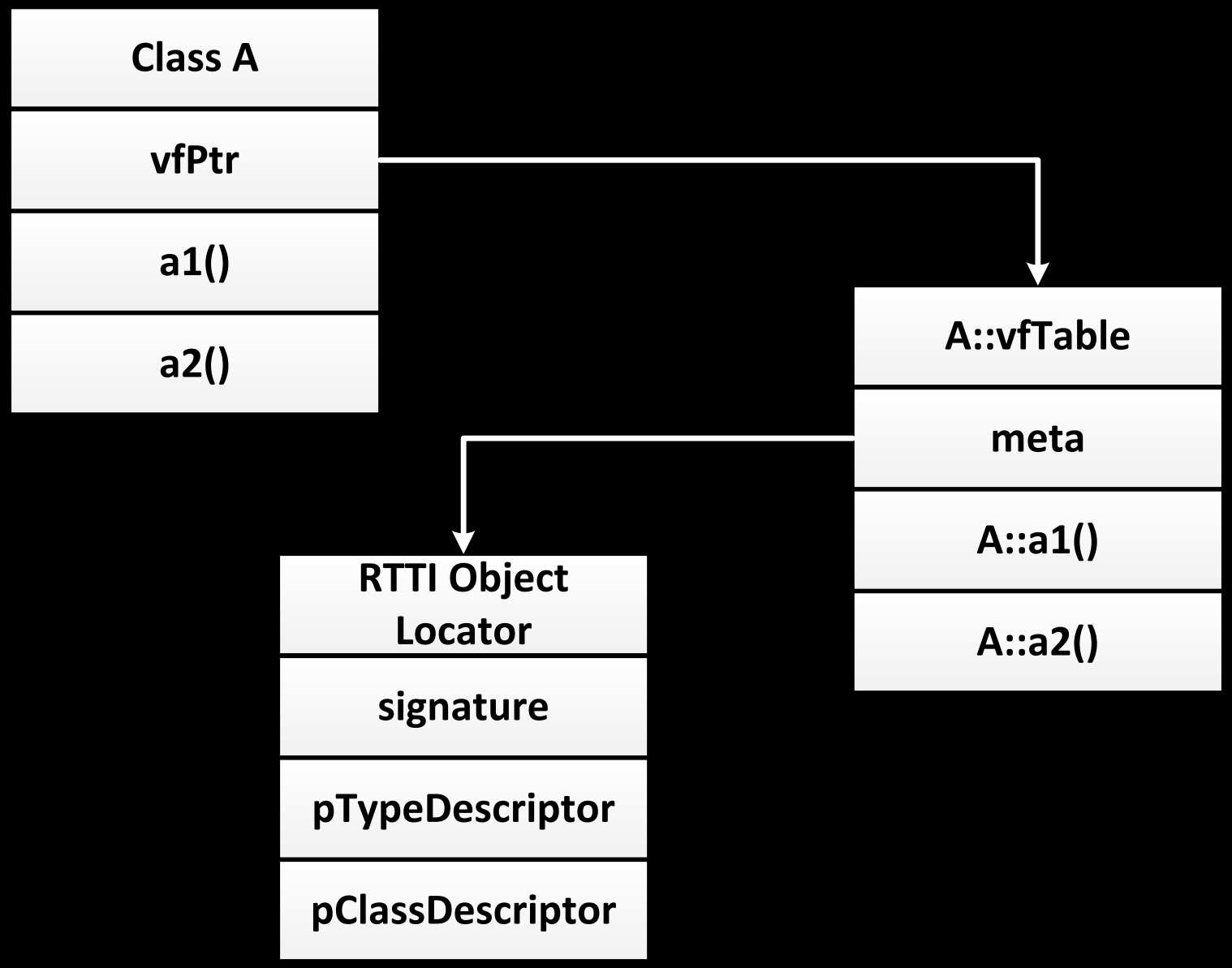
- ✓ C++ Code Reconstruction Problems
- ✓ Show problems on real examples (Flamer)
- ✓ HexRaysCodeXplorer v1.5 [H2HC Edition]

# C++ Code Reconstruction Problems

- Object identification
  - ✓ Type reconstruction
- Class layout reconstruction
  - ✓ Identify constructors/destructors
  - ✓ Identify class members
  - ✓ Local/global type reconstruction
  - ✓ Associate object with exact method calls
- RTTI reconstruction
  - ✓ vftable reconstruction
  - ✓ Associate vftable object with exact object
  - ✓ Class hierarchy reconstruction

Depend on compiler design

# C++ Code Reconstruction Problems

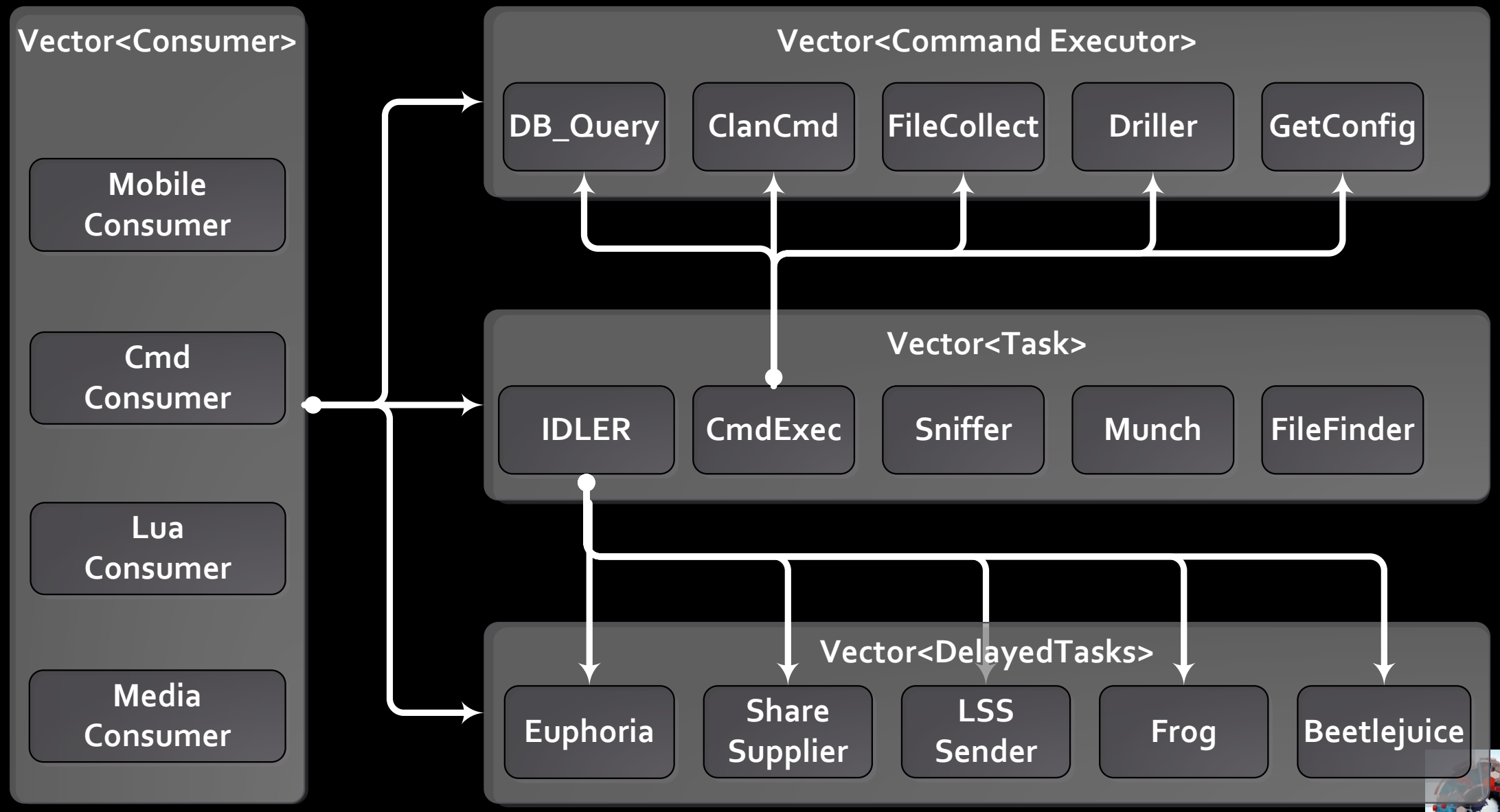


# C++ Code Reconstruction Problems

# REconstructing Flamer Framework

11ª EDIÇÃO 2014
H2HC
HACKERS TO HACKERS CONFERENCE

# An overview of the Flamer Framework




http://www.welivesecurity.com/2012/08/02/flamer-analysis-framework-reconstruction/

# An overview of the Flamer Framework

Vector<Cons

Mobile Consum

Cmd Consum

Lua Consum

Media Consum

```
0 0x10256aa0 - 0x10256afc:  VECTOR_DATA_2_VTABLE   method count: 23
1 0x10256bb0 - 0x10256bd8:  FILE_MAPPING_1_VTABLE   method count: 10
2 0x10256bd8 - 0x10256bf0:  GLOBAL_EVENT_1_VTABLE   method count: 6
3 0x102679a0 - 0x102679f0:  PROCESS_HANDLE_VTABLE   method count: 20
4 0x10267a90 - 0x10267acc:  THREAD_HANDLE_VTABLE   method count: 15
5 0x10267b08 - 0x10267b7c:  FILE_VTABLE_0   method count: 29
6 0x10267bc0 - 0x10267bd8:  EVENT_VTABLE   method count: 6
7 0x10267df0 - 0x10267e40:  PROCESS_HANDLE_VTABLE_0   method count: 20
8 0x10267e40 - 0x10267e80:  EVENTGLOBAL_HZ_VTABLE   method count: 16
9 0x10267e90 - 0x10267eb0:  KASPER_EVENT_ENTRY_VTABLE   method count: 8
10 0x10267f10 - 0x10267f34:  TOKEN_HANDLE_VTABLE   method count: 9
11 0x10268118 - 0x10268120:  USTRING_REG_PATH_VTABLE   method count: 2
12 0x10268128 - 0x102681a4:  FILE_1_vTable   method count: 31
13 0x10268260 - 0x10268298:  ENC_2_VTABLE   method count: 14
14 0x10268478 - 0x102684a8:  ZLIB_HLPR_VTABLE   method count: 12
15 0x102684e0 - 0x1026853c:  ENC_3_VTABLE   method count: 23
16 0x1026856c - 0x10268590:  SYSTEM_HANDLE_INFO_VTABLE   method count: 9
17 0x10268688 - 0x102686bc:  DICT_1_VTABLE   method count: 13
18 0x10268d78 - 0x10268dd4:  MAIN_VECT_3_VTABLE   method count: 23
19 0x10268f80 - 0x10268fe8:  CONCOL_HANDLER_VTABLE   method count: 26
20 0x102693c0 - 0x102693d0:  CMD_EXECUTER_VIPER_VTABLE   method count: 4
21 0x10269490 - 0x102694ec:  MAIN_VECT_1_VTABLE   method count: 23
22 0x102694f0 - 0x1026954c:  MAIN_VECT_2_VTABLE   method count: 23
23 0x10269550 - 0x102695ac:  MAIN_VECT_4_VTABLE   method count: 23
24 0x10269768 - 0x102697dc:  MAIN_VECT_2_IDLER_VTABLE   method count: 29
25 0x102697dc - 0x10269818:  _MAIN_VECT_2_IDLER_VTABLE   method count: 15
26 0x10269818 - 0x10269874:  VECT_VTABLE   method count: 23
27 0x10269874 - 0x10269884:  MAIN_VECT_4_TIME_UPDATER_VTABLE   method count: 4
28 0x10269a2c - 0x10269a68:  MAIN_3_VECT_1_VTABLE   method count: 15
29 0x10269b48 - 0x10269bbc:  MAIN_VECT_2_HNT_VTABLE   method count: 29
30 0x10269bc8 - 0x10269c3c:  MAIN_VECT_2_VOLUME_SUPPLIER_VTABLE   method count: 29
31 0x10269c40 - 0x10269cb4:  MAIN_VECT_2_VIRTUAL_VOLUME_SUPPLIER_VTABLE   method count: 29
32 0x10269e10 - 0x10269e84:  MAIN_VECT_2_HeadacheConsumer_VTABLE   method count: 29
```

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# An overview of the Flamer Framework

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```
0x10256aa0 - 0x10256afc:  VECTOR_DATA_2_VTABLE   method count: 23
0x10256bb0 - 0x10256bd8:  FILE_MAPPING_1_VTABLE   method count: 10
0x10256bd8 - 0x10256bf0:  GLOBAL_EVENT_1_VTABLE   method count: 6
0x102679a0 - 0x102679f0:  PROCESS_HANDLE_VTABLE   method count: 20
.rdata:10267F38 off_10267F38 dd offset sub_10014D09     ; DATA XREF: Vector1_Copy+18↑o
.rdata:10267F38                                         ; Vector1_Init+1C↑o ...
.rdata:10267F38                                         ; action
.rdata:10267F3C dd offset File_GetHandle                ; toState
.rdata:10267F40 dd offset sub_10054E04                  ; action
.rdata:10267F44 dd offset sub_10054E04                  ; toState
.rdata:10267F48 dd offset sub_1001E652                  ; action
.rdata:10267F4C dd offset sub_1001E652                  ; toState
.rdata:10267F50 dd offset sub_10035BCA                  ; action
.rdata:10267F54 dd offset sub_1019373F                  ; toState
.rdata:10267F58 dd offset sub_1001448A                  ; action
.rdata:10267F5C dd offset Data1_Vector_Insert           ; toState
.rdata:10267F60 dd offset sub_10014522                  ; action
.rdata:10267F64 dd offset sub_10014580                  ; toState
.rdata:10267F68 dd offset sub_100145A1                  ; action
.rdata:10267F6C dd offset sub_100036DD                  ; toState
.rdata:10267F70 dd offset sub_100EDD41                  ; action
.rdata:10267F74 dd offset sub_10003C05                  ; toState
.rdata:10267F78 dd offset sub_10028089                  ; action
.rdata:10267F7C dd offset sub_100145C2                  ; toState
.rdata:10267F80 dd offset sub_1001460E                  ; action
.rdata:10267F84 dd offset VectData1_CheckLimits         ; toState
.rdata:10267F88 dd offset get_less_power                ; action
.rdata:10267F8C dd offset sub_10014680                  ; toState
.rdata:10267F90 dd offset sub_10014732                  ; action
.rdata:10267F94 dd 0                                    ; toState
0x10269b48 - 0x10269bbc:  MAIN_VECT_2_HNT_VTABLE   method count: 29
0x10269bc8 - 0x10269c3c:  MAIN_VECT_2_VOLUME_SUPPLIER_VTABLE   method count: 29
0x10269c40 - 0x10269cb4:  MAIN_VECT_2_VIRTUAL_VOLUME_SUPPLIER_VTABLE   method count: 29
0x10269e10 - 0x10269e84:  MAIN_VECT_2_HeadacheConsumer_VTABLE   method count: 29
```

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# Identify Smart Pointer Structure

- Smart pointers
- Strings
- Vectors to maintain the objects
- Custom data types:
  - ✓ wrappers
  - ✓ tasks,
  - ✓ triggers
  - ✓ and etc.

# Data Types Being Used: Smart pointers

```
typedef struct SMART_PTR
{
   void        *pObject;    // pointer to the object
   int         *RefNo;      // reference counter
};
```

```
SMART_PTR_STRUCT *__userpurge SmartPtr_InializeByObject<eax>(SMART_PTR_STRUCT *a1<esi>, void *pObject)
{
  int *v2; // eax@1

  LOBYTE(v2) = new(4);
  if ( v2 )
    *v2 = 1;
  else
    v2 = 0;
  a1->RefNo = v2;
  a1->Object = pObject;
  return a1;
}
```

# Identify Smart Pointer Structure

```
SmartPtr_InializeByObject proc near     ; CODE XR
                                        ; sub_100

var_10          = dword ptr -10h
var_C           = dword ptr -0Ch
var_4           = dword ptr -4
arg_0           = dword ptr  8

                mov     eax, offset sub_101C690A
                call    __EH_prolog
                push    ecx
                push    4
                call    alloc_mem
                pop     ecx
                mov     [ebp+var_10], eax
                and     [ebp+var_4], 0
                test    eax, eax
                jz      short loc_100041F5
                mov     dword ptr [eax], 1
                jmp     short loc_100041F7
; ---------------------------------------------

loc_100041F5:                           ; CODE XR
                xor     eax, eax

loc_100041F7:                           ; CODE XR
                or      [ebp+var_4], 0FFFFFFFFh
                mov     ecx, [ebp+var_C]
                mov     [esi+4], eax
                mov     eax, [ebp+arg_0]
                mov     [esi], eax
                mov     eax, esi
                mov     large fs:0, ecx
                leave
                retn    4
SmartPtr_InializeByObject endp
```

```
SMART_PTR_STRUCT *__userpurge SmartPtr
{
  int *v2; // eax@1

  v2 = alloc_mem(4);
  if ( v2 )
    *v2 = 1;
  else
    v2 = 0;
  a1->RefNo = v2;
  a1->Object = a2;
  return a1;
}
```

# Data Types Being Used: Vectors

```
struct VECTOR
{
  void *vTable;              // pointer to the table
  int NumberOfItems;         // self-explanatory
  int MaxSize;               // self-explanatory
  void *vector;              // pointer to buffer with elements
};
```

- **Used to handle the objects:**
  - ✓ **tasks**
  - ✓ **triggers**
  - ✓ **etc.**

# Identify Exact Virtual Function Call in Vtable

```
STRUCT_4_3 *__thiscall CSocket_Cto
{
  STRUCT_4_3 *v1; // esi@1

  v1 = this;
  this->vTable = &csocket_v_table;
  this->struct44 = 0;
  this->DeviceTcp = 0;
  this->DeviceUdp = 0;
  sub_19664(&this->struct41);
  sub_13E22(&v1->struct2);
  v1->SocketNumber = 0;
  v1->RefNo = 0;
  return v1;
}
```

```
VECTOR_DATA_1_VTABLE dd offset sub_10048202
                                                    ; DATA X
                                                    ; Data1_
                     dd offset File_GetHandle
                     dd offset sub_10054E04
                     dd offset sub_10054E04
                     dd offset sub_1001E652
                     dd offset sub_1001E652
                     dd offset sub_10035BCA
                     dd offset sub_1019373F
                     dd offset sub_10047E6C
                     dd offset Data1_Vector_Insert
                     dd offset sub_10047F09
                     dd offset VectData1_GetEntry
                     dd offset sub_10047F84
                     dd offset sub_10047FCE
                     dd offset sub_10047DC6
                     dd offset sub_10047FA5
                     dd offset sub_10028089
                     dd offset sub_10047FF5
                     dd offset sub_1004803A
                     dd offset VectData1_CheckLimits
                     dd offset get_less_power
                     dd offset sub_1003844D
                     dd offset sub_100480AC
off_1026A064         dd offset sub_100476F7   ; DATA X
```

```
sh    4609h
p     eax
v     edx, eax
v     ecx, [edi+0Ch]
v     eax, [ecx]
a     edx, [ebp-8]
sh    edx
sh    dword ptr [edi+10h]
ll    dword ptr [eax+0Ch]
st    al, al
z     short loc_1BCA9
v     ecx, edi          ; this
ll    CloseTcpSocket
v     eax, 44CFh
sh    eax
p     ebx
```

Load pointer to table of virtual methods

Call virtual method

# Identify Exact Virtual Function Call in Vtable

```
int __thiscall Rc4_GetBufferSize(_RC4_STRUCT *this)
{
  return (this->Reader->vTable->GetResBufSize)();
}
```

```
; int __thiscall Rc4_GetBufferSize(_RC4_STRUCT *this)
Rc4_GetBufferSize proc near             ; DATA XREF:
                mov     ecx, [ecx+4]
                mov     eax, [ecx]
                jmp     dword ptr [eax+10h]
Rc4_GetBufferSize endp
```

```
RC4_VTABLE      dd offset Rc4_GetReader ; DATA XREF: sub_1011E919+1E↑o
                dd offset Rc4_GetWriter
                dd offset ?Destroy@EventWaitNode@details@Concurrency@@QAEXXZ
                dd offset ?Sweep@EventWaitNode@details@Concurrency@@QAE_NXZ
                dd offset Rc4_GetBufferSize
                dd offset Rc4_IncreaseSize
                dd offset Rc4_Check
                dd offset Rc4_InitEmpty
                dd offset Rc4_Release
                dd offset Rc4_GetMuxName
```

# Identify Custom Type Operations

```
; int __thiscall DataVector1_GetEntry(VECTOR_DATA_1_STRUCT *this, int a2)
DataVector1_GetEntry proc near          ; DATA XREF: .rdata:10256ACC↓o

arg_0= dword ptr  8

push    ebp
mov     ebp, esp
push    esi
push    edi
mov     edi, [ebp+arg_0]
mov     esi, ecx
mov     eax, [esi]
push    offset unk_103313A6
push    edi
call    dword ptr [eax+4Ch]
mov     eax, [esi+0Ch]
lea     eax, [eax+edi*4]
pop     edi
pop     esi
pop     ebp
retn    4
DataVector1_GetEntry endp
```

```
int __thiscall DataVector1_GetEntry(VECTOR_DATA_1_STRUCT *this, int a2)
{
  VECTOR_DATA_1_STRUCT *v2; // esi@1

  v2 = this;
  (this->vTable->CheckVectLimits)(a2, &unk_103313A6);
  return (v2->vector + 4 * a2);
}
```

# Data Types Being Used: Strings

```
struct USTRING_STRUCT
{
  void *vTable;              // pointer to the table
  int RefNo;                 // reference counter
  int Initialized;
  wchar_t *UnicodeBuffer; // pointer to unicode string
  char *AsciiBuffer;         // pointer to ASCII string
  int AsciiLength;           // length of the ASCII string
  int Reserved;
  int Length;                // Length of unicode string
  int LengthMax;             // Size of UnicodeBuffer
};
```

# Identify Objects Constructors

```
100057DD
100057DD
100057DD ; Attributes: bp-based frame
100057DD
100057DD ; void *__thiscall UStringPtr_Construct(USTRING_PTR_STRUCT *this, wchar_t *String)
100057DD UStringPtr_Construct proc near
100057DD
100057DD var_14= dword ptr -14h
100057DD var_10= dword ptr -10h
100057DD var_C= dword ptr -0Ch
100057DD var_4= dword ptr -4
100057DD String= dword ptr  8
100057DD
100057DD mov     eax, offset sub_101CF44D
100057E2 call    __EH_prolog
100057E7 push    ecx
100057E8 push    ecx
100057E9 push    ebx
100057EA mov     ebx, ecx
100057EC push    edi
100057ED push    24h
100057EF mov     [ebp+var_10], ebx
100057F2 mov     dword ptr [ebx], offset UStringPtr_Vtable
100057F8 call    alloc_mem
100057FD pop     ecx
100057FE mov     [ebp+var_14], eax
10005801 and     [ebp+var_4], 0
10005805 test    eax, eax
10005807 jz      short loc_10005817
```

```
10005809 push    esi
1000580A push    [ebp+String]    ; String
1000580D mov     esi, eax        ; a2
1000580F call    UString_InitByWcharStr
10005814 pop     esi
10005815 jmp     short loc_10005819
```

```
10005817
10005817 loc_10005817:
10005817 xor     eax, eax
```

```
10005819
10005819 loc_10005819:
10005819 or      [ebp+var_4], 0FFFFFFFFh
1000581D lea     edi, [ebx+4]
10005820 push    0
10005822 mov     [edi], eax
10005824 call    UStringPtr_Reinit
10005829 or      [ebp+var_4], 0FFFFFFFFh
1000582D mov     ecx, [ebp+var_C]
10005830 pop     edi
10005831 mov     eax, ebx
10005833 pop     ebx
10005834 mov     large fs:0, ecx
1000583B leave
1000583C retn    4
1000583C UStringPtr_Construct endp
1000583C
```

# Identify Objects Constructors

```
100057DD
100057DD
100057DD ; Attributes: bp-based frame
100057DD
100057DD ; void *__thiscall UStringPtr_Construct(USTRING_PTR_STRUCT *this, wchar_t *String)
100057DD UStringPtr_Construct proc near
100057DD
100057DD var_14= dword ptr -14h
100057DD var_10= dword ptr -10h
100057DD var_C= dword ptr -0Ch
```

```
USTRING_PTR_STRUCT *__thiscall UStringPtr_Construct(USTRING_PTR_STRUCT *this, wchar_t *String)
{
  USTRING_PTR_STRUCT *v2; // ebx@1
  USTRING_STRUCT *v3; // eax@1
  USTRING_STRUCT *v4; // eax@2

  v2 = this;
  this->vTable = UStringPtr_Vtable;
  v3 = alloc_mem(36);
  if ( v3 )
    v4 = UString_InitByWcharStr(v3, String);
  else
    v4 = 0;
  v2->String = v4;
  UStringPtr_Reinit(&v2->String, 0);
  return v2;
}
```

```
10005820 push    0
10005822 mov     [edi], eax
10005824 call    UStringPtr_Reinit
10005829 or      [ebp+var_4], 0FFFFFFFFh
1000582D mov     ecx, [ebp+var_C]
10005830 pop     edi
10005831 mov     eax, ebx
10005833 pop     ebx
10005834 mov     large fs:0, ecx
1000583B leave
1000583C retn    4
1000583C UStringPtr_Construct endp
1000583C
```

# REconstructing Object's Attributes

| | | | | |
|---|---|---|---|---|
| 141 | MAIN_VECT_3_OBJ_X_1_STRUCT | 00000010 | Auto | struct {int vTable;int field1;int field2;int field3;} |
| 159 | MAIN_VECT_3_ENTRY | 00000044 | | struct {int vTable;int field4;int field5;char field6_0;char field6_1;char field6_2;cha... |
| 143 | MAIN_VECT_3_1_STRUCT | 0000004C | Auto | struct {int vTable;MAIN_VECT_3_1_1_STRUCT Main31;GLOBAL_EVENT_STRUCT_... |
| 145 | MAIN_VECT_3_1_PTR_STRUCT | 00000008 | Auto | struct {MAIN_VECT_3_1_STRUCT *pObject;int *RefNo;} |
| 160 | MAIN_VECT_3_1_ENTRY | 00000010 | | struct {int vTable;int field0;int field1;int field2;} |
| 144 | MAIN_VECT_3_1_1_STRUCT | 00000024 | Auto | struct {int vTale;VECTOR_DATA_1_STRUCT Vect1;VECTOR_DATA_1_STRUCT Vec... |
| 132 | MAIN_VECT_2_STRUCT | 00000080 | Auto | struct {int field0;VECTOR_DATA_1_STRUCT VectorOfObjects;GLOBAL_EVENT_ST... |
| 148 | MAIN_VECT_2_OBJ_HEAD_VTABLE | 00000074 | Auto | struct {int field0;int field1;int field2;int field3;int field4;int field5;int field6;int field... |
| 133 | MAIN_VECT_2_OBJ_HEAD_STRUCT | 00000088 | Auto | struct {MAIN_VECT_2_OBJ_HEAD_VTABLE *vTable;HANDLE_INFO_STRUCT *Thr... |
| 135 | MAIN_VECT_2_OBJ_HEAD_1_STRUCT | 00000028 | Auto | struct {int vTable;_MAIN_VECT_2_OBJ_HEAD_1_STRUCT Vect21;} |
| 165 | MAIN_VECT_2_NHT_STRUCT | 00000098 | Auto | struct {MAIN_VECT_2_OBJ_HEAD_STRUCT Header;SMART_PTR_STRUCT ENtryP... |
| 136 | MAIN_VECT_2_MUNCH_OBJ_STRUCT | 000000DC | Auto | struct {MAIN_VECT_2_OBJ_HEAD_STRUCT Header;_MAIN_VECT_2_MUNCH_OB... |
| 157 | MAIN_VECT_2_JIMMY_STRUCT | 00000188 | Auto | struct {MAIN_VECT_2_JIMMY_1_STRUCT Jimmy1;MAIN_VECT_2_JIMMY_2_STRU... |
| 158 | MAIN_VECT_2_JIMMY_2_STRUCT | 00000150 | Auto | struct {MAIN_VECT_2_OBJ_HEAD_STRUCT head;GLOBAL_EVENT_STRUCT_1 Sy... |
| 156 | MAIN_VECT_2_JIMMY_1_STRUCT | 00000038 | Auto | struct {int vTable;int field1;int field2;int field3;int field4;int field5;int field6;int field... |
| 146 | MAIN_VECT_2_IDLER_STRUCT | 000000BC | Auto | struct {MAIN_VECT_2_OBJ_HEAD_STRUCT Header;_MAIN_VECT_2_IDLER_STR... |
| 162 | MAIN_VECT_2_GADGET_SUPP_STRUCT | 000003DC | Auto | struct {MAIN_VECT_2_OBJ_HEAD_STRUCT Header;EVENT_HANDLE_STRUCT Ev... |
| 163 | MAIN_VECT_2_GADGET_SUPP_1_STRUCT | 00000010 | Auto | struct {int vTable;int field0;int field1;int field2;} |
| 172 | MAIN_VECT_2_COMMAND_FILE_FINDER_STRUCT | 000000DC | Auto | struct {MAIN_VECT_2_OBJ_HEAD_STRUCT Header;MAIN_VECT_4_OBJ_HEAD_S... |
| 173 | MAIN_VECT_2_COMMAND_FILE_FINDER_NOTIF_ENTRY_... | 00000014 | | struct {HANDLE_INFO_PTR_STRUCT HandleInfo;USTRING_PTR_STRUCT FolderN... |
| 164 | MAIN_VECT_2_CMD_RUNNER_STRUCT | 0000009C | Auto | struct {MAIN_VECT_2_OBJ_HEAD_STRUCT Header;int CmdDispatcher;int Comma... |
| 130 | MAIN_VECT_1_STRUCT | 000000E4 | Auto | struct {int vTable;VECTOR_DATA_1_STRUCT VectorOfCmdDispatchers;GLOBAL_E... |
| 138 | MAIN_VECTOR_4_GLOB_STRUCT | 00000034 | Auto | struct {GLOBAL_EVENT_STRUCT_1 SyncEvent;VECTOR_DATA_1_STRUCT Vector;} |

# REconstructing Object's Attributes

| | | | | |
|---|---|---|---|---|
| 141 | MAIN_VECT_3_OBJ_X_1_STRUCT | 00000010 | Auto | struct {int vTable;int field1;int field2;int field3;} |
| 159 | MAIN_VECT_3_ENTRY | 00000044 | | struct {int vTable;int field4;int field5;char field6_0;char field6_1;char field6_2;cha... |
| 143 | MAIN_VECT_3_1_STRUCT | | | TRUCT Main31;GLOBAL_EVENT_STRUCT_... |
| 145 | MAIN_VECT_3_1_PTR_STRUCT | | | ject;int *RefNo;} |
| 160 | MAIN_VECT_3_1_ENTRY | | | field2;} |
| 144 | MAIN_VECT_3_1_1_STRUCT | | | UCT Vect1;VECTOR_DATA_1_STRUCT Vec... |
| 132 | MAIN_VECT_2_STRUCT | | | UCT VectorOfObjects;GLOBAL_EVENT_ST... |
| 148 | MAIN_VECT_2_OBJ_HEAD_VTAB | | | ield3;int field4;int field5;int field6;int field... |
| 133 | MAIN_VECT_2_OBJ_HEAD_STRU | | | LE *vTable;HANDLE_INFO_STRUCT *Thr... |
| 135 | MAIN_VECT_2_OBJ_HEAD_1_ST | | | HEAD_1_STRUCT Vect21;} |
| 165 | MAIN_VECT_2_NHT_STRUCT | | | UCT Header;SMART_PTR_STRUCT ENtryP... |
| 136 | MAIN_VECT_2_MUNCH_OBJ_STR | | | UCT Header;_MAIN_VECT_2_MUNCH_OB... |
| 157 | MAIN_VECT_2_JIMMY_STRUCT | | | T Jimmy1;MAIN_VECT_2_JIMMY_2_STRU... |
| 158 | MAIN_VECT_2_JIMMY_2_STRUC | | | UCT head;GLOBAL_EVENT_STRUCT_1 Sy... |
| 156 | MAIN_VECT_2_JIMMY_1_STRUC | | | field3;int field4;int field5;int field6;int field... |
| 146 | MAIN_VECT_2_IDLER_STRUCT | | | UCT Header;_MAIN_VECT_2_IDLER_STR... |
| 162 | MAIN_VECT_2_GADGET_SUPP_S | | | UCT Header;EVENT_HANDLE_STRUCT Ev... |
| 163 | MAIN_VECT_2_GADGET_SUPP_1 | | | field2;} |
| 172 | MAIN_VECT_2_COMMAND_FILE_ | | | UCT Header;MAIN_VECT_4_OBJ_HEAD_S... |
| 173 | MAIN_VECT_2_COMMAND_FILE_ | | | ndleInfo;USTRING_PTR_STRUCT FolderN... |
| 164 | MAIN_VECT_2_CMD_RUNNER_STRUCT | 0000009C | Auto | struct {MAIN_VECT_2_OBJ_HEAD_STRUCT Header;int CmdDispatcher;int Comma... |
| 130 | MAIN_VECT_1_STRUCT | 000000E4 | Auto | struct {int vTable;VECTOR_DATA_1_STRUCT VectorOfCmdDispatchers;GLOBAL_E... |
| 138 | MAIN_VECTOR_4_GLOB_STRUCT | 00000034 | Auto | struct {GLOBAL_EVENT_STRUCT_1 SyncEvent;VECTOR_DATA_1_STRUCT Vector;} |

**Please enter text**

Please edit the type declaration

```
struct MAIN_VECT_2_COMMAND_FILE_FINDER_STRUCT
{
  MAIN_VECT_2_OBJ_HEAD_STRUCT Header;
  MAIN_VECT_4_OBJ_HEAD_STRUCT Main4Head;
  int table;
  VECTOR_DATA_1_STRUCT vect;
  int field0;
  GLOBAL_EVENT_STRUCT_1 sync;
  EVENT_HANDLE_STRUCT EventHandle;
};
```

OK | Cancel | Help

# REconstructing Object's Methods

Please enter text

Please edit the type declaration

```
struct STRUCT_SOCKET_VTABLE
{
  int InitTransport;
  int OpenTransport;
  int CloseTransport;
  int TcpConnect;
  int TcpDisconnect;
  int field5;
  int field6;
  int ReleaseNodeFromList;
  int TcpListen;
  int TcpAccept;
  int TcpSend;
  int TcpReceive;
  int UdpSend;
  int UdpReceive;
  int TcpGetAddrInfo;
  int field15;
  int SetTimeout;
  int SendOverUdp;
  int field18;
  int field19;
  int field20;
};
```

OK Cancel Help

Please enter text

Please edit the type declaration

```
#pragma pack(push, 1)
struct STRUCT_SOCKET
{
  STRUCT_SOCKET_VTABLE *vTable;
  STRUCT_4_4 *struct44;
  int mem1;
  int field5;
  int field6;
  int field7;
  int field8;
  int field9;
  int field10;
  int field11;
  int tcp_drv_ver;
  int field13;
  int field14;
  int field15;
```

OK Cancel Help

# REconstructing Object's Methods

Please enter text

Please edit the type declaration

```
struct STRUCT_SOCKET_VTABLE
{
  if ( !v2->struct5.UdpSocket )
  {
    v2->struct5.UdpSocket = (v2->struct5.struct43->vTable->OpenTransport)(// open UDP
                             v2->struct5.struct43,
                             v1,
                             2,
                             v2,
                             0,
                             0);
    (v2->struct5.struct43->vTable->SetTimeout)(v2->struct5.UdpSocket, 4000);
  }
  result = (v2->struct5.struct43->vTable->SendOverUdp)(
             v2->struct5.UdpSocket,
             v2->struct5.domain,
             &v2->struct5.IpAddress);
  int field20;
};
```

OK Cancel Help

Please enter text

Please edit the type declaration

# HexRaysCodeXplorer

# HexRaysCodeXplorer v1.0: released in 2013 at REcon



Hex-Rays

Hex-Rays Decompiler: Manual



## Third-party plugins

Below is the list of noteworthy public third-party plugins for the decompiler.

- HexRaysCodeXplorer by Aleksandr Matrosov and Eugene Rodionov

  Hex-Rays Decompiler plugin for better code navigation Here is the main features list schedule for first release:
  - navigation through virtual function calls in Hex-Rays Decompiler window;
  - automatic type reconstruction for C++ constructor object;
  - useful interface for working with objects & classes;

- hexrays-python

  Python bindings for the Hexrays Decompiler This is an IDA Pro plugin which provides python bindings around the Hexrays Decompiler SDK API.

- More to come...

Happy analysis!

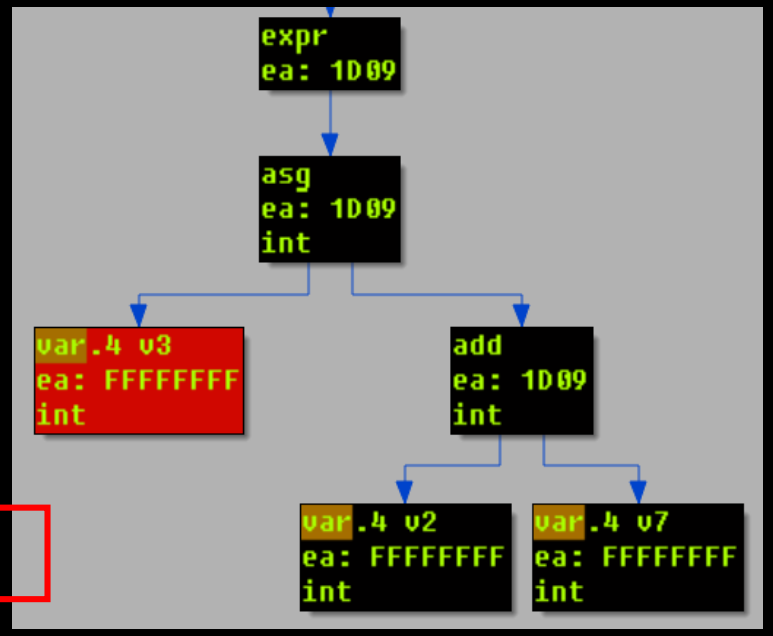
# HexRaysCodeXplorer Features

- Hex-Rays decompiler plugin
- The plugin was designed to facilitate static analysis of:
  - ✓ object oriented code
  - ✓ position independent code
- The plugin allows to:
  - ✓ navigate through decompiled virtual methods
  - ✓ partially reconstruct object type

# Hex-Rays Decompiler Plugin SDK

- At the heart of the decompiler lies *ctree* structure:
  - ✓ syntax tree structure
  - ✓ consists of *citem_t* objects
  - ✓ there are 9 maturity levels of the *ctree* structure

```
while ( 1 )
{
  LOBYTE(v2) = *v4++;
  if ( !(_BYTE)v2 )
    break;
  v7 =   ROR4  (v3, 11);
  v3 = v2 + v7;
}
```

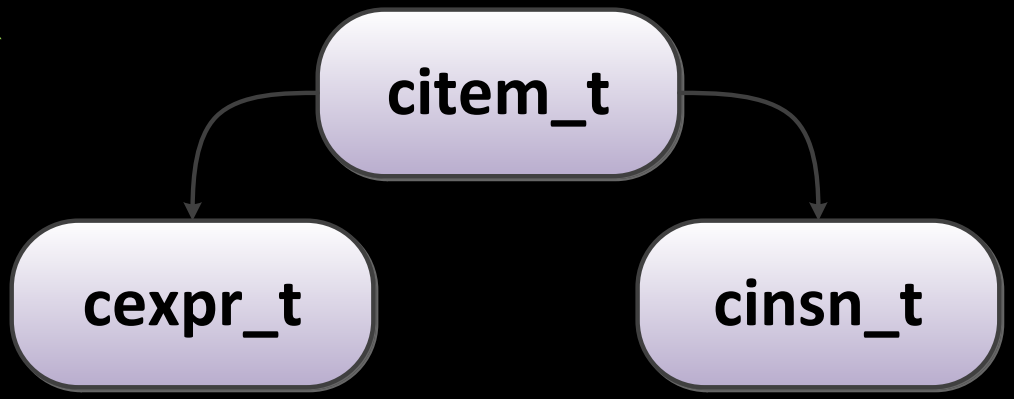


# Hex-Rays Decompiler Plugin SDK

- At the heart of the decompiler lies *ctree* structure:

```
/// Ctree maturity level. The level will increase
/// as we switch from one phase of ctree generation to the next one
enum ctree_maturity_t
{
  CMAT_ZERO,            ///< does not exist
  CMAT_BUILT,           ///< just generated
  CMAT_TRANS1,          ///< applied first wave of transformations
  CMAT_NICE,            ///< nicefied expressions
  CMAT_TRANS2,          ///< applied second wave of transformations
  CMAT_CPA,             ///< corrected pointer arithmetic
  CMAT_TRANS3,          ///< applied third wave of transformations
  CMAT_CASTED,          ///< added necessary casts
  CMAT_FINAL,           ///< ready-to-use
};
```

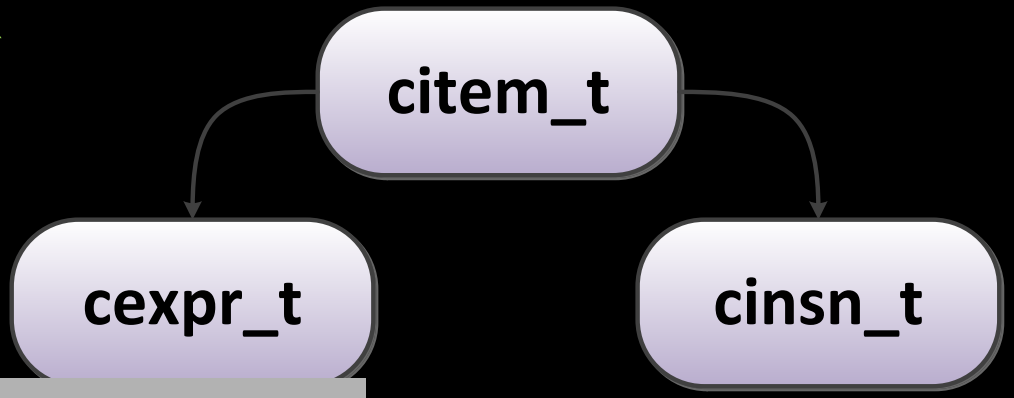
# Hex-Rays Decompiler Plugin SDK

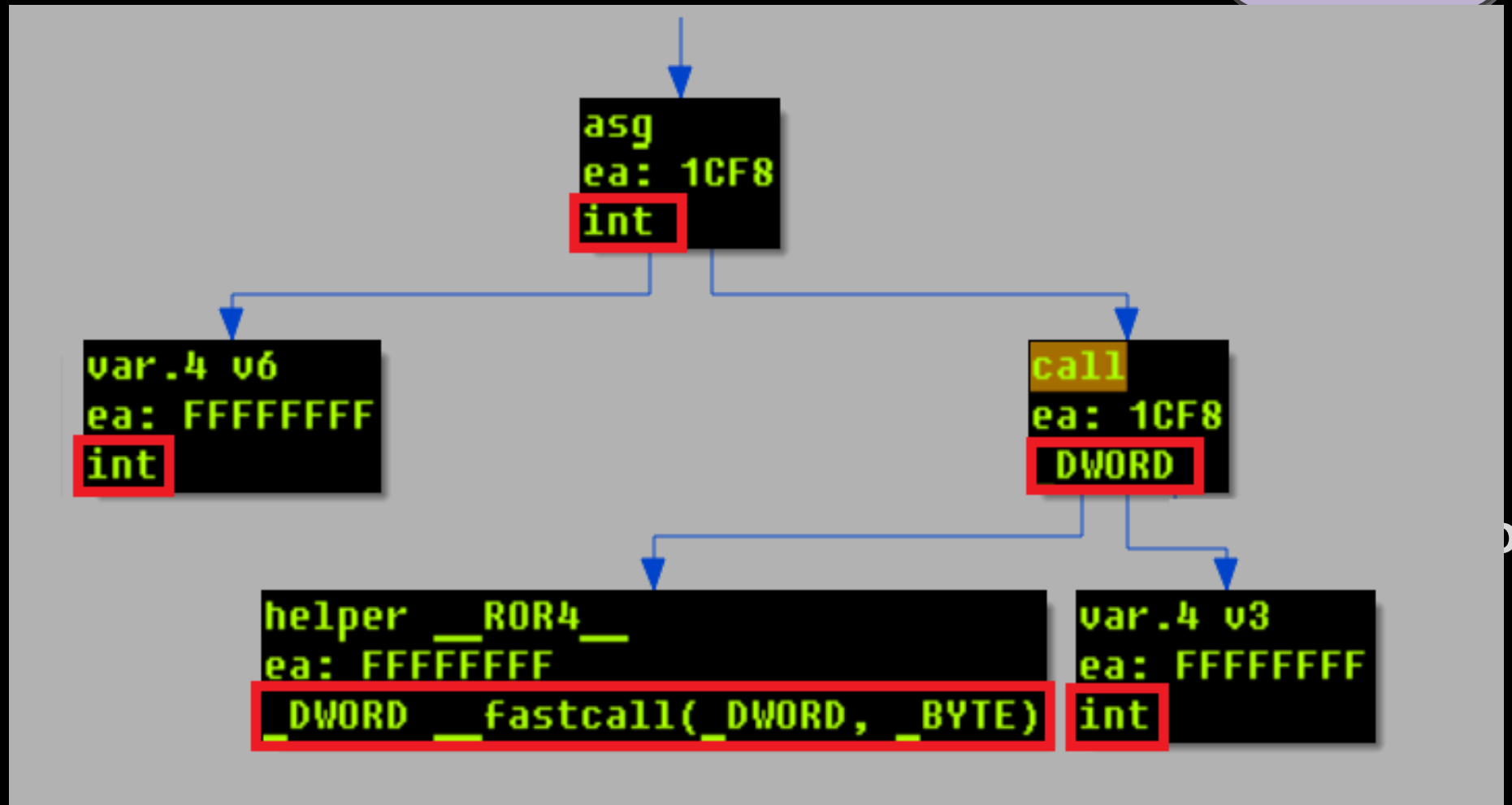



- Type *citem_t* is a base class for:
  - ✓ *cexpr_t* – expression type
  - ✓ *cinsn_t* – statement type
- Expressions have attached type information
- Statements include:
  - ✓ *block, if, for, while, do, switch, return, goto, asm*
- Hex-Rays provides iterators for traversing the *citem_t* objects within *ctree* structure:
  - ✓ *ctree_visitor_t*
  - ✓ *ctree_parentee_t*

# Hex-Rays Decompiler Plugin SDK

- Type *citem_t* is a base class for:
  - ✓ *cexpr_t* – expression type
  - ✓ *cinsn_t* – statement type




objects within *ctree*

# DEMO time :)

# HexRaysCodeXplorer: Gapz Position Independent Code

```
gl_context = (ExAllocatePoolWithTag)(0, 2576, 'ZPAG');
_gl_context = gl_context;
```

```
v12 = (get_export_by_hash)(kernel_base, hash_ntoskrnl_PsCreateSystemThread, v11);
v13 = hash_routin;
_gl_context->PsCreateSystemThread = v12;
v14 = (get_export_by_hash)(kernel_base, hash_ntoskrnl_PsTerminateSystemThread, v13);
v15 = hash_routin;
_gl_context->PsTerminateSystemThread = v14;
v16 = (get_export_by_hash)(kernel_base, hash_ntoskrnl_KeDelayExecutionThread, v15);
v17 = hash_routin;
_gl_context->KeDelayExecutionThread = v16;
```

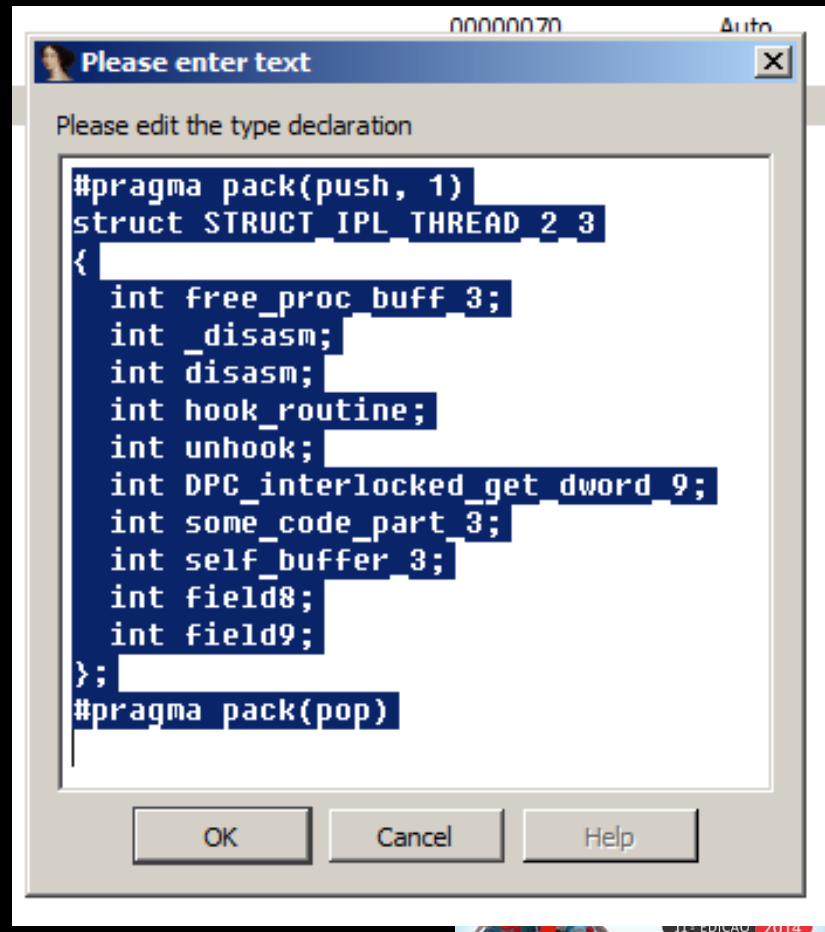
```
_gl_context->ZwOpenSymbolicLinkObject)(&hSymLink, 0x80000000, &v301)
```

# HexRaysCodeXplorer: Virtual Methods

- The IDA's 'Local Types' is used to represent object type

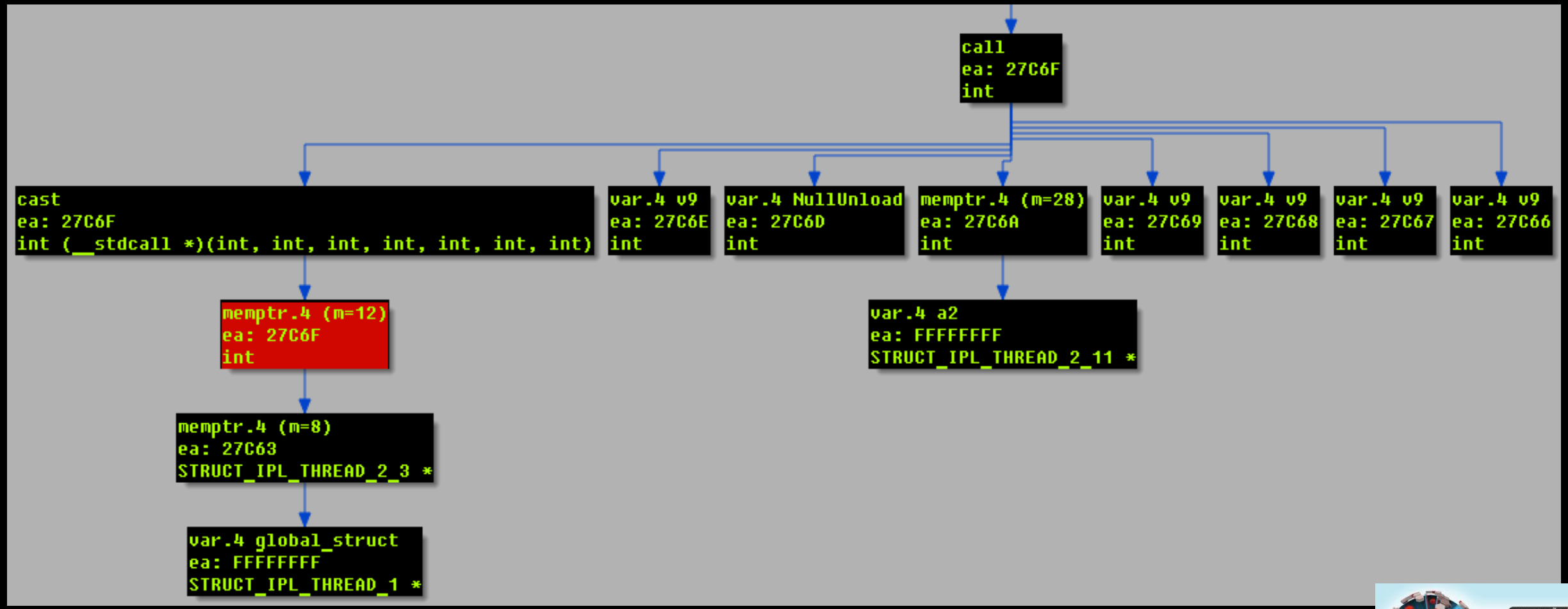
```
int __stdcall block_3_init(STRUCT_IPL_THREAD_2_3 *self_buffer, STRUCT_IPL_THREAD_1 *a2)
{
  STRUCT_IPL_THREAD_2 *v2; // ebx@1
  int _self_buffer; // esi@1
  int (*get_some_code)(void); // edi@1
  STRUCT_IPL_THREAD_2_3 *v5; // eax@1
  int v6; // eax@1
  STRUCT_IPL_THREAD_1 *v7; // ST0C_4@1

  v2 = a2->proc_buffer;
  _self_buffer = self_buffer;
  get_some_code = (&self_buffer[0x36].field8 + -self_buffer->free_proc_buff_3 + 3);
  a2->proc_buffer->alloc_mem(a2->proc_buffer, &self_buffer, 40, 0);
  v5 = self_buffer;
  a2->proc_buff_3 = self_buffer;
  v5->self_buffer_3 = _self_buffer;
  self_buffer->free_proc_buff_3 = _self_buffer - *_self_buffer + 0x112F;
  self_buffer->DPC_interlocked_get_dword_9 = _self_buffer - *_self_buffer + 0xAA7;
  self_buffer->hook_routine = _self_buffer + 0xAF0 - *_self_buffer;
  self_buffer->unhook = _self_buffer + 0xF74 - *_self_buffer;
  self_buffer->_disasm = _self_buffer + 0x388 - *_self_buffer;
  self_buffer->disasm = self_buffer->_disasm;
  v6 = get_some_code();
  v7 = a2;
  self_buffer->some_code_part_3 = v6;          // D2B7
  (v2->replace_dword)(_self_buffer + 32, *(_self_buffer + 12), 0xBBBBBBBB, v7);
  return 0;
}
```



# HexRaysCodeXplorer: Virtual Methods

- Hex-Rays decompiler plugin is used to navigate through the virtual methods



```
a2->bull_unload_hook = (global_struct->proc_buff_3->hook_routine)(
                        v9,
                        NullUnload,
                        a2->Null_unload_hook,
                        v9,
                        v9,
                        v9,
                        v9);
```

```
cast
ea: 27C6F
int (__stdcall *)(int, int, int, int, int, int, int)
```

```
var.4 v9
ea: 27C6E
int
```

```
r.4 NullUnload
: 27C6D
t
```

```
mempt (m=28)
ea: 27 A
int
```

```
var.4 v9
ea: 27C69
int
```

```
var.4 v9
ea: 27C
int
```

```
var.4 v9
ea: 27C67
int
```

```
var.4 v9
ea: 27C66
int
```

```
memptr.4 (m=12)
ea: 27C6F
int
```

```
var.4 a2
STRUCT_IPL READ_2_11 *
```

```
memptr.4 (m=8)
ea: 27C63
STRUCT_IPL_THREAD_2_3 *
```

```
var.4 global_struct
ea: FFFFFFFF
STRUCT_IPL_THREAD_1 *
```

# HexRaysCodeXplorer: Object Type REconstruction

- Hex-Rays's *ctree* structure may be used to partially reconstruct object type based on its initialization routine (constructor)

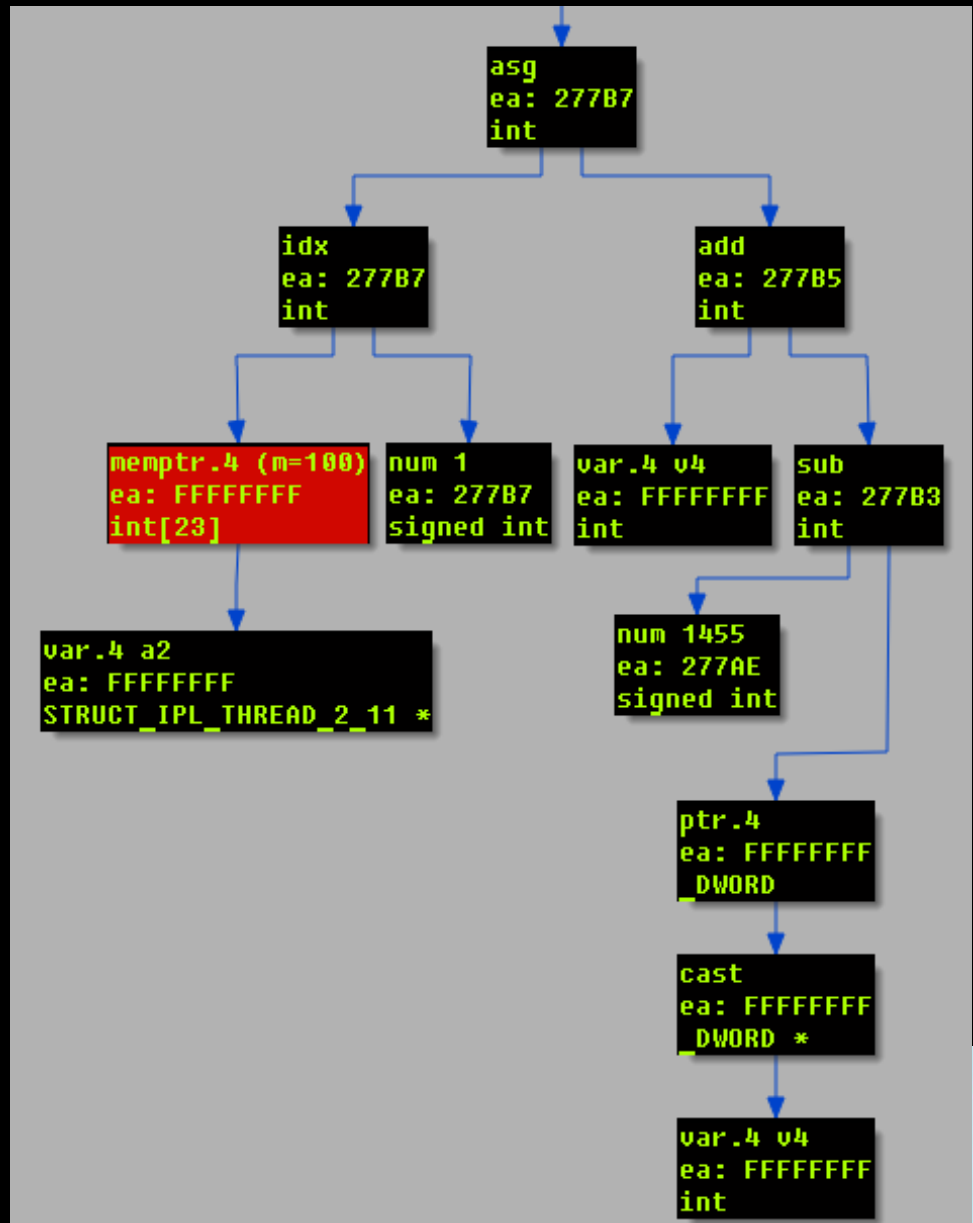
- Input:
  - ✓ pointer to the object instance
  - ✓ object initialization routine entry point

- Output:
  - ✓ C structure-like object representation

# HexRaysCodeXplorer: Object Type REconstruction

- citem_t objects to monitor:
  - ✓ *memptr*
  - ✓ *call (LOBYTE, etc.)*
  - ✓ *idx*
  - ✓ *memref*

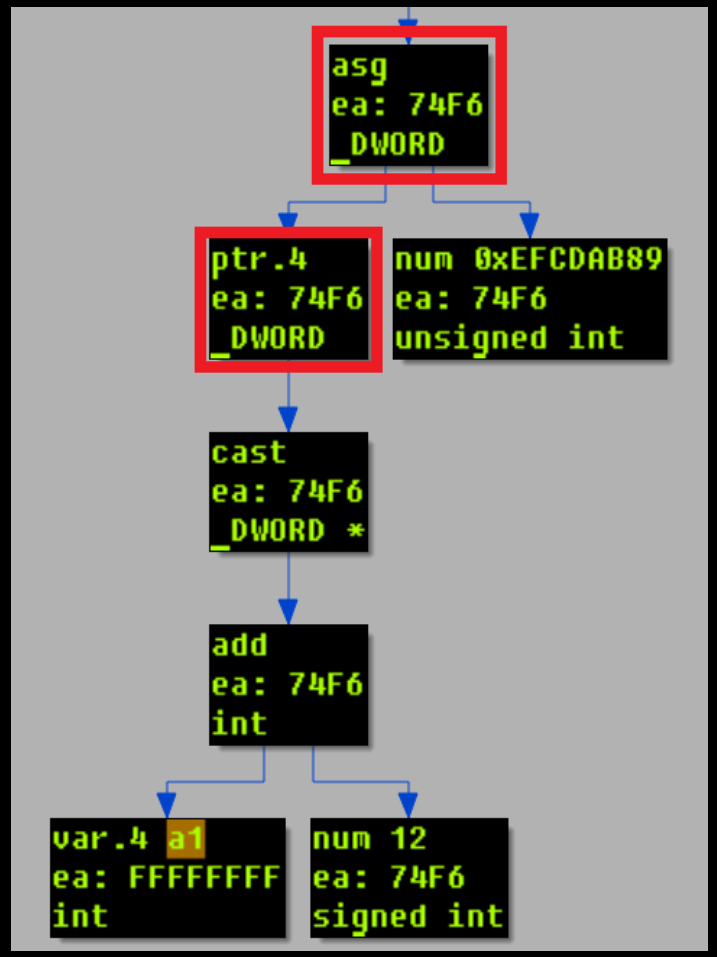
```
a2->IoControlCode_HookArray[1] = 0xFFDC243F;
a2->IoControlCode_HookDpc[2] = v4 + 1524 - *v4;
a2->IoControlCodeSubCmd_Hook[2] = 12;
a2->IoControlCode_HookArray[2] = 0xFFDC2437;
a2->IoControlCode_HookDpc[3] = v4 + 1586 - *v4;
a2->IoControlCodeSubCmd_Hook[3] = 2;
a2->IoControlCode_HookArray[3] = 0xFFDC240B;
a2->IoControlCode_HookDpc[4] = v4 + 1659 - *v4;
a2->IoControlCodeSubCmd_Hook[4] = 13;
a2->IoControlCode_HookArray[4] = 0xFFDC243B;
a2->IoControlCode_HookDpc[5] = v4 + 1726 - *v4;
a2->IoControlCodeSubCmd_Hook[5] = 3;
a2->IoControlCode_HookArray[5] = 0xFFDC240F;
a2->IoControlCode_HookDpc[6] = v4 - *v4 + 1799;
a2->IoControlCodeSubCmd_Hook[6] = 10;
a2->IoControlCode_HookArray[6] = 0xFFDC242F;
```



# HexRaysCodeXplorer: Object Type REconstruction

// reference of DWORD at offset 12 in buffer a1

*(DWORD *)(a1 + 12) = 0xEFCDAB89;




```
20  a2->free_mem = v4 - *v4 + 0x7D1E;
21  a2->base64_encode = v4 + 0x388 - *v4;
22  a2->base64_decode = v4 + 0x4CD - *v4;
23  a2->rdtsc_proc = v4 - *v4 + 0x579F;
24  a2->rnd_process_block = v4 + 0x57A2 - *v4;
25  a2->rnd_fill_buffer = v4 - *v4 + 0x6A87;
26  a2->init_rnd_buffer = v4 + 0x6ABB - *v4;
27  a2->field13 = v4 + 0x4B95 - *v4;
28  a2->md5_init = v4 - *v4 + 0x2A2C;
```

Output window

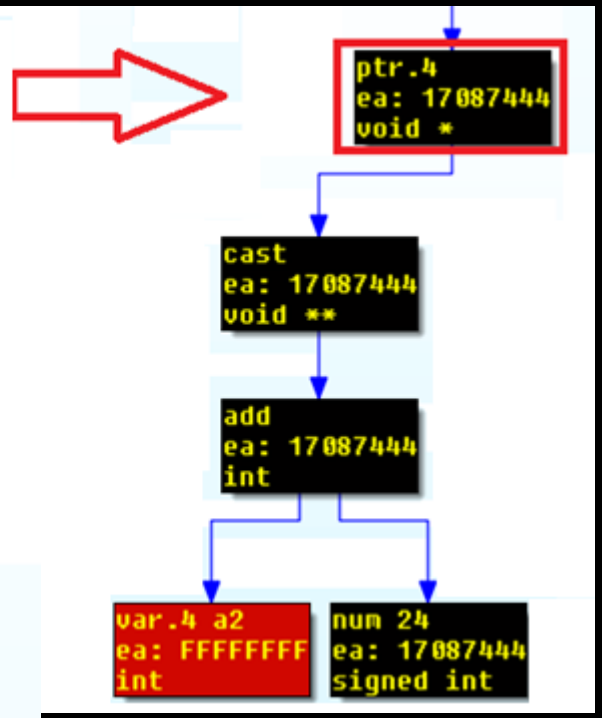
```
Field reference detected -> Offset 11217 : char
Field reference detected -> Offset 11218 : char
Field reference detected -> Offset 11219 : char
Field reference detected -> Offset 11220 : char
Field reference detected -> Offset 11221 : char
Field reference detected -> Offset 11222 : char
struct STRUCTURE_TYPE {
        int         field_0;
        int         field_1;
        int         field_2;
        int         field_3;
        int         field_4;
        int         field_5;
        int         field_6;
        int         field_7;
        int         field_8;
        int         field_9;
        int         field_10;
        int         field_11;
```

Python

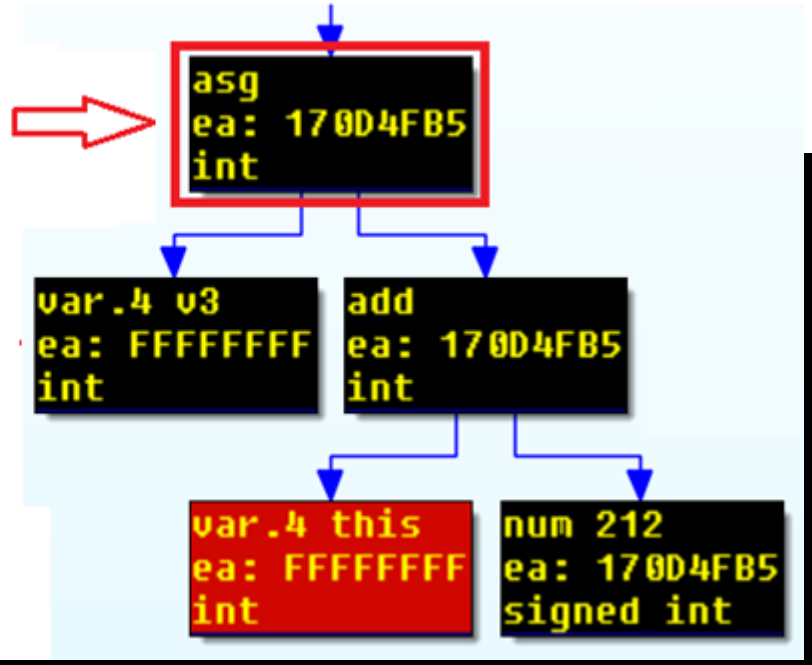
# HexRaysCodeXplorer v1.5 [H2HC Edition]

- New *citem_t* objects to monitor:
  - ✓ memptr
  - ✓ idx
  - ✓ memref
  - ✓ call (LOBYTE, etc.)
  - ✓ ptr, asg, …

```
v47 = 0;
v48 = 0;
v49 = 0;
v2 = *(void **)(a2 + 24);
v55 = 0;
```

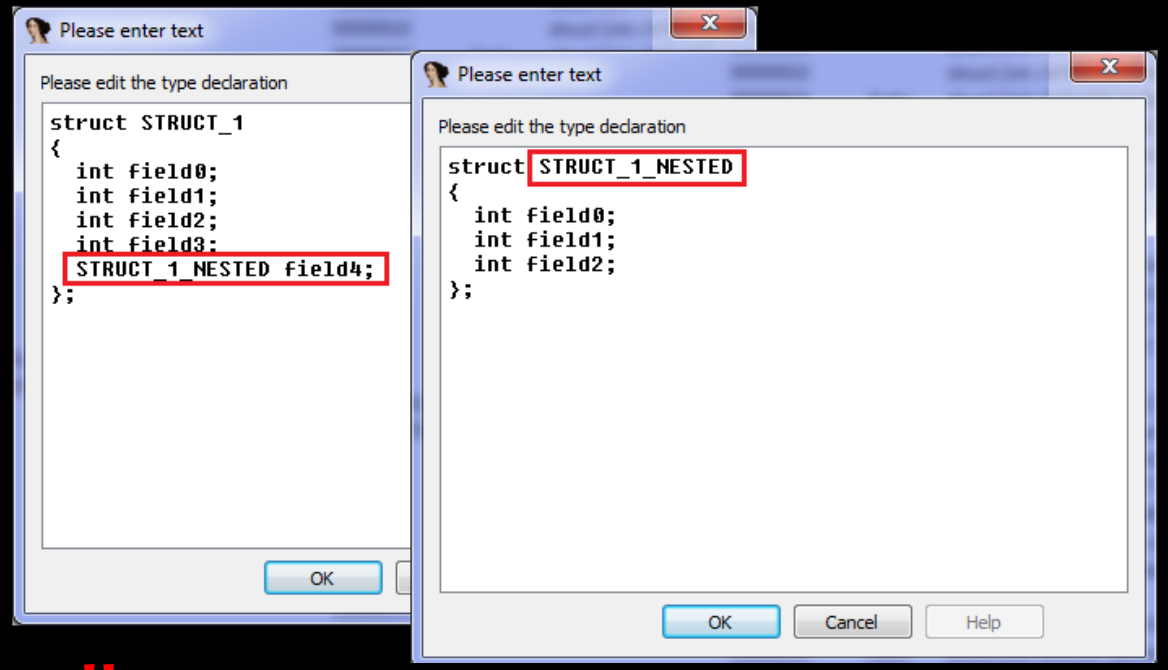



```
v2 = *(_DWORD *)(this + 216);
v3 = this + 212;
v4 = *(_DWORD *)(this + 216) + 1;
```



# HexRaysCodeXplorer v1.5 [H2HC Edition]

- New *citem_t* objects to monitor:
  - ✓ memptr
  - ✓ idx
  - ✓ memref
  - ✓ call (LOBYTE, etc.)
  - ✓ ptr, asg, …




- Type propagation for nested function calls

```
int __userpurge sub_1003490E@<eax>(int a1@<ebx>, int a2)
{
  *(_DWORD *)a2 = off_1026DDCC;
  *(_DWORD *)a2 = &off_102691D0;
  sub_10037E79(a1 + 4, a2 + 4);
  sub_10003F6B(a1 + 20, a2 + 20);
  return a2;
}
```

# HexRaysCodeXplorer v1.5 [H2HC Edition]

- Features of v1.5 [H2HC Edition] :
  - ✓ Better Type Reconstruction
    - Improvements for parsing *citem_t* objects with PTR and ASG statements
    - Recursive traversal of Ctree to reconstruct Types hierarchy
  - ✓ Navigate from Pseudo code window to Disassembly line
  - ✓ Hints for Ctree elements which point to Disassembly line
  - ✓ Support for x64 version of Hex-Rays Decompiler
  - ✓ Some bug fixes by user requests

# DEMO time :)

# HexRaysCodeXplorer: -> What are the next goals?

- Develop the next version on IdaPython
- Focus on the following features:
  - ✓ Type reconstruction (C++, Objective-C)
  - ✓ Type Navigation (C++, Objective-C)
  - ✓ Vtables parsing based on Hex-Rays API
  - ✓ Ctree graph navigation improvements
  - ✓ Patterns for  possible vuln detection

# Why python?

```python
import idaapi

class CTreeVisitor(idaapi.ctree_visitor_t):
  def __init__(self, dumper, cfunc):
    idaapi.ctree_visitor_t.__init__(self, idaapi.CV_FAST | idaapi.CV_INSNS)
    self.dumper = dumper
    self.cfunc = cfunc
    return

  def visit_insn(self, ins):
      print ins.opname
      return 0

class CDumper(object):
  def __init__(self):
    self.ret = {}

  def dump(self, ea):
    f = idaapi.get_func(ea)
    cfunc = idaapi.decompile(f)
    visitor = CTreeVisitor(self, cfunc)
    visitor.apply_to(cfunc.body, None)

def main():
  dump = CAstDumper()
  dump.dump(here())

if __name__ == "__main__":
  main()
```

```
block
expr
expr
if
block
expr
expr
block
expr
expr
expr
expr
expr
expr
expr
expr
expr
if
block
expr
expr
block
expr
expr
expr
expr
expr
expr
expr
expr
expr
return
```

# Python Arsenal Contest


- Best exploit dev tool/plugin/lib
- Best forensics tool/plugin/lib
- Best reversing tool/plugin/lib
- Best fuzzing tool/plugin/lib
- Best malware analysis tool/plugin/lib

http://2014.zeronights.org/contests/python-arsenal-contest.html

# Thank you for your attention!

## HexRaysCodeXplorer

http://REhints.com @REhints

https://github.com/REhints/HexRaysCodeXplorer