IBM Global Services

Reversing C++

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IBM Internet Security Systems
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Reversing C++

Part I. Introduction

Introduction > Purpose

- **Understand C++ concepts as they are represented in disassemblies**

- **Have a big picture idea on what are major pieces (classes) of the C++ target and how these pieces relate together (class relationships)**

Introduction > Focus On…

- **(1) Identifying Classes**
- **(2) Identifying Class Relationships**
- **(3) Identifying Class Members**

Introduction > Motivation

- **Increasing use of C++ code in malware**
  - Difficult to follow virtual function calls in static analysis
  - Examples: Agobot, Mytob, new malcodes from our honeypot
- **Most modern applications use C++**
  - For binary auditing, reversers can expect that the target can be a C++ compiled binary
- **General lack of publicly available information regarding the subject of C++ reversing**
  - Only good information is from Igor Skochinsky
  - https://www.openrce.org/articles/full_view/23

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Part II. Manual Approach

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Part II. Manual Approach

Identifying C++ Binaries & Constructs

Manual Approach > Identifying C++ Binaries & Constructs

- **Heavy use of `ecx` (*`this`* `ptr`)**

```
.text:004019E4        mov     ecx, esi
.text:004019E6        push    0BBh
.text:004019EB        call    sub_401120
```

- **`ecx` used without being initialized**

```
.text:004010D0 sub_4010D0       proc near
.text:004010D0          push    esi
.text:004010D1          mov     esi, ecx
.text:004010DD          mov     dword ptr [esi], offset off_40C0D0
.text:00401101          mov     dword ptr [esi+4], 0BBh
.text:00401108          call    sub_401EB0
.text:0040110D          add     esp, 18h
.text:00401110          pop     esi
.text:00401111          retn
.text:00401111 sub_4010D0       endp
```

Manual Approach > Identifying C++ Binaries & Constructs

- **Parameters on the stack, `ecx = this ptr`**

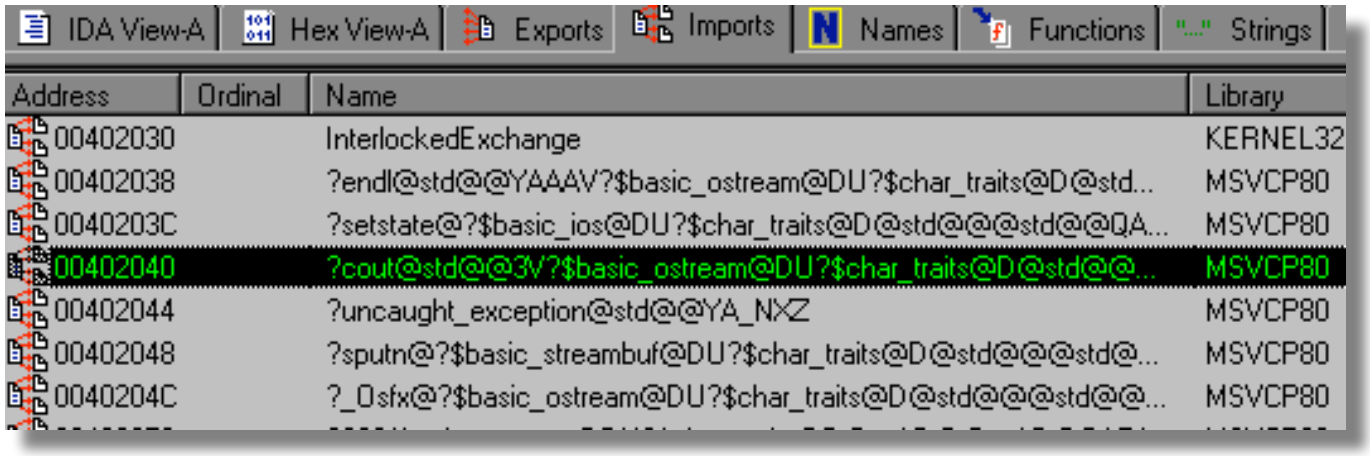
```
.text:00401994 push    0Ch
.text:00401996 call    ??2@YAPAXI@Z      ; operator new(uint)
.text:004019AB mov     ecx, eax
:::
.text:004019AD call    ClassA_ctor
```

- **Virtual function calls (indirect calls)**

```
.text:00401996 call    ??2@YAPAXI@Z      ; operator new(uint)
:::
.text:004019B2 mov     esi, eax
:::
.text:004019FF mov     eax, [esi]      ;EAX = vftable
.text:00401A01 add     esp, 8
.text:00401A04 mov     ecx, esi
.text:00401A06 push    0CCh
.text:00401A0B call    dword ptr [eax]
```

Manual Approach > Identifying C++ Binaries & Constructs

- **STL Code and Imported DLLs**

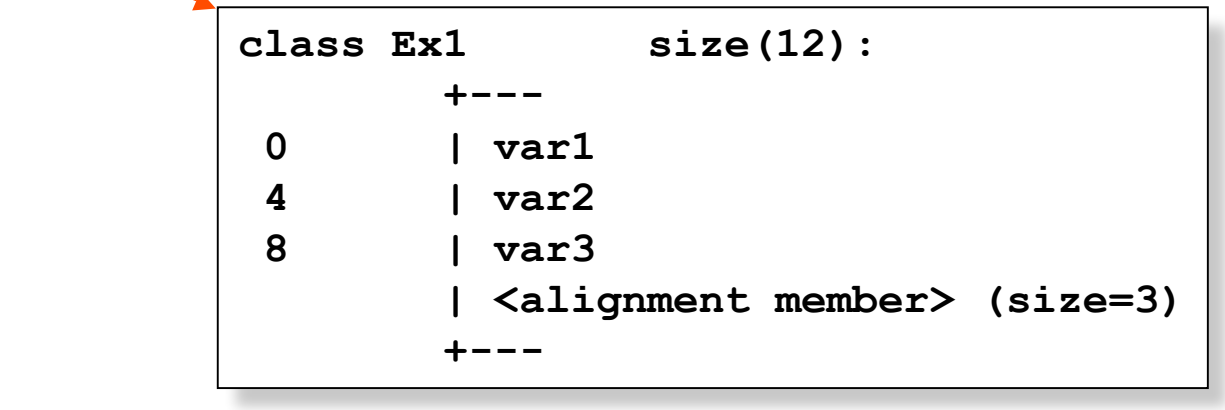



```
.text:00401201     mov      ecx, eax
.text:00401203     call
ds:?sputc@?$basic_streambuf@DU?$char_traits@D@std@@@std@@QAEHD@Z
; std::basic_streambuf<char,std::char_traits<char>>::sputc(char)
```

Manual Approach > Class Instance Layout

- **Class Instance Layout**

```
class Ex1
{
        int var1;
        int var2;
        char var3;
public:
        int get_var1();
};
```

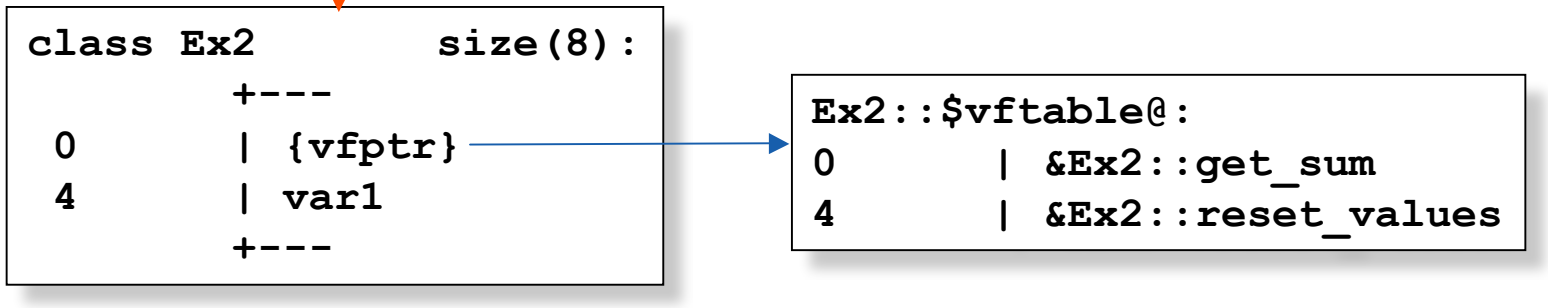


```
class Ex1       size(12):
        +---
 0      | var1
 4      | var2
 8      | var3
        | <alignment member> (size=3)
        +---
```

Manual Approach > Class Instance Layout

- **Class Instance Layout**

```
class Ex2
{
        int var1;
public:
        virtual int get_sum(int x, int y);
        virtual void reset_values();
};
```



Manual Approach > Class Instance Layout

- **Class Instance Layout**

```
class Ex3: public Ex2
{
        int var1;
public:
        void get_values();
};
```

```
class Ex3       size(12):
        +---
        | +--- (base class Ex2)
 0      | | {vfptr}
 4      | | var1
        | +---
 8      | var1
        +---
```

Manual Approach > Class Instance Layout

- **Class Instance Layout**

```
class Ex4
{
        int var1;
        int var2;
public:
        virtual void func1();
        virtual void func2();
};

class Ex5: public Ex2, Ex4
{
        int var1;
public:
        void func1();
        virtual void v_ex5();
};
```



```
class Ex5        size(24):
         +---
         | +--- (base class Ex2)
 0       | | {vfptr}
 4       | | var1
         | +---
         | +--- (base class Ex4)
 8       | | {vfptr}
12       | | var1
16       | | var2
         | +---
20       | var1
         +---
```

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Part II. Manual Approach

Identifying Classes

- **Global Objects**
  - Allocated in the data segment
  - Constructor is called at program startup
  - Destructor is called at program exit
  - *this* pointer points to a global variable
  - To locate constructor/destructor, examine cross-references

- **Local Objects**
  - Allocated in the stack
  - Constructor is called at declaration
  - *this* pointer points to an uninitialized local variable
  - Destructor is called at block exit

Local Objects

```
.text:00401060 sub_401060      proc near
.text:00401060
.text:00401060 var_C           = dword ptr -0Ch
.text:00401060 var_8           = dword ptr -8
.text:00401060 var_4           = dword ptr -4
.text:00401060
…(some code)…
.text:004010A4                 add     esp, 8
.text:004010A7                 cmp     [ebp+var_4], 5
.text:004010AB                 jle     short loc_4010CE
.text:004010AB
.text:004010AB { ← block begin
.text:004010AD                 lea     ecx, [ebp+var_8] ; var_8 is uninitialized
.text:004010B0                 call    sub_401000 ; constructor
.text:004010B5                 mov     edx, [ebp+var_8]
.text:004010B8                 push    edx
.text:004010B9                 push    offset str->WithinIfX
.text:004010BE                 call    sub_4010E4
.text:004010C3                 add     esp, 8
.text:004010C6                 lea     ecx, [ebp+var_8]
.text:004010C9                 call    sub_401020 ; destructor
.text:004010CE } ← block end
.text:004010CE
.text:004010CE loc_4010CE:                             ; CODE XREF: sub_401060+4Bj
.text:004010CE                 mov     [ebp+var_C], 0
.text:004010D5                 lea     ecx, [ebp+var_4]
.text:004010D8                 call    sub_401020
```

- **Dynamically Allocated Objects**
  - Allocated in the heap
  - Created via operator *new*
    - Allocates memory in heap
    - Calls the constructor
  - Destructor is called via operator *delete*
    - Calls destructor
    - De-allocates object instance

Dynamically Allocated Objects

```
.text:0040103D _main            proc near
.text:0040103D argc             = dword ptr  8
.text:0040103D argv             = dword ptr  0Ch
.text:0040103D envp             = dword ptr  10h
.text:0040103D
.text:0040103D                  push    esi
.text:0040103E                  push    4               ; size_t
.text:00401040                  call    ??2@YAPAXI@Z    ; operator new(uint)
.text:00401045                  test    eax, eax ; eax = address of allocated memory
.text:00401047                  pop     ecx
.text:00401048                  jz      short loc_401055
.text:0040104A                  mov     ecx, eax
.text:0040104C                  call    sub_401000 ; call to constructor
.text:00401051                  mov     esi, eax
.text:00401053                  jmp     short loc_401057
.text:00401055 loc_401055:                              ; CODE XREF: _main+Bj
.text:00401055                  xor     esi, esi
.text:00401057 loc_401057:                              ; CODE XREF: _main+16j
.text:00401057                  push    45h
.text:00401059                  mov     ecx, esi
.text:0040105B                  call    sub_401027
.text:00401060                  test    esi, esi
.text:00401062                  jz      short loc_401072
.text:00401064                  mov     ecx, esi
.text:00401066                  call    sub_40101B ; call to destructor
.text:0040106B                  push    esi             ; void *
.text:0040106C                  call    j__free ; call to free thunk function
.text:00401071                  pop     ecx
.text:00401072 loc_401072:                              ; CODE XREF: _main+25j
.text:00401072                  xor     eax, eax
.text:00401074                  pop     esi
.text:00401075                  retn
.text:00401075 _main            endp
```

Manual Approach > Identifying Classes > via RTTI

- **What is RTTI**
  - Run-time Type Information (RTTI)
  - Used for identification of object type on run-time
  - Generated for polymorphic classes (classes with virtual functions)
  - Utilized by operators **`typeid`** and **`dynamic_cast`**
  - Will give us important information on
    - Class Name
      - Rough idea what the class is all about
    - Class Hierarchy
  - Consists of several data structures

Manual Approach > Identifying Classes > via RTTI

- **RTTICompleteObjectLocator**
  - Contains pointers to two structures that identifies
    - Class information (**TypeDescriptor)**
    - Class Hierarchy (**RTTIClassHierarchyDescriptor)**
  - Located just below the class' vftable

```
.rdata:00404128                 dd offset ClassA_RTTICompleteObjectLocator
.rdata:0040412C ClassA_vftable  dd offset sub_401000 ; DATA XREF:...
.rdata:00404130                 dd offset sub_401050
.rdata:00404134                 dd offset sub_4010C0
.rdata:00404138                 dd offset ClassB_RTTICompleteObjectLocator
.rdata:0040413C ClassB_vftable  dd offset sub_4012B0 ; DATA XREF:...
.rdata:00404140                 dd offset sub_401300
.rdata:00404144                 dd offset sub_4010C0
```

Manual Approach > Identifying Classes > via RTTI

- **RTTICompleteObjectLocator**

Offset	Type	Name	Description
0x00	DW	signature	Always 0?
0x04	DW	offset	Offset of vftable within the class
0x08	DW	cdOffset	?
0x0C	DW	pTypeDescriptor	Class Information
0x10	DW	pClassHierarchy Descriptor	Class Hierarchy Information

```
.rdata:004045A4 ClassB_RTTICompleteObjectLocator
                        dd 0       ; COL.signature
.rdata:004045A8         dd 0       ; COL.offset
.rdata:004045AC         dd 0       ; COL.cdOffset
.rdata:004045B0         dd offset ClassB_TypeDescriptor
.rdata:004045B4         dd offset ClassB_RTTIClassHierarchyDescriptor
```

Manual Approach > Identifying Classes > via RTTI

- **TypeDescriptor**
  - Contains the class name (which is an important information)
  - Say **`CPacketParser`** and **`CTCPPacketParser`**

Offset	Type	Name	Description
0x00	DW	pVFTable	Always points to type_info's vftable
0x04	DW	spare	?
0x08	SZ	name	Class Name

```
.data:0041A098 ClassA_TypeDescriptor ; DATA XREF: ....
                       dd offset type_info_vftable    ; TypeDescriptor.pVFTable
.data:0041A09C         dd 0                           ; TypeDescriptor.spare
.data:0041A0A0         db '.?AVClassA@@',0  ; TypeDescriptor.name
```

Manual Approach > Identifying Classes > via RTTI

- **RTTIClassHierarchyDescriptor**
  - Information about the class hierarchy
  - Includes pointers to `BaseClassDescriptor`s for each base class

Offset	Type	Name	Description
0x00	DW	signature	Always 0?
0x04	DW	attributes	Bit 0 – multiple inheritance Bit 1 – virtual inheritance
0x08	DW	numBaseClasses	Number of base classes. Count includes the class itself
0x0C	DW	pBaseClassArray	Array of RTTIBaseClassDescriptor

Manual Approach > Identifying Classes > via RTTI

- **RTTIClassHierarchyDescriptor**
  - Example class declaration

```
class ClassA {…}
class ClassE {…}
class ClassG: public virtual ClassA, public virtual ClassE {…}
```

  - Corresponding RTTIClassHierarchyDescriptor

```
.rdata:004178C8 ClassG_RTTIClassHierarchyDescriptor ; DATA XREF: ...
.rdata:004178C8                 dd 0                    ; signature
.rdata:004178CC                 dd 3                    ; attributes
.rdata:004178D0                 dd 3                    ; numBaseClasses
.rdata:004178D4                 dd offset ClassG_pBaseClassArray ; pBaseClassArray
.rdata:004178D8 ClassG_pBaseClassArray
                             dd offset oop_re$RTTIBaseClassDescriptor@4178e8
.rdata:004178DC             dd offset oop_re$RTTIBaseClassDescriptor@417904
.rdata:004178E0             dd offset oop_re$RTTIBaseClassDescriptor@417920
```

Manual Approach > Identifying Classes > via RTTI

- **RTTIBaseClassDescriptor**
  - Information about the base class
  - Contains the `TypeDescriptor` for the base class

Offset	Type	Name	Description
0x00	DW	pTypeDescriptor	TypeDescriptor of this base class
0x04	DW	numContainedBases	Number of direct bases of this base class
0x08	DW	PMD.mdisp	vftable offset
0x0C	DW	PMD.pdisp	vbtable offset (-1: vftable is at displacement PMD.mdisp inside the class)
0x10	DW	PMD.vdisp	Displacement of the base class vftable pointer inside the vbtable
0x14	DW	attributes	?
0x18	DW	pClassDescriptor	RTTIClassHierarchyDescriptor of this base class

Manual Approach > Identifying Classes > via RTTI

- **vbtable (virtual base class table)**
  - Contains information necessary to locate the actual base class within class
  - Generated for multiple virtual inheritance and used for *upclassing* (casting to base classes)

```
class ClassG          size(28):
          +---
 0        | {vfptr}
 4        | {vbptr}
          +---
          +--- (virtual base ClassA)
 8        | {vfptr}
12        | class_a_var01
16        | class_a_var02
          | <alignment member> (size=3)
          +---
          +--- (virtual base ClassE)
20        | {vfptr}
24        | class_e_var01
          +---
```

```
ClassG::$vbtable@:
 0        | -4
 1        | 4 (ClassGd(ClassG+4)ClassA)
 2        | 16 (ClassGd(ClassG+4)ClassE)
```

Manual Approach > Identifying Classes > via RTTI

- **RTTIBaseClassDescriptor (example)**

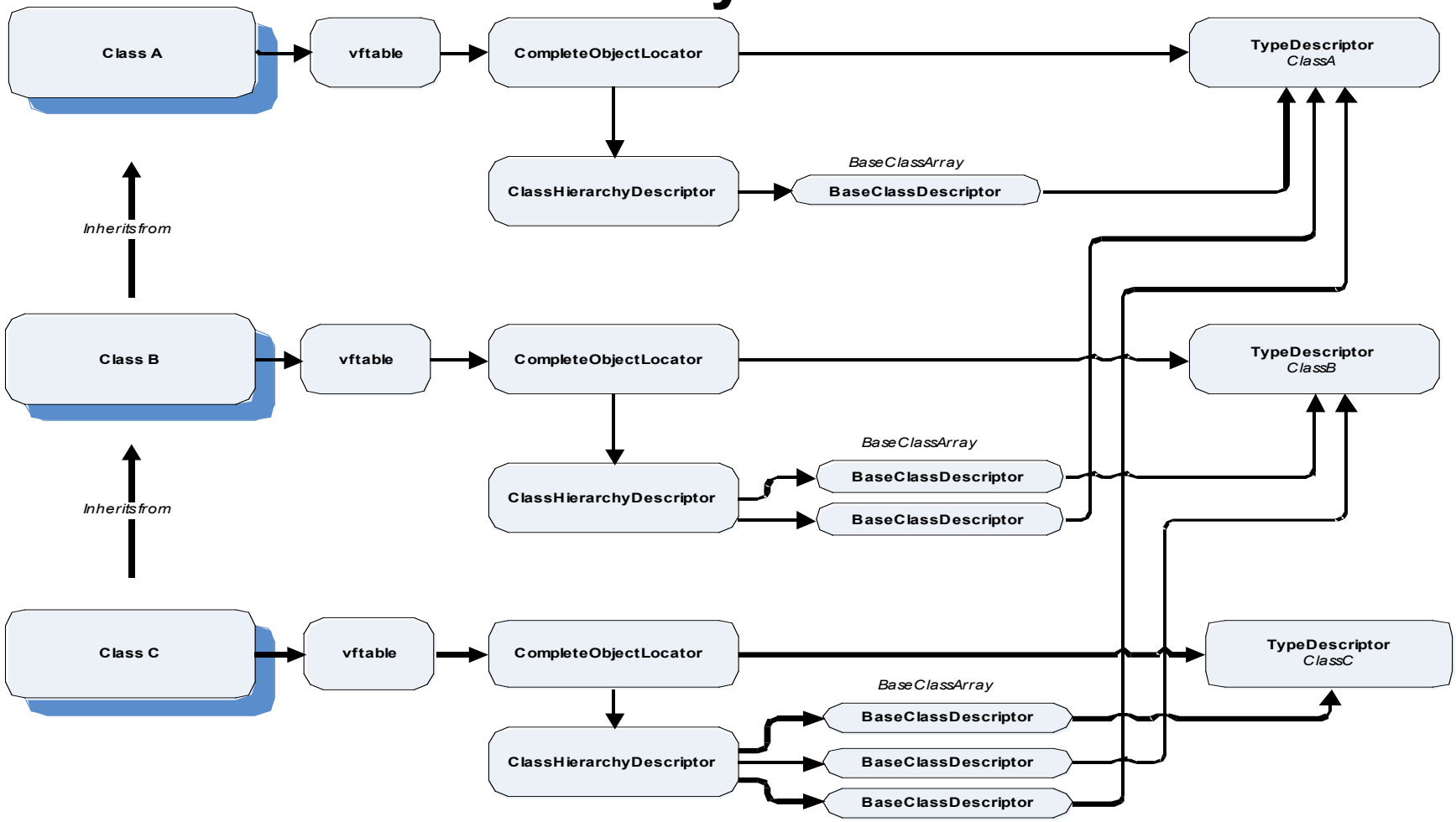
```
class ClassG          size(28):
          +---
 0        | {vfptr}
 4        | {vbptr}
          +---
          +--- (virtual base ClassA)
 8        | {vfptr}
12        | class_a_var01
16        | class_a_var02
          | <alignment member> (size=3)
          +---
          +--- (virtual base ClassE)
20        | {vfptr}
24        | class_e_var01
          +---
```

```
ClassG::$vbtable@:
 0        | -4
 1        | 4 (ClassGd(ClassG+4)ClassA)
 2        | 16 (ClassGd(ClassG+4)ClassE)
```

```
.rdata:00418AFC RTTIBaseClassDescriptor@418afc      ; DATA XREF: ...
                dd offset oop_re$ClassE$TypeDescriptor
.rdata:00418B00 dd 0                        ; numContainedBases
.rdata:00418B04 dd 0                        ; PMD.mdisp
.rdata:00418B08 dd 4                        ; PMD.pdisp
.rdata:00418B0C dd 8                        ; PMD.vdisp
.rdata:00418B10 dd 50h                      ; attributes
.rdata:00418B14 dd offset oop_re$ClassE$RTTIClassHierarchyDescriptor ;
pClassDescriptor
```

Manual Approach > Identifying Classes > via RTTI

- **RTTI Data Structures Layout**



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Part II. Manual Approach

Identifying Class Relationship

Manual Approach > Identifying Relationship > Constructor Analysis

- **Single Inheritance**

```
.text:00401010 sub_401010      proc near
.text:00401010
.text:00401010 var_4           = dword ptr -4
.text:00401010
.text:00401010                 push    ebp
.text:00401011                 mov     ebp, esp
.text:00401013                 push    ecx
.text:00401014                 mov     [ebp+var_4], ecx ; get this ptr to current object
.text:00401017                 mov     ecx, [ebp+var_4] ;
.text:0040101A                 call    sub_401000 ; call class A constructor
.text:0040101F                 mov     eax, [ebp+var_4]
.text:00401022                 mov     esp, ebp
.text:00401024                 pop     ebp
.text:00401025                 retn
.text:00401025 sub_401010      endp
```

Manual Approach > Identifying Relationship > Constructor Analysis

Multiple Inheritance

```
.text:00401020 sub_401020      proc near
.text:00401020
.text:00401020 var_4           = dword ptr -4
.text:00401020
.text:00401020                 push    ebp
.text:00401021                 mov     ebp, esp
.text:00401023                 push    ecx
.text:00401024                 mov     [ebp+var_4], ecx
.text:00401027                 mov     ecx, [ebp+var_4] ; ptr to base class A
.text:0040102A                 call    sub_401000 ; call class A constructor
.text:0040102A
.text:0040102F                 mov     ecx, [ebp+var_4]
.text:00401032                 add     ecx, 4 ; ptr to base class C
.text:00401035                 call    sub_401010 ; call class C constructor
.text:00401035
.text:0040103A                 mov     eax, [ebp+var_4]
.text:0040103D                 mov     esp, ebp
.text:0040103F                 pop     ebp
.text:00401040                 retn
.text:00401040
.text:00401040 sub_401020      endp
```

Manual Approach > Identifying Relationship

- **Multiple Inheritance**

```
class A  size(4):
         +---
 0       | a1
         +---
class C  size(4):
         +---
 0       | c1
         +---
class D  size(12):
         +---
         | +--- (base class A)
 0       | | a1
         | +---
         | +--- (base class C)
 4       | | c1
         | +---
 8       | d1
         +---
```

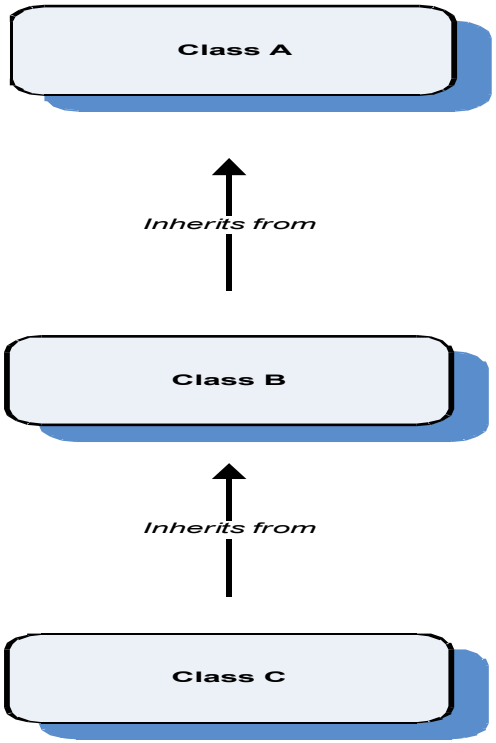
Manual Approach > Identifying Relationship > via RTTI

- **Using RTTIClassHierarchyDescriptor**
- **Contain pointers to RTTIBaseClassDescriptors (BCDs)**

Offset	Type	Name	Description
0x00	DW	signature	Always 0?
0x04	DW	attributes	Bit 0 – multiple inheritance Bit 1 – virtual inheritance
0x08	DW	numBaseClasses	Number of base classes. Count includes the class itself
0x0C	DW	pBaseClassArray	Array of RTTIBaseClassDescriptor

Manual Approach > Identifying Relationship > via RTTI

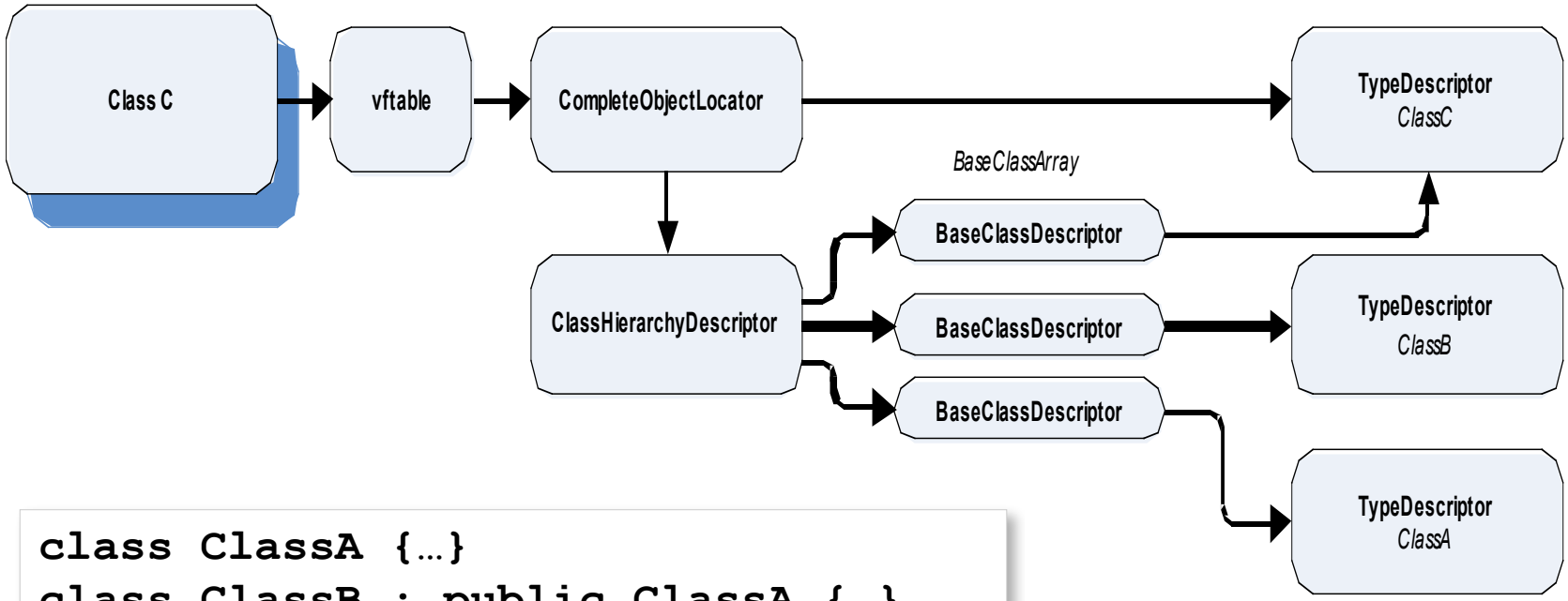
- **Example: C inherits B inherits A**




```
class ClassA {…}
class ClassB : public ClassA {…}
class ClassC : public ClassB {…}
```

Manual Approach > Identifying Relationship > via RTTI

- **Example: C inherits B inherits A**




```
class ClassA {…}
class ClassB : public ClassA {…}
class ClassC : public ClassB {…}
```

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Part II. Manual Approach

Identifying Class Members

Manual Approach > Identifying Class Members

- **Class Member Variable**

```
.text:00401003                  push    ecx
.text:00401004                  mov     [ebp+var_4], ecx
.text:00401007                  mov     eax, [ebp+var_4]
.text:0040100A                  mov     dword ptr [eax + 8], 12345h
```

Manual Approach > Identifying Class Members

- **Virtual Functions**

```
.text:00401C21                mov     ecx, [ebp+var_1C] ; ecx = this pointer
.text:00401C24                mov     edx, [ecx] ; edx = ptr to vftable
.text:00401C26                mov     ecx, [ebp+var_1C]
.text:00401C29                mov     eax, [edx+4]
.text:00401C2C                call    eax ; call virtual function
```

Manual Approach > Identifying Class Members

- **Non-virtual member functions**

```
.text:00401AFC                  push    0CCh
.text:00401B01                  lea     ecx, [ebp+var_C]  ; ecx = this pointer
.text:00401B04                  call    sub_401110
```

```
.text:00401110                  push    ebp
.text:00401111                  mov     ebp, esp
.text:00401113                  push    ecx
.text:00401114                  mov     [ebp+var_4], ecx  ; ecx
used
```

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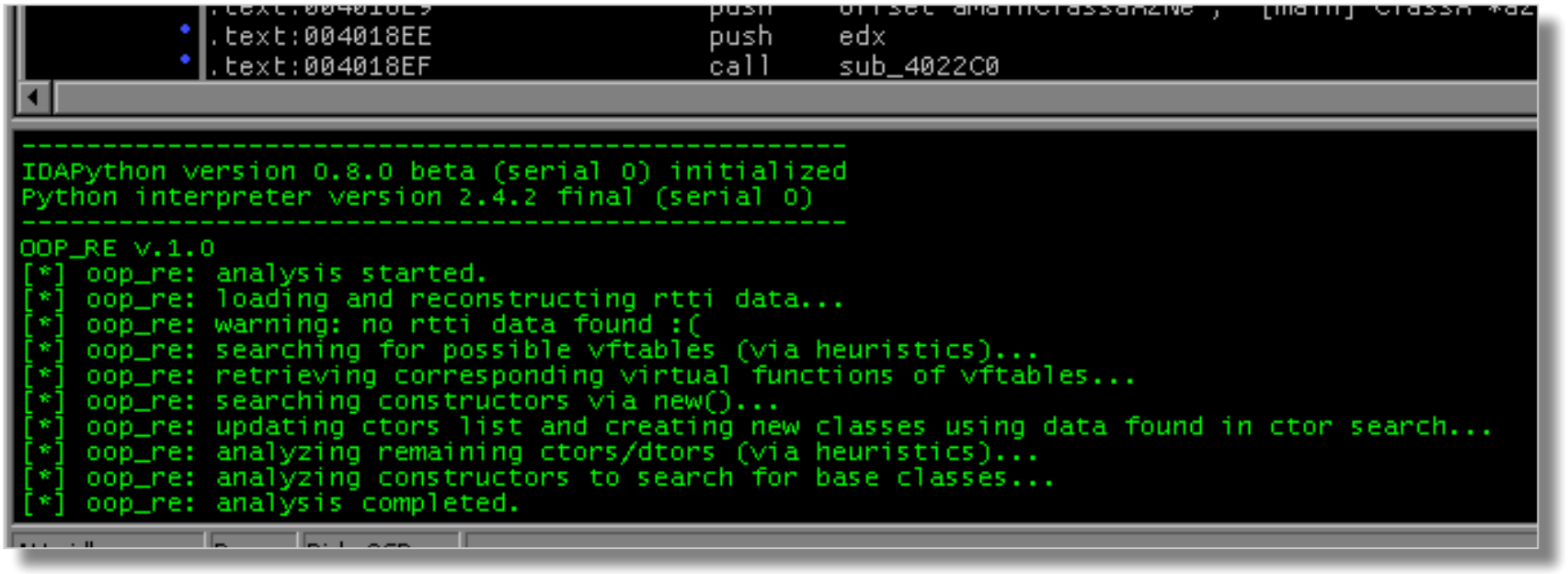
Part III. Automation

Automation > OOP_RE

- **Developed in Python**
- **Uses the IDAPython platform**
- **Identifies Classes, Relationships and Members**
- **Using Static Analysis**



Automation > Why a Static Approach?

- **Difficult to perform runtime analysis on some platforms (Symbian)**
- **Of course, a hybrid approach may produce more exact results**

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Part III. Automation

Automated Analysis Strategies

Automation > Strategies > 1. Polymorphic Class Identification via RTTI

- **Leverage RTTI data to accurately extract:**
  - Polymorphic Classes
  - Polymorphic class Name
  - Polymorphic class Hierarchy
  - Polymorphic class Virtual Function Table and Virtual Functions
  - Polymorphic class Destructors/Constructors

Automation > Strategies > 1. Polymorphic Class Identification via RTTI

Searching RTTI-related structures

- Via virtual function table (vftable) searching:
  - If item is DWORD
  - If item is a pointer to a Code
  - If item is being referenced by a Code and the instruction in this referencing code is a **`mov`** instruction (vftable assignment)

- RTTICompleteObjectLocator is just below a vftable

```
.rdata:004165B0             dd offset ClassB_RTTICompleteObjectLocator@00
.rdata:004165B4 ClassB_vftable
.rdata:004165B4             dd offset sub_401410 ; DATA XREF:...
.rdata:004165B8             dd offset sub_401460
.rdata:004165BC             dd offset sub_401230
```

Automation > Strategies > 1. Polymorphic Class Identification via RTTI

Verifying RTTICompleteObjectLocator

- Verify if RTTICompleteObjectLocator points to a valid TypeDescriptor
- TypeDescriptor is valid if TypeDescriptor.name starts with ".?AV"

```
.rdata:00418A28 ClassB_RTTICompleteObjectLocator@00
.rdata:00418A28           dd 0                  ; signature
.rdata:00418A2C           dd 0                  ; offset
.rdata:00418A30           dd 0                ; cdOffset
.rdata:00418A34           dd offset ClassB_TypeDescriptor
.rdata:00418A38           dd offset ClassB_RTTIClassHierarchyDescriptor
```

```
.data:0041B01C ClassB_TypeDescriptor
                                  dd offset type_info_vftable
.data:0041B020                    dd 0                          ;spare
.data:0041B024 a_?avclassb@@      db '.?AVClassB@@',0    ; name
```

Automation > Strategies > 1. Polymorphic Class Identification via RTTI

Class Information from RTTI (Summary)

```
new_class()
        - Identified from TypeDescriptors
new_class.class_name
        - Identified from TypeDescriptor.name
new_class.vftable/vfuncs
        - Identified from vftable-RTTICompleteObjectLocator
        relationship
new_class.ctors_dtors
        - Identified from functions referencing the vftable
new_class.base_classes
        - Identified from
RTTICompleteObjectLocator.pClassHierarchyDescriptor
```

Polymorphic Classes Identification (w/o RTTI)

- Via vftable searching (*previously discussed*)
- Base classes are not yet identified
- Class name will be automatically generated

```
new_class()
        - Identified from vftable
new_class.class_name
        - Auto-generated (based from vftable address, etc.)
new_class.vftable/vfuncs
        - Identified from vftable
new_class.ctors_dtors
        - Identified from functions referencing the vftable
```

Simple Data Flow Analyzer Algo

1. If the variable/register is overwritten, stop tracking
2. If EAX is being tracked and a call is encountered, stop tracking. (We assume that all calls return values in EAX).
3. If a call is encountered, treat the next instruction as a new block
4. If a conditional jump is encountered, follow the register/variable in both branches, starting a new block on each branch.
5. If the register/variable was copied into another variable, start a new block and track both the old variable and the new one starting on this block.
6. Otherwise, track next instruction.

Constructor Identification

- For dynamically allocated objects
  1. Look for calls to new() .
  2. Track the value returned in EAX
  3. When tracking is done, look for the earliest call where the tracked register/variable is ECX. Mark this function as constructor.

- For local objects
  - For local objects, we do the same thing. Instead of initially tracking returned values of new(), we first locate instructions where an address of a stack variable is written to ECX, then start tracking ECX

Inheritance Identification

1. Track this pointer (ECX)
2. Check blocks with ECX as tracked variable
3. See if there is call to a constructor
4. To handle multiple inheritance, track pointers to offsets relative to object address

Member Variables

- track the this pointer from the point the object is initialized.
- note accesses to offsets relative to the *this* pointer.

Non-virtual Functions

- track the this pointer from the point the object is initialized.
- note all blocks where ECX is the tracked variable, then mark the call in that block, if there is any, as a member of the current class.

Automation > Strategies > 5. Class Member Identification

- **Virtual Functions**
  - To identify virtual functions, we simply have to locate vftables first through constructor analysis.

After all of this is done, we then reconstruct the class using the results of these analysis.

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Reversing C++

Part III. Automation

Enhancing Disassembly

Automation > Disassembly Enhancement

- **RTTI structures reconstruction, naming, commenting**

```
<Original>
.rdata:004165A0            dd offset unk_4189E0
.rdata:004165A4 off_4165A4
                           dd offset sub_401170    ; DATA XREF:...
.rdata:004165A8            dd offset sub_4011C0
.rdata:004165AC            dd offset sub_401230
.rdata:004165B0            dd offset unk_418A28
```

```
<Processed>
.rdata:004165A0  dd offset oop_re$ClassA$RTTICompleteObjectLocator@00
.rdata:004165A4 oop_re$ClassA$vftable@00
                 dd offset sub_401170 ; DATA XREF: ...
.rdata:004165A8  dd offset sub_4011C0
.rdata:004165AC  dd offset sub_401230
```

Automation > Disassembly Enhancement

- **RTTI structures (another example)**

```
<Original>
.rdata:004189E0 dword_4189E0    dd 0      ; DATA XREF:...
.rdata:004189E4                 dd 0
.rdata:004189E8                 dd 0
.rdata:004189EC                 dd offset off_41B004
.rdata:004189F0                 dd offset unk_4189F4
```

```
<Processed>
.rdata:004189E0 oop_re$ClassA$RTTICompleteObjectLocator@00
                  dd 0      ; RTTICompleteObjectLocator.signature
.rdata:004189E4   dd 0      ; RTTICompleteObjectLocator.offset
.rdata:004189E8   dd 0      ; RTTICompleteObjectLocator.cdOffset
.rdata:004189EC   dd offset oop_re$ClassA$TypeDescriptor
.rdata:004189F0   dd offset oop_re$ClassA$RTTIClassHierarchyDescriptor
```

Automation > Disassembly Enhancement

- **Improving the call graph**
  - Add cross references on virtual function calls
  - Result in more accurate call graph
  - Will yield improvements on binary diffing results

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Reversing C++

Part III. Automation

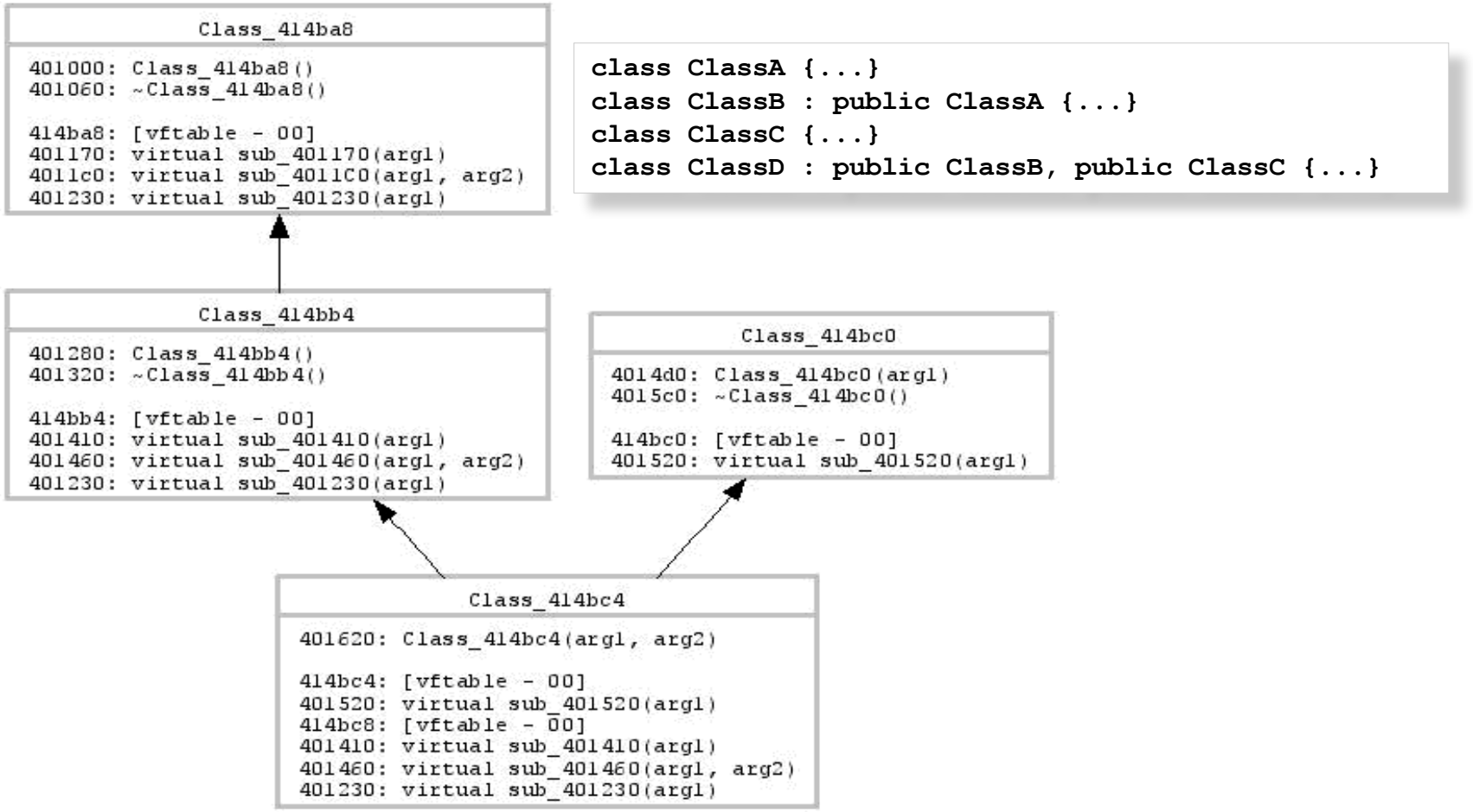
Visualization

Automation > Visualization

- **UML Diagram Generation**
  - Using **`pydot`**
  - Create a node for each class
  - Create an edge from each base classes
  - Pretty simple (once you have the data :) and Cool too… ☺
  - Very effective if RTTI exists (class names)
  - EXE2UML ?

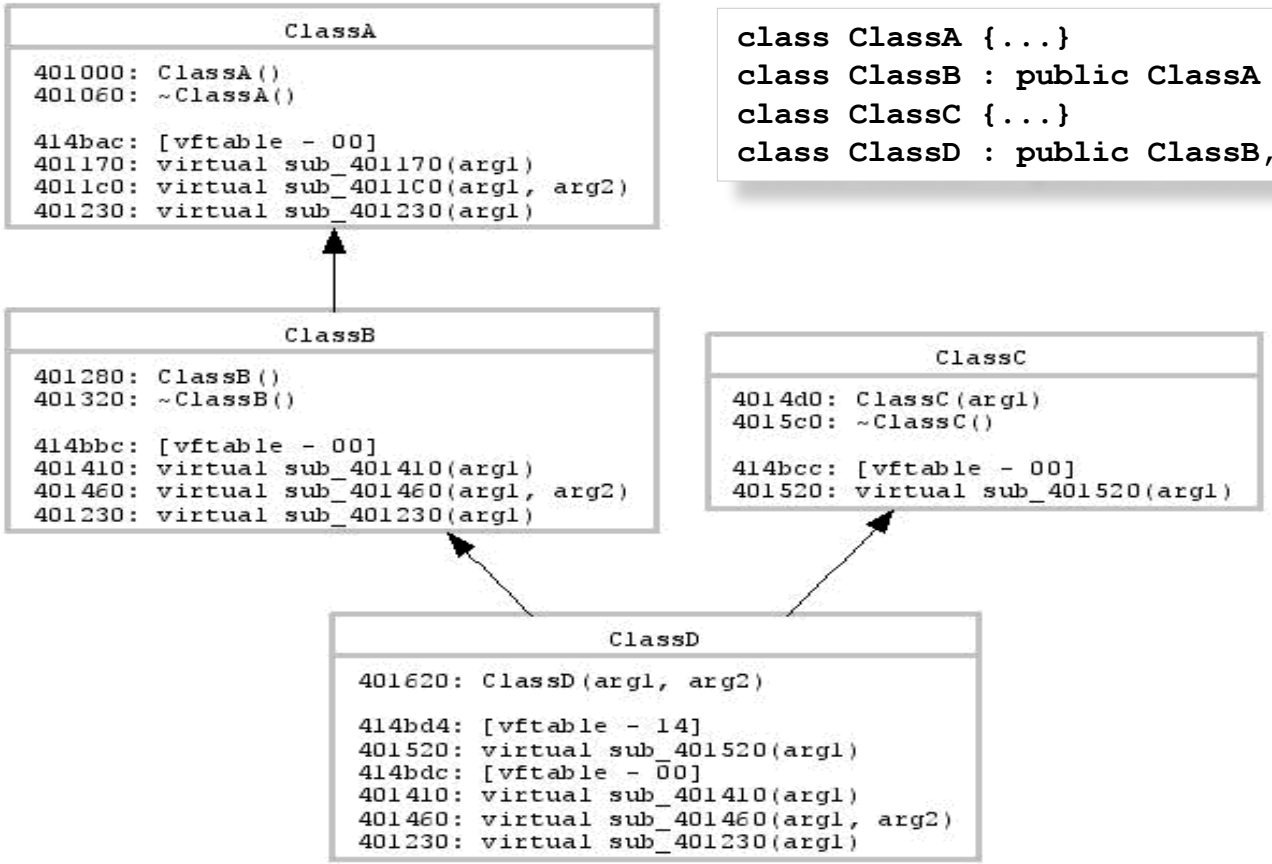
Automation > Visualization

UML Diagram Example (w/o RTTI)



Automation > Visualization

- # UML Diagram Example (w/ RTTI)




```
class ClassA {...}
class ClassB : public ClassA {...}
class ClassC {...}
class ClassD : public ClassB, public ClassC {...}
```

Reversing C++

Demo…

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Thank you!

Questions?

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