



.NET Core Memory Dump Analysis Accelerated

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Software Diagnostics Services

Prerequisites

WinDbg Commands

We use these boxes to introduce some WinDbg commands used in practice exercises

Basic .NET Core programming and debugging

Training Goals

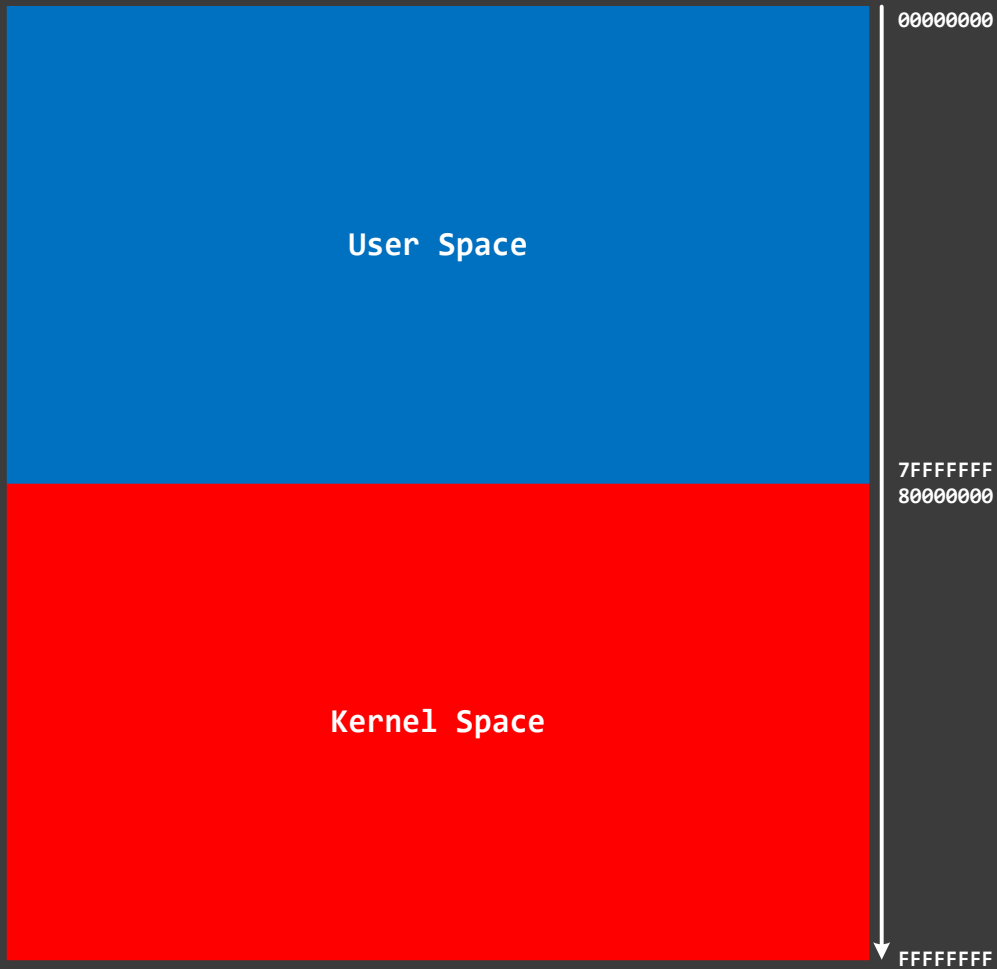
- Review fundamentals
- Learn how to analyze process dumps
- Learn necessary commands in context
- Cover CoreCLR x64

Training Principles

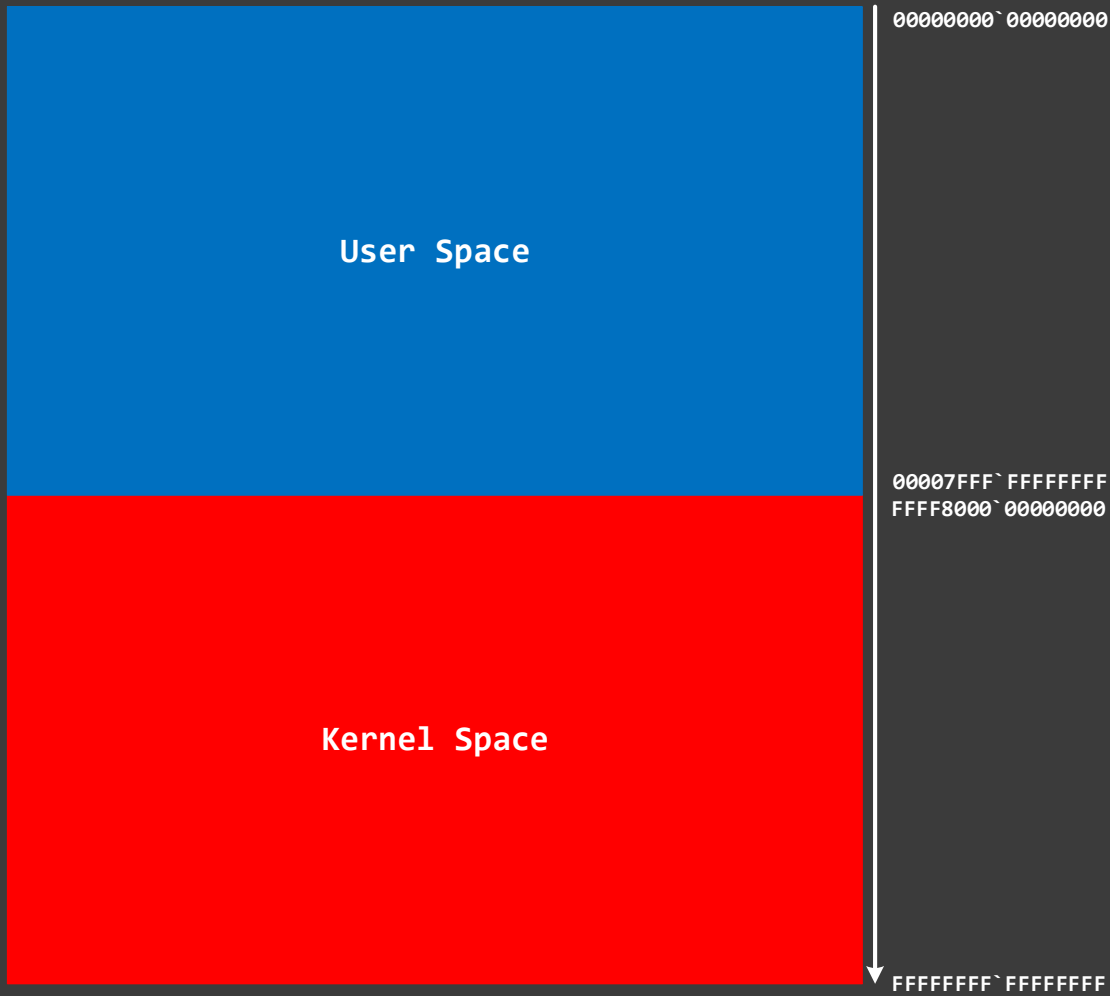
- Talk only about what I can show
- Lots of pictures
- Lots of examples
- Original content

Part 1: Fundamentals

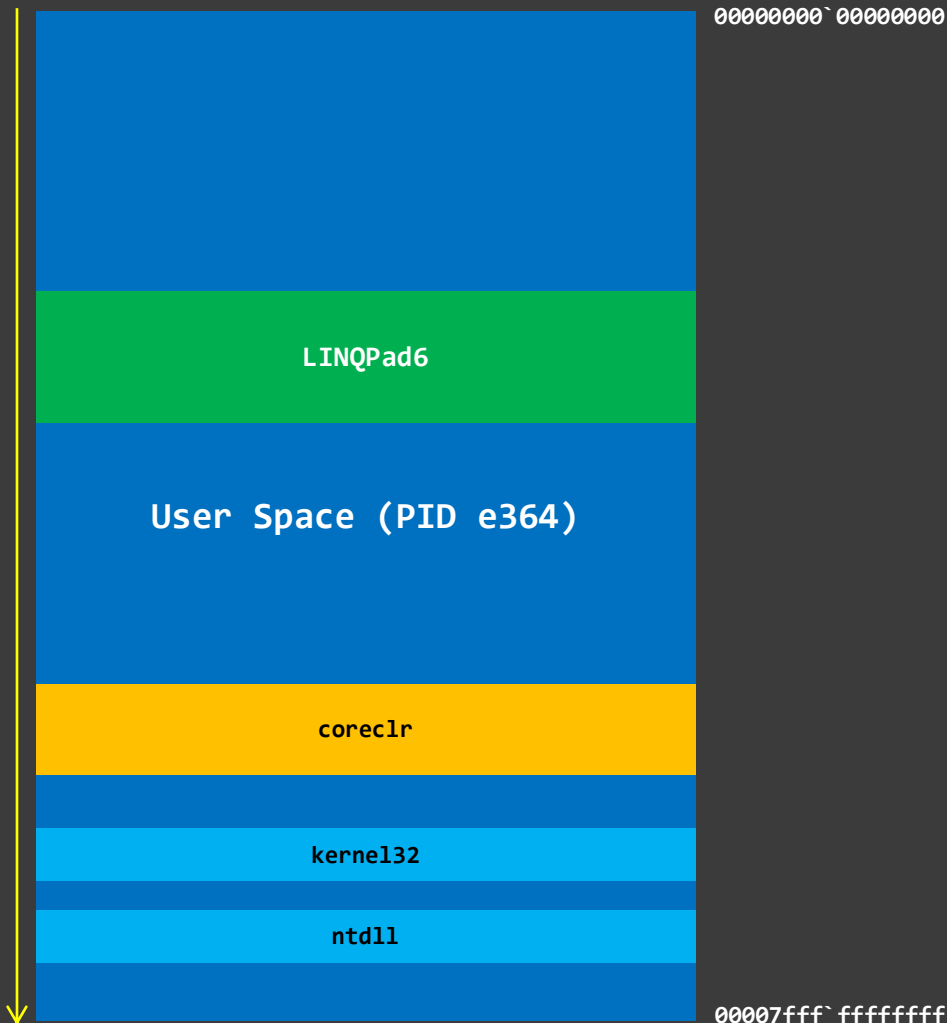
Memory Space (x86)



Memory Space (x64)



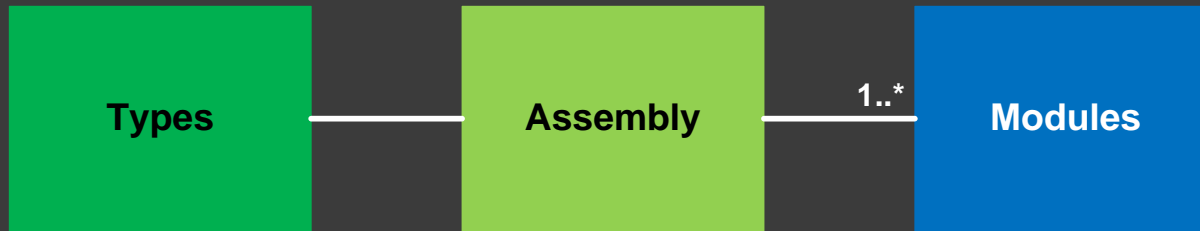
User / Managed Space



WinDbg Commands

lmv command lists all loaded modules (EXE and DLLs)

Types/Assemblies/Modules



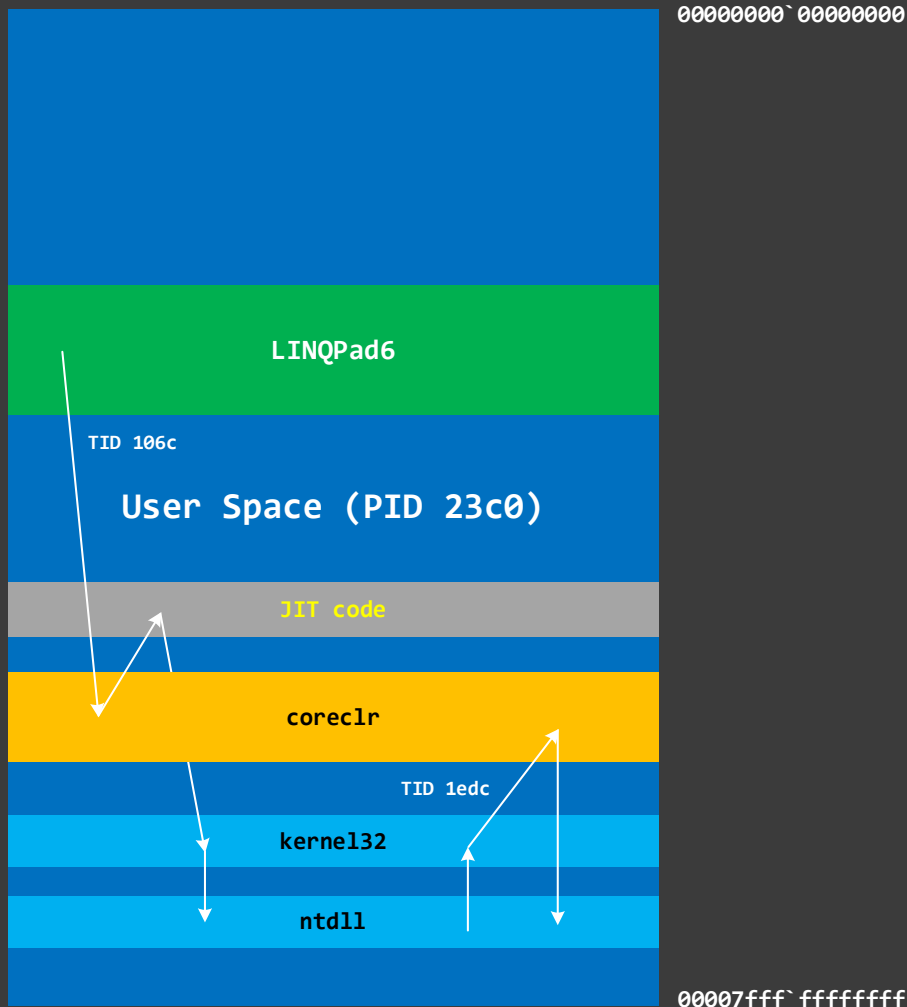
WinDbg Commands

!mv command lists all loaded modules (EXE and DLLs)

!IP2MD command shows type method and module address

!DumpModule command shows module name

Process Threads



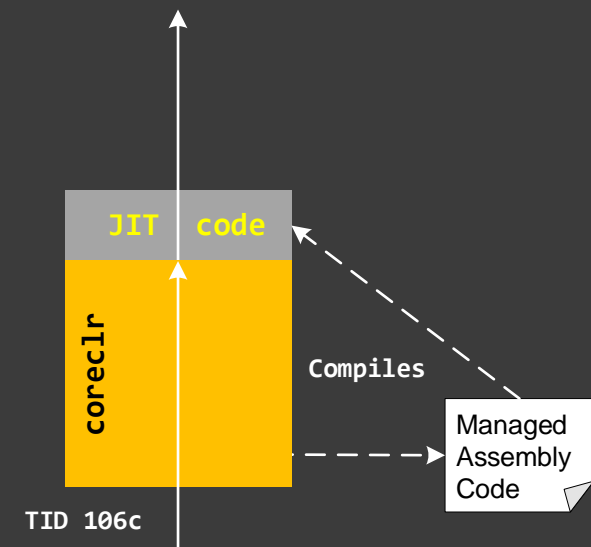
WinDbg Commands

~<n>s command switches between threads

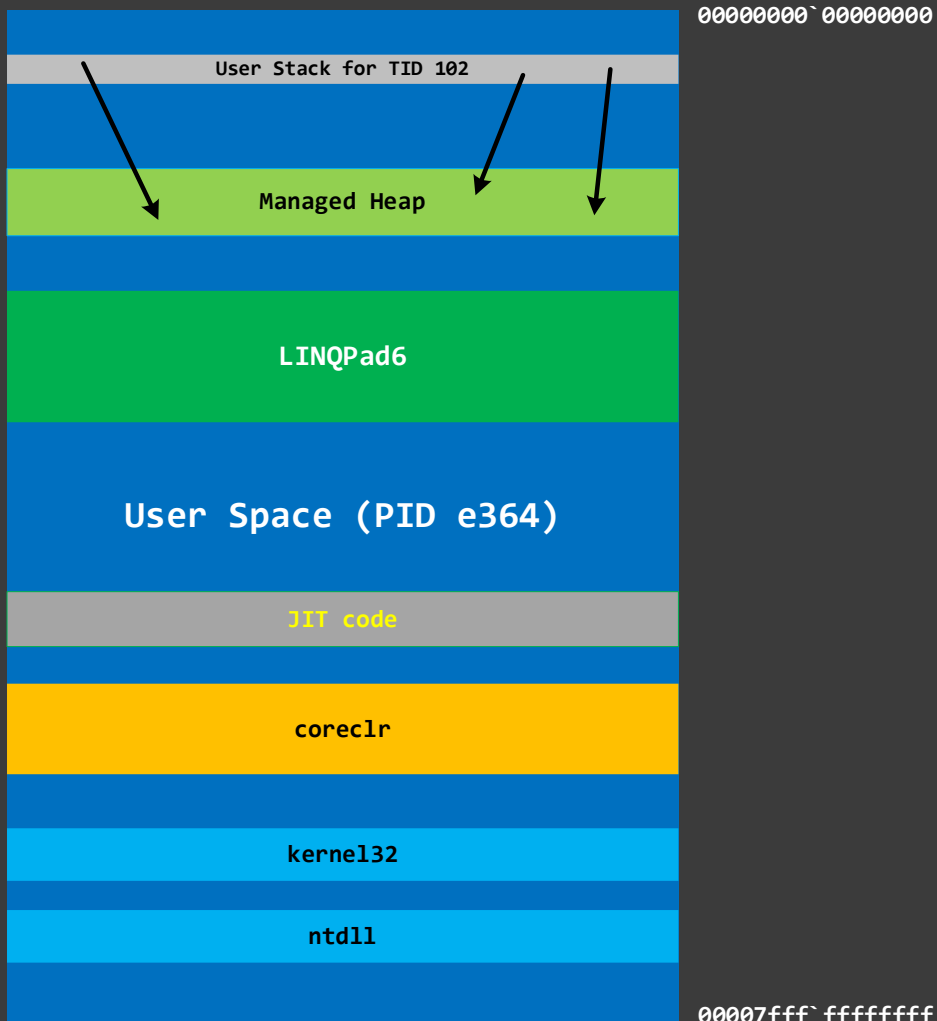
k command shows unmanaged stack trace

!Threads command shows managed threads

!CLRStack command shows managed stack trace



Thread Stack Raw Data



WinDbg Commands

Get stack range:

!teb

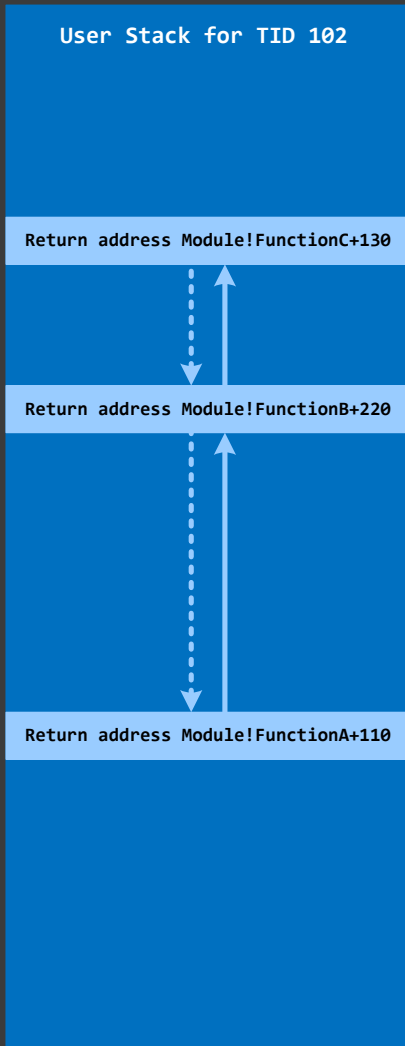
Dump raw data:

dc / dps / dpp / dpa / dpu

Dump managed references:

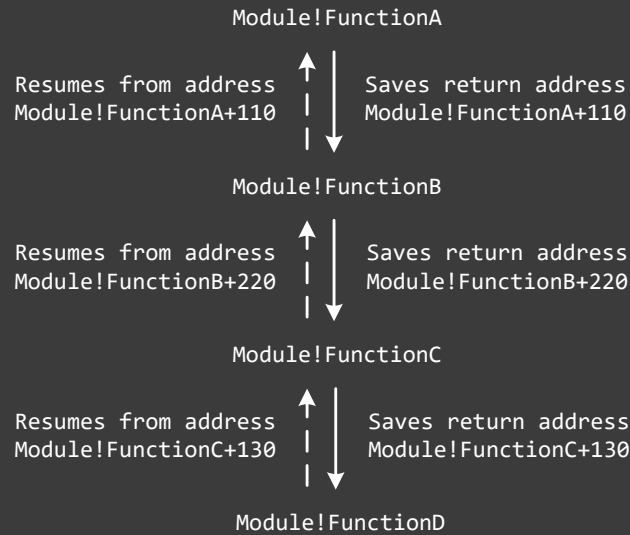
!DumpStackObjects

Thread Stack Trace

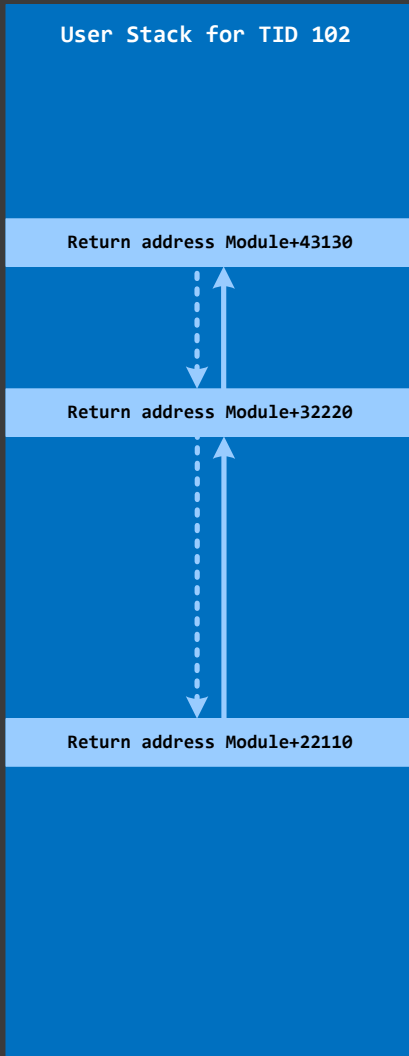


```
FunctionA()  
{  
  ...  
  FunctionB();  
  ...  
}  
FunctionB()  
{  
  ...  
  FunctionC();  
  ...  
}  
FunctionC()  
{  
  ...  
  FunctionD();  
  ...  
}
```

```
WinDbg Commands  
  
0:000> k  
Module!FunctionD  
Module!FunctionC+130  
Module!FunctionB+220  
Module!FunctionA+110
```



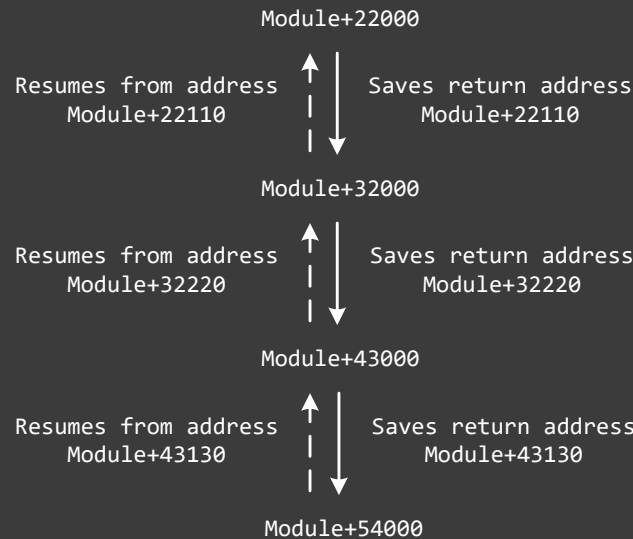
Thread Stack Trace (no PDB)



```
FunctionA()  
{  
  ...  
  FunctionB();  
  ...  
}  
FunctionB()  
{  
  ...  
  FunctionC();  
  ...  
}  
FunctionC()  
{  
  ...  
  FunctionD();  
  ...  
}
```

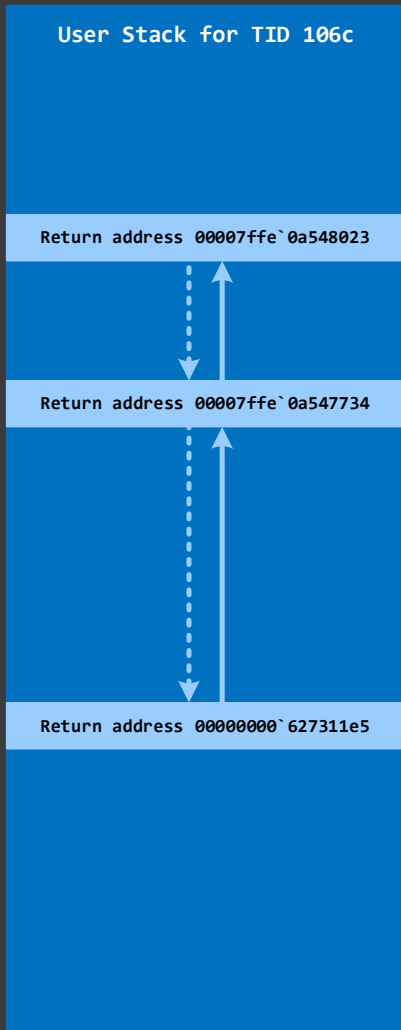
```
Symbol file Module.pdb  
  
FunctionA 22000 - 23000  
FunctionB 32000 - 33000  
FunctionC 43000 - 44000  
FunctionD 54000 - 55000
```

No symbols for Module



```
WinDbg Commands  
  
0:000> k  
Module+0  
Module+43130  
Module+32220  
Module+22110
```

Thread Stack Trace (JIT Code)



C# Code	JIT Code
System.Windows.UIElement.RaiseEvent(...)	→ 00000000`627311b0
{	
...	
System.Windows.UIElement.RaiseEventImpl(...);	
...	→ 00000000`627311e5
}	
System.Windows.UIElement.RaiseEventImpl(...)	→ 00007ffe`0a547640
{	
...	
System.Windows.EventRoute.InvokeHandlersImpl(...);	
...	→ 00007ffe`0a547734
}	
System.Windows.EventRoute.InvokeHandlersImpl(...)	→ 00007ffe`0a547ee0
{	
...	
ApplicationA.MainWindow.Button_Click(...);	
...	→ 00007ffe`0a548023
}	
ApplicationA.MainWindow.Button_Click(...)	→ 00007ffe`0a6a95d0
{	
...	
*p = 1;	→ 00007ffe`0a6a9609
...	PresentationCore+0x4011e5
}	



```
WinDbg Commands

0:000> k
...
0x00007ffe`0a6a9609
0x00007ffe`0a548023
0x00007ffe`0a547734
PresentationCore+0x4011e5
...
```

Example: Unmanaged Stack Trace

```
0:000> kL
# Child-SP          RetAddr           Call Site
00 00000029`6e3add78 00007ffa`7eb90458 win32u!NtUserWaitMessage+0x14
01 00000029`6e3add80 00007ffa`d7244d61 0x00007ffa`7eb90458
02 00000029`6e3ade40 00007ffa`d7247486 System_Windows_Forms!...+0x581
03 00000029`6e3adf50 00007ffa`d7247026 System_Windows_Forms!...+0x416
04 00000029`6e3ae000 00007ffa`d6ef212b System_Windows_Forms!...+0x46
05 00000029`6e3ae060 00007ffa`7cb021e4 System_Windows_Forms!...+0x3b
06 00000029`6e3ae0a0 00007ffa`7cae2534 0x00007ffa`7cb021e4
07 00000029`6e3ae350 00007ffa`7c70a16d 0x00007ffa`7cae2534
08 00000029`6e3ae680 00007ffa`7c7015c2 0x00007ffa`7c70a16d
09 00000029`6e3ae6e0 00007ffa`dc226ce3 0x00007ffa`7c7015c2
0a 00000029`6e3ae7b0 00007ffa`dc1bcc42 coreclr!CallDescrWorkerInternal+0x83
0b (Inline Function) -----`----- coreclr!CallDescrWorkerWithHandler+0x57
0c 00000029`6e3ae7f0 00007ffa`dc1c3c09 coreclr!MethodDescCallSite:...+0x196
0d (Inline Function) -----`----- coreclr!MethodDescCallSite::Call+0xb
0e 00000029`6e3ae930 00007ffa`dc1c4097 coreclr!RunMain+0x1f5
0f 00000029`6e3aeb10 00007ffa`dc1c4841 coreclr!Assembly::ExecuteMainMethod+0x1cb
10 00000029`6e3aeea0 00007ffa`dc0e21c1 coreclr!CorHost2::ExecuteAssembly+0x221
11 00000029`6e3af030 00007ffb`2ef54e2d coreclr!coreclr_execute_assembly+0x101
12 00000029`6e3af0d0 00007ffb`2ef62e27 hostpolicy!coreclr_t::execute_assembly+0x2d
13 00000029`6e3af120 00007ffb`2ef62a36 hostpolicy!run_app_for_context+0x387
14 00000029`6e3af280 00007ffb`2ef64262 hostpolicy!run_app+0x46
15 00000029`6e3af2d0 00007ffb`36ff3a7e hostpolicy!corehost_main+0x132
16 00000029`6e3af480 00007ffb`36ff72d8 hostfxr!execute_app+0x1de
17 (Inline Function) -----`----- hostfxr!?A0xd51c85dd::read_config...+0x10a
18 00000029`6e3af570 00007ffb`36ff5b5b hostfxr!fx_muxer_t::handle_exec...+0x214
19 00000029`6e3af660 00007ffb`36ff2109 hostfxr!fx_muxer_t::execute+0x39b
1a 00000029`6e3af7a0 00007ffb`ea712361 hostfxr!hostfxr_main_startupinfo+0x89
1b 00000029`6e3af8a0 00007ffb`ea712758 LINQPad6!exe_start+0x651
1c 00000029`6e3afad0 00007ffb`ea714608 LINQPad6!wmain+0x88
1d (Inline Function) -----`----- LINQPad6!invoke_main+0x22
1e 00000029`6e3afb00 00007ffb`58387034 LINQPad6!__scrt_common_main_seh+0x10c
1f 00000029`6e3afb40 00007ffb`5a002651 kernel32!BaseThreadInitThunk+0x14
20 00000029`6e3afb70 00000000`00000000 ntdll!RtlUserThreadStart+0x21
```

```
0:000> !IP2MD 0x00007ffa`7cae2534
MethodDesc: 00007ffa7c7f5aa0
Method Name: LINQPad.UIProgram.Go(System.String[])
Class: 00007ffa7c803a28
MethodTable: 00007ffa7c7f7078
mdToken: 00000000060001A4
Module: 00007ffa7c79f798
IsJitted: yes
Current CodeAddr: 00007ffa7cae1b90
Version History:
  ILCodeVersion: 0000000000000000
  ReJIT ID: 0
  IL Addr: 0000000000000000
  CodeAddr: 00007ffa7cae1b90
(MinOptJitted)
NativeCodeVersion: 0000000000000000
```

```
0:000> !DumpModule 00007ffa7c79f798
Name: C:\Program Files\LINQPad6\LINQPad.GUI.dll
Attributes: PEFile
SupportsUpdateableMethods
Assembly: 00000177c5cdece0
BaseAddress: 00000177DFDE0000
PEFile: 00000177C5CDE0E0
ModuleId: 00007FFA7C7D1860
ModuleIndex: 0000000000000001
LoaderHeap: 0000000000000000
TypeDefToMethodTableMap: 00007FFA7C7A0020
TypeRefToMethodTableMap: 00007FFA7C7A1860
MethodDefToDescMap: 00007FFA7C7A4138
FieldDefToDescMap: 00007FFA7C7AF300
MemberRefToDescMap: 0000000000000000
FileReferencesMap: 00007FFA7C7B7F78
AssemblyReferencesMap: 00007FFA7C7B7F80
MetaData start address: 00000177DFE887DC (719936 bytes)
```

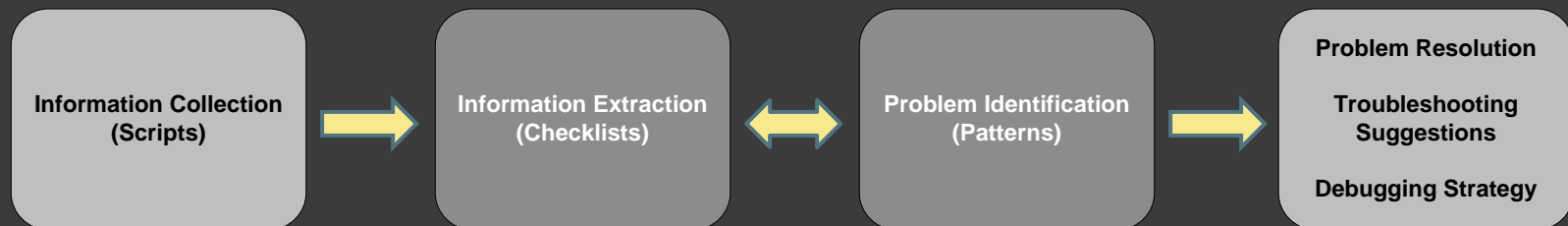
Pattern-Oriented Diagnostic Analysis

Diagnostic Pattern: a common recurrent identifiable problem together with a set of recommendations and possible solutions to apply in a specific context.

Diagnostic Problem: a set of indicators (symptoms, signs) describing a problem.

Diagnostic Analysis Pattern: a common recurrent analysis technique and method of diagnostic pattern identification in a specific context.

Diagnostics Pattern Language: common names of diagnostic and diagnostic analysis patterns. The same language for any operating system: Windows, Mac OS X, Linux, ...



Checklist: <http://www.dumpanalysis.org/windows-memory-analysis-checklist>

Part 2: Practice Exercises

Links

- Memory Dumps:

Included in Exercise 0

- Exercise Transcripts:

Included in this book

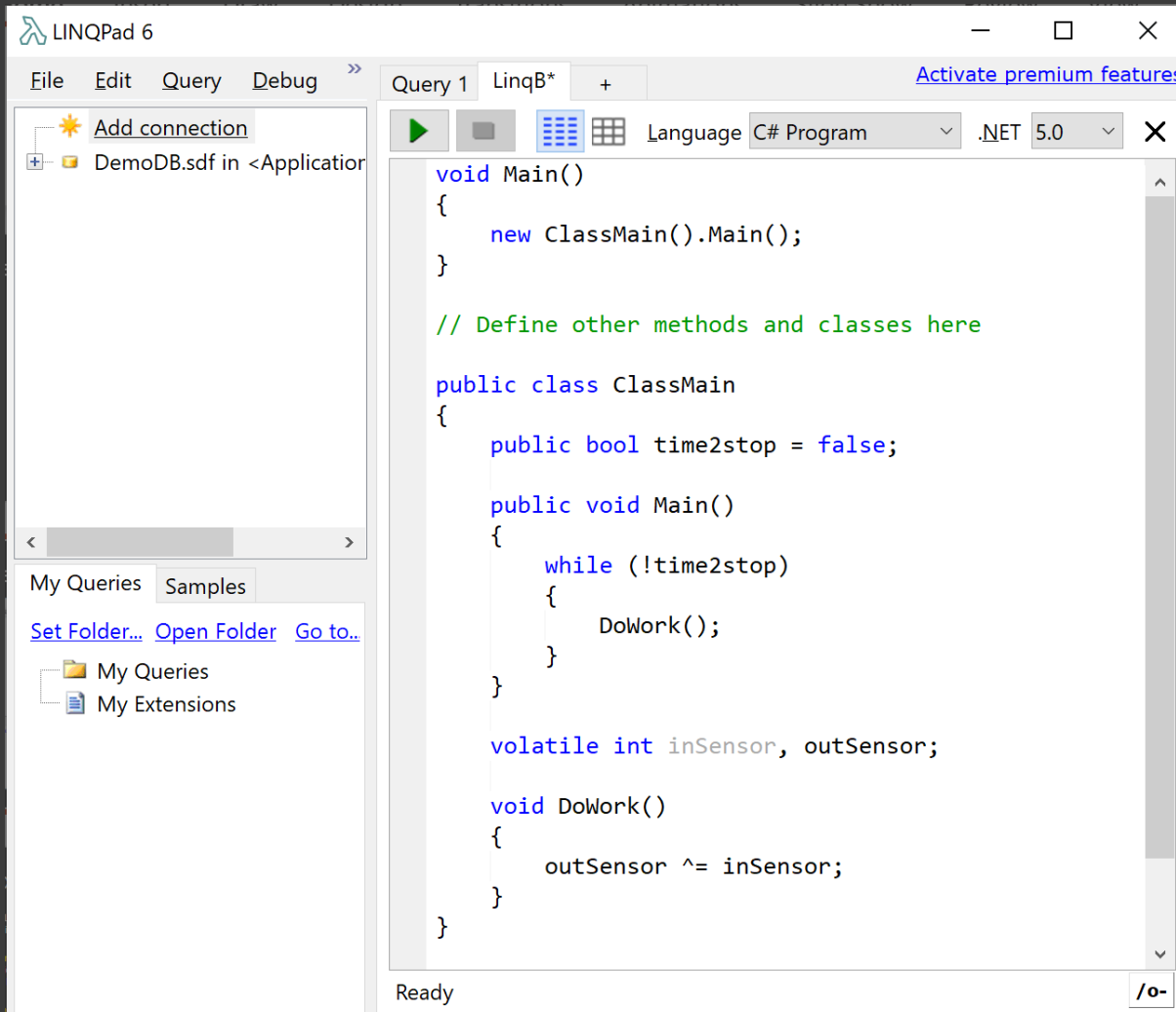
Exercise 0

- ⦿ **Goal:** Install Debugging Tools for Windows or WinDbg Preview or pull Docker WinDbg image, and check that symbols are set up correctly
- ⦿ **Patterns:** Stack Trace; Incorrect Stack Trace; Truncated Stack Trace
- ⦿ **Commands:** k
- ⦿ [\ANETCMDA-Dumps\Exercise-0-Download-Setup-WinDbg.pdf](#)

Process Memory Dumps

Practice Exercises PNC1-PNC8

Modeling with LINQPad 6/7



<http://www.linqpad.net/>

Exercise PNC1

- ◎ **Goal:** Learn how to use the SOS WinDbg extension to analyze managed space for the presence of exceptions
- ◎ **Patterns:** Stack Trace Collection (Unmanaged Space); CLR Thread; Software Exception; Exception Stack Trace; Managed Code Exception; Managed Stack Trace; Invalid Pointer; NULL Pointer (Data)
- ◎ **Commands:** .logopen, version, !peb, ~*k, ~*kL, .load, !pe, ~*e, !mv, .chain, .unload, !analyze -v, !CLRStack, .logclose
- ◎ [\ANETCMDA-Dumps\Exercise-PNC1-Analysis-process-dump-ApplicationA.pdf](#)

Exercise PNC2

- ◎ **Goal:** Compare the 64-bit process memory dump from exercise PNC1 with a 32-bit process memory dump
- ◎ **Patterns:** Platform-Specific Debugger
- ◎ [\ANETCMDA-Dumps\Exercise-PNC2-Analysis-process-dump-ApplicationA-32.pdf](#)

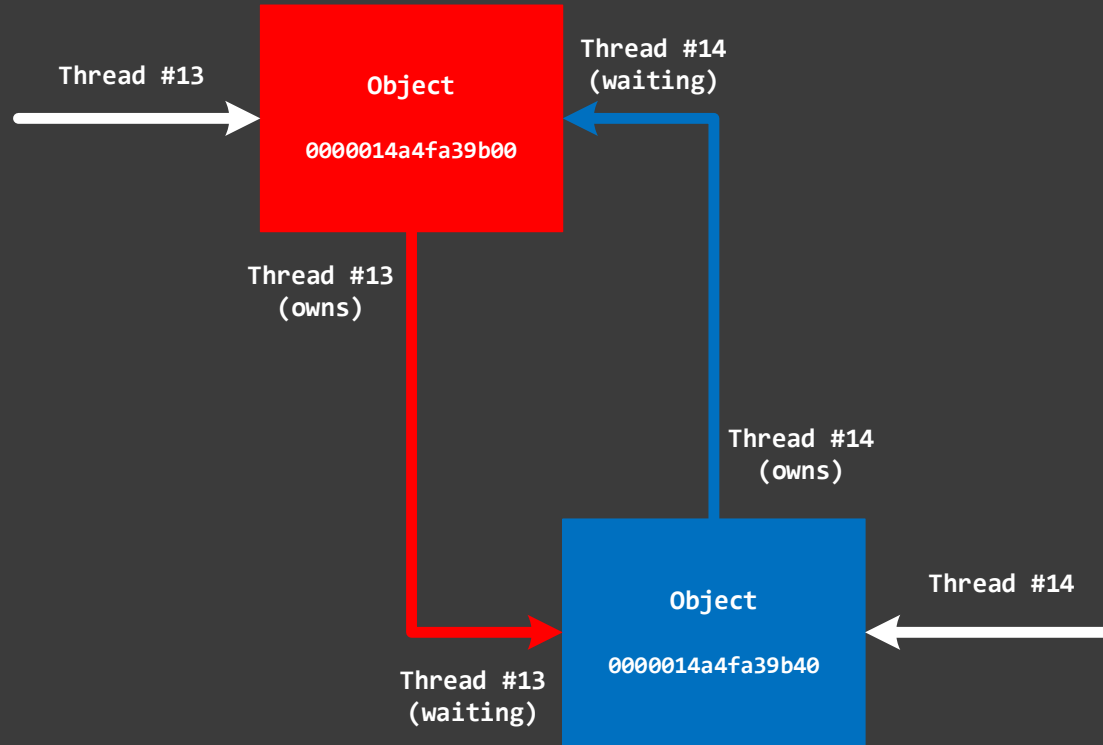
Exercise PNC3

- ◎ **Goal:** Learn how to find problem assemblies, modules, classes and methods, disassemble code, analyze CPU spikes
- ◎ **Patterns:** Active Thread; Manual Dump (Process); Technology-Specific Subtrace (JIT .NET Code); Spiking Thread; JIT Code; Annotated Disassembly (JIT .NET Code)
- ◎ **Commands:** !analyze -v -hang, !IP2MD, !runaway, ~<>k, !U, !DumpMD, !DumpClass, !DumpMT, !DumpModule, !DumpAssembly, !DumpDomain, !DumpIL
- ◎ [\ANETCMDA-Dumps\Exercise-PNC3-Analysis-process-dump-LINQPadB.pdf](#)

Exercise PNC4

- ⦿ **Goal:** Learn how to recognize and analyze deadlocks using SOS, execution residue, handled exceptions, dump object references
- ⦿ **Patterns:** Special Thread (.NET CLR); Wait Chain (CLR Monitors); Deadlock (Managed Space); Execution Residue (User and Managed Spaces); Value References; Hidden Exception (User and Managed Spaces); Handled Exception (.NET CLR); Coincidental Symbolic Information; Rough Stack Trace (Unmanaged Space); Caller-n-Callee
- ⦿ **Commands:** ~<>s, !Threads, !syncblk, !DumpObj, ub, dps, !DumpStack, !teb, dpS, !DumpStackObjects
- ⦿ [\ANETCMDA-Dumps\Exercise-PNC4-Analysis-process-dump-LINQPadC.pdf](#)

Deadlock



Exercise PNC5

- ◎ **Goal:** Learn how to analyze multiple managed exceptions
- ◎ **Patterns:** Stack Trace Collection (Managed Space); Multiple Exceptions (Managed Space)
- ◎ **Commands:** .sympath+, !help
- ◎ [\ANETCMDA-Dumps\Exercise-PNC5-Analysis-process-dump-ApplicationD.pdf](#)

Exercise PNC6

- ⦿ **Goal:** Learn how to diagnose heap and handle leaks
- ⦿ **Patterns:** Handle Leak; Object Distribution Anomaly (.NET Heap); Memory Leak (.NET Heap)
- ⦿ **Commands:** !heap, !address, !DumpHeap, ?, !eeheap, !GCHandles, !FinalizeQueue, !handle
- ⦿ [\ANETCMDA-Dumps\Exercise-PNC6-Analysis-process-dump-LINQPadD.pdf](#)

Exercise PNC7

- ◎ **Goal:** Learn how to recognize and analyze heap corruption
- ◎ **Patterns:** Regular Data; Dynamic Memory Corruption (Managed Heap)
- ◎ **Commands:** .formats, !VerifyHeap
- ◎ [\ANETCMDA-Dumps\Exercise-PNC7-Analysis-process-dump-LINQPadE.pdf](#)

Exercise PNC8

- ⦿ **Goal:** Learn how to navigate virtual memory, search stack traces and memory for data and objects
- ⦿ **Patterns:** Stack Overflow (Managed Space); Stack Trace Set
- ⦿ **Commands:** .kframes, !VMMap, !address, !ListNearObj, !ObjSize, !uniqstack, !findstack, !DumpArray, dpa, dpu, s
- ⦿ [\ANETCMDA-Dumps\Exercise-PNC8-Analysis-process-dump-LINQPadF.pdf](#)

Pattern Links

[CLR Thread](#)

[Managed Code Exception](#)

[Stack Trace Collection](#)

[Memory Leak](#)

[JIT Code](#)

[Managed Stack Trace](#)

[Multiple Exceptions](#)

[Caller-n-Callee](#)

[Hidden Exception](#)

[Technology-Specific Subtrace](#)

[Stack Overflow](#)

[Dynamic Memory Corruption](#)

[Special Thread](#)

[Execution Residue](#)

[Handled Exception](#)

[Annotated Disassembly](#)

[Wait Chain](#)

[Deadlock](#)

[Object Distribution Anomaly](#)

**CLR-related
and managed
([full list](#))**

[Incorrect Stack Trace](#) [Execution Residue](#) [Stack Trace](#)

[NULL Pointer \(Data\)](#) [Handle Leak](#) [Exception Stack Trace](#)

[Software Exception](#) [Platform-Specific Debugger](#)

[Spiking Thread](#) [Hidden Exception](#) [Regular Data](#)

[Coincidental Symbolic Information](#) [Active Thread](#)

[Truncated Stack Trace](#) [Value References](#) [Manual Dump](#)

[Stack Trace Set](#) [Rough Stack Trace](#) [Stack Trace Collection](#)

**Unmanaged
user space**

SOS Checklist

- ⦿ CLR module and SOS extension versions (`!mv` and `.chain`)
- ⦿ Managed exceptions (`~*e !pe -nested`)
- ⦿ Managed threads (`!Threads -special`)
- ⦿ Managed stack traces (`!CLRStack -all`)
- ⦿ Managed execution residue (`~*e !DumpStackObjects`)
- ⦿ Managed heap (`!VerifyHeap`, `!DumpHeap -stat` and `!eeheap -gc`)
- ⦿ GC handles (`!GCHandles`)
- ⦿ Finalizer queue (`!FinalizeQueue`)
- ⦿ Sync blocks (`!syncblk`)

Q&A

Please send your feedback using the contact form on PatternDiagnostics.com

Thank you for attendance!