Public Preview Version

.NET Memory Dump Analysis Accelerated

Version 3.0

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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 programming and debugging

Training Goals

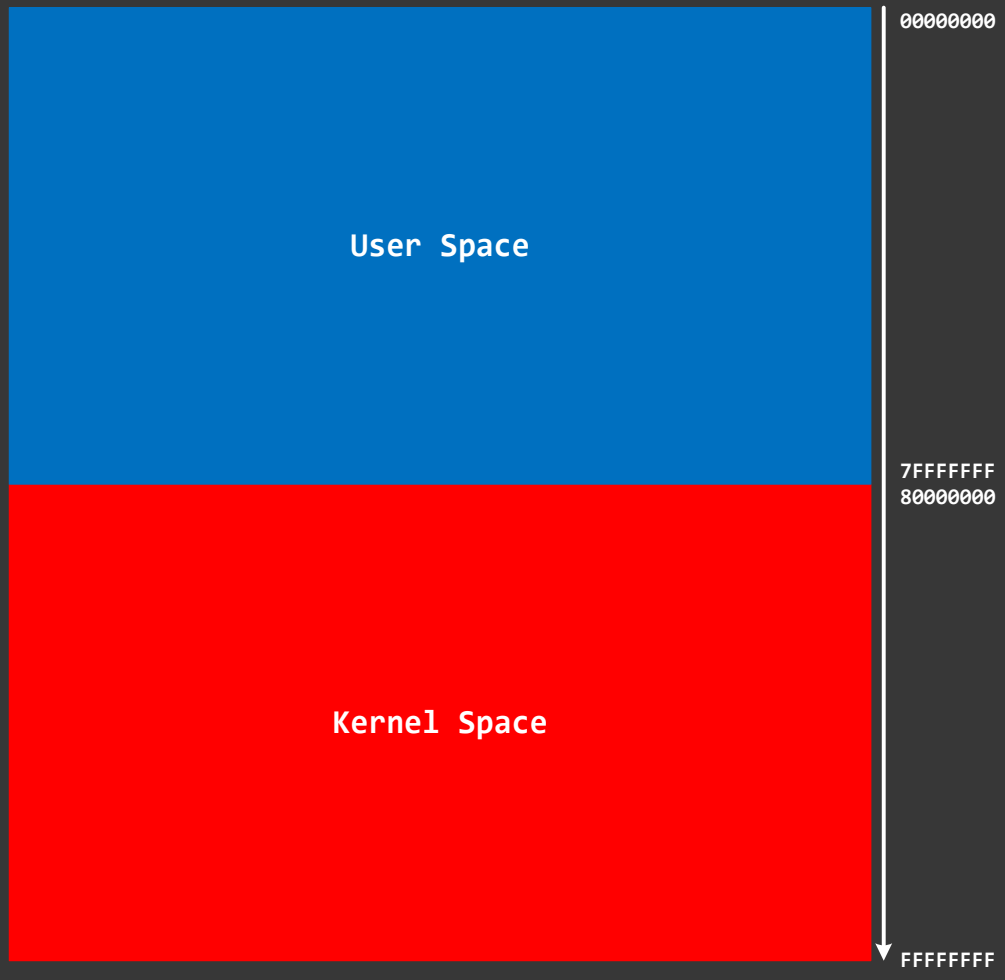
- Review fundamentals
- Learn how to analyze process dumps
- Learn necessary commands in context
- Cover CLR 4 (x86 and x64)

Training Principles

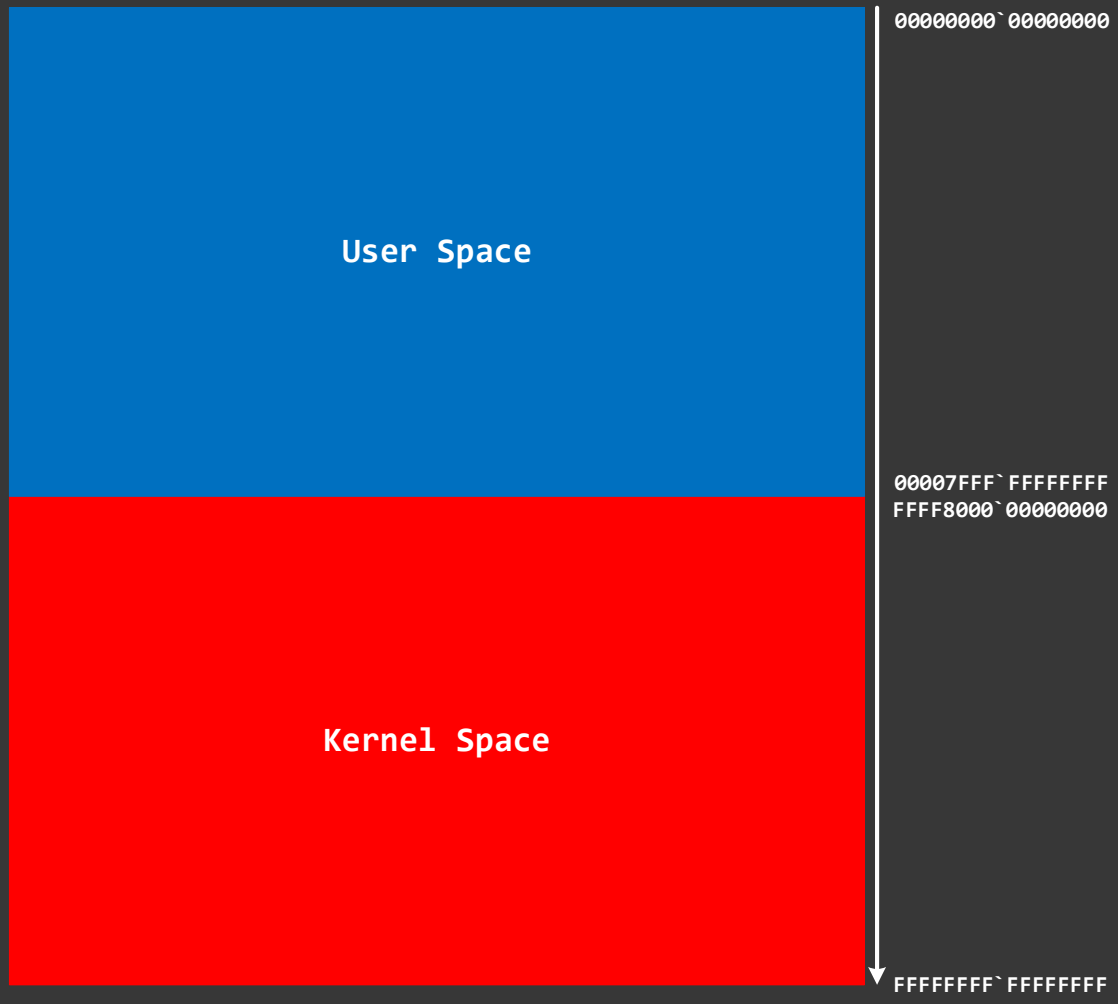
- Talk only about what I can show
- Lots of pictures
- Lots of examples
- Original content and examples

Part 1: Fundamentals

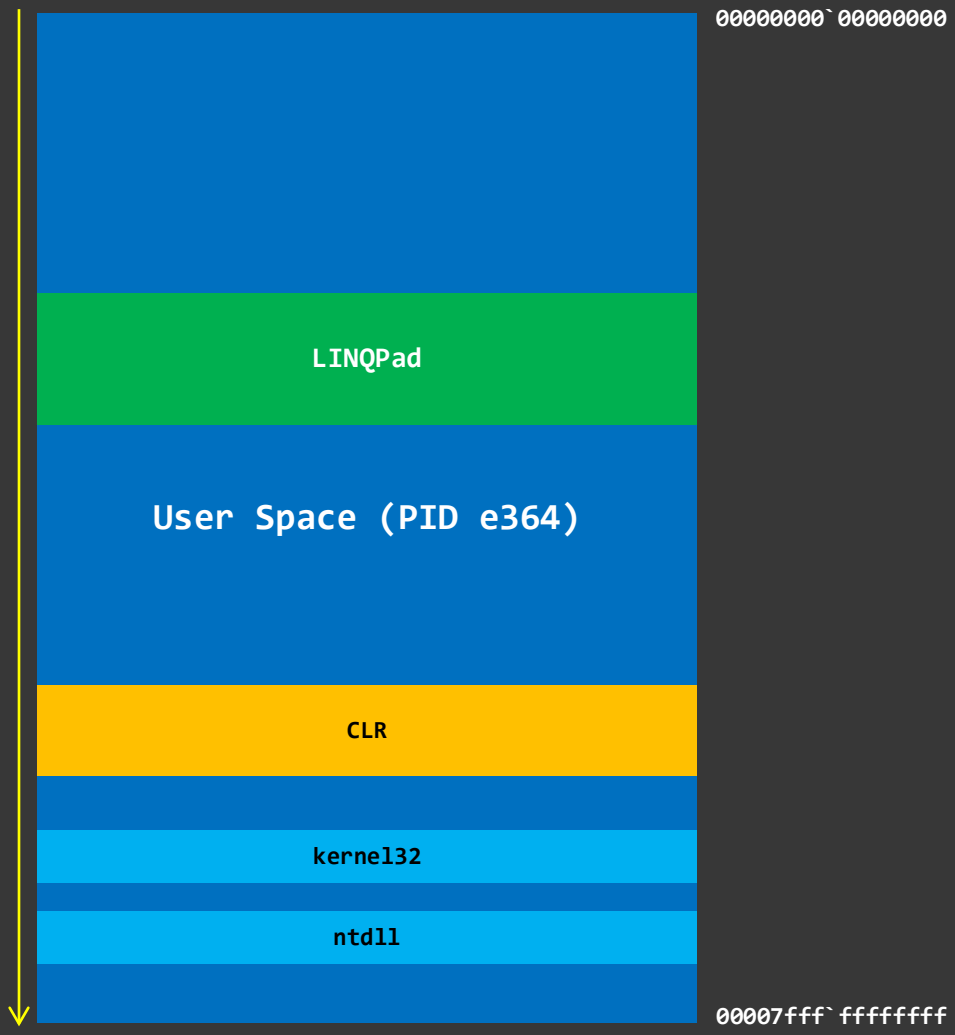
Memory Space (x86)



Memory Space (x64)



User / Managed Space



WinDbg Commands

lmv command lists all loaded modules (EXE and DLLs)

Types/Assemblies/Modules

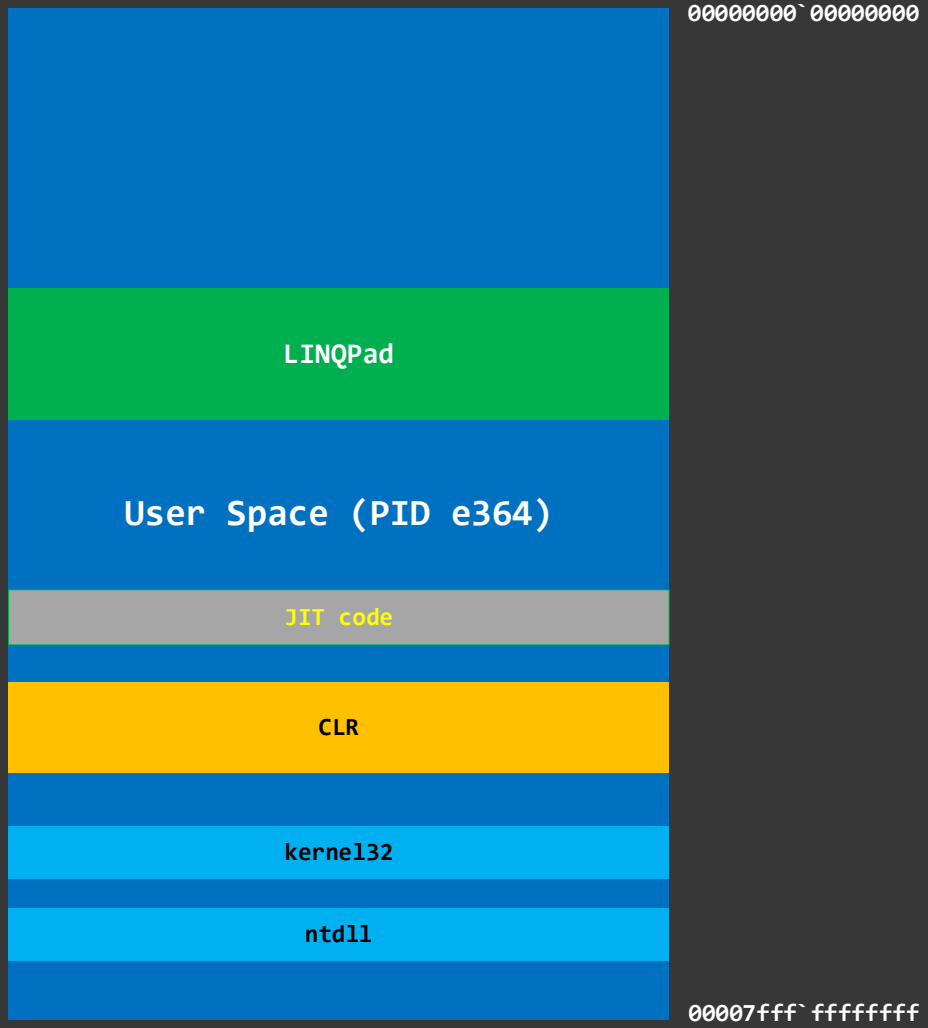
WinDbg Commands

lmv 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

.load *<a path to SOS>*
Loads SOS WinDbg extension

~<n>s command switches between threads

k command shows unmanaged stack trace

!Threads command shows managed threads

!CLRStack command shows managed stack trace

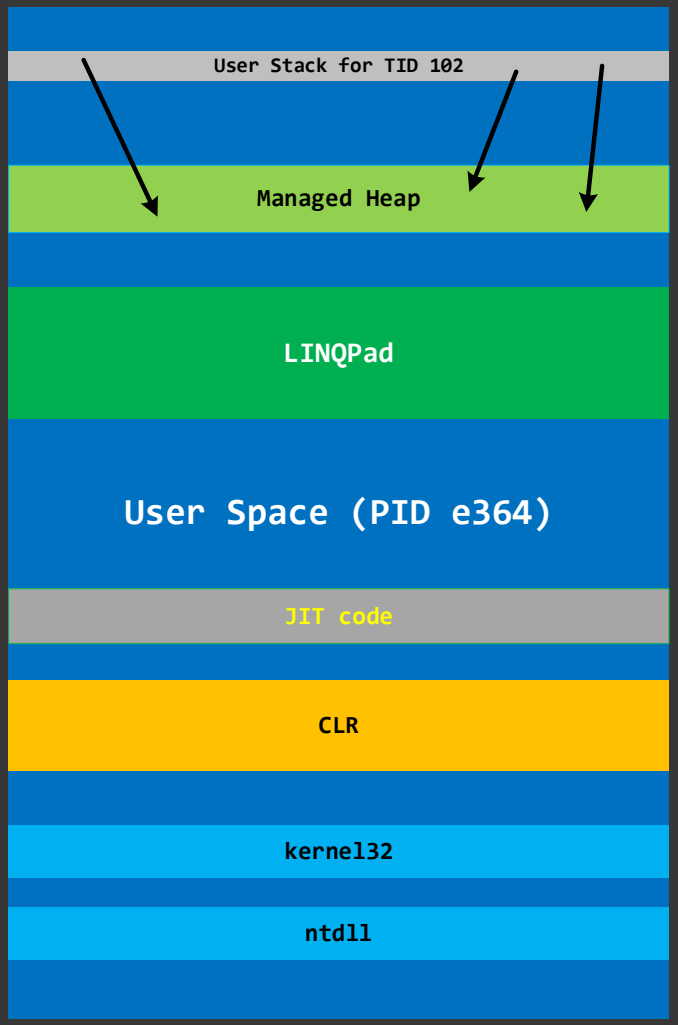
Example

```
0:000> k
 # Child-SP          RetAddr           Call Site
00 000000dc`219be178 00007ffb`41ddddb8 win32u!NtUserWaitMessage+0x14
01 000000dc`219be180 00007ffb`41d71535 System_Windows_Forms_ni+0x2cddb8
02 000000dc`219be230 00007ffb`41d70c88 System_Windows_Forms_ni+0x261535
03 000000dc`219be330 00007ffb`41d70a8f System_Windows_Forms_ni+0x260c88
04 000000dc`219be3d0 00007ffb`12f4dbc0 System_Windows_Forms_ni+0x260a8f
05 000000dc`219be430 00007ffb`12f45a94 0x00007ffb`12f4dbc0
06 000000dc`219be5e0 00007ffb`12f41c9d 0x00007ffb`12f45a94
07 000000dc`219bed20 00007ffb`12f420b6 0x00007ffb`12f41c9d
08 000000dc`219bee00 00007ffb`12f406e4 0x00007ffb`12f420b6
09 000000dc`219bee30 00007ffb`724d5863 0x00007ffb`12f406e4
0a 000000dc`219bef20 00007ffb`724d5702 clr!CallDescrWorkerInternal+0x83
0b 000000dc`219bef60 00007ffb`724d5e05 clr!CallDescrWorkerWithHandler+0x4e
0c 000000dc`219befa0 00007ffb`72633598 clr!MethodDescCallSite::CallTargetWorker+0xf8
0d 000000dc`219bf0a0 00007ffb`72633ede clr!RunMain+0x1e7
0e 000000dc`219bf280 00007ffb`72633d9d clr!Assembly::ExecuteMainMethod+0xb6
0f 000000dc`219bf570 00007ffb`72633750 clr!SystemDomain::ExecuteMainMethod+0x639
10 000000dc`219bfb90 00007ffb`726336ce clr!ExecuteEXE+0x3f
11 000000dc`219bfc00 00007ffb`72634234 clr!_CorExeMainInternal+0xb2
12 000000dc`219bfc90 00007ffb`72ec7a6d clr!CorExeMain+0x14
13 000000dc`219bfcd0 00007ffb`7303a44c mscoreei!CorExeMain+0x112
14 000000dc`219bfd30 00007ffb`85591fe4 MSCOREE!CorExeMain_Exported+0x6c
15 000000dc`219bfd60 00007ffb`8797f061 KERNEL32!BaseThreadInitThunk+0x14
16 000000dc`219bfd90 00000000`00000000 ntdll!RtlUserThreadStart+0x21
```

```
0:000> !IP2MD 0x00007ffb`12f45a94
MethodDesc:   00007ffb12f81c40
Method Name:  LINQPad.Program.Go(System.String[])
Class:        00007ffb12f322e0
MethodTable:  00007ffb12f81e10
mdToken:      0000000006000579
Module:       00007ffb12dc4110
IsJitted:     yes
CodeAddr:     00007ffb12f436f0
Transparency: Critical

0:000> !DumpModule 00007ffb12dc4110
Name:       C:\Program Files\LINQPad5\LINQPad.exe
Attributes: PEFile
Assembly:   000001f80c3cf620
LoaderHeap:                   0000000000000000
TypeDefToMethodTableMap: 00007ffb12ed0020
TypeRefToMethodTableMap: 00007ffb12ed3a88
MethodDefToDescMap:      00007ffb12ed7000
FieldDefToDescMap:       00007ffb12eefcc8
MemberRefToDescMap:      0000000000000000
FileReferencesMap:       00007ffb12f036c8
AssemblyReferencesMap:   00007ffb12f036d0
MetaData start address:  000001f808cffb04 (1498300
bytes)
```

Thread Stack Raw Data



WinDbg Commands

Get stack range:
!teb

Dump raw data:
dc / **dps** / **dpp** / **dpa** / **dpu**

Dump managed references:
!DumpStackObjects

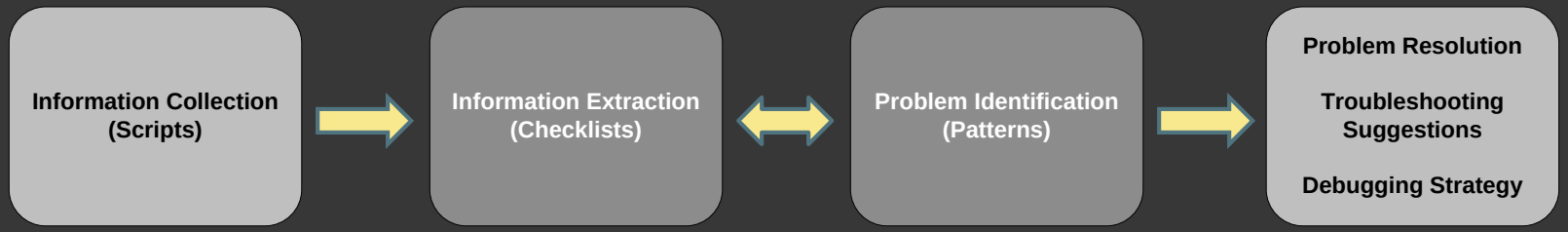
Pattern-Oriented Diagnostic Analysis

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:

Not available in preview version

- Exercise Transcripts:

Not available in preview version

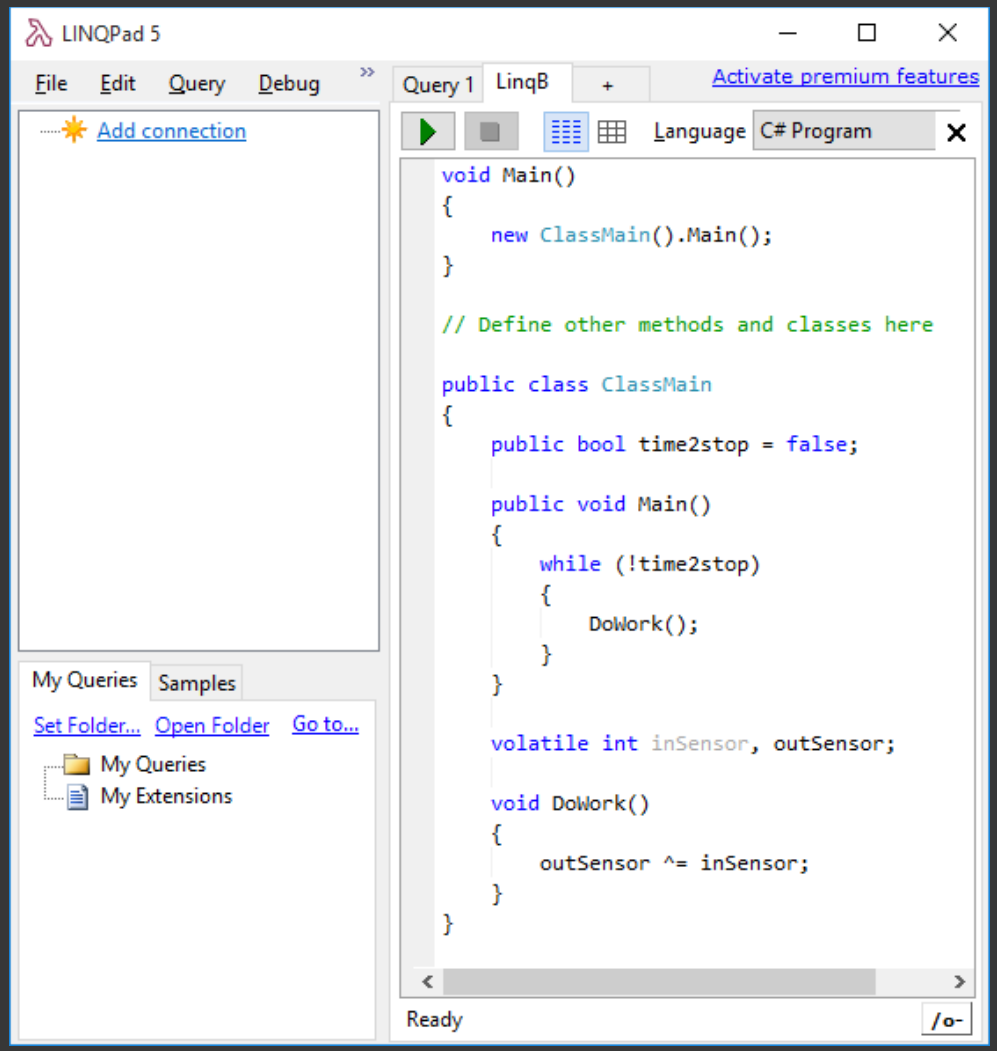
Exercise 0

- **Goal:** Install Debugging Tools for Windows and learn how to set up symbols correctly
- **Patterns:** Incorrect Stack Trace
- **Commands:** .symfix, .reload, k
- \ANETMDA-Dumps\Exercise-0-Download-Setup-WinDbg.pdf

Process Memory Dumps

Exercises PN1 – PN12

Modeling with LINQPad



http://www.linqpad.net/

Exercise PN1

- **Goal:** Learn how to load the correct .NET SOS WinDbg extension and analyze managed space
- **Patterns:** Stack Trace Collection; CLR Thread; Version-Specific Extension; Software Exception; Exception Stack Trace; Managed Code Exception; Managed Stack Trace
- **Commands:** .logopen, .symfix, .reload, ~*k, .load, !pe, ~*e, lmv, .chain, .unload, !analyze -v, !CLRStack, .logclose
- \ANETMDA-Dumps\Exercise-PN1-Analysis-process-dump-ApplicationA.pdf

Exercise PN2

- **Goal:** Compare 64-bit process memory dump from exercise PN1 with 32-bit process memory dump
- **Patterns:** Platform-Specific Debugger
- \ANETMDA-Dumps\Exercise-PN2-Analysis-process-dump-ApplicationA-32.pdf

Exercise PN3

- **Goal:** Learn how to find problem assemblies, modules, classes and methods, disassemble code, analyze CPU spikes
- **Patterns:** Active Thread; Technology-Specific Subtrace; JIT Code; Spiking Thread; Annotated Disassembly
- **Commands:** !analyze -v -hang, !IP2MD, !runaway, .prompt_allow, ~<>s, ~<>k, !U, !DumpMD, !DumpClass, !DumpMT, !DumpModule, !DumpAssembly, !DumpDomain
- \ANETMDA-Dumps\Exercise-PN3-Analysis-process-dump-LINQPadB.pdf

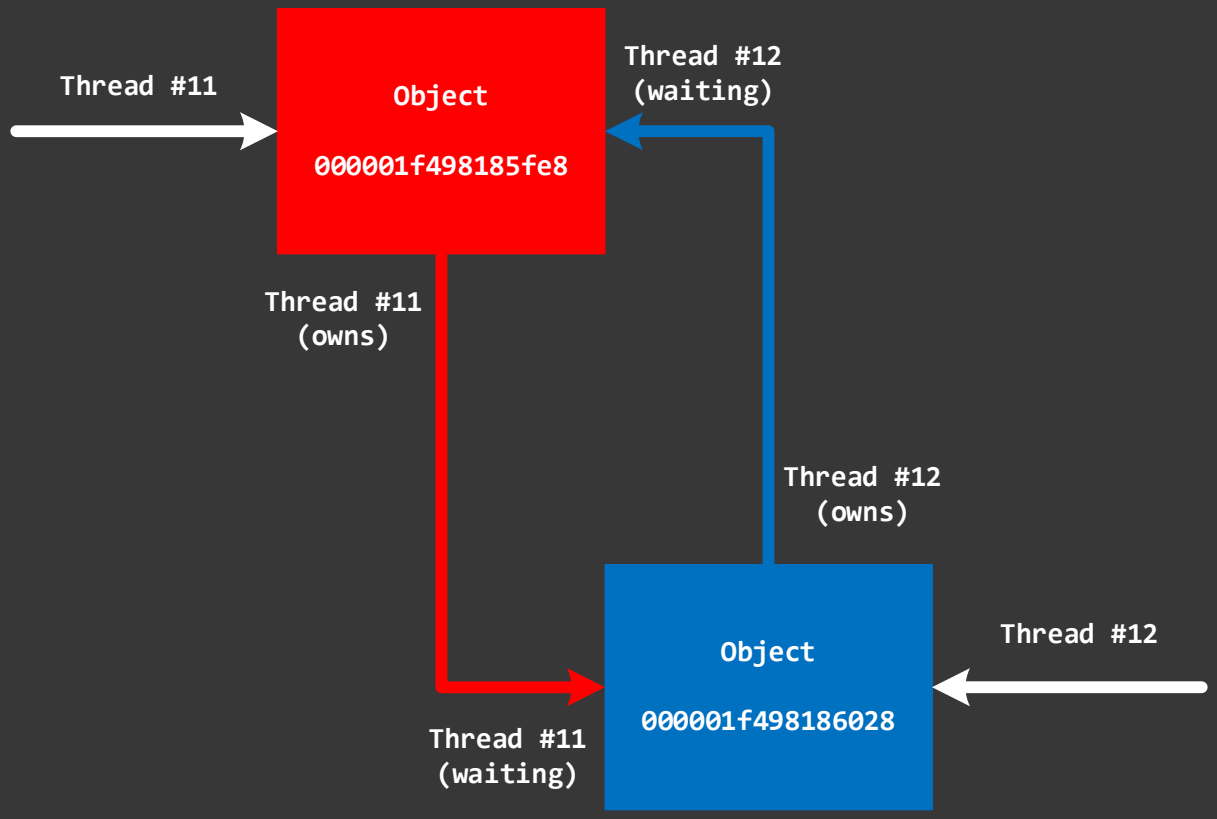
Exercise PN4

- **Goal:** Compare 64-bit process memory dump from exercise PN3 with 32-bit process memory dump
- \ANETMDA-Dumps\Exercise-PN4-Analysis-process-dump-LINQPadB-32.pdf

Exercise PN5

- **Goal:** Learn how to recognize and analyze deadlocks using SOS(EX), execution residue, handled exceptions, dump object references
- **Patterns:** Special Thread; Wait Chain; Deadlock; Execution Residue (user space); Hidden Exception (user space); Coincidental Symbolic Information; Caller-n-Callee
- **Commands:** ~*kL, !Threads, !syncblk, !DumpObj, ub, dp, !dlk, !DumpStack, !teb, dpS
- \ANETMDA-Dumps\Exercise-PN5-Analysis-process-dump-LINQPadC.pdf

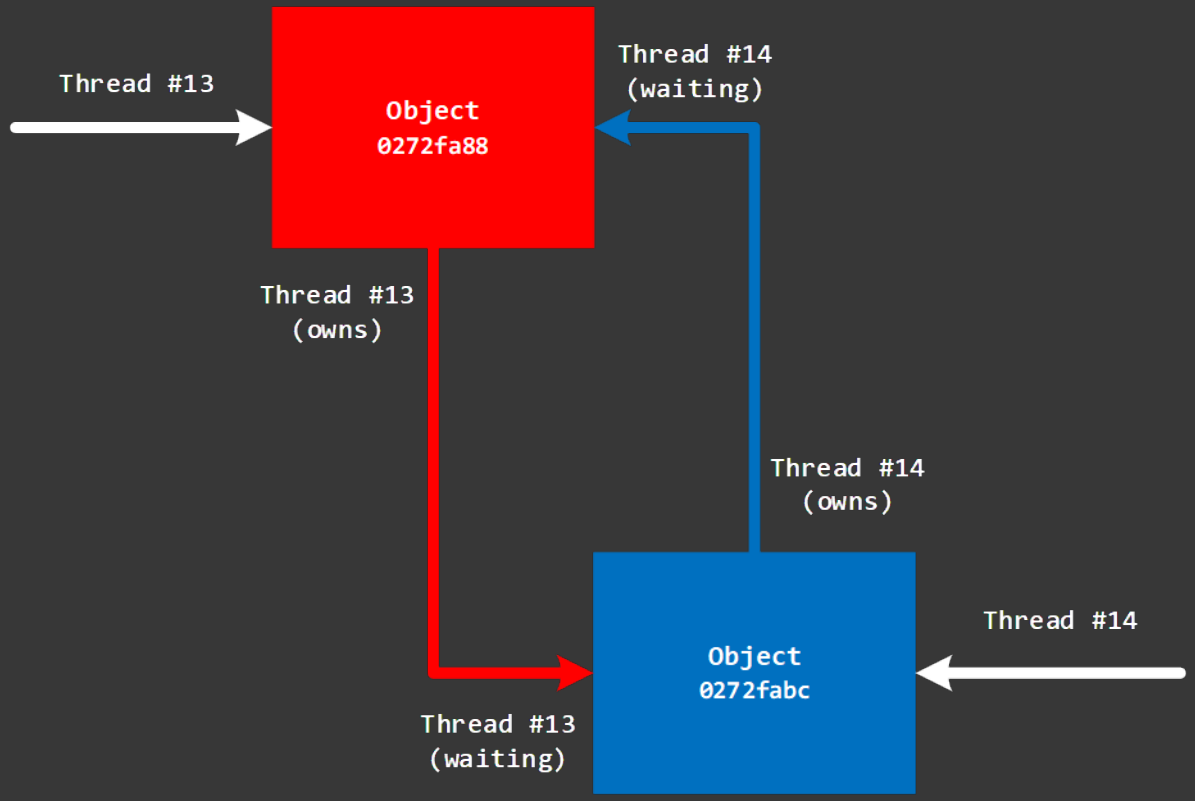
Deadlock



Exercise PN6

- **Goal:** Compare 64-bit process memory dump from exercise PN5 with 32-bit process memory dump
- **Patterns:** Execution Residue (managed space); Hidden Exception (managed space), Handled Exception
- **Commands:** !DumpStackObjects
- \ANETMDA-Dumps\Exercise-PN6-Analysis-process-dump-LINQPadC-32.pdf

Deadlock (x86)



Exercise PN7

- **Goal:** Learn how to analyze multiple managed exceptions
- **Patterns:** Managed Stack Trace Collection; Multiple Exceptions; Nested Exceptions; NULL Pointer
- \ANETMDA-Dumps\Exercise-PN7-Analysis-process-dump-ApplicationD.pdf

Exercise PN8

- **Goal:** Compare 64-bit process memory dump from exercise PN7 with 32-bit process memory dump
- \ANETMDA-Dumps\Exercise-PN8-Analysis-process-dump-ApplicationD-32.pdf

Exercise PN9

- **Goal:** Learn how to diagnose heap and handle leaks
- **Patterns:** Handle Leak; Memory Leak
- **Commands:** !heap, !address, !DumpHeap, ?, !eeheap, !GCHandles, !FinalizeQueue, !handle, .cxr
- \ANETMDA-Dumps\Exercise-PN9-Analysis-process-dump-LINQPadD.pdf

Exercise PN10

- **Goal:** Compare 64-bit process memory dump from exercise PN9 with 32-bit process memory dump
- \ANETMDA-Dumps\Exercise-PN9-Analysis-process-dump-LINQPadD-32.pdf

Exercise PN11

- **Goal:** Learn how to recognize and analyze heap corruption
- **Patterns:** Invalid Pointer; Regular Data; Managed Heap Corruption
- **Commands:** .formats, !VerifyHeap
- \ANETMDA-Dumps\Exercise-PN11-Analysis-process-dump-LINQPadE.pdf

Exercise PN12

- **Goal:** Compare 64-bit process memory dump from exercise PN11 with 32-bit process memory dump
- \ANETMDA-Dumps\Exercise-PN12-Analysis-process-dump-LINQPadE-32.pdf

Pattern Links

CLR Thread
Managed Code Exception
Nested Exceptions
Mixed Exception
Memory Leak
JIT Code
Managed Stack Trace
Multiple Exceptions
Version-Specific Extension
Caller-n-Callee
Hidden Exception

Deadlock
Duplicate Extension
Stack Trace Collection
Dynamic Memory Corruption
Special Thread
Execution Residue
Handled Exception
Annotated Disassembly
Technology-Specific Subtrace
Wait Chain
Object Distribution Anomaly

CLR-related and managed

Incorrect Stack Trace Execution Residue
NULL Pointer Handle Leak Exception Stack Trace
Software Exception Platform-Specific Debugger
Spiking Thread Hidden Exception Regular Data
Coincidental Symbolic Information

Unmanaged user space

SOS Checklist

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

Resources

- WinDbg Help / WinDbg.org (quick links) / DumpAnalysis.org
- C# 7.0 Pocket Reference
- CLR via C#, Fourth Edition
- Advanced .NET Debugging
- Debugging Microsoft .NET 2.0 Applications
- Shared Source CLI 2.0 Internals
- Accelerated Windows Memory Dump Analysis, 4th edition
- Memory Dump Analysis Anthology (Volumes 1 – 10)

Q&A

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

Thank you for attendance!