Complete
Crash and Hang
Memory Dump Analysis

Fundamentals

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Memory Dump Analysis Services

Prerequisites

To Be Discussed Later

We use these boxes to introduce useful vocabulary to be discussed in later slides

Working knowledge of:

- WinDbg (installation, symbols)
- Basic user process dump analysis
- Basic kernel memory dump analysis

Agenda (Summary)

- Basics
- Patterns
- Exercise
- Guide

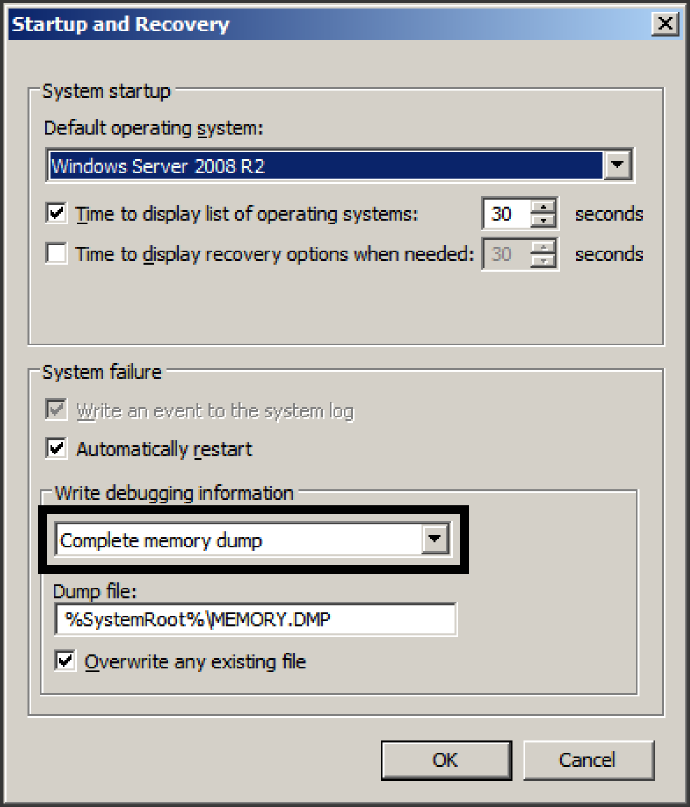
Agenda (Basics)

- Dump generation
- Memory spaces
- Major challenges
- Common commands

Dump Generation

To Be Discussed Later
Truncated Dump pattern Manual Dump pattern

- Control Panel \ System \ Advanced system settings \ Startup and Recovery
- Page file size should be greater than the amount of physical memory by a few MB
- For small system partitions or virtual disk systems: DedicatedDumpFile (KB969028)



Startup and Recovery

System startup

Default operating system: Windows Server 2008 R2

[✓] Time to display list of operating systems: 30 seconds

[ ] Time to display recovery options when needed: 30 seconds

System failure

[✓] Write an event to the system log

[✓] Automatically restart

Write debugging information

Complete memory dump

Dump file: %SystemRoot%\MEMORY.DMP

[✓] Overwrite any existing file

Troubleshooting note:

HKLM \ SYSTEM \ CurrentControlSet \ Control \ CrashControl
CrashDumpEnabled = 1 (DWORD)

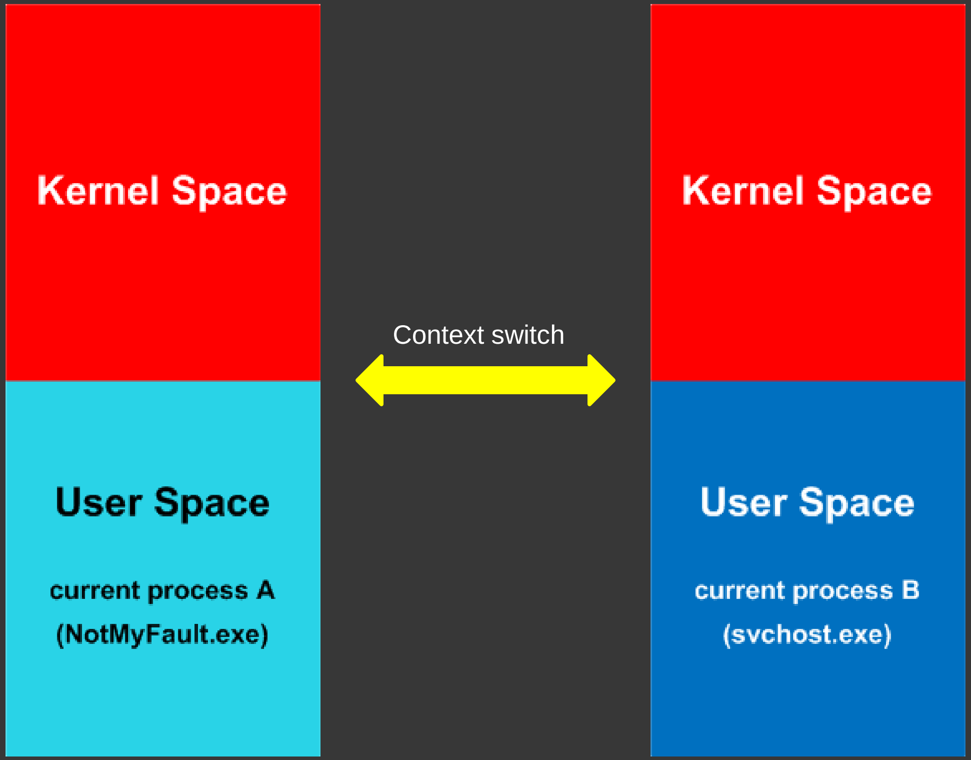
Memory Spaces

To Be Discussed Later

WinDbg command to switch to a different process context:

.process

- Complete memory == Physical memory
- We always see the current process space



Major Challenges

To Be Discussed Later

WinDbg extension command to dump all stack traces:

!process 0 ff

- Vast memory space to search
- Multiple processes (user spaces) to examine
- User space view needs to be correct when we examine another thread
- Huge file size (x64)

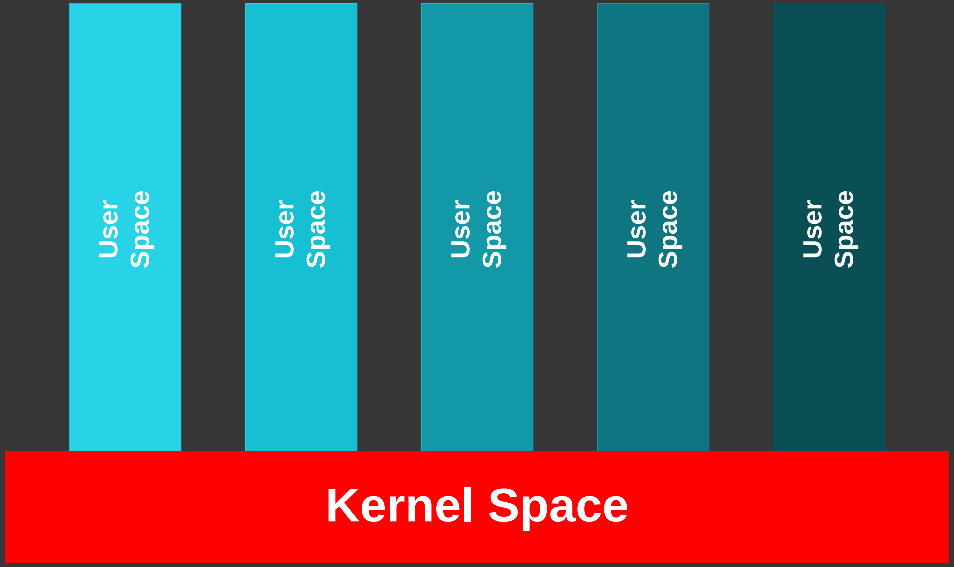
To Be Discussed Later
Wait Chain patterns

Fiber Bundles

The name borrowed from mathematics (topology)

Problem: mild freeze of a 64GB memory system

Solution: dump domain specific processes and generate a kernel memory dump



Common Commands

- **.logopen <file>**
  Opens a log file to save all subsequent output

- View commands
  Dump everything or selected processes and threads (context changes automatically)

- Switch commands
  Switch to a specific process or thread for a fine-grain analysis

View Commands

- **!process 0 3f**
  Lists all processes (including times, environment, modules) and their thread stack traces
- **!process 0 1f**
  The same as the previous command but without PEB information (more secure)
- **!process <address> 3f or !process <address> 1f**
  The same as the previous commands but only for an individual process
- **!thread <address> 1f**
  Shows thread information and stack trace
- **!thread <address> 16**
  The same as the previous command but shows the first 3 parameters for every function

Switch Commands

To Be Discussed Later

x86 stack trace from WOW64 process:

.thread /w

- **.process /r /p <address>**

  Switches to a specified process. Its context becomes current. Reloads symbol files for user space. Now we can use commands like !cs

```
0: kd> .process /r /p fffffa80044d8b30
Implicit process is now fffffa80`044d8b30
Loading User Symbols
.................................
```

- **.thread <address>**

  Switches to a specified thread. Assumes the current process context

  Now we can use commands like k*

- **.thread /r /p <address>**

  The same as the previous command but makes the thread process context current and reloads symbol files for user space:

```
0: kd> .thread /r /p fffffa80051b7060
Implicit thread is now fffffa80`051b7060
Implicit process is now fffffa80`044d8b30
Loading User Symbols
.................................
```

Agenda (Patterns)

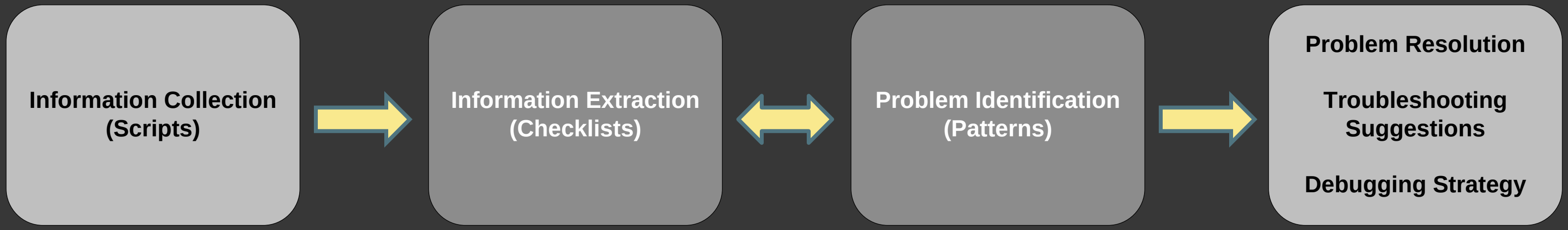
- Pattern-driven analysis
- Pattern classification
- Pattern examples
- Common mistakes

Pattern-driven Analysis

To Be Discussed Later

CARE
Crash Analysis Report Environment

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


Information Collection (Scripts)
Information Extraction (Checklists)
Problem Identification (Patterns)
Problem Resolution
Troubleshooting Suggestions
Debugging Strategy

Note: we do not discuss BSOD crashes here as most of the time kernel memory dumps are sufficient for analysis

CARE System

CARE means **C**rash **A**nalysis **R**eport **E**nvironment
It includes a pattern-driven debugger log analyzer and standards for structured audience-driven reports

Research Prototype:

http://www.dumpanalysis.org/care

Phase 1: Log collection (currently)

Phase 2: Beta version (end of 2010)

Phase 3: Commercial version (2011)

Pattern Classification

- Blocked threads
- Wait chains
- Resource consumption
- Corruption signs
- Special processes

Example: Blocked Thread

```
THREAD fffffa800451db60  Cid 07f4.0b8c  Teb: 000007fffffd6000 Win32Thread: fffff900c27c0c30 WAIT: (WrUserRequest) UserMode Non-
      Alertable
           fffffa8004e501e0  SynchronizationEvent
       Not impersonating
       DeviceMap                 fffff8a001e84c00
       Owning Process            fffffa8004514630       Image:         ApplicationA.exe
       [...]
       Stack Init fffff88005b7fdb0 Current fffff88005b7f870
       Base fffff88005b80000 Limit fffff88005b77000 Call 0
       Priority 11 BasePriority 8 UnusualBoost 0 ForegroundBoost 2 IoPriority 2 PagePriority 5
       Child-SP          RetAddr           Call Site
       fffff880`05b7f8b0 fffff800`01a93992 nt!KiSwapContext+0x7a
       fffff880`05b7f9f0 fffff800`01a95cff nt!KiCommitThreadWait+0x1d2
       fffff880`05b7fa80 fffff960`0011b557 nt!KeWaitForSingleObject+0x19f
       fffff880`05b7fb20 fffff960`0011b5f1 win32k!xxxRealSleepThread+0x257
       fffff880`05b7fbc0 fffff960`0012e22e win32k!xxxSleepThread+0x59
       fffff880`05b7fbf0 fffff800`01a8b993 win32k!NtUserWaitMessage+0x46
       fffff880`05b7fc20 00000000`775cbf5a nt!KiSystemServiceCopyEnd+0x13 (TrapFrame @ fffff880`05b7fc20)
       00000000`022ff7c8 00000000`775d7214 USER32!ZwUserWaitMessage+0xa
       00000000`022ff7d0 00000000`775d74a5 USER32!DialogBox2+0x274
       00000000`022ff860 00000000`776227f0 USER32!InternalDialogBox+0x135
       00000000`022ff8c0 00000000`77621ae5 USER32!SoftModalMessageBox+0x9b4
       00000000`022ff9f0 00000000`7762133b USER32!MessageBoxWorker+0x31d
       00000000`022ffbb0 00000000`77621232 USER32!MessageBoxTimeoutW+0xb3
   >>> 00000000`022ffc80 00000001`3f3c1089 USER32!MessageBoxW+0x4e
       00000000`022ffcc0 00000001`3f3c11fb ApplicationA+0x1089
       00000000`022ffcf0 00000001`3f3c12a5 ApplicationA+0x11fb
       00000000`022ffd20 00000000`776cf56d ApplicationA+0x12a5
       00000000`022ffd50 00000000`77803281 kernel32!BaseThreadInitThunk+0xd
       00000000`022ffd80 00000000`00000000 ntdll!RtlUserThreadStart+0x1d
```

To Be Discussed Later

Complete Dump Analysis Exercise

Example: Wait Chain

To Be Discussed Later

Complete Dump Analysis Exercise

```
THREAD fffffa8004562b60  Cid 0b34.0858  Teb: 000007fffffae000 Win32Thread: 0000000000000000 WAIT: (UserRequest) UserMode Non-
       Alertable
>>>         fffffa8004b96ce0  Mutant - owning thread fffffa8004523b60
        Not impersonating
        DeviceMap                 fffff8a001e84c00
        Owning Process            fffffa8005400b30       Image:         ApplicationC.exe
        Attached Process          N/A            Image:         N/A
        Wait Start TickCount      36004          Ticks: 4286 (0:00:01:06.862)
        Context Switch Count      2
        UserTime                  00:00:00.000
        KernelTime                00:00:00.000
        Win32 Start Address ApplicationC (0x000000013f7012a0)
        Stack Init fffff88005b1ddb0 Current fffff88005b1d900
        Base fffff88005b1e000 Limit fffff88005b18000 Call 0
        Priority 11 BasePriority 8 UnusualBoost 0 ForegroundBoost 2 IoPriority 2 PagePriority 5
        Child-SP          RetAddr           Call Site
        fffff880`05b1d940 fffff800`01a93992 nt!KiSwapContext+0x7a
        fffff880`05b1da80 fffff800`01a95cff nt!KiCommitThreadWait+0x1d2
        fffff880`05b1db10 fffff800`01d871d2 nt!KeWaitForSingleObject+0x19f
        fffff880`05b1dbb0 fffff800`01a8b993 nt!NtWaitForSingleObject+0xb2
        fffff880`05b1dc20 00000000`7781fefa nt!KiSystemServiceCopyEnd+0x13 (TrapFrame @ fffff880`05b1dc20)
        00000000`00e2f658 000007fe`fda910ac ntdll!NtWaitForSingleObject+0xa
        00000000`00e2f660 00000001`3f70112e KERNELBASE!WaitForSingleObjectEx+0x79
        00000000`00e2f700 00000001`3f70128b ApplicationC+0x112e
        00000000`00e2f730 00000001`3f701335 ApplicationC+0x128b
        00000000`00e2f760 00000000`776cf56d ApplicationC+0x1335
        00000000`00e2f790 00000000`77803281 kernel32!BaseThreadInitThunk+0xd
        00000000`00e2f7c0 00000000`00000000 ntdll!RtlUserThreadStart+0x1d
```

Example: Consumption

To Be Discussed Later

Complete Dump Analysis Exercise

```
1: kd> !vm

*** Virtual Memory Usage ***
       Physical Memory:     1031581 (   4126324 Kb)
       Page File: \??\C:\pagefile.sys
         Current:   4433524 Kb  Free Space:   4433520 Kb
         Minimum:   4433524 Kb  Maximum:     12378972 Kb
       Available Pages:      817652 (   3270608 Kb)
       ResAvail Pages:       965229 (   3860916 Kb)
       Locked IO Pages:           0 (         0 Kb)
       Free System PTEs:   33555714 ( 134222856 Kb)
       Modified Pages:        15794 (     63176 Kb)
       Modified PF Pages:     15793 (     63172 Kb)
       NonPagedPool Usage: 88079121 ( 352316484 Kb)
       NonPagedPoolNx Usage:  12885 (     51540 Kb)
       NonPagedPool Max:     764094 (   3056376 Kb)
>>>    ********** Excessive NonPaged Pool Usage *****
       PagedPool 0 Usage:     35435 (    141740 Kb)
       PagedPool 1 Usage:      3620 (     14480 Kb)
       PagedPool 2 Usage:       573 (      2292 Kb)
       PagedPool 3 Usage:       535 (      2140 Kb)
       PagedPool 4 Usage:       538 (      2152 Kb)
       PagedPool Usage:       40701 (    162804 Kb)
       PagedPool Maximum:  33554432 ( 134217728 Kb)
       Session Commit:         9309 (     37236 Kb)
       Shared Commit:          6460 (     25840 Kb)
       Special Pool:              0 (         0 Kb)
       Shared Process:         5760 (     23040 Kb)
       PagedPool Commit:      40765 (    163060 Kb)
       Driver Commit:          2805 (     11220 Kb)
       Committed pages:      212472 (    849888 Kb)
       Commit limit:        2139487 (   8557948 Kb)
```

```
1: kd> !process 0 0
**** NT ACTIVE PROCESS DUMP ****
PROCESS fffffa8003baa890
    SessionId: none  Cid: 0004    Peb: 00000000  ParentCid: 0000
    DirBase: 00187000  ObjectTable: fffff8a000001a80  HandleCount: 558.
    Image: System

PROCESS fffffa8004277870
    SessionId: none  Cid: 011c    Peb: 7fffffdf000  ParentCid: 0004
    DirBase: 133579000  ObjectTable: fffff8a00000f3d0  HandleCount:  35.
    Image: smss.exe

PROCESS fffffa80048f3950
    SessionId: 0  Cid: 016c    Peb: 7fffffdf000  ParentCid: 0154
    DirBase: 128628000  ObjectTable: fffff8a001d62f90  HandleCount: 387.
    Image: csrss.exe


[...]

PROCESS fffffa800541a060
    SessionId: 1  Cid: 0b94    Peb: 7fffffde000  ParentCid: 06ac
>>> DirBase: a6ba9000  ObjectTable: fffff8a0098efaf0  HandleCount:
       20013.
    Image: ApplicationE.exe

[...]
```

Example: Corruption

To Be Discussed Later

Complete Dump Analysis Exercise

```
 THREAD fffffa8004514060  Cid 0abc.087c  Teb: 000007fffffae000 Win32Thread: 0000000000000000 WAIT: (UserRequest) UserMode
       Alertable
            fffffa800518fb30  ProcessObject
        [...]
        Child-SP          RetAddr           Call Site
        fffff880`05a6c940 fffff800`01a93992 nt!KiSwapContext+0x7a
        fffff880`05a6ca80 fffff800`01a95cff nt!KiCommitThreadWait+0x1d2
        fffff880`05a6cb10 fffff800`01d871d2 nt!KeWaitForSingleObject+0x19f
        fffff880`05a6cbb0 fffff800`01a8b993 nt!NtWaitForSingleObject+0xb2
        fffff880`05a6cc20 00000000`7781fefa nt!KiSystemServiceCopyEnd+0x13 (TrapFrame @ fffff880`05a6cc20)
        00000000`00dde928 00000000`77895ce2 ntdll!NtWaitForSingleObject+0xa
        00000000`00dde930 00000000`77895e85 ntdll!RtlReportExceptionEx+0x1d2
        00000000`00ddea20 00000000`77895eea ntdll!RtlReportException+0xb5
        00000000`00ddeaa0 00000000`77896d25 ntdll!RtlpTerminateFailureFilter+0x1a
        00000000`00ddead0 00000000`777e5148 ntdll!RtlReportCriticalFailure+0x96
        00000000`00ddeb00 00000000`7780554d ntdll!_C_specific_handler+0x8c
        00000000`00ddeb70 00000000`777e5d1c ntdll!RtlpExecuteHandlerForException+0xd
        00000000`00ddeba0 00000000`777e62ee ntdll!RtlDispatchException+0x3cb
        00000000`00ddf280 00000000`77896cd2 ntdll!RtlRaiseException+0x221
        00000000`00ddf8c0 00000000`77897396 ntdll!RtlReportCriticalFailure+0x62
        00000000`00ddf990 00000000`778986c2 ntdll!RtlpReportHeapFailure+0x26
        00000000`00ddf9c0 00000000`7789a0c4 ntdll!RtlpHeapHandleError+0x12
        00000000`00ddf9f0 00000000`7783d1cd ntdll!RtlpLogHeapFailure+0xa4
        00000000`00ddfa20 00000000`776d2c7a ntdll! ?? ::FNODOBFM::`string'+0x123b4
>>>     00000000`00ddfaa0 00000001`3fa71274 kernel32!HeapFree+0xa
        00000000`00ddfad0 00000001`3fa710c3 ApplicationD+0x1274
        00000000`00ddfb00 00000001`3fa71303 ApplicationD+0x10c3
        00000000`00ddfb30 00000001`3fa713ad ApplicationD+0x1303
        00000000`00ddfb60 00000000`776cf56d ApplicationD+0x13ad
        00000000`00ddfb90 00000000`77803281 kernel32!BaseThreadInitThunk+0xd
        00000000`00ddfbc0 00000000`00000000 ntdll!RtlUserThreadStart+0x1d
```

Example: Special Process

```
1: kd> !vm

[...]

         0744 svchost.exe      19725 (     78900 Kb)
         06ac explorer.exe     11444 (     45776 Kb)
         0920 iexplore.exe      8828 (     35312 Kb)
         0354 svchost.exe       5589 (     22356 Kb)
         040c audiodg.exe       4003 (     16012 Kb)
         0334 svchost.exe       3852 (     15408 Kb)
         04e4 spoolsv.exe       3230 (     12920 Kb)
         012c svchost.exe       2802 (     11208 Kb)
         0168 iexplore.exe      2106 (      8424 Kb)
         0384 svchost.exe       2090 (      8360 Kb)
         042c svchost.exe       1938 (      7752 Kb)
         0218 lsass.exe         1314 (      5256 Kb)
         03d4 svchost.exe       1128 (      4512 Kb)
>>>      0a78 WerFault.exe      1107 (      4428 Kb)
         0210 services.exe      1106 (      4424 Kb)
         0288 svchost.exe        980 (      3920 Kb)
         02d8 svchost.exe        891 (      3564 Kb)
         0438 msdtc.exe          851 (      3404 Kb)
         071c mscorsvw.exe       821 (      3284 Kb)
         0378 taskhost.exe       795 (      3180 Kb)
         01a8 psxss.exe          685 (      2740 Kb)
         08a0 jusched.exe        667 (      2668 Kb)
         09e0 jucheck.exe        621 (      2484 Kb)
         0828 mscorsvw.exe       600 (      2400 Kb)
         0538 mdm.exe            595 (      2380 Kb)
         0220 lsm.exe            595 (      2380 Kb)
[...]
```

To Be Discussed Later

Complete Dump Analysis Exercise

Common Mistakes

- Not switching to the appropriate context
- Not looking at full stack traces
- Not looking at all stack traces
- Not using checklists
- Not looking past the first found evidence

Note: Listing both x86 and x64 stack traces

http://www.dumpanalysis.org/blog/index.php/2010/02/09/complete-stack-traces-from-x64-system/

Agenda (Exercise)

- Run processes that model abnormal behavior
- Generate a complete memory dump
- Analyze the memory dump

Note: Due to security concerns I'm not making a complete memory dump downloadable. You can generate your own complete memory dump after downloading and running model applications

Exercise: Run Processes

These processes model specific patterns:

ApplicationA , ApplicationB, ApplicationC, ApplicationD, ApplicationE
For demonstration I run x64 versions plus x86 version of ApplicationA

Note: Run applications in alphabetical order

Can be downloaded from this location:
www.DumpAnalysis.com/Training/FreeWebinars/CMDA-Examples.zip
There are x86 and x64 versions

Exercise: Force A Dump

The system is x64 Windows Server R2

I used NotMyFault SysInternals tool

Note: Wait at least 10 seconds after running model applications to have them properly initialize their dependencies

Exercise: Dump Analysis

Now I switch to a WinDbg session...

Agenda (Guide)

- Patterns related to complete memory dumps
- Pattern cooperation case studies from complete memory dumps

Pattern Examples

Some patterns that are relevant to complete memory dumps (not a complete list):

- Incorrect Symbolic Information
- Semantic Split
- Paged Out Data
- Wait Chain (thread objects)
- Wait Chain (LPC/ALPC)
- Last Error Collection
- Suspended Thread
- Coupled Processes (strong)
- Truncated Dump
- Spiking Thread
- Deadlock (critical sections)
- No System Dumps
- Message Box
- Inconsistent Dump
- Wait Chain (critical sections)
- Wait Chain (process objects)
- Special Process
- Historical Information
- Stack Trace Collection
- Insufficient Memory (handle leak)
- Main Thread
- Suspended Thread

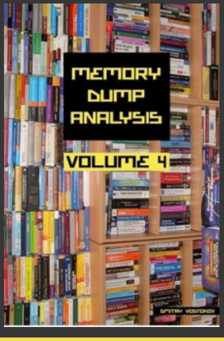
Case Studies

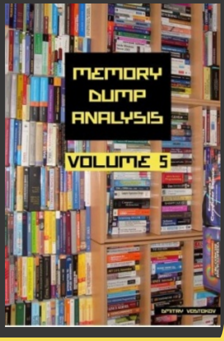
17 pattern interaction case studies using complete memory dumps:

http://www.dumpanalysis.org/blog/index.php/category/complete-memory-dump-analysis/

Resources

- WinDbg Help
- DumpAnalysis.org
- Windows Internals, 5th ed.
- Advanced Windows Debugging
- Memory Dump Analysis Anthology



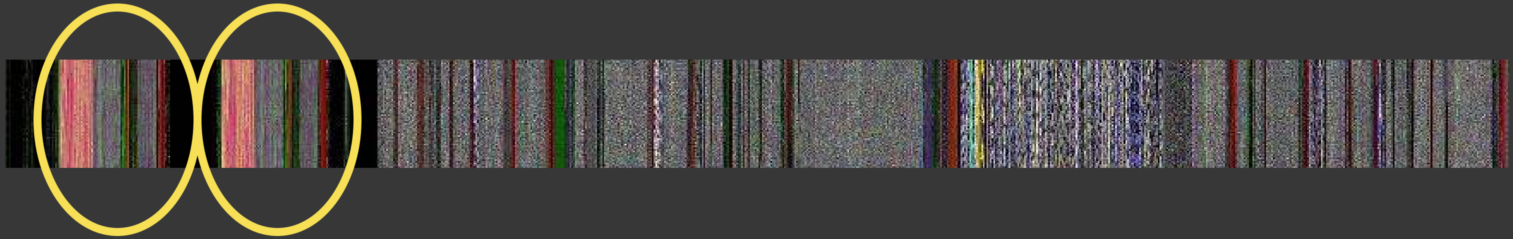


Forthcoming, 2010

Q&A

Question:

Why do we have 2 identical regions in the following image?



Please send your answer using the contact form on DumpAnalysis.com

Q&A

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

Thank you for attendance!