

Complete
Crash and Hang
Memory Dump Analysis

Fundamentals

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Memory Dump Analysis Services

Prerequisites

Working knowledge of:

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

Agenda (Summary)

- Basics
- Patterns
- Exercise
- Guide

Agenda (Basics)

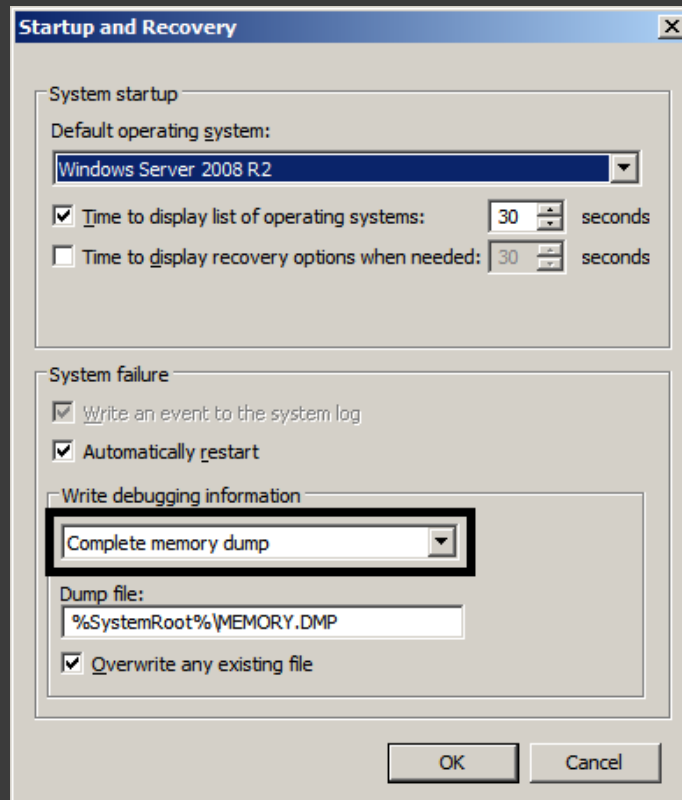
- Dump generation
- Memory spaces
- Major challenges
- Common commands

To Be Discussed Later

Truncated Dump pattern
Manual Dump pattern

Dump Generation

- 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](#))



Troubleshooting note:

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

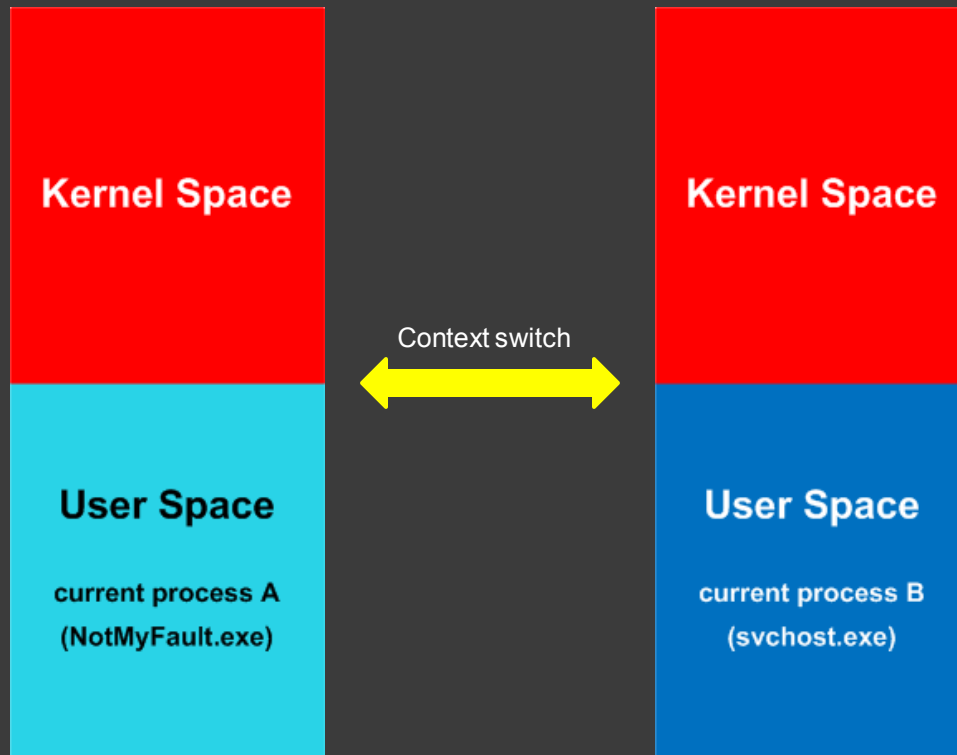
Memory Spaces

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

- 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

WinDbg extension command
to dump all stack traces:

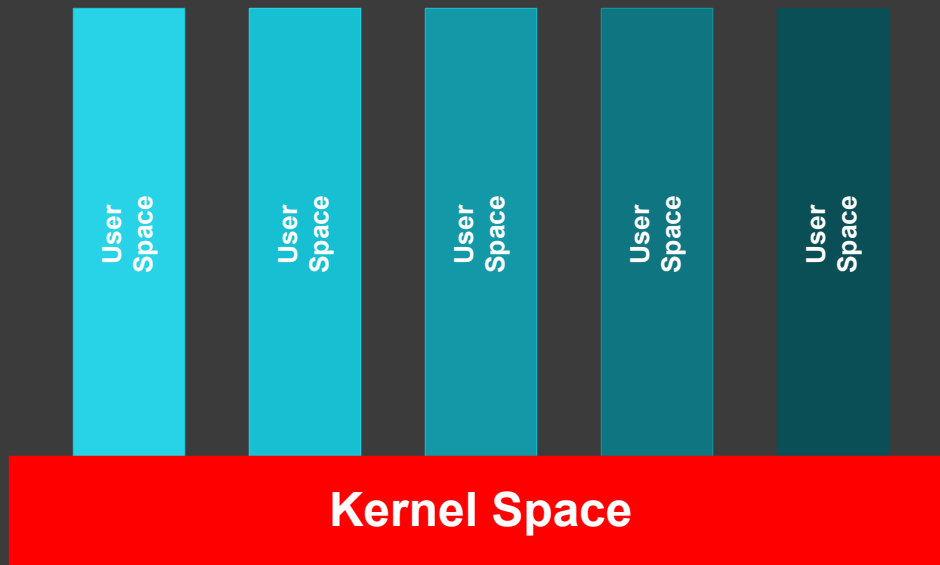
```
!process 0 ff
```

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 ff**
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> ff or !process <address> 1f**
The same as the previous commands but only for an individual process
- ◉ **!thread <address> ff**
Shows thread information and stack trace
- ◉ **!thread <address> f6**
The same as the previous command but shows the first 3 parameters for every function

Switch Commands

- **.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:

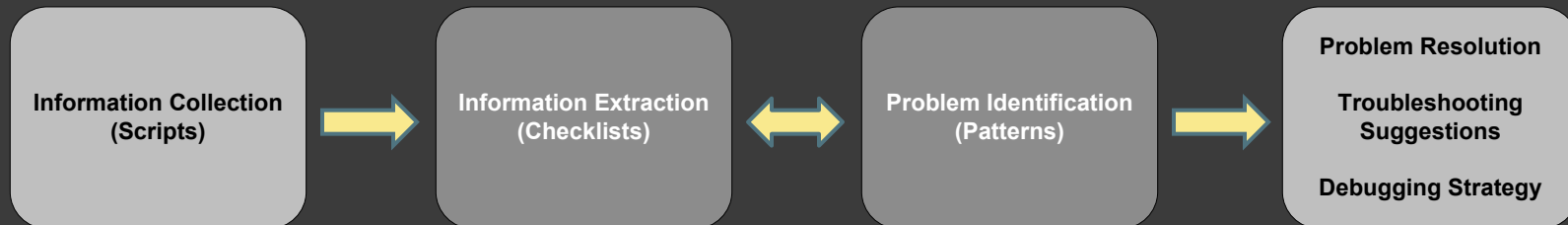
```
0: kd> .thread /r /p fffffa80051b7060
Implicit thread is now fffffa80`051b7060
Implicit process is now fffffa80`044d8b30
Loading User Symbols
.....
```

Agenda (Patterns)

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

Pattern-driven Analysis

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



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`022ffc00 00000001`3f3c11fb ApplicationA+0x1089
00000000`022ffc00 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

```
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 (0x0000000013f7012a0)
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`7781fefaf 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

```
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: 7fffffff000  ParentCid: 0004
DirBase: 133579000  ObjectTable: fffff8a00000f3d0  HandleCount: 35.
Image: smss.exe
```

```
PROCESS fffffa80048f3950
```

```
SessionId: 0  Cid: 016c  Peb: 7fffffff000  ParentCid: 0154
DirBase: 128628000  ObjectTable: fffff8a001d62f90  HandleCount: 387.
Image: csrss.exe
```

```
[...]
```

```
PROCESS fffffa800541a060
```

```
SessionId: 1  Cid: 0b94  Peb: 7fffffffde000  ParentCid: 06ac
>>> DirBase: a6ba9000  ObjectTable: fffff8a0098efaf0  HandleCount: 20013.
Image: ApplicationE.exe
```

```
[...]
```

Example: Corruption

```

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`7781fefaf nt!KiSystemServiceCopyEnd+0x13 (TrapFrame @ fffff880`05a6cc20)
00000000`00dde928 00000000`77895ce2 ntdll!NtWaitForSingleObject+0xa
00000000`00dde930 00000000`77895e85 ntdll!RtlReportExceptionEx+0x1d2
00000000`00dde940 00000000`77895eea ntdll!RtlReportException+0xb5
00000000`00dde950 00000000`77896d25 ntdll!RtlpTerminateFailureFilter+0x1a
00000000`00dde960 00000000`777e5148 ntdll!RtlReportCriticalFailure+0x96
00000000`00dde970 00000000`7780554d ntdll!_C_specific_handler+0x8c
00000000`00dde980 00000000`777e5d1c ntdll!RtlpExecuteHandlerForException+0xd
00000000`00dde990 00000000`777e62ee ntdll!RtlDispatchException+0x3cb
00000000`00dde9a0 00000000`77896cd2 ntdll!RtlRaiseException+0x221
00000000`00dde9b0 00000000`77897396 ntdll!RtlReportCriticalFailure+0x62
00000000`00dde9c0 00000000`778986c2 ntdll!RtlpReportHeapFailure+0x26
00000000`00dde9d0 00000000`7789a0c4 ntdll!RtlpHeapHandleError+0x12
00000000`00dde9e0 00000000`7783d1cd ntdll!RtlpLogHeapFailure+0xa4
00000000`00dde9f0 00000000`776d2c7a ntdll! ?? ::FNODOBFM::`string'+0x123b4
>>> 00000000`00ddf000 00000001`3fa71274 kernel32!HeapFree+0xa
00000000`00ddf010 00000001`3fa710c3 ApplicationD+0x1274
00000000`00ddf020 00000001`3fa71303 ApplicationD+0x10c3
00000000`00ddf030 00000001`3fa713ad ApplicationD+0x1303
00000000`00ddf040 00000000`776cf56d ApplicationD+0x13ad
00000000`00ddf050 00000000`77803281 kernel32!BaseThreadInitThunk+0xd
00000000`00ddf060 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/Webinars/FCMDA-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)

- ① Patterns related to complete memory dumps
- ① 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](#)

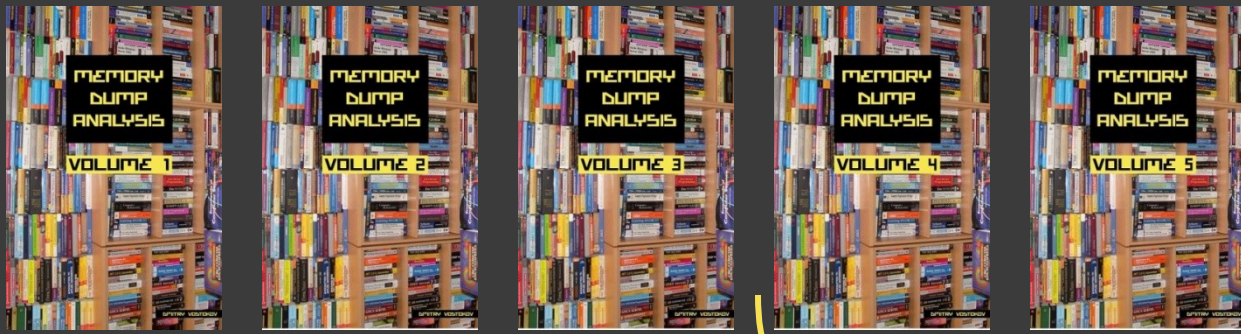
Case Studies

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

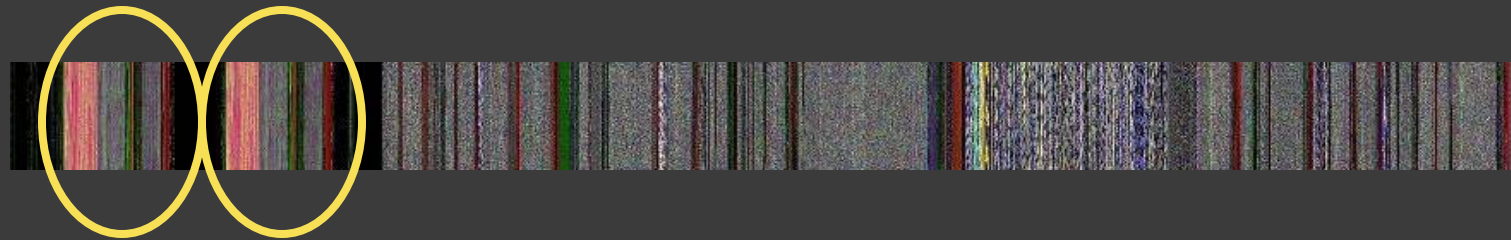


Forthcoming, 2010

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!