#CyberSBC2024

Advanced Forensic Analysis

Ricardo J. Rodríguez
Universidad de Zaragoza (España)

Cybersecurity Summer Bootcamp

LEÓN - 2024

8 al 18 julio de 2024

León, España

Organizado por:

GOBIERNO DE ESPAÑA · MINISTERIO PARA LA TRANSFORMACIÓN DIGITAL Y DE LA FUNCIÓN PÚBLICA · SECRETARÍA DE ESTADO DE DIGITALIZACIÓN E INTELIGENCIA ARTIFICIAL

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$whoami

- **Ricardo J. Rodríguez**
  - PhD on Computer and Systems Engineering
  - Associate Professor (public servant) at the University of Zaragoza
  - **Researcher in cybersecurity issues**, especially in:
    - Program binary analysis
    - Digital forensics (in particular, in memory)
    - Systems security
  - **DisCo research group**
    - RME-DisCo: https://reversea.me
    - Follow us on Twitter and on Telegram! @reverseame
  - **E-mail**: rjrodriguez@unizar.es
    - Feel free to contact me if you have questions after the workshop!
  - **Personal website**: http://www.ricardojrodriguez.es

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Agenda

1. **Introduction**
   - Incident Response
   - Memory forensics
   - Malware
2. **Previous Concepts**
   - Program Structure. Loading Executables into Memory
   - Virtual Memory. Pages and Processes. Issues
3. **Malware Analysis in Memory Forensics**
   - Malware Analysis Phases
   - Malware Analysis Phases in Memory Forensics

Agenda

4. **Collection of Memory Evidence**
   - Memory acquisition
   - Memory Dump Analysis: *Volatility*
   - Detection of Indicators of Compromise with *Volatility*
5. **Advanced Detection of Indicators of Compromise**
   - Unofficial Plugins
6. **Development of Own Analysis Tools**
7. **Methodology for Evidence Analysis in Memory Forensics**

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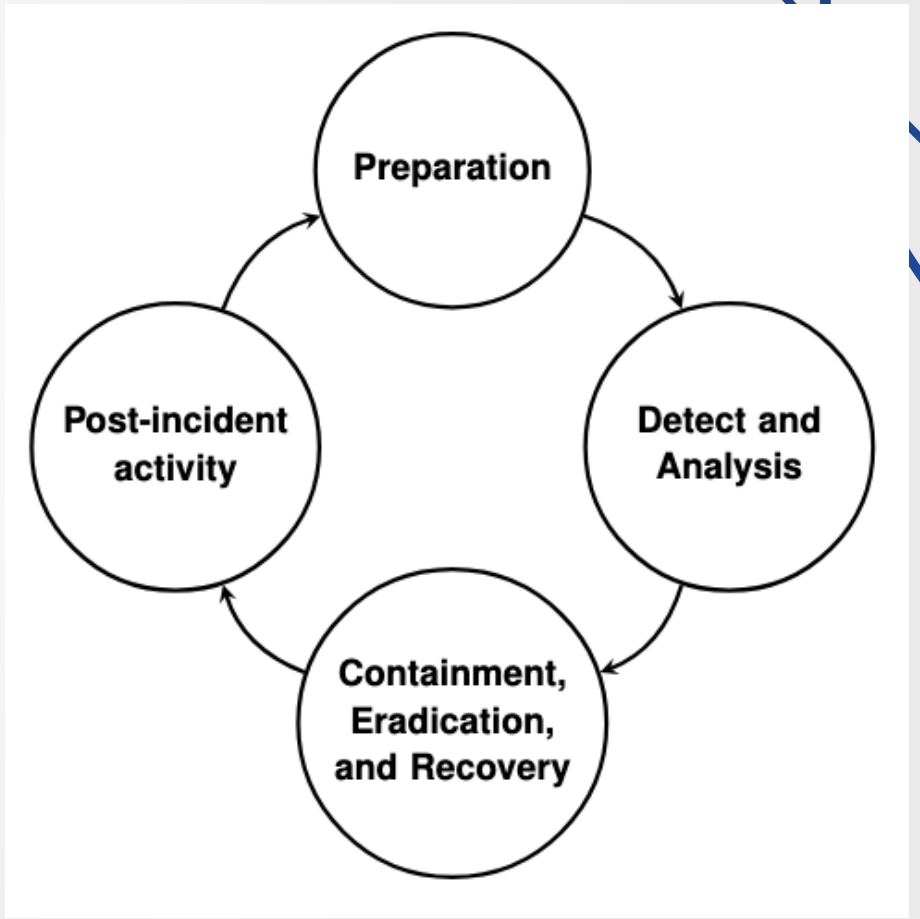
1. Introduction

1. Introduction

Incident Response

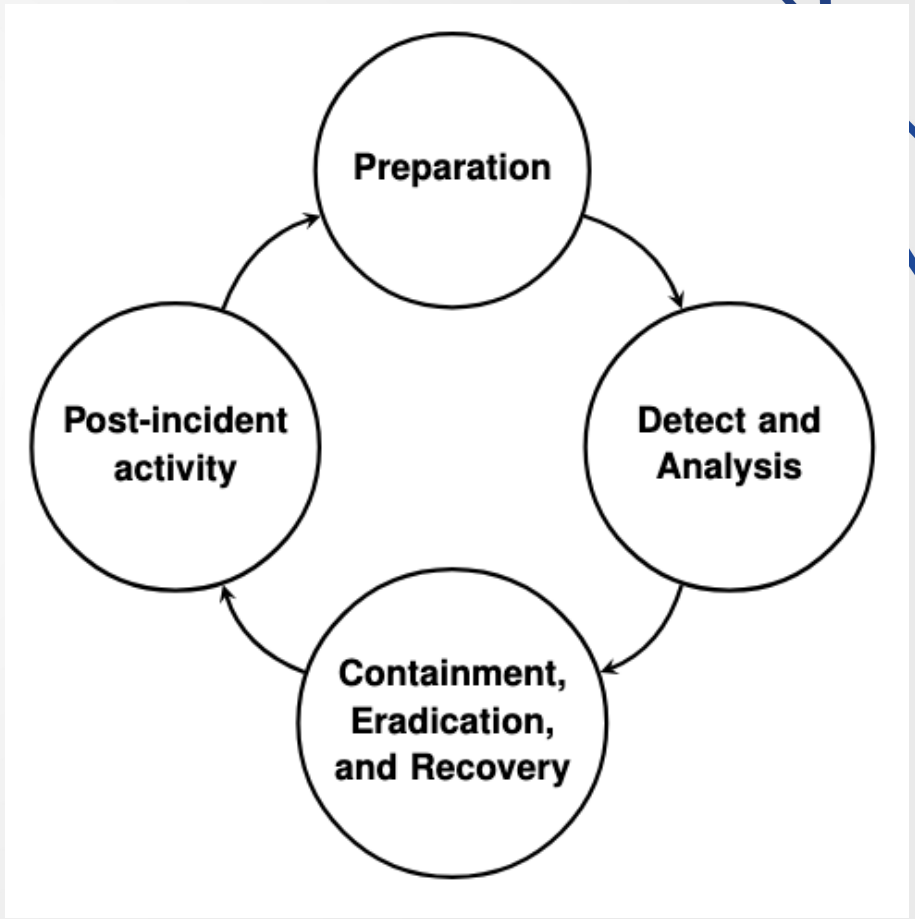
- **Incident response phases (NIST SP 800-61)**
  1. **Preparation**
     - Preparedness for incident management
     - Incident prevention
  2. **Detect and Analysis**
     - Attack vectors
     - Indicators of incidence
     - Sources of precursors and indicators
     - Incident analysis, documentation, prioritization and notification
  3. **Containment, Eradication, and Recovery**
  4. **Post-incident activity**



1. Introduction

Incident Response

- **Incident response phases (NIST SP 800-61)**
  1. **Preparation**
  2. **Detect and Analysis**
  3. **Containment, Eradication, and Recovery**
     - Containment strategies
     - Collection and management of evidence
     - Identification of attackers
     - Eradication and recovery
  4. **Post-incident activity**
     - Learned lessons
     - Use of information collected from the incident
     - Evidence retention



1. Introduction

Incident Response

- **Know what has happened, preserving all the information** related to the incident
- Respond to the well-known 6 W's: *what, who, why, how, when*, and *where*
- **Usual incident**: presence of malicious software (*malware*)
- **Various aspects of forensic analysis**:
  - ***Device forensics***
    - Digital media
    - ***Memory***
  - Forensic analysis of communications

1. Introduction

Memory Forensics

- **Can I use memory forensics to detect malware?**
  - **Yes. And no.**
  - **Problems related to the content available in memory**
    - Page swapping
    - Load on demand (also called *lazy loading*)
    - Page smearing
  - The best would be to use the forensic analysis of digital media **as a complement**
    - That is, that memory forensics is not only what we rely on

1. Introduction

Malware

- ***Malicious software***
  - **Software specially designed to do some kin**
  - **Different types, depending on their functio**
    - They can have several functionalities at the
  - **Lifecycle**
    1. Initial compromise (social engineering atta
    2. Persistence
    3. Communication with C&C servers
    4. Lateral movement
    5. Data exfiltration / malicious activity

Windows Auto-Start Extensibility Points	*Characteristics*					
	Write permissions	**Execution privileges**	**Tracked down in memory forensics†**	**Freshness of system**	**Execution scope**	**Configuration scope**
System persistence mechanisms						
Run keys (HKLM root key)	yes	user	yes	user session	application	system
Run keys (HKCU root key)	no	user	yes	user session	application	user
Startup folder (%ALLUSERSPROFILE%)	yes	user	no	user session	application	system
Startup folder (%APPDATA%)	no	user	no	user session	application	user
Scheduled tasks	yes	any	no	not needed‡	application	system
Services	yes	system	yes	not needed‡	application	system
Program loader abuse						
Image File Execution Options	yes	user	yes	not needed	application	system
Extension hijacking (HKLM root key)	yes	user	yes	not needed	application	system
Extension hijacking (HKCU root key)	no	user	yes	not needed	application	user
Shortcut manipulation	no	user	no	not needed	application	user
COM hijacking (HKLM root key)	yes	any	yes	not needed	system	system
COM hijacking (HKCU root key)	no	user	yes	not needed	system	user
Shim databases	yes	any	yes	not needed	application	system
Application abuse						
Trojanized system binaries	yes	any	no	not needed	system	system
Office add-ins	yes	user	yes	not needed	application	user
Browser helper objects	yes	user	yes	not needed	application	system
System behavior abuse						
Winlogon	yes	user	yes	user session	application	system
DLL hijacking	yes	any	no	not needed	system	system
AppInit DLLs	yes	any	yes	not needed	system	system
Active setup (HKML root key)	yes	user	yes	user session	application	system
Active setup (HKCU root key)	no	user	yes	user session	application	application

†*If the memory is paging to disk, it would be not possible to track down these ASEPs in memory forensics.*
‡*Depends on the trigger conditions defined to launch the program.*

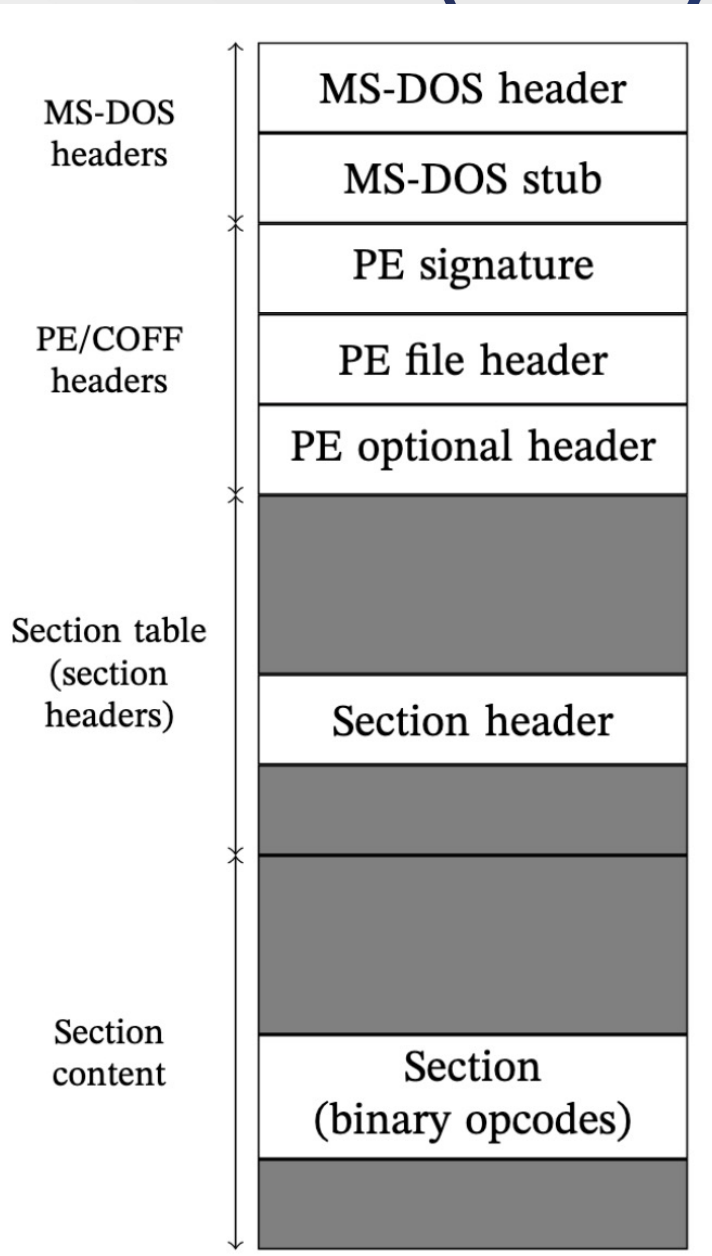
More details: Uroz, D. & Rodríguez, R. J. **Characteristics and Detectability of Windows Auto-Start Extensibility Points in Memory Forensics**. Digital Investigation, 2019, 28, S95-S104, Elsevier. https://doi.org/10.1016/j.diin.2019.01.026

2. Previous Concepts

2. Previous Concepts

Program Structure

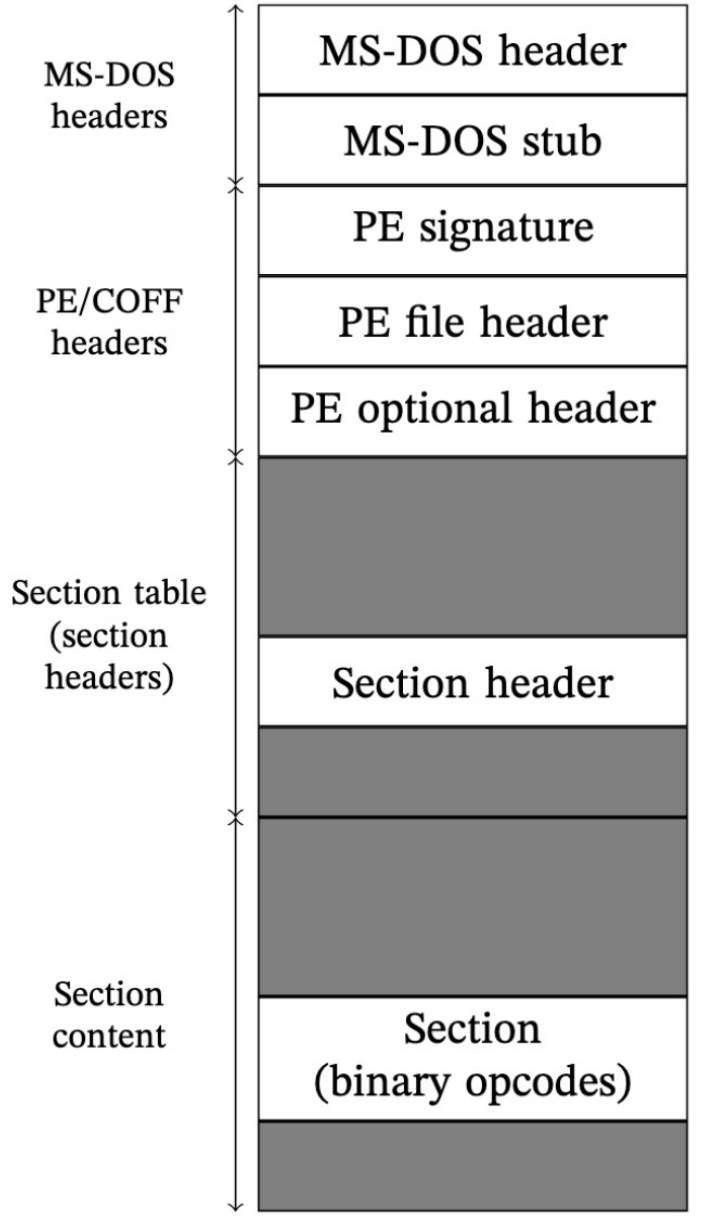
- Since Windows NT 3.1
- **PE: Portable Executable**
  - Data structure defined in WinNT.h (Microsoft Windows SDK)
  - Three parts: MS-DOS headers, PE/COFF headers, Section headers
  - https://docs.microsoft.com/en-us/windows/win32/debug/pe-format
- **MS-DOS headers**
  - First 64 bytes
  - e_magic: MZ (Mark Zbikowski)
  - e_lfanew: offset to PE/COFF headers



2. Previous Concepts

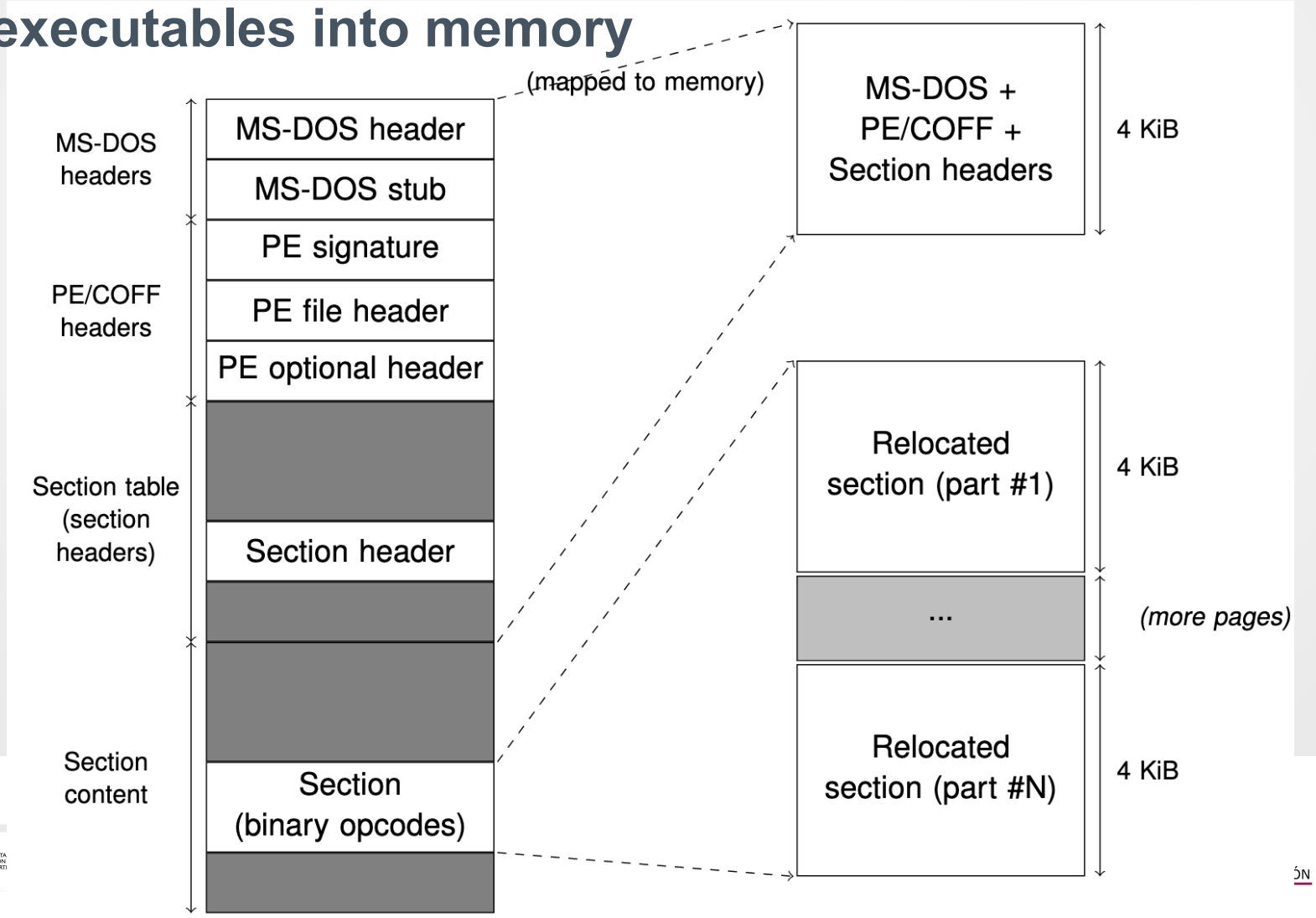
Program Structure

- **PE/COFF headers**
  - **PE signature** (“PE\0\0”)
  - **PE file header**
    - Define target machine, number of sections, characteristics, etc.
  - **PE optional header**
    - Optional for some object files
    - Fields of interest: ImageBase, BaseOfCode, AddressOfEntryPoint
    - DataDirectory: Directory table. Each entry has a meaning
- **Section headers**
  - IMAGE_SECTION_HEADER structure
  - Common sections: .text/.code, .rdata/.rodata, .data, .reloc, …



2. Previous Concepts

Loading executables into memory



2. Previous Concepts

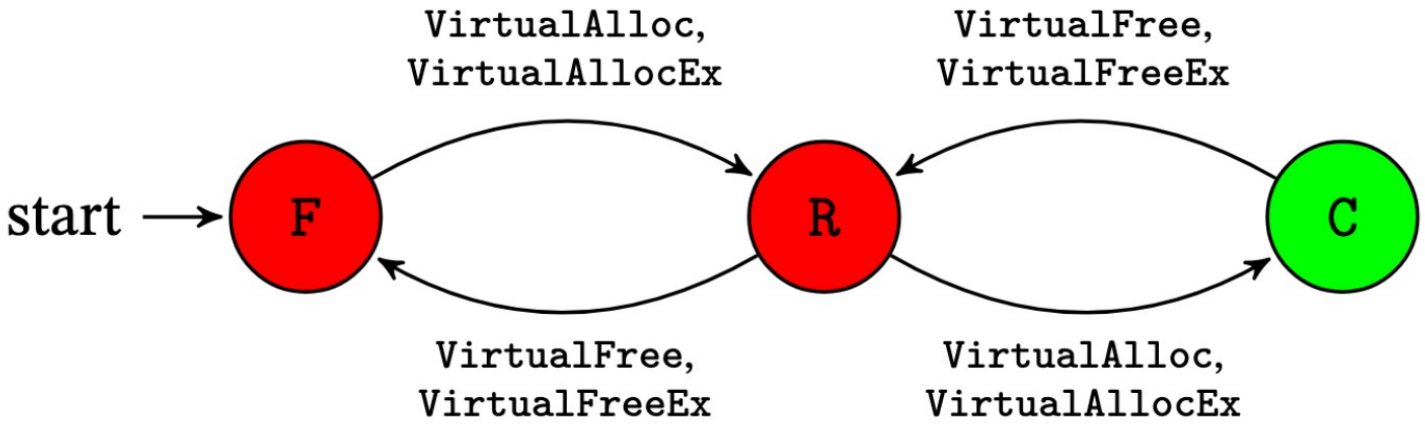
Virtual Memory

- **Physical address** vs. **Virtual address**
  - Translation performed by the memory management unit (MMU)
  - PTE: *page table entries*
    - Each process and the kernel itself have their own page tables
    - **Map virtual address to physical address**
- **Virtual memory space of a process**
  - **Contiguous regions**
  - Different uses: file mapping (disk file backup), unmapped memory
- *Virtual Address Descriptor* (VAD)
  - Kernel structure to represent a contiguous region of memory (can contain multiple pages)
  - Balanced tree
  - Different permissions (we will comment later…)

2. Previous Concepts

Virtual Memory: Pages

- **Page: minimal memory granularity**
  - Contiguous, fixed-size block of virtual memory
  - Small (4KiB) and large (for example, 2MiB on x86 and x64, 4MiB on ARM)
- **States:**
  - Free: initial state
  - Reserved: for future use
  - Committed (ready to use)



2. Previous Concepts

Virtual Memory: Problems

1. **Page swapping**
   - Memory space available for **a** process in 32 bits: 2GiB
   - Is it physically possible?
   - MMU manages memory pages that are accessed and paged, retrieving them from disk and placing them back into memory
2. **Load on demand**
   - Only the memory pages that are needed are loaded, and when they are needed (lazy loading)
   - Copy-on-Write (CoW) mechanism
3. **Page smearing**
   - Memory is a living entity, continually changing
   - Memory capturing issue on running systems
     - Possible references between very distant memory areas

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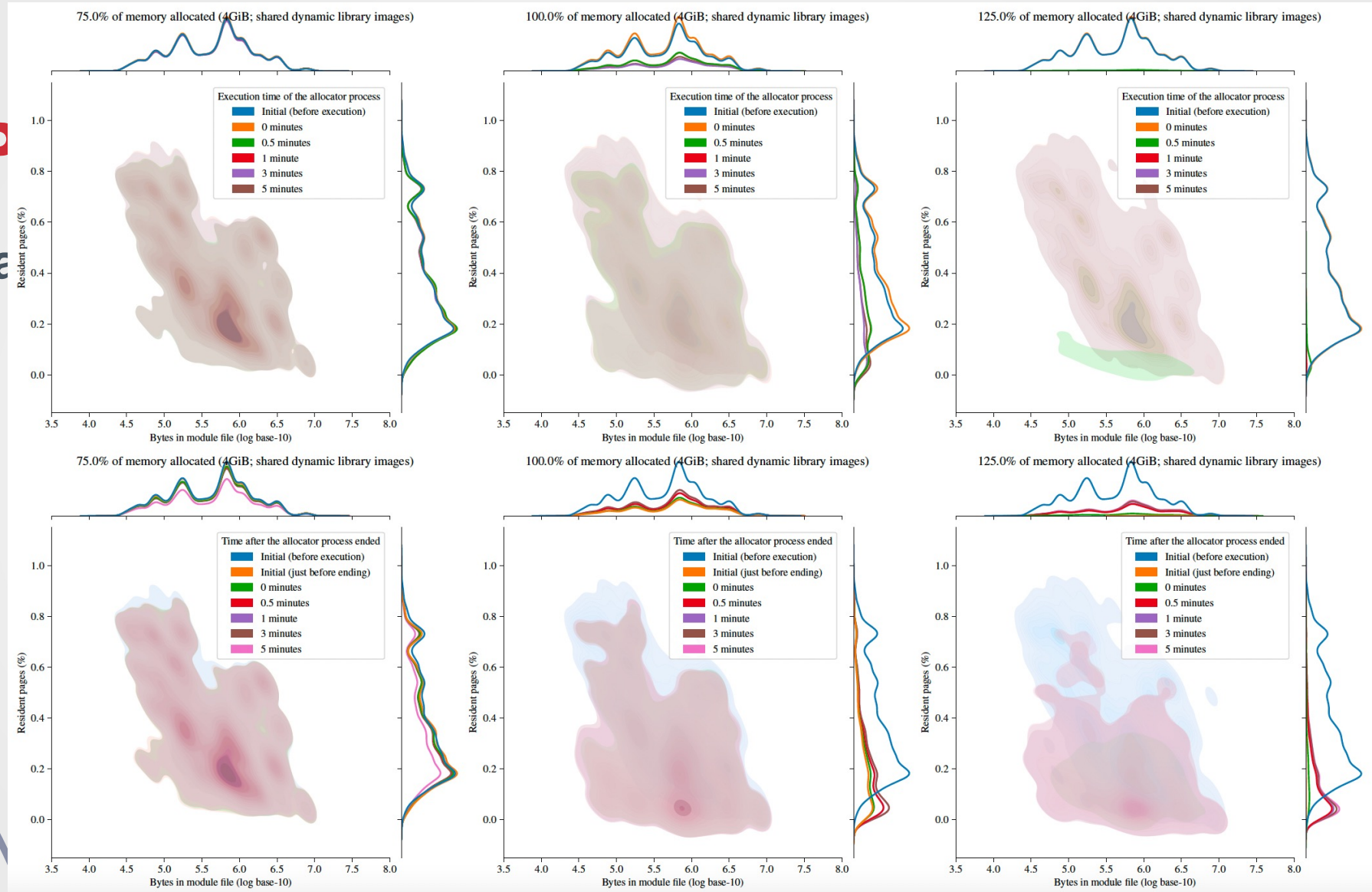
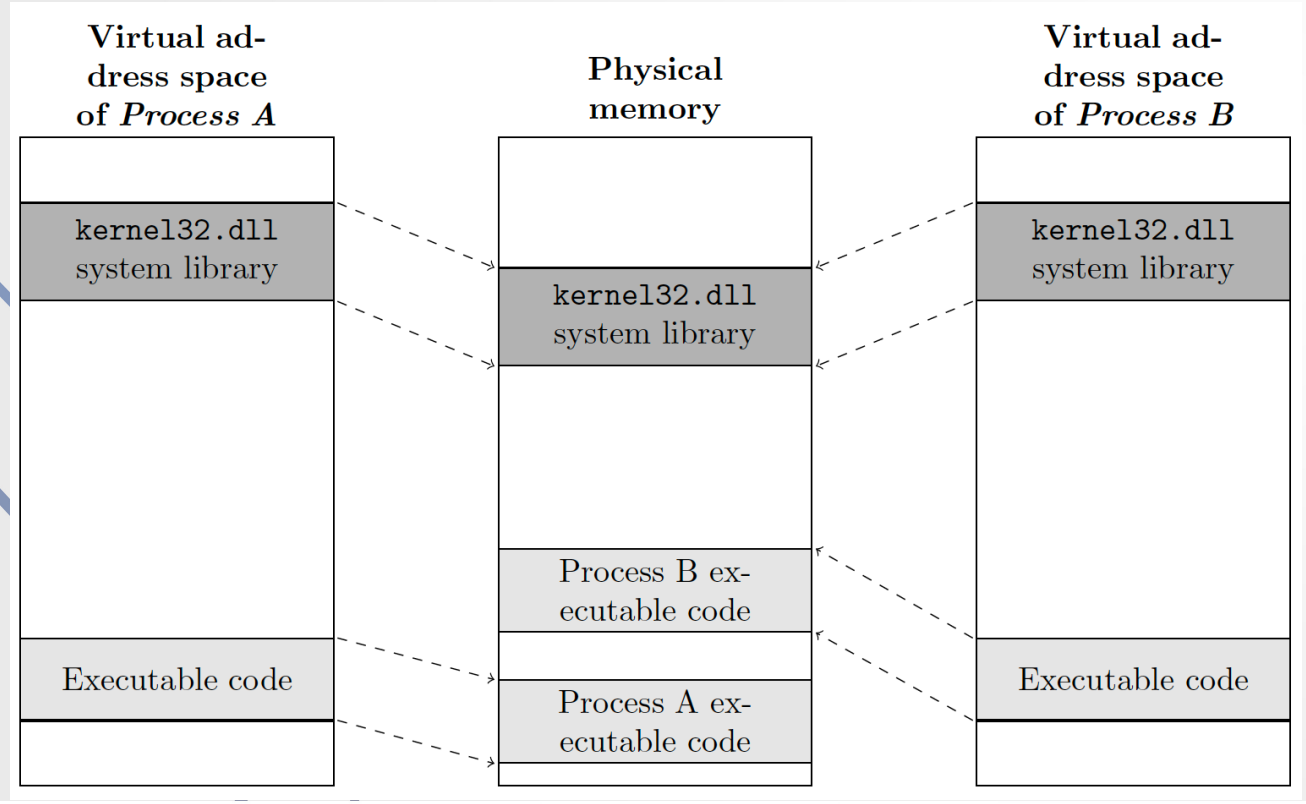
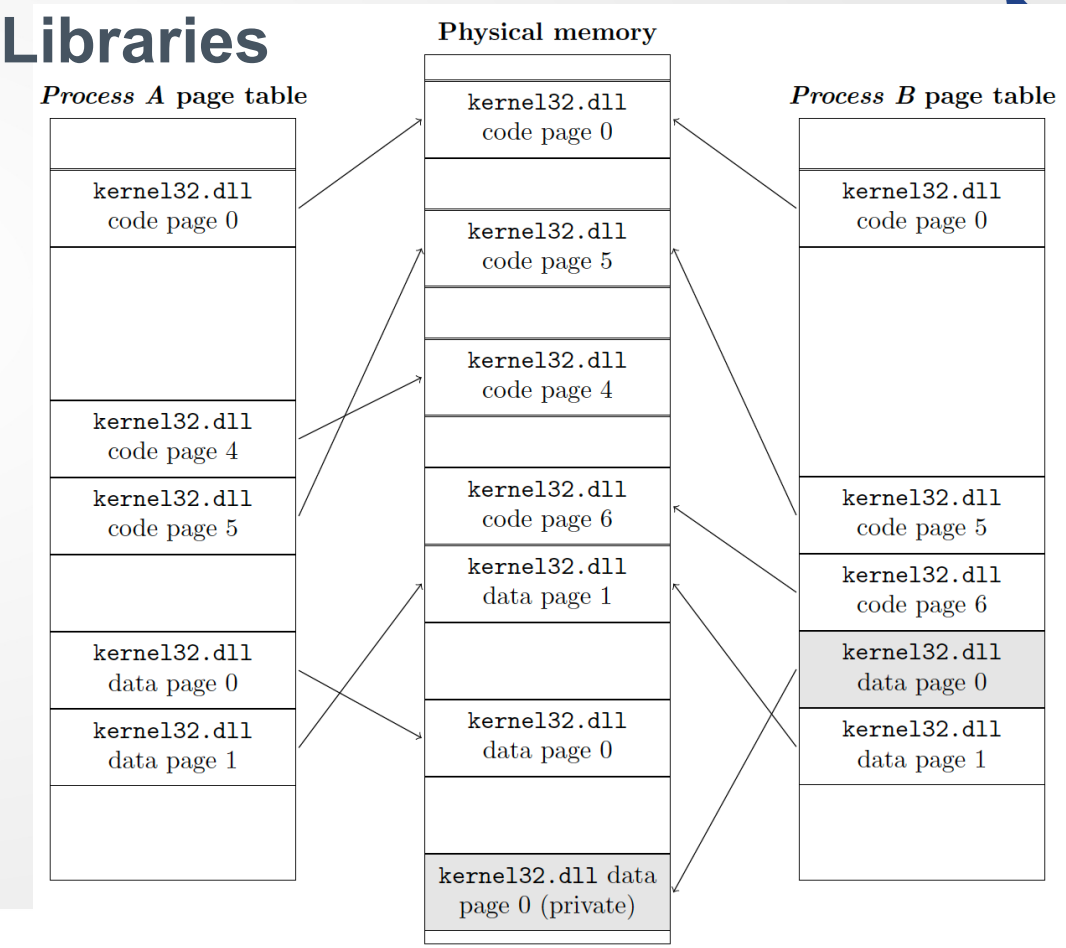


More details: Martín-Pérez, M., Rodríguez, R.J. (2022). **Quantifying Paging on Recoverable Data from Windows User-Space Modules**. In: *Digital Forensics and Cyber Crime*. ICDF2C 2021. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 441. Springer. https://doi.org/10.1007/978-3-031-06365-7

2. Previous Concepts

Virtual Memory: Processes and Shared Libraries





3. Malware Analysis in Memory Forensics

3. Malware Analysis in Memory Forensics

Malware Analysis Methodology

- **Static analysis** (the program does not run)
  - Crypto-hashes (MD5, SHA-1, SHA-256…)
    - HashTab, md5sum, sha1sum, WinMD5Free, …
  - Strings
    - strings
  - PE properties
    - Fields of interest (obfuscated? packed?)
    - External functions set in *Import Address Table* (IAT)
    - Resources within the PE

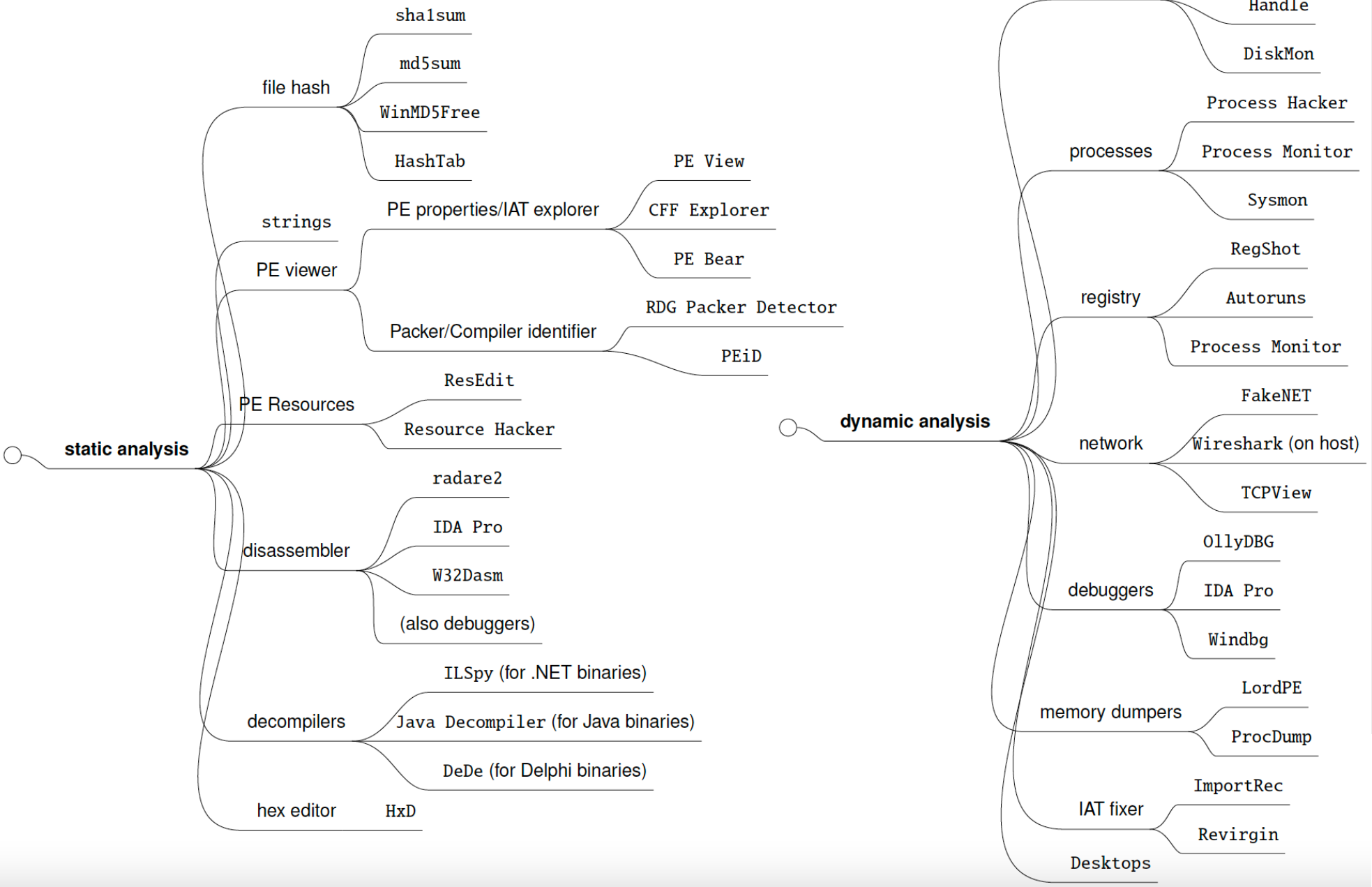
3. Malware Analysis in Memory Forensics

Malware Analysis Methodology

- **Dynamic analysis** (the program runs – typically in an isolated environment)
  - OS interaction: files
    - Creation? Access? Modification? Deletion?
  - OS interaction: Windows Registry
    - Creation? Access? Modification? Deletion?
  - OS interaction: processes
    - Creation? Access?
  - Interaction with the outside: network communications
    - IP addresses
    - Domain names

3.

Mal



3. Malware Analysis in Memory Forensics

Malware Analysis Phases in Memory Forensics

- **Memory dumps**
  - Contains item **artifacts** that were running at the time of acquisition
    - **Running processes, connected users, open sockets, etc.**

Process: memory representation of a program

1. **Memory mapped executable file**
   - Page alignment → *inconclusive hash signatures*
2. **Load on demand**
   - **Partial content**: *problem to know the real malicious activity carried out by the sample*
   - The way of acquiring memory can affect
3. **Resolved IAT Function Table**
   - *Difficulty of subsequent execution in the same or other environments*

4. Collection of memory evidence

4. Collection of Memory Evidence

Memory Acquisition

- **Various acquisition techniques**
  - Tobias Latzo, Ralph Palutke, Felix Freiling, "*A universal taxonomy and survey of forensic memory acquisition techniques*," Digital Investigation, Volume 28, 2019, pp. 56-69, ISSN 1742-2876, https://doi.org/10.1016/j.diin.2019.01.001
- **Software tools for getting a complete memory dump**
  - WinPmem: https://github.com/Velocidex/WinPmem
    - Apache license
    - Support for Windows XP up to Windows 10, for 32 and 64 bits
    - Example: winpmem_mini_x64.exe physmem.raw
  - Linux Memory Extractor (LiME): https://github.com/504ensicsLabs/LiME
    - GNU/GPLv2 license
    - Support for Linux and Android
    - Extraction via local port connection
  - FTK Imager: https://accessdata.com/product-download/ftk-imager-version-4-2-1
    - Commercial tool
    - Support for Windows

4. Collection of Memory Evidence

Memory Acquisition

- **Acquisition in virtual machines**
  - VirtualBox
    - vboxmanage debugvm "Win7" dumpvmcore --filename test.elf
  - VMWare
    1. Create a snapshot of the virtual machine execution (.vmss and .vmem files are generated)
    2. vmss2core tool: https://flings.vmware.com/vmss2core??src=vmw_so_vex_mraff_549
- **Other tools for extracting Windows processes or modules**
  - ProcDump: https://docs.microsoft.com/en-us/sysinternals/downloads/procdump
    - procdump -ma 4572
    - Single dump (fichero .dmp)
  - Windows Memory Extractor: https://github.com/pedrofdez26/windows-memory-extractor
    - GNU/GPLv3 license
    - WindowsMemoryExtractor_x64.exe --pid 1234
    - Create sectional dump of process memory

4. Collection of Memory Evidence

Memory Dump Analysis: *Volatility*

- **De facto standard** to analyze memory dumps
- FOSS (GNU/GPLv2 license)
- Published in 2007 in BH USA, called *Volatoools*
- Support for Windows, Linux and MacOS, in 32 and 64 bits
- Very extensive API for your own implementations
- Version 2.6 vs. Version 3
  - Python2 vs Python3
  - Version 3 is already stable! https://github.com/volatilityfoundation/volatility3

4. Collection of Memory Evidence

Memory Dump Analysis: *Volatility*

- Virtual machine provided: Debian 10.10
  - Volatility 2.6 and Volatility 3.0 already installed
  - User/password: alumno / alumno
- **Help**:
  - python vol.py –h
- **Memory dump to analyze** :
  - python vol.py --f mem.dmp --profile Win7SP1x86
  - The profile is only necessary in version 2.6. It indicates where are the internal structures of the SO
- *How to know the profile to use?* → imageinfo plugin
  - python vol.py --f mem.dmp imageinfo
- **Plugins are always indicated at the end of the command**

4. Collection of Memory Evidence

Detection of Indicators of Compromise with *Volatility*

- **Processes and DLLs**
  - pslist, pstree (psscan for possible rootkits)
  - dlllist, dlldump
  - handles
  - enumfuncs (list of imported and exported functions, by process/dll)
- **Process memory**
  - memmap, memdump
  - procdump
  - Vadinfo, vadwalk, vadtree, vaddump
  - evtlogs
  - iehistory
- **Network**
  - connections, connscan
  - sockets, sockscan
  - netscan (network artifacts in Win7)

https://github.com/volatilityfoundation/volatility/wiki/Command-Reference

4. Collection of Memory Evidence

Detection of Indicators of Compromise with *Volatility*

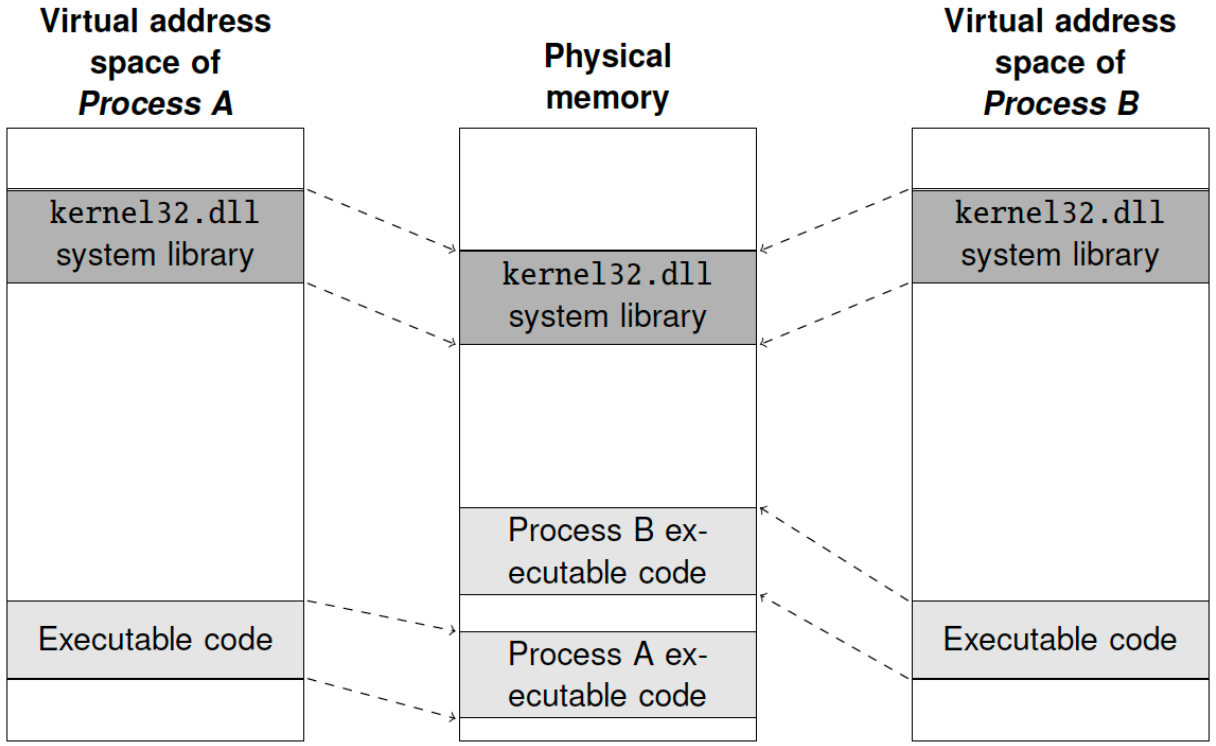
- **Kernel memory and other (internal) objects**
  - modules, modscan, moddump
  - driverscan
  - filescan
- **Register**
  - hivescan, hivelist, hivedump
  - printkey
  - lsadump
  - userassist, shellbags, shimcache
  - dumpregistry
- **Filesystem**
  - mbrparser, mftparser
- **Hibernation file analysis or other dumps**

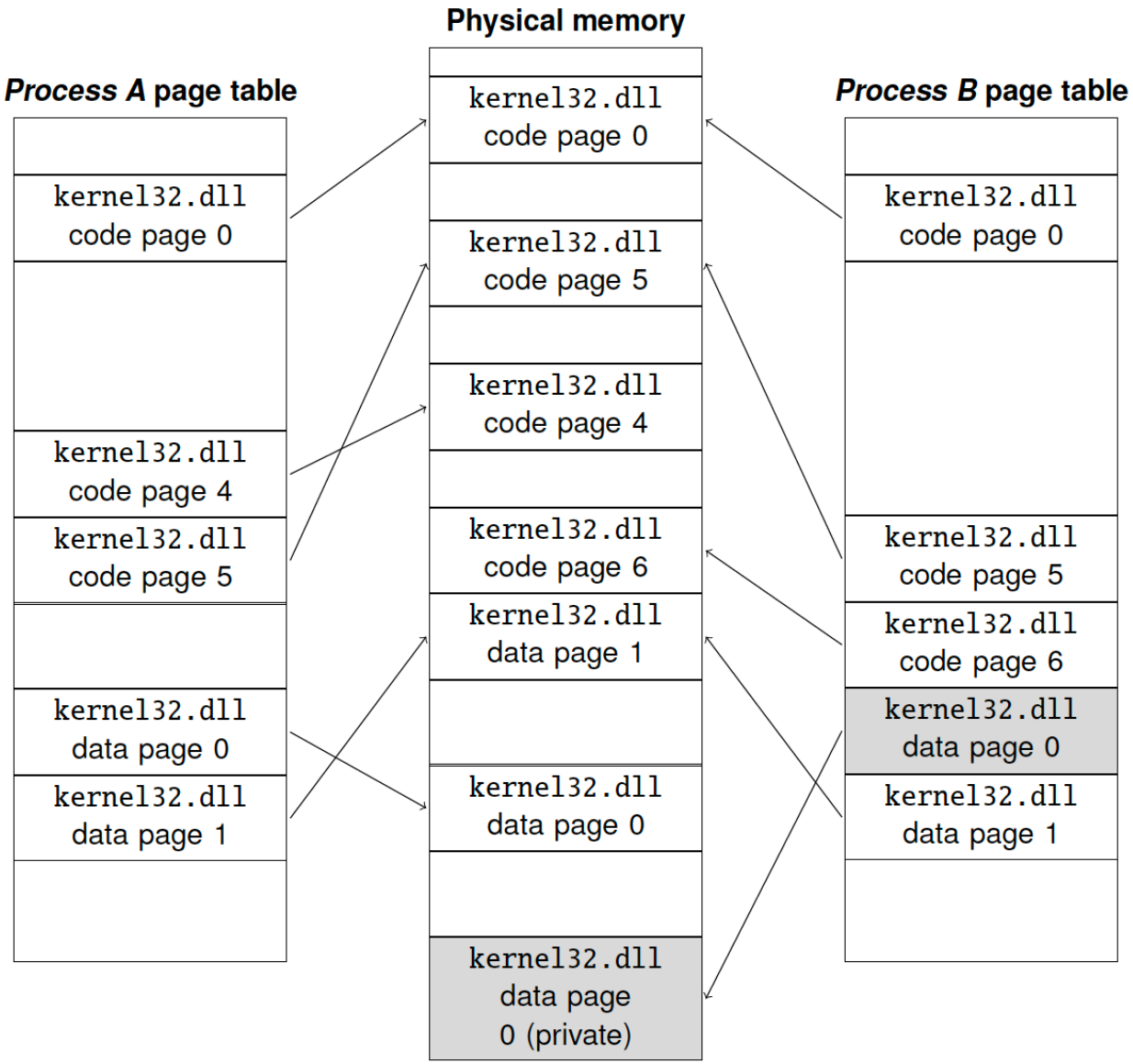
https://github.com/volatilityfoundation/volatility/wiki/Command-Reference

4. Collection of Memory Evidence

Memory Forensic & Malware Analysis: Related Problems

- **Imprecision of memory dump content**
  - The content of an image is not faithful to its image file
  - Mainly due to:
    - Paginated effect (4kiB alignment causes null bytes filling)
    - Relocation (resolved IAT addresses or lack of some sections)
  - **Solutions?**
    - Use of approximate similarity algorithms (sum plugin)
    - Database construction with allowed hashes





4. Collection of Memory Evidence

Memory Forensic & Malware Analysis: Related Problems

- **Imprecision of memory dump**
  - Memory is continuously updated and acquired in a non-atomic way
  - Especially relevant when there are acquisitions in living systems
  - Highly probable. Inconsistency due to:
    - Pointers
    - Memory fragmentation
  - Sophisticated malware can force inconsistencies deliberately (DKOM attacks)
  - **Solutions?**
    - Use of other acquisition techniques
    - Check the temporary consistency of the data: *temporal forensics* *(Pagani, F.; Fedorov, O. & Balzarotti, D. Introducing the Temporal Dimension to Memory Forensics. ACM Trans. Priv. Secur., vol. 22, no. 2, pp. 9:1-9:21, ACM, https://doi.org/10.1145/3310355)*

4. Collection of Memory Evidence

Memory Forensic & Malware Analysis: Related Problems

- **Stealthy malware**
  - VAD are unreliable sources of information
    - Pages permissions are not updated if they are changed after putting the initial permissions
  - You can “swap” pages deliberately
  - *Process hollowing* attacks
  - **Solutions?**
    - Malware signatures (but not based on cryptographic hashes)
    - Robust kernel signatures
    - Volatility Plugins: *malfind*, *malscan*, *impfuzzy*

4. Collection of Memory Evidence

Example: ZeuS

LAB SESSION 1

- **"zeus.vmem" memory dump** (from "Malware Analyst's Cookbook" book)
- Follow the laboratory workbook provided on the workshop's website: https://webdiis.unizar.es/~ricardo/sbc-2024/advanced-forensic-analysis/laboratories/lab1_introduction.pdf
  - Details many Volatility plugins of interest for memory dump analysis

5. Advanced Detection of IoC

5. Advanced Detection of IoC

Unofficial Plugins

- There are many additional plugins that expand Volatility functionality
- Mode of use
  1. Plugin installation (for instance, source code repository download)
  2. Execution: volatility --plugins="/path/to/plugin" -f file [OPTIONS] pluginname

5. Advanced Detection of IoC

Unofficial Plugins

- **MalConfScan**: https://github.com/JPCERTCC/MalConfScan
  - Extract configuration, deciphered strings or DGA domains from some malware families
- **Malscan**: https://github.com/reverseame/malscan (for Volatility 2.6)
  - GNU/GPLv3 license
  - Integrates Malfind with ClamAV-daemon (only available in Linux). Less false negatives
  - Operating modes: Normal (regions +WX, any executable module, and VADs-type private memory) and full-scan (regions with +x)
  - VADs without associated executables, beginnings of function and empty pages followed by code

```
➜  ~ python2 volatility/vol.py --plugins=/home/alumno/malscan -f /mnt/volcados/alina1G.elf
--profile=Win7SP1x86 malscan
Volatility Foundation Volatility Framework 2.6.1

Process: ALINA_CJLXYJ.e Pid: 1828 Space Address: 0xc20000-0xc44fff
Vad Tag: Vad  Protection: PAGE_EXECUTE_WRITECOPY
Flags: CommitCharge: 5, Protection: 7, VadType: 2
Scan result: Win.Trojan.Alina-4

0x00c20000  4d 5a 90 00 03 00 00 00 04 00 00 00 ff ff 00 00   MZ..............
0x00c20010  b8 00 00 00 00 00 00 00 40 00 00 00 00 00 00 00   ........@.......
0x00c20020  00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00   ................
0x00c20030  00 00 00 00 00 00 00 00 00 00 00 00 f0 00 00 00   ................
```

5. Advanced Detection of IoC

Unofficial Plugins

- **Similarity Unrelocated Module**: https://github.com/reverseame/similarity-unrelocated-module (for Volatility 2.6)
  - GNU/GPLv3 license
  - Calculate approximate signatures on the modules of a dump:
    - Algorithms: dcfldd, ssdeep, sdhash, TLSH
    - A module is an executable file or library of functions loaded in memory
  - Allows comparison between modules of different memory dumps
  - Undoes the changes made by the operating system (relocation). Two methods :
    - Guided De-relocation
    - Linear Sweep De-relocation
  - **More details**: M. Martín-Pérez, R. J. Rodríguez,D. Balzarotti, "*Pre-processing Memory Dumps to Improve Similarity Score of Windows Modules*", Computers & Security, vol. 101, p. 102119, 2021, https://doi.org/10.1016/j.cose.2020.102119

5. Advanced Detection of IoC

Unofficial Plugins

- **Winesap**: https://github.com/reverseame/winesap (for Volatility 2.6)
  - AGPLv3 license
  - Look for all Windows ASEPs in memory dump
  - Binary or unknown registration keys: they are analyzed as PE
  - Strings related to usual malware file routes (%Appdata%,%TMP%,%Temp%, Appdata), NTFS ADS, Shells commands (e.g., rundll32.exe shell32.dll, Shellexecute_rundll)
  - **More details**: D. Uroz, R. J. Rodríguez, "Characteristics and Detectability of Windows Auto-Start Extensibility Points in Memory Forensics", Digital Investigation, vol. 28, p. S95-S104, 2019, https://doi.org/10.1016/j.diin.2019.01.026

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Startup folder (%ALLUSERSPROFILE%)	yes	user	no	user session	application	system
Startup folder (%APPDATA%)	no	user	no	user session	application	user
Scheduled tasks	yes	any	no	not needed‡	application	system
Services	yes	system	yes	not needed‡	application	system
Program loader abuse						
Image File Execution Options	yes	user	yes	not needed	application	system
Extension hijacking (HKLM root key)	yes	user	yes	not needed	application	system
Extension hijacking (HKCU root key)	no	user	yes	not needed	application	user
Shortcut manipulation	no	user	no	not needed	application	user
COM hijacking (HKLM root key)	yes	any	yes	not needed	system	system
COM hijacking (HKCU root key)	no	user	yes	not needed	system	user
Shim databases	yes	any	yes	not needed	application	system
Application abuse						
Trojanized system binaries	yes	any	no	not needed	system	system
Office add-ins	yes	user	yes	not needed	application	user
Browser helper objects	yes	user	yes	not needed	application	system
System behavior abuse						
Winlogon	yes	user	yes	user session	application	system
DLL hijacking	yes	any	no	not needed	system	system
AppInit DLLs	yes	any	yes	not needed	system	system
Active setup (HKML root key)	yes	user	yes	user session	application	system
Active setup (HKCU root key)	no	user	yes	user session	application	application

†*If the memory is paging to disk, it would be not possible to track down these ASEPs in memory forensics.*
‡*Depends on the trigger conditions defined to launch the program.*

5. Advanced Detection of IoC

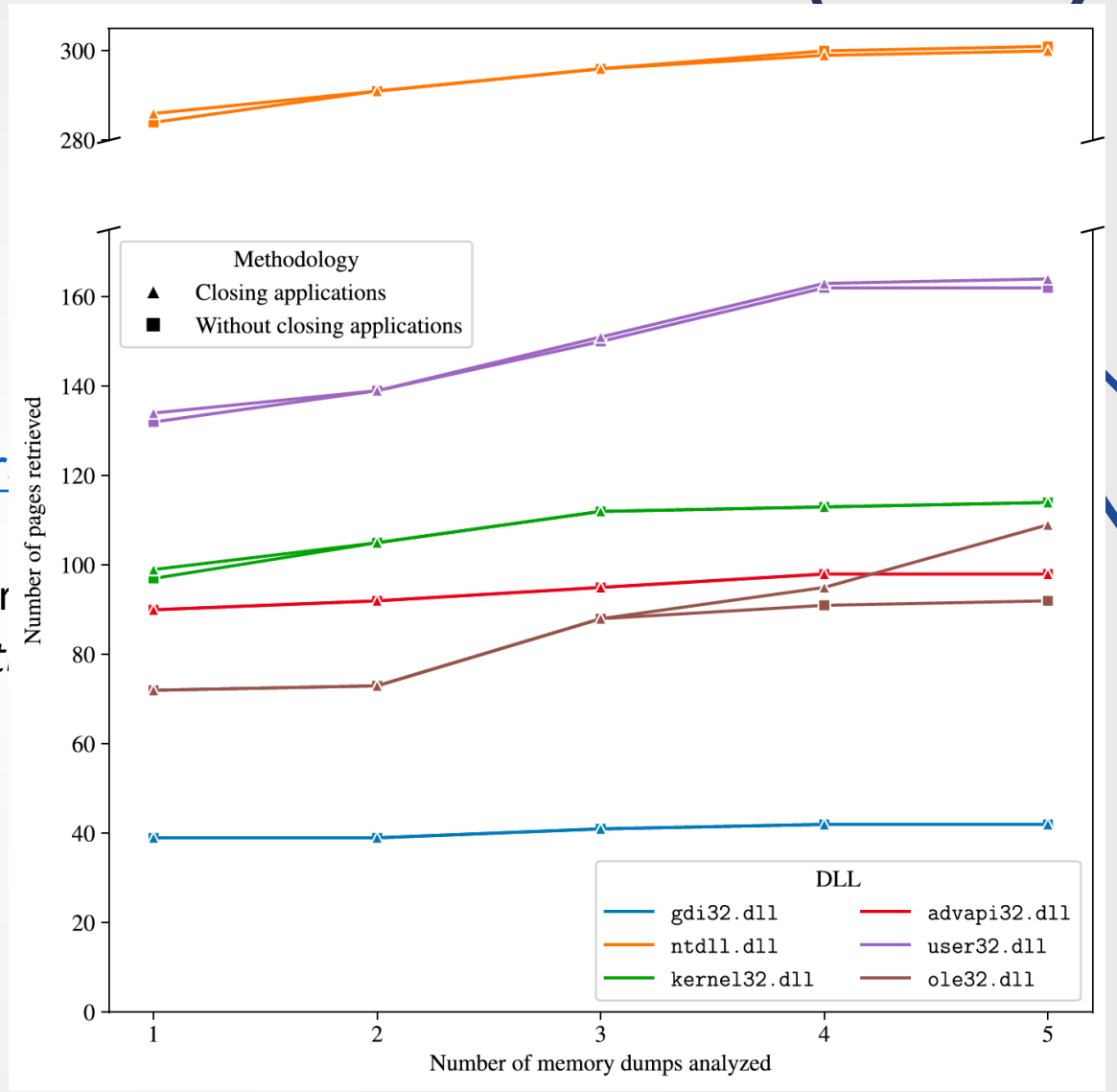
Unofficial Plugins

- **Sigcheck**: https://github.com/reverseame/sigcheck (for Volatility 2.6)
  - GNU/GPLv3 license
  - Verify PE files digitally signed with Microsoft Authenticode
  - Two signature methods: embedded (in the PE), by catalog (in external file)
  - **IMPORTANT**: Verify that the executable file that began was original
    - If a malware does *process hollowing* would not be detected with this method
  - **More details**: D. Uroz, R. J. Rodríguez, "On Challenges in Verifying Trusted Executable Files in Memory Forensics", Forensic Science International: Digital Investigation, vol. 32, p. 300917, 2020, https://doi.org/10.1016/j.fsidi.2020.300917

5. Advanced Detection

Unofficial Plugins

- **Modex/Intermodex:** https://github.com/rever
  - GNU/GPLv3 license
  - Allows you to extract modules more completely fr
    - *Recall that each process has only the pages t*
  - Ability to detect DLL hijacking attacks



More details: Pedro Fernández, Ricardo J. Rodríguez, "*Module Extraction and DLL Hijacking Detection via Single or Multiple Memory Dumps*", Forensic Science International: Digital Investigation, vol. 44, p. 301505, 2023. DOI: 10.1016/j.fsidi.2023.301505

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5. Advanced Detection of IoC

Example: WannaCry

LAB SESSION 2

- **“wannacry.elf” memory dump**
- Follow the laboratory workbook provided on the workshop's website: https://webdiis.unizar.es/~ricardo/sbc-2024/advanced-forensic-analysis/laboratories/lab2_example_wannacry.pdf

6. Development of Own Analysis Tools

5. Development of Own Analysis Tools

Hands-on

LAB SESSION 3

- **“alina1G.elf” memory dump**
- Follow the laboratory workbook provided on the workshop's website: https://webdiis.unizar.es/~ricardo/sbc-2024/advanced-forensic-analysis/laboratories/lab3_plugin_development.pdf

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7. Methodology for Evidence Analysis in Memory Forensics

7. Methodology for Evidence Analysis in Memory Forensics

(inspired in the methodology followed by Defence Research and Development Canada)

1. **Protect the memory dump**
   - Store it in read-only filesystems
   - Set special permissions to prevent accidental changes (e.g., `chattr +i`)
2. **Preliminary memory dump analysis**
   - Analyze it with different AVs and check results
3. **Data carving, file hashing, and file identification**
   - Extract content and analyze the extracted data
   - Use of several UNIX commands, pipelining them

7. Methodology for Evidence Analysis in Memory Forensics

(inspired in the methodology followed by Defence Research and Development Canada)

4. Process-based Volatility plugin memory analysis

- Identify the underlying machine (`windows.info`)
- Processes (windows.pslist, windows.psscan). See differences in output
  - Another good plugin is psxview, but it is only available for Volatility2 (at the moment)
- Commands typed into a command shell (`windows.cmdline`)
- Network connections (`windows.netscan`, `windows.netstat`)
  - Analyze the IP addresses (WHOIS, DNS reputation, etc.)
  - Relationship between processes and open sockets (check the ports)
- File handles in memory (`windows.filescan`)
- Windows-thread mutexes (`windows.mutantscan`)
- Other handles (`windows.handles`)
- Drivers (`windows.driverscan`, `windows.driverirp`)
- Modules (`windows.modscan`)
- Services (`windows.svcscan`)

7. Methodology for Evidence Analysis in Memory Forensics

(inspired in the methodology followed by Defence Research and Development Canada)

4. **Process-based Volatility plugin memory analysis**
   - Linked modules per process (`windows.ldrmodules` in Volatility3)
   - DLLs loaded (`windows.dlllist`)
   - Thread analysis (`threads` and `thdrscan`, only Volatility2)
5. **Detection and extraction of suspicious drivers, processes, and other elements of interest**
   - Create appropriate directories for storing outputs
   - For each output, analyze it with AVs and calculate hashes
   - Plugins:
     - `windows.malfind`
     - With option `--dump`: `windows.pslist`, `windows.dlllist`, `windows.modules`, `windows.memmap`
     - `windows.lsadump`
     - `windows.dumpfiles`
   - **Analyze extracted files using the malware analysis methodology** explained before. *Enjoy*! ☺

7. Methodology for Evidence Analysis in Memory Forensics

(inspired in the methodology followed by Defence Research and Development Canada)

6. Windows Registry memory analysis

- Check Registry hives available in the memory dump:
  - `windows.registry.hivelist`, `windows.registry.hivescan`
- Get Registry keys: `windows.registry.printkey` (more details with --recurse)
- Check UserAssist: `windows.registry.userassist` (useful for persistence)

7. Optional step

- Relationship between device drivers and their required Windows services:
  - `windows.devicetree`
- Unofficial plugins

Recommended Bibliography

Recommended Bibliography

- The Art of Memory Forensics
  - Additional material available here
- Practical Malware Analysis. The Hands-On Guide to Dissecting Malicious Software
- Malware Analyst's Cookbook
- Documentación de Volatility 3

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