An Overview Of Modern Windows Malware Analysis

A Researcher's Perspective

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Goals of this talk

- (Windows) malware analysis from a researcher's point of view
  - Emphasis on the state of the art → "Title" conf/journal year
  - Oriented to large-scale analysis
- But… practical and modern
  - Everything I will mention is tested, working and maintained
  - Slides are verbose for quick reference
- Not self-referential
  - Not about our papers
  - About "how" we made them

Malware - Definition

Malware (**mal**icious soft**ware**) is any software *intentionally* designed to

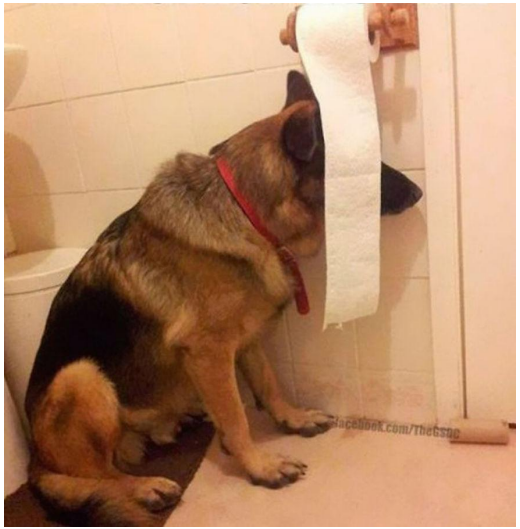
unknowingly interferes with security (CIA triad) and privacy of users and organizations

Reasons?

- Making money 🤑
- Activism
- Data theft
- Vandalism/Prank
- Nation state-sponsored operations
- ...

Malware Analysis - (My) Definition

*"**Program analysis** of a software that does not want to be analyzed"*



Malware Types

- *Infection*
  - **Worm**: self-replicate/propagate
  - **Virus**: requires human interaction to spread
  - **Trojan**: benign appearance but hidden malicious features
- *Features*
  - **Adware:** displays unwanted or malicious advertising
  - **Bot:** performs a task given a remote command
  - **Exploit:** exploits a software vulnerability to gain authorized access
  - **HackTool:** exploiting, attack and scanning tools
  - **Ransomware:** encrypts device's data for ransom
  - **RootKit:** stealth and actively hiding software with elevated permissions
  - **Spyware:** software that invades the user’s privacy
  - ...

Windows Malware

Microsoft Windows is an amusement park for malware authors

- Native support for Android apps 😍
- No applicatio

"Survivalism: Systematic Analysis of Windows Malware Living-Off-The-Land" S&P 2021

- Support for old technologies (Classic Visual Basic)
- Scripting languages (Batch, Powershell, Javascript)
- Office Macro (VBA, Javascript)
- Portable Executable format (`exe`, `dll`)
  - Can "hide" a virtual machine (.NET, VB, Python)
  - Different structure w.r.t. language (C++, Go, Rust)
  - Same structure w.r.t. packer/protector (UPX, Themida) and virtual machine

Types Of Malware Analysis

Static Analysis

"SOK: (State of) The Art of War: Offensive Techniques in Binary Analysis" S&P 2016

Static techniques reason about a program without executing it

1. **Code** (original or lifted to a Intermediate Representation)
    - Data-flow analysis
        - Reason on the Control-Flow Graph (CFG)
        - Determine possible set of values calculated at various points in the program
    - Abstract interpretation
        - The program is interpreted ("executed") over an abstract domain
    - Symbolic execution
        - Determine what inputs cause each part of a program to execute
2. **File structure**
    - Byte Patterns
    - Executable file format

ta Analysis Tools [1/2]

le w o does not know where to go" – Seneca

le

lk: PE) format

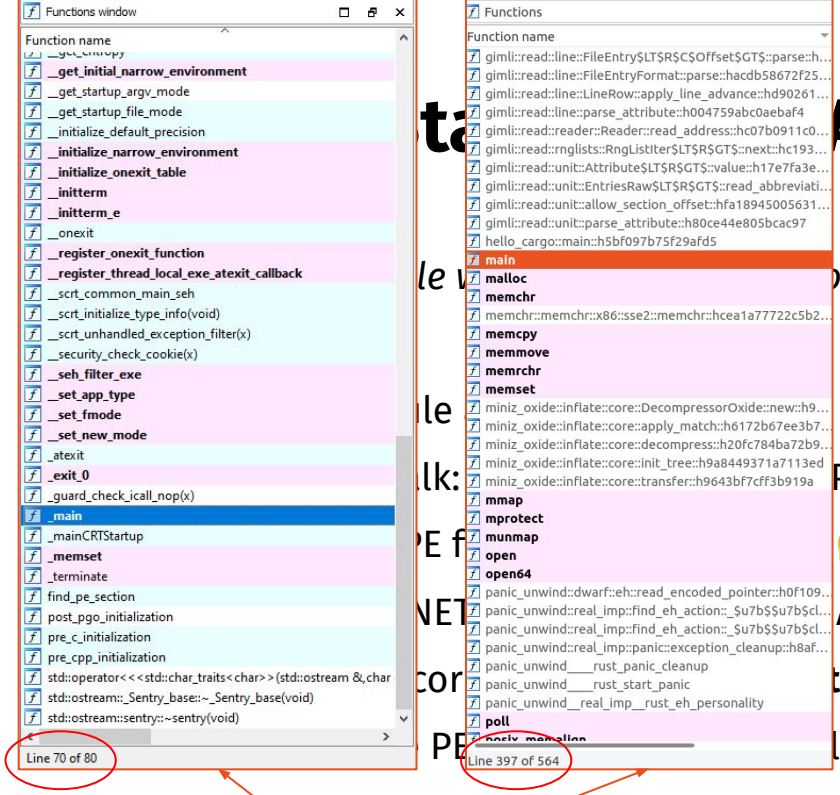
PE f 🤔

NET AHK, ...

cor **tual** code

PE ler/language?

- C, C++, Go, Rust, ...



Static (code) Analysis Tools [2/2]

- **IDA Pro** by Hex-Rays
  - Pros: since 1991, fast, best decompiler, awesome Windows support ⇒ industry standard
  - Cons: proprietary, very expensive (decompiler not included), low-level API
- **Ghidra** by National Security Agency (NSA)
  - Pros: oss, high-level API, collaborative projects, built-in program analysis
  - Cons: written in Java, immature debugger
- **Binary Ninja** by Vector 35
  - Pros: high-level API, multi-level IL ⇒ best for program analysis
  - Cons: proprietary, bugs with complicated analysis
- Last but not least
  - https://github.com/radareorg/**radare2** ⑂ https://github.com/rizinorg/**rizin**
  - https://github.com/cea-sec/**miasm**
  - https://github.com/angr/**angr**

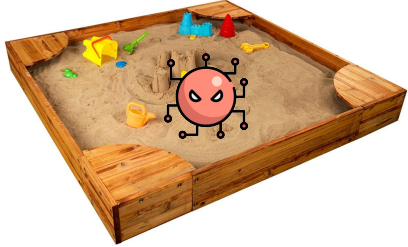
Static (file) Analysis Tools

Multiplatform and suited for large-scale analysis

- **Yara** – https://github.com/VirusTotal/yara
  - Binary patterns signatures ⇒ fast
  - Signatures DB scattered around the internet – https://github.com/InQuest/awesome-yara
- **Detect It Easy** – https://github.com/horsicq/Detect-It-Easy
  - Fine-grained signatures ⇒ slow
  - Signatures DB unique and well maintained
- **Capa** – https://github.com/mandiant/capa
  - Detects capabilities (what a program can do) in executable files
- **Manalyze** – https://github.com/JusticeRage/Manalyze – https://manalyzer.org/
  - Combines several tools + plugin architecture
- Python Modules
  - **Pefile** – PE files parsing – https://github.com/erocarrera/pefile
  - **Signify** – Verifies PE Authenticode-signed binaries – https://github.com/ralphje/signify
  - **LIEF** – Parsing and editing of several executable file formats – https://github.com/lief-project/LIEF

Types Of Malware Analysis

Dynamic Analysis



Executing a sample inside an isolated and instrumented *environment* to *analyse* its behavior

Also known as: **Sandbox**

- Runtime Environment
  - Virtual Machines (VM) – virtualized or emulated hw
  - Bare metal
- Analysis Component
  - In-guest
    - User-space (debugger or Dynamic Binary Instrumentation tool)
    - Kernel-space (module or driver)
  - Out-of-guest
    - Hypervisor or Emulator “APIs”

Dynamic Analysis Tools

Requirements: instruction granularity + suitable for large-scale

1. **Intel Pin** - DBI
   - https://www.intel.com/software/pintool
   - Pros: well documented, stable, full control
   - Cons: just x86-64, closed source
2. **PANDA** - emulator (QEMU) based
   - https://github.com/panda-re/panda
   - Pros: multiarch, oss, record & replay executions, taint engine
   - Cons: just monitoring, records need disk space
3. **Triton** - DBA
   - https://github.com/JonathanSalwan/Triton
   - Pros: multiarch, oss, different inputs (Pin, QEMU, ...), symbolic|taint engine
   - Cons: bugs

Large-Scale Dynamic Analysis

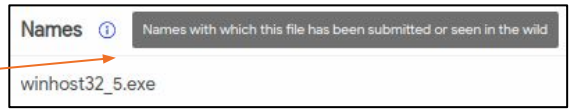
Two approaches

1. Single machine, multiple emulators
    - Best control over the instances
        - But you have to write all the management APIs
    - If the machine gets stuck… 😡
2. Multiple machines, single runtime environment
    - Type-1 hypervisor (ESXi, KVM, …) and management (vCenter, Proxmox, …)
    - Off-the-shelf virtualization management APIs
        - Not meant for being stressed 🥵

Large-Scale Dynamic Analysis – Tips

- Prepare a Windows machine
  - Minimum: Windows 7 x32 wi
  - Make it look “used”: install programs, surf the internet, populate with documents, …
  - Install SSH for remote management and take a snapshot at the end
- Buy RAM 💸 and abuse RAM Disks
- Try to use the original filename of the sample
  - How? Check VirusTotal report
- State-Of-The-Art: Run the sample for at least 2 minutes
  - But consider the overhead introd
- Simulate common internet services
  - https://www.inetsim.org/
- Mitigate evasive techniques…

“Spotless sandboxes:
Evading malware analysis systems using wearand-tear artifacts”
S&P 2017



“Does Every Second Count?
Time-based Evolution of Malware Behavior in Sandboxes”
NDSS 2021

Evasive Techniques

Malware does not want to be analyzed ⇒ evasive techniques

"On the dissection of evasive malware" IEEE Forensics and Security 2020

“Longitudinal Study of the Prevalence of Malware Evasive Techniques” arXiv 2021

Taxonomy

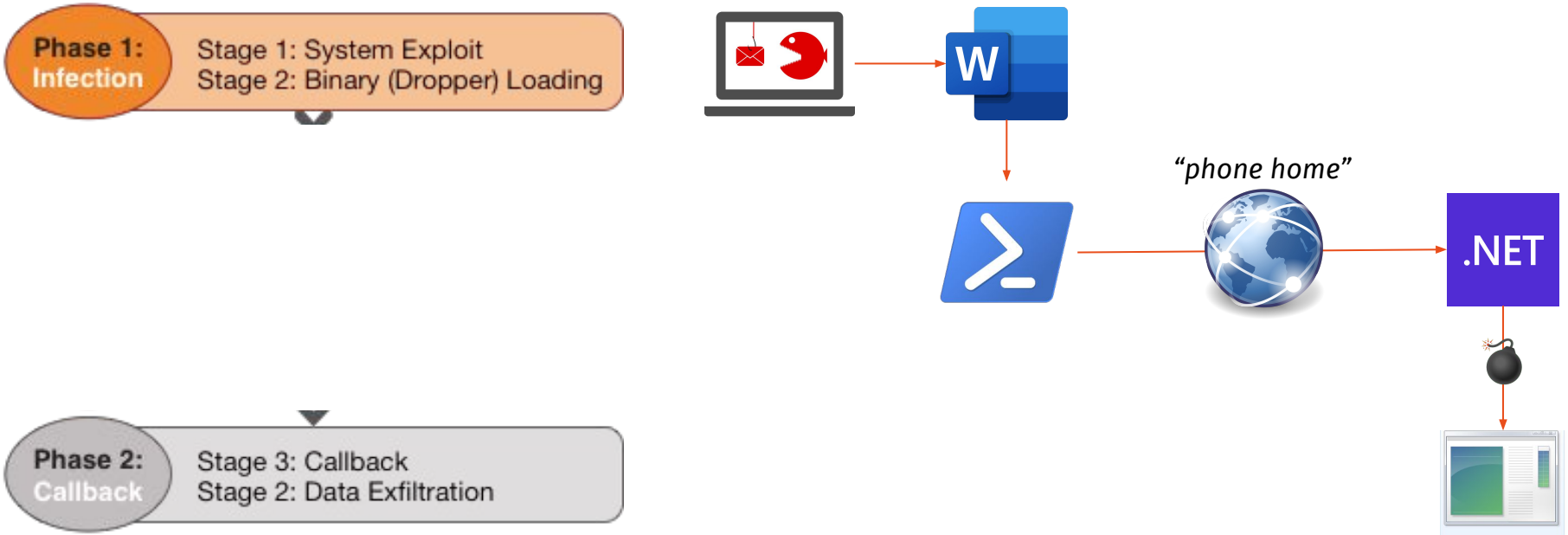
- Anti Debug
- Anti Dump
- Anti Instrumentation
- Code Injections
- Resource Profiling
- VM Checks
- Timing Attacks (time stalling & runtime measurements)

Resources

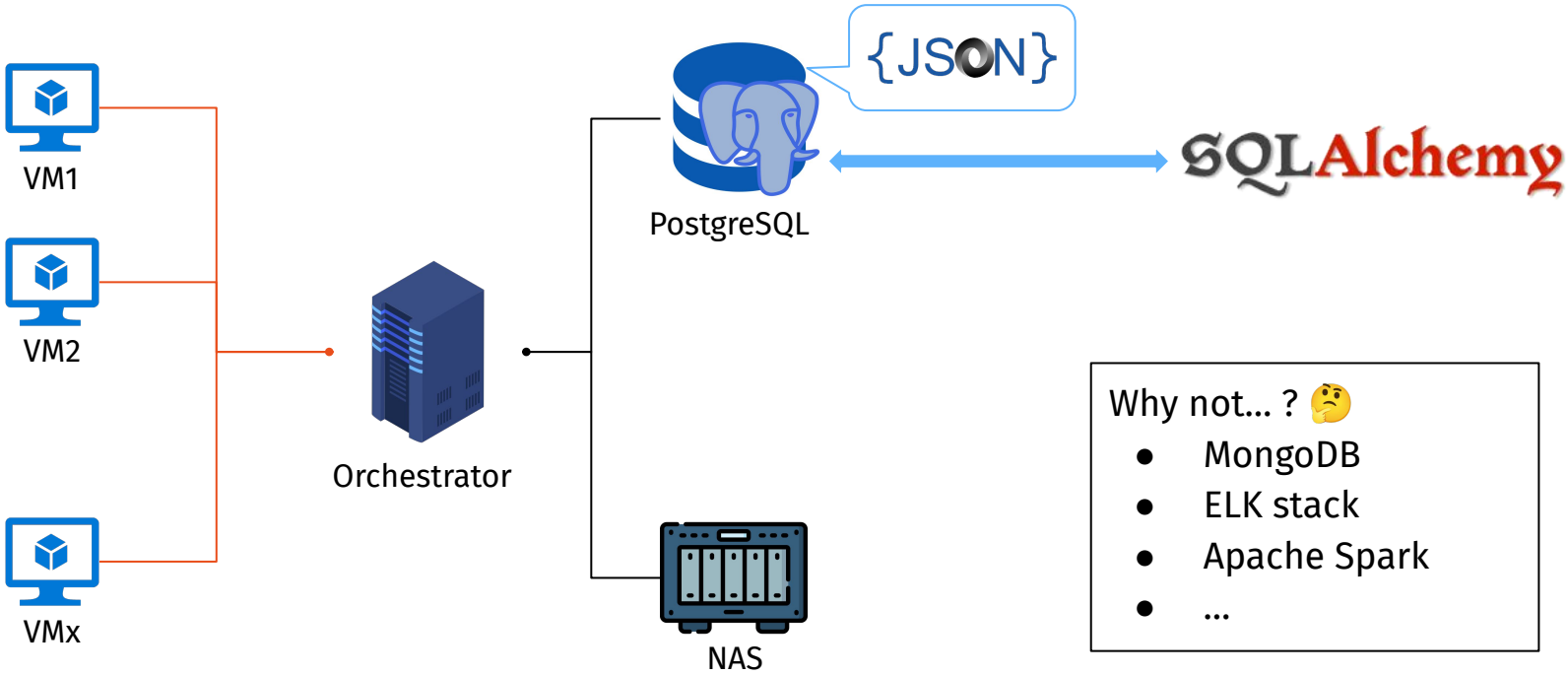
- Public evasive techniques: https://github.com/LordNoteworthy/al-khaser
- Detection and Mitigation: https://github.com/Maff1t/JuanLesPIN-Public

Follow the white rabbit 🐰

Malware often jumps between different technologies, for example *Ursnif*



Large-Scale Dynamic Analysis – Architecture



Why not… ? 🤔

- MongoDB
- ELK stack
- Apache Spark
- …

Types Of Malware Analysis

Memory (Analysis|Forensics)

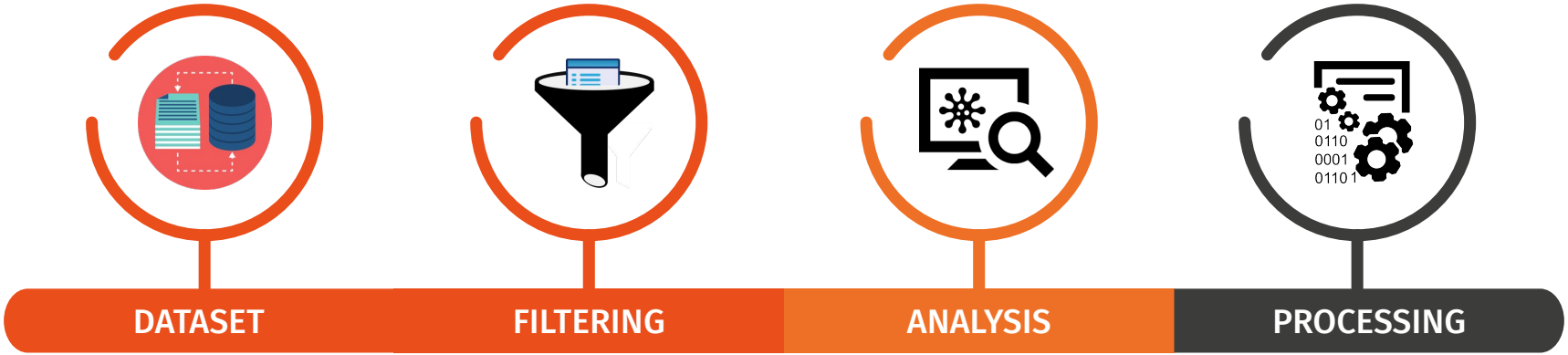
Analyzing the computer's RAM for forensic artifacts

- Large research area ⇒ focus on malware
- Malware often write components only in memory (e.g., unpacking)
  - … but can only exists exclusively in RAM (AKA, fileless malware)

Two phases

- Memory Acquisition
  - Suspend VM (`.vmem`)
  - https://github.com/Velocidex/WinPmem
  - https://docs.microsoft.com/en-us/sysinternals/downloads/procdump
    - ⇒ Minidump crash report
- Analysis of memory dump
  - https://github.com/volatilityfoundation/volatility3/
    - procdump plugin
  - https://github.com/skelsec/minidump

Pipeline



Datasets

- 🔝 https://www.virustotal.com/ 🔝
  - Insanely expensive 💸
- https://www.virussign.com/
  - “Cheap” live feed
- https://virusshare.com/
  - Torrents (must be tidy up)
- https://urlhaus.abuse.ch/
  - Malicious URLs
- https://bazaar.abuse.ch/
  - Advanced APIs
- https://www.vx-underground.org/
  - APT samples, organized in families, and source codes
- https://malshare.com/
  - Daily digest, researchers often upload famous samples

Filtering

1. File structure
   - Compiler, packer, protector, …
   - https://github.com/packmad/Siggregator
2. Family distribution is crucial
   - CARO naming convention 😓
   - VirusTotal report ➡ AVClass2 ➡ family
   - https://github.com/malicialab/avclass

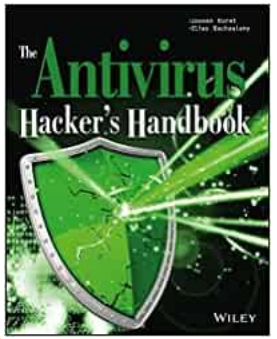
Acronis (Static ML)	Suspicious	Ad-Aware	Generic.TeslaCryptC.B878C4A3
AhnLab-V3	Trojan/Win32.Poseidon.R230029	Alibaba	TrojanDownloader:Win32/Zdowbot.4588...
ALYac	Generic.TeslaCryptC.B878C4A3	Antiy-AVL	Trojan/Generic.ASMalwS.1A2A8BC
Avast	Win32:Malware-gen	AVG	Win32:Malware-gen
Avira (no cloud)	TR/Crypt.XPACK.Gen3	BitDefender	Generic.TeslaCryptC.B878C4A3
BitDefenderTheta	AI:Packer.605213541F	Bkav Pro	W32.AIDetect.malware2
CAT-QuickHeal	Trojan.GenericRI.S21298173	ClamAV	Win.Malware.Teslacryptc-7652404-0
Comodo	Malware@#2ud0albu08v3v	CrowdStrike Falcon	Win/malicious_confidence_100% (W)
Cybereason	Malicious.15d681	Cylance	Unsafe
Cynet	Malicious (score: 100)	DrWeb	Trojan.Chanitor.28
Elastic	Malicious (high Confidence)	Emsisoft	Generic.TeslaCryptC.B878C4A3 (B)

TeslaCrypt

"AVclass2: Massive Malware Tag Extraction from AV Labels" ACSAC 2020

Vendors and Engines

Vendors	Website	Country	Third Party Engine
Avast	https://www.avast.com	Czech Republic	
AVG	https://www.avg.com	Czech Republic	Avast
Avira	https://www.avira.com	Germany	
Bitdefender	https://www.bitdefender.com	Romania	
Check Point (ZoneAlarm)	https://www.zonealarm.com	Israel	Kaspersky
Dr. Web	https://www.drweb.com	Russia	
Emsisoft	https://www.emsisoft.com	New Zealand	Bitdefender
ESET	https://www.eset.com	Slovakia	
F-Secure	https://www.f-secure.com	Finland	Avira
G Data	https://www.gdata.de	Germany	Bitdefender
K7 Computing	https://www.k7computing.com	India	
Kaspersky	https://www.kaspersky.com	Russia	
Malwarebytes	https://www.malwarebytes.org	USA	
McAfee	https://www.mcafee.com	USA	



FYI engines are a software...

- Reverse engineering
- Exploit

Consumer: https://www.av-comparatives.org/list-of-consumer-av-vendors-pc/
Enterprise: https://www.av-comparatives.org/list-of-enterprise-av-vendors-pc/

Research In Malware Analysis

1. Machine Learning
2. Adversarial Machine Learning
3. (De)obfuscation
4. Measurements
5. Big-data Algorithms
6. Dynamic Analysis Improvements
7. Operations
8. Memory Forensic
9. Humans

Books 📚

- [2010] Malware Analyst's Cookbook and DVD: Tools and Techniques for Fighting Malicious Code
- [2012] Practical Malware Analysis: The Hands-On Guide to Dissecting Malicious Software
- [2014] Practical Reverse Engineering: x86, x64, ARM, Windows Kernel, Reversing Tools, and Obfuscation
- [2014] The Art of Memory Forensics: Detecting Malware and Threats in Windows, Linux, and MAC Memory
- [2015] The Antivirus Hacker's Handbook
- [2018] Learning Malware Analysis: Explore the concepts, tools, and techniques to analyze and investigate Windows malware
- [2018] Malware Data Science: Attack Detection and Attribution
- [2019] Rootkits and Bootkits: Reversing Modern Malware and Next Generation Threats
- [2020] Learn Computer Forensics: A beginner's guide to searching, analyzing, and securing digital evidence
- [2021] Malware Analysis Techniques: Tricks for the triage of adversarial software

Learning ⬆️ – Reading ⬇️

- [2019] Sandworm: A New Era of Cyberwar and the Hunt for the Kremlin's Most Dangerous Hackers
- [2021] This Is How They Tell Me the World Ends: The Cyberweapons Arms Race

– The End –
Thanks for your attention