A Highly Immersive Approach to Teaching Reverse Engineering

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What?

• A hands-on course in reverse engineering, focusing on malware
• Provide solid background in theory of reversing
  – Code generation
  – How tools work: e.g., disassemblers, debuggers
  – Anti-analysis and anti-debug strategies
• Interleaved with hard reversing / analysis projects
• Not a collection of Powerpoint and toy examples
• Not a general “hacking” course
  – Not because I object (I don’t)
  – Not enough time in one semester to cover any additional “hacking” topics
• Goal: Students develop serious, usable reverse engineering skills in one semester
Why So Little RE in Academia?

• Because it’s hard for the instructor?
• Perception that skills can’t be developed in a single semester?
• The university won’t allow it
• Should we be doing this?
• Lack of student interest?
• I’m here to discover the others
Aside: Building Trust

- I personally have no problems getting courses like this approved.
- I **seriously** lay down the law concerning what will happen to:
  - Classes like this being offered
  - Access to all the cool toys, HW, and SW in my security lab
- ...should things go “horribly wrong”
- Historically, despite teaching very hands-on courses in:
  - OS internals
  - Digital forensics
  - Network security
- And despite having classes of students running around with root privileges on the machines in the lab...
Aside: Building Trust (2)

• Nothing external and nothing significant has been destroyed
• Students understand network is monitored and impact of blowing something up outside my lab
• As a result, students are careful and self-policing
• I’ve been around for a long time and haven’t blown anything up
• Your mileage may vary
Why Do It?

• 60%: RE is useful and **should** be taught
  – Great way to motivate students to dig deeper into systems
  – ASM skills, OS internals, Intel manuals as recreational reading
  – Computing != Computer + Java

• 20%: Students begging
  – Resistance: I knew it would be a lot of work to do correctly, tho it’s been coming together for awhile

• 20%: I’m a hacker in professorial clothing
  – Good chance to do what I like
Who?

- Class taught in Spring 2009 for the first time
- 25 students, 2/3 graduate, 1/3 undergrad
- ~20% had taken an OS internals course
- 100% had taken the Intro to Security course
- ~50% had taken or were enrolled in a digital forensics course
- Few had serious assembler skills
- 1 student had nearly expert RE skills
- 2-3 others had at least basic RE skills
- “The hardest course I’ve ever had”
- 1 student dropped in Spring 2009
Aside: ASM Courses: Don’t Get Me Started

• Serious problem: Students have poor ASM skills
• Don’t know about yours, but our ASM course is (IMO) worthless
• Didn’t use to be…I took that course in 1983!
• Can’t volunteer to teach that course…no time
• No time to “teach” the ASM course inside RE
• Solution:
  – (Nearly) compassion-free immersion
  – ASM every day
  – Tight deadlines assignments requiring ASM comprehension
Topics

• Goals of reverse engineering
  – Software interoperability, patch verification, malware analysis, cracking

• Ethics and legal issues
  – DMCA, EULAs, RE == jail, seek ye lawyers

• Techniques / Tools for RE
  – Static vs. dynamic analysis, disassemblers, debuggers, live forensics tools, memory dumpers, packing / unpacking, ...

• Malware background
  – Types, propagation strategies, payload delivery, poly- and metamorphic malware, ...

• Basic Intel assembler (a few lectures, then “on the job”)
  – Registers, flags, common instructions, data formats, 32 vs. 64bit code, hardware components, paging, debugging architecture, examples
Topics (2)

• Windows Portable Executable (PE) format
• C control structure, function, array, struct/union patterns generated by common compilers
• Common malware functionality
  – Delta offset calculation, API address discovery, infection and propagation, …
• Anti-debugging / anti-VM functionality
  – Dynamic jumps, instruction prefetch attacks, LDT/GDT/IDT location analysis, use of debugging facilities
• Packing and unpacking techniques
  – Hand-rolled, UPX, Armadillo, …
Laboratory Setup

• Isolated gigabit network with fast, private fileserver (16 x 15K SAS drives) – has to serve VMWare images
• Workstations running Linux + VMWare
• User accounts including XP VMWare image stored by file server
• XP image contains:
  – sysinternals suite
  – Visual C++ Express Edition
  – MASM32
  – ollydbg
  – IDA Pro 5.x + x86emu plugin for x86 emulation
  – HBGary Responder (thanks, Penny!)
  – FACE, Volatools, ptfinder, …
• Networking OFF in VMWare image whenever possible
Approach: Challenges

• Time is short!
• ASM skills
• Flipping Powerpoint guaranteed to fail
• Want actual, rather than theoretical, skills to emerge
• Skills at end of semester should be (almost?) sufficient to analyze modern malware
• Must hurt students (a lot) to achieve skill levels without completely discouraging them
WHEN SCOTTY TEACHES REVERSE ENGINEERING:

AAAACH CAPTAIN!
THE STUDENTS, THEY CAHN’T
TAKE MUCH MORE! AH CAHN GIVE YE
A WALKTHROUGH AND A WEE BIT MORE,
BUT I CANNO’ GUARANTEE HOW
MUCH LONGER THEY’LL LAST!
Approach: Malware Sampler

• Requirements:
  – Students start RE immediately
  – With each new malware sample, push students *almost to breaking point* 😊 but not quite

• Michelangelo → DOS-7 → SQL Slammer → Murkry → Lucius → Harulf → Conficker

• These were interleaved with short “malware” samples (that I wrote) to introduce:
  – Registry hacking
  – Replacement of system binaries
  – Addition of user accounts
  – …
Approach: Workflow

Traditional lectures w/ Powerpoint for necessary background

Documented ASM walkthroughs on document camera: **team assignments**

Lab sessions in lieu of lecture to introduce use of tools or concepts such as unpacking

Reversing assignments of increasing difficulty, in teams of 2-3

Documented ASM walkthroughs on document camera: **new malware**

Midterm / Final:
60% reverse engineering assignments
40% background material
Approach: Assignments

• Series of team-based malware analyses
• Goal is to produce fully documented disassemblies
• Initially, uncommented but correct disassemblies
• Later, only a binary malware sample
  – Must coax tools to generate correct disassembly
  – Deal with packing, anti-analysis techniques
• Modest expectations initially, increase sharply as the semester progresses
• In some cases:
  – Solutions accepted and signed
  – Necessary concepts for complete solution discussed in class
  – Solution returned and then may be resubmitted
• Always let students try (and potentially fail) before giving away the solution
NukeHD:
  sub cx,cx

NukeDism:
  inc cx
  push cs
  pop es
  mov ax,FE05h
  jmp $-2

sub ax,E702h
mov bh,1
mov dx,80h
int 13h
jmp short NukeDism
NukeHD:
  sub cx,cx ; cx == sector number <-- 0
  ; FALL THROUGH...

NukeDism:
  inc cx ; target next sector
  push cs ;
  pop es ; es <-- cs
  mov ax,FE05h ; ax <-- FE05h
  jmp $-2 ; jumps into middle of last instruction
  ; last instruction disassembled =
  ; B8 05 FE EB FC
  ;
  ; JMP targets 05 byte which is the
  ; opcode for a 16-bit immediate add
  ; to AX, thus ax <-- ax + EBFeh
  ;
  ; the remaining byte, FC, is the
  ; opcode for the single byte instruction
  ; CLD (clear direction flag)
  ;
  sub ax,E702h ; ax <-- ax - 0E702h = 301h
  mov bh,1 ;
  mov dx,80h ; first hard drive
  int 13h ; write 1 sector to hard drive
  jmp short NukeDism ; write "forever"
Approach: Exams

• **30%: Abstract scenarios / “Book material”**
  – “You discover that a binary is packed with UPX. To discover the original entry point (OEP), you…”
  – “A malware sample makes heavy use of dynamic JMPs. Which disassembler design is more likely to encounter problems? Why? Solutions?”

• **70%: References to RE exercises**
  – Precise, detailed answers required
  – Hard to answer within available time if student didn’t participate in the team-based analyses
  – “When you analyzed the following section of Harulf, what did you discover? Comment each line.”
  – Example follows on next slide
Start:
    jmp stuck
    sig_1 dd 0
    sig_2 dd 0

stuck:
    call here
    jmp getdelta

here:
    assume fs:nothing
    mov eax,[esp]
    push eax
    push fs:[0]
    mov fs:[0],esp
    xor eax,eax
    mov eax,[eax]
    ret

getdelta:
    ...
    pop fs:[0]
    pop edx
    pop ebp
    sub ebp,offset here
    add ebp,2h
    cmp ebp,0
    je skipdecrypt
Start:

    jmp stuck
    sig_1 dd 0
    sig_2 dd 0

stuck:

    call here ; start delta offset calculation,  ; trip up debuggers with stack-based SEH
            ; this will be new SEH
    jmp getdelta

here:

    assume fs:nothing
    mov eax,[esp] ; address of “jmp getdelta” in eax
    push eax      ; save address on stack (new SEH)
    push fs:[0]   ; save old SEH head
    mov fs:[0],esp ; “jmp getdelta” is new SEH
    xor eax,eax   ; zero eax
    mov eax,[eax] ; null ptr reference, invokes SEH
    ret

getdelta:

    ... ; restore SEH
    pop fs:[0]
    pop edx
    pop ebp    ; address of getdelta
              ; subtract compile-time offset of ‘here’
    sub ebp,offset here
    add ebp,2h ; jmp getdelta is two bytes
    cmp ebp,0  ; are we at entry point?
    je skipdecrypt ; yes, no need to decrypt body
Final Thoughts

• It’s fun
• It’s hard (for you and for students)
• Lots of initial student interest, interest sustained
• Student feedback was overwhelmingly positive
• Great way to generate students with sufficient background in systems to do real research
• Potential benefit to students is high
• In many cases, job interviews are “won” with a single data point—this course provides many
• RE will be offered regularly at UNO
Thanks.

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